cie2018

April 24-28, Taipei

ABSTRACT BOOKLET

of

CIE 2018 Conference on Smart Lighting

Contents

Note: For Sessions SE1, SE2, SE3 (invited presentations of the Local Organizing Committee) abstracts are only partly available.

PROGRAMME

Thursday, April 26

	Grand Ballroom I			
09:00 - 09:20	**OPENING CEREMONY** **(CIE President, local organizers, ISC chair)**			09:00 - 09:20
09:20 - 10:00	**Keynote Presentation:** **Ed Ebrahimian, US** **City of Los Angeles LED Program and Smart City Initiatives** (Chair: TBA)			09:20 - 10:00
10:00 - 10:40	**Keynote Presentation:** **Patrick Fan, TW** **Future Smart Living LEDilized by Today's III-V Optoelectronics** (Chair: TBA)			10:00 - 10:40
10:40 - 11:10	**COFFEE BREAK**			10:40 - 11:10
11:10 - 12:10	***Panel Discussion:*** **Standards Needs for Smart Lighting** (Chair: Kathy Nield)			11:10 - 12:10
12:10 - 13:30	**LUNCH**			12:10 - 13:30
	Room: To be announced	**Room: To be announced**	**Room: To be announced**	
13:30 - 14.50	PA1-1 Integrative lighting and health (1) (Chair: TBA)	PA1-2 Adaptive, intelligent and dynamic lighting in interior environment (Chair: TBA)	PA1-3 Colour quality (Chair: TBA)	13:30 - 14.50
13:30 - 13:45	**OP01** **Franz Wenzl, AT** **PREFERENCES OF THE LIGHTING CONDITIONS FOR ACTIVATION AND RELAXATION IN DEPENDENCE OF GENDER AND AGE**	**OP05** **Ching-Wei Lin, TW** **OFFICE LIGHTING DESIGN IN CONSIDERATION OF EYE FATIGUE AND TASK PERFORMANCE**	**OP09 (Invited Talk)** **Yoko Mizokami, JP** **STABLE COLOUR APPEARANCE AMONG CHANGE IN THE DIFFUSENESS OF ILLUMINATION**	13:30 - 13:45
13:45 - 14:00	**OP02** **Chien-Yu Chen, TW** **CAN A DYNAMIC LIGHTING HELP PEOPLE FAST SLEEP?**	**OP06** **Aleix Llenas, ES** **ENHANCING COMFORT, ALTERNESS AND PRODUCTIVITY IN INDOOR WORKING ENVIROMENTS USING DYNAMIC MULTI-CHANNEL LED LIGHTING SYSTEMS THAT MIMIC DAYLIGHT**	**OP10** **Yu Hu, CN** **ASSESSING CCT UNIFORMITY ON THE WORK SURFACE IN A REAL LIT ENVIRONMENT**	13:45 - 14:00
14:00 - 14:15	**OP03** **Huihui Wang, CN** **INFLUENCE OF CIRCADIAN STIMULUS AND COLOUR TEMPERATURE ON CHILDREN'S STUDY PERFORMANCE AND FATIGUE**	**OP07** **Han Li, JP** **DEVELOPMENT OF AN AUTONOMOUS SUN-SHADING DEVICE INTEGRATED WITH HIGH EFFICIENT OFFICE LIGHTING**	**OP11** **Ming Ronnier Luo, CN** **COMPREHENSIVE MODELLING OF COLOUR QUALITY FOR LED LIGHTING**	14:00 - 14:15
14:15 - 14:30	**OP04** **Yandan Lin, CN** **EFFECTIVENESS OF BRIGHT LIGHT THERAPY IN THE TREATMENT FOR MOOD DISORDER**	**OP08** **Vladimir Budak, RU** **COMPUTER GRAPHICS AND LIGHTING TECHNOLOGY SCIENCE. ON THE WAY TO THE CRITERIA OF THE ILLUMINATION QUALITY**	**Discussion**	14:15 - 14:30
14:30 - 14:50	**Discussion**	**Discussion**		14:30 - 14:50
14:50 - 15.20	**COFFEE BREAK**			14:50 - 15.20
15.20 - 17:00	PA2-1 Displays and imaging devices with lighting applications (Chair: TBA)	PA2-2 Adaptive, intelligent and dynamic lighting in exterior environment (Chair: TBA)	PA2-3 Colour and vision (1) (Chair: TBA)	15.20 - 17:00
15:20 - 15:35	**OP13 (Invited Talk)** **Yasuki Yamauchi, JP** **PSYCHOPHYSICAL APPROACH FOR EVALUATION OF OLED PANEL PERFORMANCE**	**OP17 (Invited Talk)** **Saori Kitaguchi, JP** **PEDESTRIANS SUPPORT SYSTEM USING VISIBLE LIGHT COMMUNICATION**	**OP22 (Invited Talk)** **Miyoshi Ayama, JP** **KANSEI EVALUATION OF COLOUR IMAGES IN VARIOUS COLOUR GAMUTS USING DIFFERENT RED PRIMARIES**	15:20 - 15:35
15:35 - 15:50	**OP14** **Dandan Hou, CN** **AN ADAPTIVE DISPLAY DIMMING CURVE FOR ENHANCED WORK PERFORMANCE AND VISUAL COMFORT**	**OP18** **Biao Yang, CN** **NEW EMPIRICAL DATA FOR PEDESTRIAN LIGHTING EFFECT ON RECOGNITION ABILITY ON REAL 3D FACIAL EXPRESSION**	**OP23** **Xuling Yu, CN** **INFLUENCE OF FREQUENCY, WAVEFORM AND COLOUR ON THE VISIBILITY OF THE PHANTOM ARRAY EFFECT**	15:35 - 15:50
15:50 - 16:05	**OP15** **Shao-Tang Hung, TW** **INVESTIGATION OF GLARE METRICS FOR REFLECTED GLARE ON DISPLAYS**	**OP19** **Paolo Di Lecce, IT** **ADAPTIVE LIGHTING IN MOTORIZED TRAFFIC ROAD: REAL INSTALLATIONS SHOW THAT IOT TECHNOLOGIES CAN SUPPORT THE CORRECT USE OF STANDARDS**	**OP24** **Yunyang Shi, CN** **A STUDY OF VISUAL TARGET VISIBILITY IN MESOPIC VISION BASED ON ELECTROENCEPHALOGRAM**	15:50 - 16:05
16:05 - 16.20	**OP16** **Cheng-Hsien Chen, TW** **CONTRAST RATIO STUDIES OF A LED-FLASHED TRAFFIC SIGN AT A FOGGY ROAD**	**OP20** **Erkki Ikonen, FI** **INFLUENCE OF ADAPTIVE STREET LIGHTING ON LED LUMINAIRE LIFETIME**	**OP25** **Zhou Li, CN** **STRUCTURAL MATERIAL EFFECTS ON DISCOMFORT GLARE IN THE DARK CAB**	16:05 - 16.20
16.20 - 16:35	**Discussion**	**OP21** **Dionyz Gasparovsky, SK** **POTENTIAL OF ENERGY SAVINGS IN TRAFFIC FLOW CONTROLLED STREET LIGHTING SYSTEMS**	**OP26** **Shining Ma, BE** **THE INFLUENCE OF ADAPTING FIELD EXTENT ON CHROMATIC ADAPTATION**	16.20 - 16:35
16.35 - 17:00		**Discussion**	**Discussion**	16.35 - 17:00

Friday, April 27

	Room: To be announced	Room: To be announced	Room: To be announced	
09:00 - 10:40	SE1 Seminar LOC invited papers (Chairs: Li-Chen Ou, James M. Shyu)	SE2 Seminar LOC invited papers (Chairs: Chien-Yu Chen, Bao-Jen Pong)	SE3 Seminar LOC invited papers (Chairs: Tsung-Hsun Yang, Jong-Wei Whang)	09:00 - 10:40
09:00 - 09:20	**SP01** **Ronnier Luo, TW** **Modelling glare and colour appearance of light stimuli using a unrelated colour appearance model**	**SP06** **David Sliney, US** **The Visual Field of View and Non-Visual Effects**	**SP11** **Ching-Cherng Sun, TW** **LED SSL : from lighting technology to lighting quality and intelligence**	09:00 - 09:20
09:20 - 09:40	**SP02** **Shoji Tominaga, JP** **Appearance simulator of fluorescent objects under different light sources**	**SP07** **Yukio Akashi, JP** **Impact of ageing changes in human visual system on discomfort glare sensation and printed text readability**	**SP12** **Hirohisa Yaguchi, JP** **Do ipRGCs affect to colour matches between metameric white lights?**	09:20 - 09:40
09:40 - 10:00	**SP03** **Tetsuya Sato, JP** **Colour Depth: A Key for Understanding the Relationship among Colour Systems, Colour Tones, and Colour Emotions**	**SP08** **Minchen Wei, HK** **Quantification of external lighting on human circadian system in metropolises at night**	**SP13** **Fumiaki Obayashi, JP** **Intellectual Concentration Index and Room Enviroment Lighting**	09:40 - 10:00
10:00 - 10:20	**SP04** **Yung Kyun Park, KR** **Colour Appearance for Virtual Reality System Display**	**SP09** **Tongsheng Mou, CN** **Blue Light Evaluation for Health Centric Lighting**	**SP14** **Taiichiro Ishida, JP** **Influence of Correlated Colour Temperature and DUV of Illumination on Visual Impression of a Lighting Space**	10:00 - 10:20
10:20 - 10:40	**SP05** **Norimichi Tsumura, JP** **Material Appearance Management with Relighting Using Light Field Camera**	**SP10** **Horng-Ching Hsiao, TW** **Title to be announced**	**SP15** **Youngshin Kwak, KR** **Hue and warm-cool feeling of lighting colours**	10:20 - 10:40
10:40 - 11:10	**COFFEE BREAK**			10:40 - 11:10
11:10 - 12:30	PA3-1 Integrative lighting and health (2) (Chair: TBA)	PA3-2 Solid-State Lighting (SSL) technologies (Chair: TBA)	PA3-3 Colour and vision (2) (Chair: TBA)	11:10 - 12:30
11:10 - 11:25	**OP27** **Jie Qiang, CN** **A LIGHT THAT CAN IMPROVE SLEEPING QUALITY IN TERMS OF HERMONE CONCENTRATION**	**OP31** **Anna Vaskuri, FI** **JUNCTION TEMPERATURE OF SMART LIGHTING LUMINAIRES OBTAINED WITH PULSED DIMMING**	**OP34** **Babak Zandi, DE** **EXPERIMENTAL EVALUATION OF DIFFERENT BRIGHTNESS PERCEPTION MODELS BASED ON HUMAN PUPIL LIGHT RESPONSES**	11:10 - 11:25
11:25 - 11:40	**OP28** **Yandan Lin, CN** **EFFECTS OF COLOUR TEMPERATURE ON HEART RATE, BLOOD PRESSURE, AND ELECTROENCEPHALOGRAPH UNDER RESTING STATE**	**OP32** **Tsung-Hsun Yang, TW** **NON-INVASIVE MEASUREMENT OF PHOSPHOR TEMPERATURE FOR PC-WLEDS**	**OP35** **Peter Bodrogi, DE** **MODELLING BRIGHTNESS IN TERMS OF ROD, S-CONE AND IPRGC SIGNALS BASED ON A NEW VISUAL EXPERIMENT**	11:25 - 11:40
11:40 - 11:55	**OP29** **Eric Dinet, FR** **USING LIGHT TO FACILITATE THE MOBILITY OF LOW VISION PEOPLE**	**OP33** **Xuan-Hao Lee, TW** **LIMIT OF LUMINOUS EFFICACY AND PACKAGING EFFICIENCY IN PC-WLEDS**	**OP36** **Chu-Yun Yeh, TW** **A CROSS-CULTURAL STUDY OF COLOUR EMOTION FOR INTERIOR LIGHTING**	11:40 - 11:55
11:55 - 12:10	**OP30** **Johanna Enger, SE** **EXPERIENCE OF LIGHT IN COMPARISON WITH RETINAL RESPONSE TO RADIATION**	**Discussion**	**OP37** **Jui-Han Yu, TW** **HUMAN VISUAL RESPONSES TO PAINTING AFFECTED BY LIGHTING CONDITIONS**	11:55 - 12:10
12:10 - 12:30	**Discussion**		**Discussion**	12:10 - 12:30
12:30 - 13:40	**LUNCH**			12:30 - 13:40

	Room: To be announced	Room: To be announced	Room: To be announced	
13:40 - 14:20	PS1 Presented Posters (Chair: TBA)	PS2 Presented Posters (Chair: TBA)	PS2 Presented Posters (Chair: TBA)	13:40 - 14:20
13:40 - 13:45	PP01 Shun Ueki, JP AN OPTICAL FILM-BASED DAYLIGHTING SYSTEM WITH HIGH DAYLIGHTING PERFORMANCE AND LESS DISCOMFORT GLARE	PP09 Junki Yoshii, JP MATERIAL APPEARANCE MANAGEMENT TECHNIQUES WITH AFFECTIVE MONITORING	PP17 Minchen Wei, HK EFFECT OF AMBIENT LIGHTING CHROMATICITIES ON PERCEPTION OF NEUTRAL WHITE OF A TABLET	13:40 - 13:45
13:45 - 13.50	PP02 Dionyz Gasparovsky, SK DEPRECIATION OF ROOM SURFACES REFLECTANCE AND THEIR INFLUENCE ON MAINTENANCE FACTOR OF LIGHTING SYSTEMS	PP10 Jaeyoung Heo, JP A STUDY ON THE STAIR ILLUMINATION METHOD CONSIDERING THE ELDERLY	PP18 Wei-Chun Hung, TW A VISUAL EVALUATION OF COLOUR DIFFERENCES BETWEEN 3D OBJECTS	13:45 - 13.50
13.50 - 13:55	PP03 Chien-Yu Chen, TW THE OPTIMIZATION OF A SMALL OFFICE LIGHTING BASED ON THE DYNAMIC TAGUCHI METHOD	PP11 Yu-Man Shang, TW ASSESSING ROAD SAFETY CONCERN FOR LIGHT-EMITTING-DIODE-BASED AUTOMOTIVE HEADLIGHT GLARE	PP19 Suchitra Sueeprasan, TH CHROMATIC INDUCTION AFFECTED BY SHAPE	13.50 - 13:55
13:55 - 14:00	PP04 Yu Hu, CN EXPLORING THE COLOUR APPEARANCE IN HDR TERRITORY	PP12 Wang Chen, CN INVESTIGATION OF PHYSICAL ENVIRONMENT OF ATRIUMS IN LARGE PUBLIC BUILDINGS IN BEIJING, TIANJIN AND HEBEI PROVINCE	PP20 Dong-Hoon Lee, KR SPECTRALLY VARIABLE SOURCE BASED ON SPATIAL CONTROL OF WHITE-LIGHT BEAM	13:55 - 14:00
14:00 - 14:05	PP05 Ma Xiufeng, CN RESEARCH ON THE APPLICATION BENEFITS OF THE LED LIGHT SOURCE BASED ON THE ROAD LIGHTING SYSTEM FOR THE SMART CITY ---IN TIANJIN REGION AS AN EXAMPLE	PP13 Hao Li, CN INVESTIGATION ON THE LIGHT ENVIRONMENT OF CHINA'S ACTIVE WIDE-BODY AIRCRAFT	PP21 Lintao Zhang, CN PILOT STUDY ON THE IMPACT OF MESOPIC VISION ON THE PURITY PERCEIVED BY HUMAN EYES	14:00 - 14:05
14:05 - 14:10	PP06 Teng Hai Lau, CN A STUDY ON HIGH EFFICIENT AND ENERGY SAVING LIGHTING SYSTEM FOR JIUZI ANCIENT TOWN IN CHINA	PP14 Qing Fan, CN RESEARCH ON DESIGN STRATEGY OF GLARE PREVENTION AND CONTROL OF GLASS CURTAIN WALL CONSTRUCTION	PP22 Franz Wenzl, AT A COMPREHENSIVE DISCUSSION ON COLOUR STABILITY OF PHOSPHOR CONVERTED LEDS	14:05 - 14:10
14:10 - 14.15	PP07 Yi-Chun Chen, TW COMPARISONS OF FOUR DIFFERENT DESIGNS OF LED FREEWAY SIGNS	PP15 Diego Ospina, CO ALTERNATIVE METHOD FOR LUMINOUS INTENSITY DISTRIBUTION ASSESSMENT	PP23 Kees Teunissen, NL A COLOUR GAMUT INDEX AND COLOUR-SHIFT INFORMATION BASED ON CIE 13.3	14:10 - 14.15
14.15 - 14:20	PP08 T.X. Lee, TW VISIBILITY AND GLARE STUDY OF LED-EMBEDDED SIGNS	PP16 Qian Li, CN MAIN UNCERTAINTY CONTRIBUTION FACTORS ANALYSIS OF GLARE MEASUREMENT USING ILMD	PP24 Yunzhuo Wang, CN OPTIMIZATION OF BIMODAL QUANTUM DOTS CONVERTED WHITE LEDS FOR HIGH COLOUR RENDITION	14.15 - 14:20
14:20 - 14:25	PP25 Yingying Meng, CN EXPLORING THE PREFERRED LUMINANCE OF VDT AND INDICATOR LIGHTS IN AIRCRAFT COCKPIT FOR AUTOMATIC DIMMING	PP26 Jialu Wu, CN EXPLORING THE OPTIMISTIC DAYLIGHTING DESIGN METHOD: IS COMPUTATIONAL SIMULATION ACCURATE ENOUGH?		14:20 - 14:25
14:25 - 14:50	**COFFEE BREAK**			14:25 - 14:50
	Room: To be announced			
14:50 - 16:20	Poster Session			14:50 - 16:20
16:20 - 16:50	**COFFEE BREAK / Poster removal**			16:20 - 16:50
16:50 - 17:00	**CLOSING CEREMONY**			16:50 - 17:00

Posters:

PO01	Yi-Chun	Chen	TW	ILLUMINATION CONTROL MODEL FOR COMFORTABLE INDOOR READING
PO02	I-Chieh	Chen	TW	ATTENTION COMPARISON OF DIFFERENT OFFICE LIGHTING SCENARIOS BY BRAINWAVE MEASUREMENTS AND EMPIRICAL MODE DECOMPOSITION
PO03	Chien-Yu	Chen	TW	THE GREY RELATIONAL ANALYSIS OF PSYCHOLOGICAL AND PHYSIOLOGICAL EVALUATIONS FOR VISUAL FATIGUE IN THE OFFICE LIGHTING
PO04	Zhao	Guilan	CN	PARAMETRIC DESIGN APPLICATION IN INTELLIGENT LIGHTING
PO05	Jae-Kyu	Ko	KR	INVESTIGATION OF AFFECTIVE FACTOR EVALUTION METHODOLOGY
PO06	Chan-Su	Lee	KR	OPTIMIZATION METHOD FOR LED LIGHTINGS CONSIDERING CCT, ILLUMINANCE, AND CRI
PO07	Chung-Chi	Liu	TW	COLOUR BARRIER-FREE ILLUMINATION USING MULTISPECTRAL LIGHTING SYSTEM
PO08	Baojen	Pong	TW	LIGHT POLLUTION IMPACT STUDY OF DYNAMIC DOT MATRIX LED SIGNS IN TAIPEI AND HSINCHU
PO09	Wei-Chih	Su	TW	USING MULTI-LED SYSTEM TO INCREASE VIVIDNESS OF TEXTILES
PO10	Pei-Jung	Wu	TW	NON-SUBJECTIVE AND SUBJECTIVE EVALUATIONS OF CONCENTRATION OF OFFICE WORKERS IN LIGHTING CONDITIONS WITH DIFFERENT BLUE LIGHTS
PO11	Ke-Ching	Chang	TW	OPTICAL DESIGN OF THE NON-BILATERAL SYMMETRICAL ELLIPTICAL REFLECTOR WITH NEAR INFRARED LED APPLIED IN NON-INVASIVE BLOOD GLUCOSE MEASUREMENT
PO12	Pei-Yang	Chen	TW	ANALYSIS OF TOLERANCE IN CONCENTRATION OF VOLUME SCATTERING DIFFUSER AND COLOUR CONSISTENCY IN AN ANTI-GLARE WHITE LED LIGHTING
PO13	Shau-Wei	Hsu	TW	VISIBILITY OF ROAD MARKINGS ON A LED-LIGHTED FOGGY ROAD
PO14	Brenda	Lam	HK	CALIBRATION OF TOTAL LUMINOUS FLUX, SPECTRAL RADIANT FLUX AND CORRELATED COLOUR TEMPERATURE OF LED LAMPS BY INTEGRATING SPHERE
PO15	Edwin	Mofokeng	ZA	WAVELENGTH CALIBRATION OF A SPHERE-SPECTROMETER MEASUREMENT CONFIGURATION.
PO16	J.Y.	Shen	TW	WHITE LIGHT LED SPECTRAL OPTIMIZATION IN UNDERWATER ILLUMINATION
PO17	Z. W.	Wang	TW	COLOUR DEVIATION SENSING AND COMPENSATION METHOD FOR MULTI-SPECTRAL LED LIGHTING SYSTEM
PO18	Jun-Yi	Wu	TW	IMPROVEMENT OF THE COLOURFUL UNIFORMITY BY THREE DIFFERENT MEDIUMS OF THE PACKAGING LENS IN THE WHITE LIGHT LED
PO19	Ye Seul	Baek	KR	VISUAL EVALUATION OF 3D COLOUR VOLUME
PO20	T. X.	Lee	TW	IMPROVED CIECAM02 MODEL TO PREDICT HUMAN BRIGHTNESS PERCEPTION UNDER HIGH SURROUND LUMINANCE LEVELS
PO21	Hongbing	Wang	CN	A STUDY ON IDENTIFICATION OF OBJECTS BY INTRODUCING COLOUR CONTRAST BASED ON METAMERISM PHENOMENON
PO22	Guo-Qiang	Zhong	TW	SPARKLE ESTIMATION OF METALLIC SAMPLES USING A LOW-COST SYSTEM
PO23	Yuki	Nakajima	JP	PROPOSAL FOR THE NEW FORMULA OF COLOUR RENDERING PROPERTIES TAKING ACCOUNT OF ILLUMINANCE-EFFECTS AND GAMUT-SHAPE-EFFECTS
PO24	Seo-Young	Choi	KR	SMART GARNISH LIGHT/DISPLAY FOR VISUAL ASSISTANCE IN AUTOMOBILE
PO25	Yu-Ting	Hsiao	TW	OPTIMIZING IMAGE APPEARANCE OF AN OPTICAL SEE-THROUGH HMD FOR MIXED-REALITY APPLICATIONS
PO26	Ryota	Mitsuhashi	JP	DUAL-BAND VIDEO-BASED MEASUREMENT FOR NONCONTACT PULSE RATE ESTIMATION IN INFRARED
PO28	Han-Kuei	Fu	TW	PSYCHOLOGICAL INFLUENCE OF COLOURFUL LIGHT-EMITTING DIODE LUMINAIRE
PO29	Aiying	Wang	CN	MAIN PROBLEMS AND SOLUTIONS FOR TEMPORARY EXHIBITION SPACE LIGHTING
PO30	Alexey	Bartsev	RU	MEASUREMENT OF PHOTOSYNTHETIC PHOTON FLUX (PPF) AND FLUX DENSITY (PPFD) FOR GREEN HOUSE LED IRRADIATORS
PO31	Jongsung	Han	KR	PROBLEMS ASSOCIATED WITH THE APPLICATION OF CURRENT STANDARDS ON LIGHT POLLUTION AND NEED IMPROVEMENT
PO32	Zi-Yi	Lian	TW	INNOVATIVE PUPIL DETECTOR EQUIPMENT
PO33	Wen-Chun	Liu	TW	TRANSMITTANCE HAZE MEASUREMENT FOR HIGH HAZE MATERIALS
PO34	Hung-Wen	Luo	TW	COLOUR FADING MODEL OF LEDS FOR CONTEMPORARY PHOTOGRAPHIC MATERIALS
PO35	Takumi	Otsuka	JP	COMPARISON OF PHYSIOLOGICAL RESPONSE BETWEEN LED AND OLED DURING TASK EXECUTION
PO36	Alexandra	Tran	AU	SMART LED STREET LIGHTING
PO37	Mingchung	Liu	TW	EFFECTS OF AGE AND GENDER ON VISUAL PERCEPTION OF COMMODITY WITH DIFFERENT MATERIALS IN COMMERCIAL REFRIGERATOR
PO38	Yu-Jung	Lin	TW	A REAL-TIME SYSTEM TO ENHANCE LEGIBILITY AND AWARENESS OF TEXT INFORMATION FOR AN OPTICAL SEE-THROUGH HMD

Presented Posters:

PO39 (PP01)	Shun	Ueki	JP	AN OPTICAL FILM-BASED DAYLIGHTING SYSTEM WITH HIGH DAYLIGHTING PERFORMANCE AND LESS DISCOMFORT GLARE
PO40 (PP02)	Dionyz	Gasparovsky	SK	DEPRECIATION OF ROOM SURFACES REFLECTANCE AND THEIR INFLUENCE ON MAINTENANCE FACTOR OF LIGHTING SYSTEMS
PO41 (PP03)	Chien-Yu	Chen	TW	THE OPTIMIZATION OF A SMALL OFFICE LIGHTING BASED ON THE DYNAMIC TAGUCHI METHOD
PO42 (PP04)	Yu	Hu	CN	EXPLORING THE COLOUR APPEARANCE IN HDR TERRITORY
PO43 (PP05)	Ma	Xiufeng	CN	RESEARCH ON THE APPLICATION BENEFITS OF THE LED LIGHT SOURCE BASED ON THE ROAD LIGHTING SYSTEM FOR THE SMART CITY ---IN TIANJIN REGION AS AN
PO44 (PP06)	Teng Hai	Lau	CN	A STUDY ON HIGH EFFICIENT AND ENERGY SAVING LIGHTING SYSTEM FOR JIUZI ANCIENT TOWN IN CHINA
PO45 (PP07)	Yi-Chun	Chen	TW	COMPARISONS OF FOUR DIFFERENT DESIGNS OF LED FREEWAY SIGNS
PO46 (PP08)	T. X.	Lee	TW	VISIBILITY AND GLARE STUDY OF LED-EMBEDDED SIGNS
PO47 (PP09)	Junki	Yoshii	JP	MATERIAL APPEARANCE MANAGEMENT TECHNIQUES WITH AFFECTIVE MONITORING
PO48 (PP10)	Jaeyoung	Heo	JP	A STUDY ON THE STAIR ILLUMINATION METHOD CONSIDERING THE ELDERLY
PO49 (PP11)	Yu-Man	Shang	TW	ASSESSING ROAD SAFETY CONCERN FOR LIGHT-EMITTING-DIODE-BASED AUTOMOTIVE HEADLIGHT GLARE
PO50 (PP12)	Wang	Chen	CN	INVESTIGATION OF PHYSICAL ENVIRONMENT OF ATRIUMS IN LARGE PUBLIC BUILDINGS IN BEIJING, TIANJIN AND HEBEI PROVINCE
PO51 (PP13)	Hao	Li	CN	INVESTIGATION ON THE LIGHT ENVIRONMENT OF CHINA'S ACTIVE WIDE-BODY AIRCRAFT
PO52 (PP14)	Qing	Fan	CN	RESEARCH ON DESIGN STRATEGY OF GLARE PREVENTION AND CONTROL OF GLASS CURTAIN WALL CONSTRUCTION
PO53 (PP15)	Diego	Ospina	CO	ALTERNATIVE METHOD FOR LUMINOUS INTENSITY DISTRIBUTION ASSESSMENT
PO54 (PP16)	Qian	Li	CN	MAIN UNCERTAINTY CONTRIBUTION FACTORS ANALYSIS OF GLARE MEASUREMENT USING ILMD
PO55 (PP17)	Minchen	Wei	HK	EFFECT OF AMBIENT LIGHTING CHROMATICITIES ON PERCEPTION OF NEUTRAL WHITE OF A TABLET
PO56 (PP18)	Wei-Chun	Hung	TW	A VISUAL EVALUATION OF COLOUR DIFFERENCES BETWEEN 3D OBJECTS
PO57 (PP19)	Suchitra	Sueeprasan	TH	CHROMATIC INDUCTION AFFECTED BY SHAPE
PO58 (PP20)	Dong-Hoon	Lee	KR	SPECTRALLY VARIABLE SOURCE BASED ON SPATIAL CONTROL OF WHITE-LIGHT BEAM
PO59 (PP21)	Lintao	Zhang	CN	PILOT STUDY ON THE IMPACT OF MESOPIC VISION ON THE PURITY PERCEIVED BY HUMAN EYES
PO60 (PP22)	Franz	Wenzl	AT	A COMPREHENSIVE DISCUSSION ON COLOUR STABILITY OF PHOSPHOR CONVERTED LEDS
PO61 (PP23)	Kees	Teunissen	NL	A COLOUR GAMUT INDEX AND COLOUR-SHIFT INFORMATION BASED ON CIE 13.3
PO62 (PP24)	Yunzhuo	Wang	CN	OPTIMIZATION OF BIMODAL QUANTUM DOTS CONVERTED WHITE LEDS FOR HIGH COLOUR RENDITION
PO63 (PP25)	Yingying	Meng	CN	EXPLORING THE PREFERRED LUMINANCE OF VDT AND INDICATOR LIGHTS IN AIRCRAFT COCKPIT FOR AUTOMATIC DIMMING
PO64 (PP26)	Jialu	Wu	CN	EXPLORING THE OPTIMISTIC DAYLIGHTING DESIGN METHOD: IS COMPUTATIONAL SIMULATION ACCURATE ENOUGH?

ORAL PRESENTATIONS

Session PA1-1
Integrative lighting and health (1)
Thursday, April 26, 13:30–14:50

OP01

PREFERENCES OF THE LIGHTING CONDITIONS FOR ACTIVATION AND RELAXATION IN DEPENDENCE OF GENDER AND AGE

Wenzl, F.P.[1], Schweitzer, S.[1], Schinagl, C.[2], Djuras, G.[2], Frühwirth, M.[3], Hoschopf, H.[4], Wagner, F.[4], Schulz, B.[5], Nemitz, W.[1], Grote, V.[3], Reidl, S.[2], Pritz, P.[5], Moser, M.[3]

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In recent years, LED lighting became an indispensable alternative to conventional lighting systems. Sophisticated solutions offer not only comfortable white light with a good colour rendering. They also provide the possibility of changing illuminance and colour temperature. Some systems even mimic daylight over the entire day, some including natural variations as due to clouds. Such systems are supposed to support the chronobiological needs of human and to have a positive effect on well-being, performance, sleep-quality and health.

Still, research regarding suitable light-settings for specific situations is still incomplete. Therefore, we investigated the subjective preferences of men and women regarding light-settings for activity and relaxation as examples. We supplied two rooms and four cubes with light sources that provide the possibility of tuning individual light properties like illuminance and colour temperature. Individuals – belonging to four groups differing in gender and age – were asked to imagine activating and relaxing situations for which they were asked to adjust suitable and pleasant lighting by tuning the above mentioned light properties or they were exposed to predefined lighting conditions.

In the first phase we invited 85 persons to participate in the study. They were assigned to four different groups: young men (age from 18 to 30 years, 20 persons), young women (18 to 30 years, 20 persons), old men (50 to 80 years, 22 persons) and old women (50 to 80 years, 23 persons). The subjects were asked to look inside a white cube which was placed in a white room. The light settings of the cube could be tuned via twist dimmers. When the light settings in the cube were modified, the light in the room changed in the same manner For the tests, the participants were asked to imagine situations of activation and relaxation and to tune either illuminance, colour temperature, or $\Delta u'v'$ (with two of these parameters fixed), or they could change all of those variables simultaneously, while looking into the cube, until they felt comfortable with the light in the cube for the envisioned situation.

In a second phase we invited 50 persons that were seated in the white rooms and were asked to do performance tests and to relax in fixed light situations that were chosen from the results of the first phase. Performance and preference values in the different light situations were deduced from this second phase to assess the influence of illuminance, CCT and $\Delta u'v'$ on activation and relaxation.

From the results, it becomes evident that there are clear differences in the lighting conditions preferred for two situations of activation and relaxation. Also some combined gender- and age-specific differences, in particular with respect to young women and young men, became apparent.

OP02

CAN A DYNAMIC LIGHTING HELP PEOPLE FAST SLEEP?

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Abstract

The high-pressure environment in the fiercely competitive society nowadays has increased the number of sleepless people who are influenced the physical and mental conditions because of inadequate rest time. A lot of people therefore seek for medication; however, it would cause bad side effects. It is expected to propose a method with less stimulation but being able to help people fall asleep faster, have sufficient sleep, and effective improve the quality of life.

To enhance the quality of sleep, a dynamic lighting system which could assist people in fast falling asleep is proposed in this study. The dynamic lighting source would periodically change the colour with time. Total 30 participants join in the experiment for 3 sets of experiment. The lighting environment for each experiment contains dynamic lighting (with 30-minutes colour change of red, yellow, and purple), low-colour temperature flat lighting (with illumination 9.1lux and colour temperature 2800K), and complete darkroom. The full experiment lasts for 1 hour, a questionnaire is preceded before and after the experiment, and the brainwave and electrocardiography are measured in the full experiment. The questionnaire is used for the subjective evaluation, and brainwave and the analysis of heart rate variability is regarded as the non-subjective evaluation.

According to the experimental results, the use of dynamic lighting could more easily have the participants fall asleep. A series of discussions aiming at promoting sleep will be preceded in this study to explain the effect of such lighting on sleep through the induction of light source changes to brain and the colour perception of people with closed eyes. Furthermore, such dynamic lighting will be applied to clinic, expecting to help sleepless people.

OP03

INFLUENCE OF CIRCADIAN STIMULUS AND COLOUR TEMPERATURE ON CHILDREN'S STUDY PERFORMANCE AND FATIGUE

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Introduction

Over the years, researchers have strived to find the relationship between the lighting parameters and human biological and psycho-physiological responses. More intensive studies have been carried out after the finding of intrinsically photosensitive retinal ganglion cells (ipRGCs) which contains the photopigment melanopsin. The mechanism behind lighting and human biological performance is now becoming more clearly. It was also reported that since children's lens have a higher transmittance than adults', they may be more sensitive to lighting than adults. Some research results showed that lightings to have the same level of circadian stimulus (CS), adolescent have more melatonin suppression that that of adults.

In this study, the spectral power distributions of lightings were specially designed by optimising CS and CCT using a spectrum tuneable LED system. Furthermore, considering the daily life of primary school student, different testing methods surrounding study performance and eye fatigue were designed. Five different lighting conditions were investigated in this study according to three CCTs (3000, 4000 and 5000K) and two CS levels (0.2 and 0.4). They were designated as 3000K0.2CS, 3000K0.4CS, 4000K0.2CS, 4000K0.4CS and 5000K0.4CS, having a lux level of 500 at desk level. The melanopsin illuminance of each lighting source were 29, 34, 37, 53 and 65 respectively. Three different aspects of testing methods were adopted to evaluate study performance and fatigue: cognitive tasks, eye fatigue measurement and subjective questionnaire.

Methods

The experiment was set up in a typical office room at the university. The windows were covered with heavy curtain so daylight was cut off from the room and the only light source was an 11-channel spectrum tuneable LED lighting system on the celling. Twelve junior students including 6 girls and 6 boys have a mean age of 9.3 took part in the experiment. There were 5 different lighting conditions so that each participant came to the lab at 5 different days at a certain time period of each day. Each participant was asked to keep a regular sleeping schedule during the experiment.

Comprehensive methods were used in this experiment. For cognitive performance, d2 test was used to measure the attention and concentration level. Reading novels, painting colour and copying textbooks were adopted as the metal load tasks, which were similar to the routine work at school. Critical flicker frequency (CFF) and near point accommodation (NPA) were used to measure the degree of eye fatigue. SpO2 was measured by an oximeter which represent the degree of brain fatigue. Visual performance was measured by the Landolt rings with different size and orientations of gap generated by a computer software. Subjective questionnaires were also conducted including three parts: mood (sad\happy\angry\fun\laughing (exciting)), sleepiness (shown by 5 different pictures) and eye fatigue (eye uncomfortable\blurred vision\body pain).

The procedure was as following. Before the formal experiment, a 10-minutes training session was conducted to familiarize the testing methods. Participants then had a 5-minutes adaptation. And then did the questionnaire and the four fatigue tests to establish the base line result. Subsequently, they did the d2 test and three mental loads tasks which took about 65 minutes. Finally, eye fatigue and questionnaire were again measured. Each session lasted about 120 minutes. In total, 38 hours were spent and the whole experiment lasted about 1 week.

Results

The task performance results showed that CS had a significant effect on two tasks (d2 and reading speed), i.e. participants had a higher d2 score under higher CS lighting ($p=0.024$, M-U test) and also faster reading speed under high CS lighting ($p=0.029$, M-U test) on both 3000K and 4000K. This implies that a higher CS lighting help to improve concentration and alertness which may cause a better study

performance. CCT also produced great effect on d2 test because 4000K lighting to have the highest score among all the CCTs especially comparing to 5000K (p=0.011, M-U test). This indicates that 4000K is a suitable CCT for children to raise attention.

For eye fatigue tests, CFF and NPA represent the difference between the post- and the pro-measurement. The larger the CFF and NPA difference values are, the heavier eye fatigue participants will feel after the tasks. Both CFF and NPA results showed the trend that a higher CS lighting would cause more eye fatigue than that of a lower CS lighting. The effect on CFF was much stronger than NPA. CFF showed that different CCT levels have influence on it (p=0.086, K-S test) and there was significant difference between 3000K and 4000K (p=0.044, M-U test), i.e. 4000K to have the highest CFF value (the highest eye fatigue) amongst all the lightings.

Participants performed better visual capacity test under a higher CS lighting, especially at 4000K. For the fatigue questionnaire “body pain”, 3000L and 4000L lighting caused higher body pain than 3000H and 4000H. Among all the CCTs, 4000K is more beneficial for higher visual acuity. Lighting source didn’t have significant effect on SpO2.

For different questionnaires, only “laughing” (excitement) showed a significant impact. A higher CS lighting made participants feel more exciting comparing to a lower CS lighting (p=0.031, M-U test).

Conclusions

- Children tend to have higher concentration level and more excited under higher CS lighting conditions, but also higher CS lightings may lead to more fatigue.
- Children’s cognitive performance may not improve at higher CCT level. They had the highest attention level at 4000K lighting condition.
- Among all the CCTs, 5000K caused lower eye fatigue on children.
- Among all the methods in this experiment, d2 test was the most effective test to evaluate the cognitive performance, CFF was the most effective test for measuring eye fatigue.
- Both subjects’ attention level and eye fatigue had a significant weak negative correlation.

OP04

EFFECTIVENESS OF BRIGHT LIGHT THERAPY IN THE TREATMENT FOR MOOD DISORDER

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Abstract

1. Motivation, specific objective

The mood disorder of depression is a common mental disease, which can be divided into seasonal affective disorder (SAD) and non-seasonal depression. Bright light therapy, as an effective treatment for seasonal affective disorder, has been studied for more than two decades. It has been found that bright light therapy has effective therapeutic effect on seasonal affective disorder, while the effect of bright light therapy on non-seasonal depression needs further investigation. The purpose of this study is to assess the evidence for the effect of bright light therapy on non-seasonal depression and depression oriented people.

2. Methods

This paper laid out two cases of treatment, each carried out with different bright light therapy conditions, based on the condition of effective bright light therapy for seasonal affective disorder. Two bright light therapy conditions were 6000 lux at 4400K with a period of 90 min in the morning and 4000 lux at 4400K with a period of 90 min in the evening. The participants were randomly selected between ages of 18-50 years old, with total number of 30 including 12 males and 18 females, average age at 22.54±(std)5.615. None of the participants took psychotropic drugs before and during the experiment.

Before the experiment, we used the Beck Depression Inventory (BDI), scoring from 0 to 40, to scale the degree of depression, with a higher BDI for a higher degree of depression. Before and after entering the light room, participants were asked to fill in the scale of PANAS (Positive and Negative Affect Schedule) which was used to measure the emotion, scoring from -20 to 20, with a higher score for more positive emotion. Also, we measured blood pressure and heart rate to evaluate the physiological health before and after the experiment.

3. Results

Both two conditions conducted showed significant effect ($p<0.05$) on the treatment for non-seasonal depression and depression oriented people. Both of the bright light therapy carried out in the morning at 6000 lux or in the evening at 4000 lux can lead to positive mood, raise heart rate, and improve blood pressure. Both of the non-seasonal depression group and depression oriented group showed similar variation ($p>0.05$) under bright light therapy of the two cases.

Also, there were differences in mood change and improvement before and after two cases of bright light therapy. The effect of evening bright light therapy condition used in this experiment were significantly better than morning bright light therapy condition used ($p=0.004 <0.05$). Bright light therapy carried out in the evening at 4400K of 4000 lux showed better improvement in the alleviation of non-seasonal depression.

4. Conclusions

The study of bright light therapy for non-seasonal depression and depress oriented people has been carried out. Experiments showed that both two cases reached improvement. Bright light therapy used had positive effect on emotion, leading to significant drop of heart rate and blood pressure. In this study, we obtained an optimum bright light therapy condition: LED light at 4400K of 4000 lux conducted in the evening tend to have good effect on non-seasonal depression and depress oriented people.

In conclusion, it verified the effect of improvement of bright light therapy for people with mood disorder of non-seasonal depression and oriented people.

Session PA1-2
Adaptive, intelligent and dynamic lighting in interior environment
Thursday, April 26, 13:30–14:50

OP05

OFFICE LIGHTING DESIGN IN CONSIDERATION OF EYE FATIGUE AND TASK PERFORMANCE

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Abstract

1. Motivation, specific objective

People stay in artificial lighting for a long time in modern life. An intelligent lighting in the future possibly considers health and performance of human beings. Many lighting researches discussed health effects and human performance effects of correlated colour temperature (CCT) and illuminance. However, previous spectrums are limited by traditional lighting technologies, such as fluorescent lamp. With tunable LED lighting technology, a designed health-promotion illuminant is possible.

Because intrinsically photosensitive retinal ganglion cells discovered in 2002 mainly go in a non-imaging forming pathway to regulate human body, two lighting metamers look the same may offer different photobiological effects. However, there are seldom researches comparing the health or performance effects of lighting metamers. The objective of this research is a health-promotion office lighting based on eye fatigue and task performance under 12 lighting conditions. These lighting conditions not only vary in CCT and illuminance, but also three different blue-light peak wavelengths, which generates a series of lighting metamers. We are aiming to find the effects of CCT, illuminance and peak wavelengths by statistics. Moreover, IEC 62471 stipulates photobiological safety of lamps and lamp systems and formulates retinal thermal hazard and retinal blue-light hazard. We also intent to check whether retinal blue-light hazard value affects task performance or eye fatigue.

2. Methods

These 12 lighting conditions are built by the mixture of 11 specific narrow-band LEDs. They are designed under 3 independent variables including 2-level correlated colour temperature (4000 K, 6000 K), 2-level illuminance (400 lux, 700 lux) and 3-level blue-light peak wavelength (420 nm, 460 nm, 480 nm). According to IEC 62471, these lightings belong to exempt group (no-risk) and have 12 different retinal blue-light hazard values (0.217 ~ 0.904 $W/m^2 \cdot sr$), which is the forth independent variable.

To measure eye fatigue, we tested (1) subjective questionnaire with 5 questions, and (2) critical flicker fusion (CFF). To measure performance, we tested (3) paper-based Landolt C task performance (task performance is defined as correct ratio multiplies speed), (4) paper-based proofreading correct ratio under three kinds of tasks (Chinese article, random pairs of characters, colourful paired images formed by alphabets), and (5) monitor-based Go/No-Go task performance. 12 subjects (6 males, 6 females, 23 to 25 years old) participated in experiment under each lighting condition for two hours. Eye fatigue test and Landolt C task were performed in the beginning and the end of the experiment. The other task performance tests and several assigned reading works were carried out in the middle.

Repeated measures ANOVA is applied to compare the effects of CCT, illuminance, and blue-light peak wavelength. Pearson correlation and linear regression is applied to verify the effects of no-risk retinal blue-light hazard value. Paired t test is applied to check the difference between the beginning and the end.

3. Results

(A) Eye fatigue

During the two-hour experimental period, subjective feeling “eyes are tired” increases significantly more under 6000 K lighting condition than 4000 K ($p = 0.034$). The increases are both significant (6000 K: $p < 0.001$, 4000 K: $p < 0.001$). Subjective feeling “difficulty in gazing at objects” increases significantly more under 700 lux lighting condition than 400 lux ($p = 0.040$). The increases are significant under 700 lux condition ($p = 0.002$) but insignificant under 400 lux condition ($p = 0.284$). Considering individual difference, the difference of “eyes are tired” is significantly ($p = 0.004$) low-correlated ($R = 0.233$) to retinal blue light-hazard value. There is no significant CFF difference in this research.

(B) Task performance

During the two hours, Landolt C task performance significantly increases under 6000 K / 700 lux lighting condition ($p = 0.020$), but significantly decreases under 4000 K / 700 lux lighting condition ($p = 0.044$). Performance under 400 lux lighting condition, neither 6000 K nor 4000 K, changes significantly. There is an interaction between CCT and illuminance ($p = 0.017$).

There are some significant influences on performances among the independent variables. For example, CCT significantly affects Go/No-Go task performance and Chinese articles proofreading correct ratio. These two performances under 4000 K lighting condition are significantly better than 6000 K. Considering individual difference, Go/No-Go task performance is significantly ($p = 0.023$) low-correlated ($R = 0.185$) to retinal blue-light hazard value.

(C) Effects of blue light (including lighting metamers and retinal blue-light hazard values)

Since none of the eye fatigue or performance is significant influenced by blue-light peak wavelength, the effect of lighting metamers cannot be proofed in this research. However, retinal blue-light hazard value is significantly low-correlated to eye fatigue and some task performance as mentioned.

4. Conclusions

With tunable LED lighting technology, we designed 12 office lighting conditions with 12 different retinal blue-light hazard values according to 2 CCT (4000 K, 6000 K), 2 illuminance levels (400 lux, 700 lux) and 3 blue-light peak wavelengths (420 nm, 460 nm, 480 nm) and measured eye fatigue and task performance of 12 subjects. Subjective feeling “difficulty in gazing at objects” increases significantly less in a 400 lux environment than a 700 lux environment during two hours working period. Subjective feeling “eyes are tired” increases significantly less in a 4000 K illuminated environment than a 6000 K illuminated environment. “Eyes are tired” difference is significantly low-correlated to retinal blue-light hazard value. Thus, we conclude that a 400 lux and 4000 K illuminated environment (which has the lowest no-risk retinal blue light hazard in this research) is an eyes-health-promote office lighting condition. Task performance is influenced by lighting conditions. Detail results and conclusions will be reported in the full paper.

Retinal blue-light hazard value indeed influences human beings more than blue-light peak wavelength. Since low retinal blue-light hazard value is significantly but low-correlated to performance and eye fatigue. Besides CCT and illuminance, choosing a low retinal blue-light hazard spectrum may be a good strategy. To summarize, we promote that a 4000 K / 400 lux office lighting is the best one within our designed lighting conditions.

OP06

ENHANCING COMFORT, ALTERNESS AND PRODUCTIVITY IN INDOOR WORKING ENVIROMENTS USING DYNAMIC MULTI-CHANNEL LED LIGHTING SYSTEMS THAT MIMIC DAYLIGHT

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Abstract

1. Motivation and specific objectives

Light sources that generate white or coloured light are well known and can be easily found in the marketplace. In recent days, more indicators are appearing that account for the interaction between the spectral power distribution of a light source and different biological systems, such as the human brain, plants or other animals. All these applications, each of them with their own indicators, highlight the importance that a control over the spectral power distribution of the light has in professional environments where the properties of light need to be carefully controlled.

The light source is composed of individually addressable wavelength light channels and a control unit for calculating the Pulse Width Modulation (PWM) weights that need to be sent in order to sculpt the target spectrum (by minimizing the root-mean-square error or RMSE) between the two functions. In this process, several non-linearities occur that generate undesired deviations between target and emitted spectra. Over time (due to age or temperature-driven effects), the type of corrections that need to be undergone are twofold; (i) the LED's efficiency of each channel decreases differently and (ii) channel colour shifts need to be corrected to accurately reproduce lighting spectra.

Within this work several methods to compensate such differences will be discussed, with strong emphasis on how to use an integrated low-cost colour sensor to monitor changes in the spectral components of the emitted light. This approach may seem counterintuitive since colour sensors measure only colour. However, we use advanced spectral algorithms that show how colour sensors can be used to match spectral shapes, without sacrificing much accuracy as compared to using more expensive devices (spectrophotometers or multi-band sensors).

Finally, the use of these multi-channel luminaires is validated in working environments. In particular, the light engines have been tested in a 24/7 working room over 1 year with a CCT-changing sequence designed for critical-task performing (the spectral shapes have been calculated from the outcomes of the project HI-LED, funded by the European Commission, http://www.hi-led.eu). This technology not only is used throughout the eight-hour shift work in tune with the employees' biological clock (circadian rhythms) but it also aims at decreasing the task error rate of the workers (which are operators of highly critical environments in production plants).

2. Methods

The tunable light source developed is made of 10 different LED channels, essentially spread all over the most sensitive part of the visible region (400-700 nm). The amplitude of an LED channel is controlled with a pulse-width modulation (PWM) constant current driver with a 12 bit-depth resolution. A low-cost colour sensor is adapted inside the tunable LED light source and can collect a small fraction of the emitted light, after having been mixed by a mixing chamber and a diffuser.

Thus, we have designed a computationally efficient PID controller for accurate spectral fidelity against thermal junction variations and LED luminous flux depreciation. The integrated colour sensor reads real-time information of the colour coordinates and infers changes in the spectral shape, colour shifts and luminous flux variations. All the information is passed to the PID controller and a fine-tune of the weights for each channel is made when differences are found.

To test the light engines in a real environment setup, several luminaires were mounted in the ceiling of a 24/7 working room with 18 employees over a full year. These special luminaires were programmed to follow a pre-defined light sequence adapted to each work shift schedule depending on the time of the day. The lighting sequence changes automatically by gathering every few seconds the local time

information and reproducing the right spectrum accordingly. The degree of comfort and alertness was periodically rated by the workers and the production increment is currently underway. We expect to have further results on productivity that will be presented at the congress.

3. Results

Results prove that the use of complex algorithms combined with low-cost colour sensors in multi-channel LED light engines can give outstanding results in terms of colour quality and spectral fidelity. Our system can reproduce any arbitrary light spectra in the visible range with an accuracy within a 2-step MacAdam ellipse and <5% variation in spectral shape.

The employees under test, were workers performing critical control tasks in a refinery industry, where the lighting conditions are considered to be critical over the day to control the task error rate. The results of this study rate the new lighting system with a 8.6 out of 10, as compared to the old installation. When rated by the room workers, the results are also very promising; they have increased their level of satisfaction in comparison with the previous lighting systems from 6 (old installation) to a rating of 8.13 (new installation) out of 10. As stated before, statistical evaluation of task errors needs longer times and we are expecting to get the results from the company by Q1 2018.

4. Conclusions

Our results show that the use of a controller based on a colour sensor can be used to obtain relative spectral errors and Δuv' between target and emitted spectra significantly below threshold values (Δuv' < 0.0025 in all cases, or within 2-step MacAdam ellipse).

These smart engines with added intelligence and spectral awareness offer great possibilities to create healthier and more productive living spaces by having a complete control over the full visible spectrum. The methods developed in this work provide tools and robust algorithms for the advent of novel SSL tunable light sources that can be used to improve the working conditions and to boost the levels of alertness and productivity.

OP07

DEVELOPMENT OF AN AUTONOMOUS SUN-SHADING DEVICE INTEGRATED WITH HIGH EFFICIENT OFFICE LIGHTING

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Abstract

1. Motivation, specific objective

Considering the appeal for more energy efficient buildings, it is necessary to reduce the amount of electric lighting in buildings. Utilizing daylight is a means to light the interior of offices building as well as reduce the amount of energy for electric lighting. Besides, solar energy is a means of producing electricity on site, directly from the sun, without environmental harm. But using conventional windows to let daylight come into the building will cause thermal and visual problems.

Facade systems including louvers or blinds can block out daylight in order to reduce the need of cooling the inside of a room and to reduce disruption by glare. However, most of daylight only reaches the part of a room nearest to the window, barely reaching the back of the room. And the intensity of daylight fluctuates greatly over the whole day. It is necessary to take both daylighting and electric lighting into account for office lighting design.

The research is to develop a façade system with a sun-shading device that is autonomously controlled as an integrated solution for daylight and electric lighting. The façade system has photovoltaic sensors on the outer surface of the sun-shading device and can monitor daylight illuminance by using output of the photovoltaic sensors. The photovoltaic cell modules can supply the electric power for the operation of the autonomously controlled façade system.

2. Methods

Firstly, this research examined thresholds of vertical global illuminance for the sun-shading control. The monthly thresholds were obtained from data of daylight illuminance and solar irradiance collected at the International Daylight Measurement Program (IDMP) station in Lyon, France. The monthly thresholds of vertical global illuminance, which considering the effect of seasons and window directions, were drawn as a function of the solar altitude or profile angle for judging whether the windows receive direct sunlight or not.

Secondly, this research proposed a new optimal sun-shading strategy named ‘PV-slat angle’. The ‘PV-slat angle’ is calculated from the solar profile angle and kept the surface of blind slats perpendicular to the direct sunlight.

Thirdly, this research processed illuminance simulations of electric lighting and daylighting. The electric lighting simulation was sat to solve the problem of insufficient daylight in the depths of the room under automatic the sun-shading control. The simulation of the interior illuminance distribution was carried out to examine differences of the electric lighting between control methods using the new PV-slat angle and the common cut-off angle control.

3. Results

Considering effects of the seasons and window directions, the sun profile angle is more suitable as a valuable than the solar altitude for the window facing between the southwest and west (or the east and southeast). But, for the window facing between the southeast and southwest, it is considered that solar altitude is appropriate.

The simulations of the interior illuminance distribution showed the proposed sun-shading control method using the PV-slat angle could provide advantages of building energy performance and visual comfort against the common control method.

4. Conclusions

This research proposes a new concept of a façade system with a sun-shading device that is autonomously controlled as an integrated solution for daylight and electric lighting. The photovoltaic cell module on the outer surface of the sun-shading device is capable of daylight sensing and power supply.

In this research work the orientation of the window was taken into account in the control. Thresholds of vertical global illuminance for judging direct sunlight presence were obtained from daylight measurements at the IDMP station in France. This research also proposes the automatic sun-shading control method named “PV-slat angle”.

Further study is needed to generalize the thresholds of vertical global illuminance. Moreover, the next goal of this research includes development of an intellectual electric lighting system concerning the control methods of the proposed autonomous sun-shading device.

OP08

COMPUTER GRAPHICS AND LIGHTING TECHNOLOGY SCIENCE. ON THE WAY TO THE CRITERIA OF THE ILLUMINATION QUALITY

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Abstract

1. Motivation, specific objective

At the beginning of the century, it was a great revolution in the design of lighting facilities (LF) - the transition from engineering methods of calculation of lighting facilities to modelling it an on a computer. The foundation of the revolution was laid even earlier, with the formulation of the global illumination equation (J. Kajiya, 1986) which called in the computer graphics - rendering equation. Should be noted that even earlier in 1940 P. Moon formulated this equation for diffuse reflection (the radiation equation), and by Z. Yamauti in 1926 in the discrete form. However, only half a century later, in 1999, the release of the Lightscape program opens a new era in the design of an LF. Lightscape itself did not make a big bang in the lighting design, but it makes a boon for the development of programs that became de facto standard in the modelling of the LF - DIALux, Relux, and others. A feature of many modern programs is that they are not based on the solution of the global illumination equation, but on the modeling of the radiative equation. It leads to the fact that they simulate the illumination. Nevertheless, the human eye reacts to radiance but not to illumination. The next step in the development of LF simulation programs became DIALux Evo, which implements the photon map algorithm, which applies to modelling the global illumination equation and allowing to simulate the radiance directly.

Nonetheless, there is a vicious circle. In most legal documents, the illumination for indoor lighting is normalized, where multiple reflections of light must be taken into account. Radiance, however, normalizes only in external illumination, where there are no multiple reflections, so that radiance should not be considered!

Nevertheless, in addition to the quantitative characteristics of lighting, there are also qualitative ones. The most commonly used in engineering practice is the Unified Glare Rating (UGR). UGR is calculated based on the radiance of the glare sources. Note that it considers only small-sized direct bright sources, while the extended reflections formed during reflection are not included in the UGR model.

As it showed in the classical works on the study of the discomfort of Ferree, 1915, Luckiesh M. and Guth S.K., 1949, it is the space-angular distribution of radiance in the field of view that makes the most significant contribution to the perception of the quality of illumination.

Thus, having the possibility of modelling the spatial-angular distribution of radiance, we can reconsider the approach to determining the discomfort and quality of illumination. As a result, it is possible to set a more ambitious task - the transition from LF design to specified quantitative characteristics to design for a given quality.

2. Methods

In our paper, we considered one of the methods for modeling the global illumination equation - local estimations of the Monte Carlo method. The method is well known in atomic physics and goes back to the work of Kalos, 1963. Further development of the method can be found in the optics of the atmosphere and the ocean in the solution of the radiation transfer equation. Note that the equation of global illumination is a consequence of radiation transfer equation. A similar algorithm for modeling the global lighting equation would be formulated in a phenomenological approach to the work of Keller, 1997. The implementation of the local estimation algorithm showed that it is not biased and converges. Research shows that the algorithms of local estimates are more efficient than direct modeling of the order of 1-2 for many practical problems.

Based on the research, we propose criteria of the illumination quality, based on the generalization of contrast as a ratio of the average contrast gradient to the threshold contrast. The result of calculating the criteria is the number, same as in the case of UGR. However, the absence of an eye model that

takes into account psychophysical perception requires the construction of a scale to determine the perception of this number: good or poorly lit, comfortable or uncomfortable, etc.

For this purpose, we created an experimental facility, which has similar features with the facility in Luckiesh, 1949. With this facility, it is possible to conduct perceptual studies and link the calculated quality criterion with psychophysical perception.

3. Results

To validate the experimental facility, we did the similar experiment as Luckiesh, 1949. Nonetheless, due to the differences between our setup from Lukiesh: the type of source (LED), its chromaticity, the different geometry of the installation, the learning process, etc. - the results of our experiments differed from Lukiesh. Consecutive elimination of these factors showed a shift in the results of research toward the values obtained in the work of Luckiesh, 1949.

In parallel, an additional series of studies of the quality criterion was carried out. At the time of registration of the sensation according to comfort-discomfort scale, the camera was photographed in RAW format, and the radiance of the glare source was measured. Based on these data, considering the calibration curves, a quality criterion was calculated. The results of the studies show that the quality criterion well describes the sharp transition of sensations for radiance at the comfort-discomfort boundary. At the same time, the criterion behaves smoothly in the region of comfortable sensations of radiance. It is a convincing proof of the correct choice of the spatial-angular distribution of radiance as the basis for the criterion of the quality of illumination.

4. Conclusions

Even today it can be argued that the proposed criterion can describe the quality of lighting based on the spatial-angular distribution of radiance, considering the psychophysical perception of the human eye.

The further work is connected both with a collecting of statistics of experiments on the created installation and with the transition to real lighting facilities. On the next steps, we assume modeling of a large extended bright surface, rather than of point glare sources, and an investigation of the behavior of the quality criterion on them.

The result of such studies should be an unambiguous scale describing the distribution of the quality criterion - "good - bad." As a result, even at the design stage of the lighting facilities, it will be possible to assess its quality on the basis of an analysis of the total space-angular distribution of radiance, taking into account multiple reflections of light, rather than on the basis of an analysis of direct glare sources, as it’s implemented in the UGR case.

Session PA1-3
Colour quality
Thursday, April 26, 13:30–14:50

OP09

STABLE COLOUR APPEARANCE AMONG CHANGE IN THE DIFFUSENESS OF ILLUMINATION

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Abstract

1. Motivation

The recent development of new solid-state lamps including OLED lighting would realize a wide variety of lighting conditions by controlling the spectral power distribution and distribution of light. Especially, OLED lighting would be a surface light source with strong diffuseness. The appearance of object surface could be largely influenced by lighting conditions and object materials. However, it has not been systematically analysed how surface appearance is influenced by the diffuseness of lighting. Our previous study showed that the diffuseness of lighting influenced the appearance of the glossiness and the roughness of an object (ICVS 2017). Here, we specifically focus on the influence of the diffuseness on colour appearance which is one of the important properties of objects.

2. Methods

We examined how the colour appearance of object surface was influenced by the diffuseness of lighting in real miniature rooms. We used two miniature rooms illuminated by a diffused light and a direct light, respectively. We presented a test sample at the center of the room. Test samples were thick square-shape resin patches with sine-wave surface which depth were 1.0, 0.5 and 0 mm. Both glossy and matte surface materials with five colours (red, orange, green, blue, and grey) were prepared for the samples. We tested two illumination colour conditions (correlated colour temperature 4200 K and 3000 K). An observer judged the colour appearance of a colour sample under each lighting condition by selecting a corresponding colour from a Munsell colour chart placed in a separate viewing box illuminated uniformly by the same colour as the test room. Each observer repeated the judgment three times for each condition. Three observers with normal colour vision participated.

3. Results

The results of corresponding colour for test samples were similar in both diffused and direct lighting conditions even if the luminance distribution of the surface was largely changed depending on the diffuseness of lighting and the surface glossiness. This trend was similar in all colour samples and two illumination colour conditions. These results suggest that the colour appearance of samples that we tested was quite stable.

4. Conclusions

Although surfaces appearance such as glossiness and roughness were influenced by the diffuseness of illumination and the surface material of an object, the colour appearance hardly changed, implying stable colour appearance among the change in material and illumination. However, it should be noted that the materials and conditions which we tested in this study are limited and further investigation would be needed to clarify the influence in the wider range of illuminations and materials.

OP10

ASSESSING CCT UNIFORMITY ON THE WORK SURFACE IN A REAL LIT ENVIRONMENT

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Abstract

1. Motivation, specific objective

Uniform light distribution is an important parameter of lighting quality. The extent of uniformity frequently depends on the function of the space and the type of activities. Normally only illuminance or luminance uniformity is considered. With the recent development of multichannel LED lighting technology, spectral power distribution (SPD) become tunable. Therefore, many parameters of light can be precisely controlled, such as light density, correlated colour temperature (CCT) and colour rendering index (CRI) etc. It is now possible to produce different levels of nonuniform CCT distribution with completely uniform illuminance.

The present study is a continuation of the earlier study on illuminance uniformity under indoor lighting. There are three goals in this study: to investigate how human eye assesses CCT uniformity on a work surface, to find an appropriate method to evaluate CCT uniformity, and to propose tolerance of an acceptable CCT uniformity for lighting design.

2. Methods

The experiment was carried out to study the uniformity of CCT in an office-like room. The work surface had a size of 1.6m x 0.8m x 0.75m. The room was lit by twelve 11-channels LED illuminators. Each illuminator can be individually controlled and can produce white light varying CCT from 2000K to 20000K. Due to the mired (micro-reciprocal) scale is a better measure of perceptual colour difference of white lights than the CCT scale, the LED system is used to produce a smooth variation CCT in mired scale along the work surface of a desk. All lighting conditions were accumulated at two CCT levels, with 4000K and 4800K at the middle of work surface respectively. At each CCT level, lighting conditions were divided into 9 levels of uniformity, which were 0.99, 0.95, 0.88, 0.83, 0.76, 0.70, 0.66, 0.60, and 0.53 in terms of min-max ratio. The average illuminance of all light distributions was 600 $\pm$ 25 lux.

Twenty normal colour vision observers were asked to assess each lighting condition in terms of acceptability, uniformity, and comfort. All observers were the students at Zhejiang university. They had an average age of 25 ranged from 21 to 34.

Each observer viewed the test lighting conditions following a random order. They were first asked to undertake a short task, which was to finish a 6 by 6 Schulte table. It was only used for observers quickly adapt to the lighting, and the results were not subsequently analysed. Observers were then asked to answer three questions: 1. Do you think this lighting environment is acceptable for office lighting? (Yes or No) 2. How uniform is the work surface? (1~5) 3. Do you feel the light comfortable or uncomfortable to work on? (-3~3). Question 2 was answered using a five-point categorical scale: 1. very uniform, 2. just notice non-uniform, 3. small non-uniform, 4. non-uniform, 5. very non-uniform. After answer the questions, next light was presented. All light distributions were repeated in another session. It took 1.5 hrs to finish two sessions for each observer. There was a break of 5 minutes in between.

3. Results

Wrong decision was used as a measure to quantify observer variation for the comfort and acceptability ratings. The results showed that for intra-observer variation, the mean results were 0.19 and 0.11 for comfort and acceptability respectively. While the mean results of inter-observer variation were 0.24 and 0.21 respectively. It is expected that the intra-observer variability is more consistent than inter-observer variability for both attributes. The observer variation of uniformity rating was quantified by STRESS value. Inter-observer variation ranged from 10 to 29, with a mean STRESS value of 17. While intra-observer variation ranged from 14 to 38, with a mean STRESS value of 22. This indicates that the uniformity rating results are reliable and repeatable.

Mean observer estimates were calculated for all light distributions. The results showed that comfort rating correlated well with non-uniformity rating (R^2 = 0.970). It indicates that a more uniform light distribution on CCT will be more comfortable. Various uniformity metrics have been compared with the mean score of non-uniformity rating. The mired range performed the best to evaluate the non-uniformity of CCT regardless of the CCT level (R^2 = 0.970). Other metrics were also found to agree well with the perceived non-uniformity rating. However, their non-uniformity ratings at two CCT levels did not coincide, unlike the mired range. Therefore, the latter is proposed to evaluate uniformity of CCT.

Two methods were used to obtain the acceptable uniformity of CCT. According to the relationship of unacceptable rate and mired range, lighting condition with smaller mired range is more acceptable to observer. And 50% unacceptable level corresponded to range value of 56.5 MK^{-1}. Another method to obtain acceptable uniformity was via comfort rating. Neutral point of comfort rating corresponded to non-uniformity score of 3.362, which led to a range value of 55.8 MK^{-1}. Two threshold values of acceptable uniformity agree very well. So, it can be concluded that the uniformity of CCT is acceptable when mired range is smaller than 56 MK^{-1}. Normally the CCT is more familiar than the mired value. Therefore, the kelvin ranges for different target CCT were also provided to produce comfortable lighting. For instance, the acceptable range of 6500K has a range between 5500K and 7950K, and between 2767K and 3275K for 3000K.

4. Conclusions

Experiment was conducted to assess three perception attributes including uniformity, comfort and acceptability under a series of CCT-nonuniform lighting. From the above results, the following conclusions can be drawn:

- Observers feel more comfortable when light distribution to have a more uniform CCT.
- The mired range performed the best to evaluate the nonuniformity of CCT, much better than those based on CCT.
- The uniformity of CCT is acceptable when mired range is smaller than 56 MK^{-1}. A look-up table has been established between the CCT and the acceptance limit in terms of CCTs corresponding to 56 MK^{-1}.

OP11

COMPREHENSIVE MODELLING OF COLOUR QUALITY FOR LED LIGHTING

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Abstract

1. Objective

Colour Quality of lighting has usually been assessed as naturalness, colourfulness (vividness) and preference by asking observers to assess some familiar objects, such as apple, banana, vegetables, etc. This topic has been extensively studied by many researchers such as those by Wei et al, Royer et al, Khanh et al, Xu et al, Liu et al, Zhai et al. The experimental results were used to test and develop colour rendering metrics such as CIE-Ra, GAI by Rea, MCRI by Smet et al, CQS- Qg and Qp by Davis and Ohno, ΔC* (using CQS test samples by Khanh and Bodrogi), GVI by Liu et al, IES-TM-30 Rf and Rg by David et al, IES-TM-30 Rch1 by Royer, and CQ by Zhang et al. They can be divided into three categories, colour fidelity, colour gamut and colour preference of familiar objects. In this study, a comprehensive colour quality modelling between metrics and different sets of visual data were conducted. Several combined models were devised and the latest version of uniform colour space CAM16 by Li et al was adopted to replace CIELAB or CIECAM02 in the models.

2. Models and Results

The data of visual assessments of naturalness, colourfulness (vividness) and preference under testing lightings in previous studies were selected and grouped according to the environments (living, museum, mart), sample types (objects from natural world, artificial objects, paintings, objects grouped by hue), and CCT range (multi CCT/duv or metameric lighting which includes lighting having the same CCT and Duv but varying spectral power distributions). In total, experimental data under over sixty lighting conditions were accumulated. The correlation coefficient calculated between the visual data and metric's predictions was used to report each model's performance.

The first test was conducted for the existing individual metrics including CIE-Ra, GAI, MCRI, IES-TM-30 (Rf, Rg and Rch1), CQS, CQS-ΔC*, GVI. It was found that CIE-Ra and Rf performed best in naturalness prediction as expected. Rch1 outperformed the other metrics for colourfulness data. GVI provided the most accurate prediction for preference data. This agrees well with the earlier findings from Liu et al and Xu et al. Note that the original GVI was calculating gamut volume in CIELAB, which was replaced by the most recent CAM16.

In consideration of comprehensive colour quality definitions, Rf, Rg or GVI, Rch1 and their cross term were modelled in polynomial equations to include all colour quality properties of fidelity, gamut size and gamut shape. Those were selected because they performed more or less the best in the first test. The present models were first trained by the data of metameric lightings with strict controlled parameters from the authors' earlier data. For naturalness prediction, the term of Rf affected the results most while for colourfulness Rg, GVI or Rch1 play more important role than Rf. The polynomial equations of these four metrics were found to be the best choices. Pearson and Spearman correlation coefficients and STRESS values were used to test the performance of the models. Other data sets from previous studies were used as testing samples. The CAM16 was used to replace CIELAB or CIECAM02 in the models. Detail results will be given in the full paper.

3. Conclusions

Rch1 and GVI calculated by CAM16 outperformed other single metrics in predicting colourfulness and preference of lighting. Polynomial equations of several metrics were modelled and tested using different visual assessments data of naturalness, colourfulness and preference. The present results clearly support the general concept of the IES-TM 30 to have a colour fidelity and a colour gamut metric to describe a colour preference. In addition, the colourfulness increment in the red direction would further enhance the metric.

Session PA2-1
Displays and imaging devices with lighting applications
Thursday, April 26, 15:20–17:00

OP13

PSYCHOPHYSICAL APPROACH FOR EVALUATION OF OLED PANEL PERFORMANCE

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Abstract

1. Motivation

Organic Light-Emitting Diode (OLED) is recently expected as one of the next generation lighting devices. OLEDs have many unique characteristics such as thickness and flexibility. One of the most unique features is that it is a planar, 2-dimensional surface-emitting lighting device. Since the OLED is a panel-shaped lighting device, non-uniformity of OLED is easily detected compared with conventional point or line light-emitting devices. Furthermore, due to the electric properties of the OLED and physical factors in its production process, OLED panels essentially have some non-uniformity in the chromaticity and luminance. Non-uniform current density mediates non-uniformity in luminance distribution, and the interference of the thin layers and films mediates angular dependent colour non-uniformity. Therefore, luminance uniformity inside the panel, and angular dependent uniformity in chromaticity are both important features that should be properly assessed for the performance of the OLED panel.

TC 2-68 has been working to propose appropriate measurement methods of the optical properties of OLED panel. The evaluation of luminance non-uniformity and angular dependent colour non-uniformity have been studied to find an evaluation metric to assess the uniformity of the OLED panel. It would be desirable if such metrics reflect human perceptual characteristics, as they are intuitively comprehensive. Thus, we have conducted several psychophysical experiments which enable us to propose a metric based on human perception.

2. Methods

We conducted two experiments on luminance non-uniformity (Exp. 1) and angular colour change (Exp.2). Both experiments were conducted with an LCD display, mimicking the real OLED panel.

In Exp. 1, we simulated 14 different patterns of luminance gradients to the square shaped stimulus. First the subjects were asked to score the intensity of the observed non-uniformity included in the stimulus. Then, the subjects conducted 2AFC experiment. In this session, the subjects observed a reference stimulus with random pattern non-uniformity and a test stimulus with luminance gradient, and selected the stimulus with larger non-uniformity. The magnitude of the luminance gradient was changed and a point of subjective equality (PSE) was obtained for each gradient pattern.

In Exp. 2, first the angular colour shifts were simulated as a temporally modulated colour change. The colour of the stimulus was modulated temporally along several colour directions. Considering the situation of the evaluation of the panel for angular dependent colour shift, it might be desirable that the observer can freely select the direction of the gaze. We developed a new device for this evaluation. The subject observed a stimulus whose chromaticity (and the shape) was changed according to the orientation of a tablet which the subject could freely manipulate. This mimicked the performance of an OLED panel. Three luminance levels and 8 different trajectories of colour shifts were tested. The task of the subject is to rate the perceived magnitude of chromatic change of the stimulus.

3. Results

From Exp. 1, it was found that, as expected, the larger the luminance gradient, the less uniform the stimulus appeared, and they showed the similar trends regardless of the gradient patterns and directions. However, when compared with a reference pattern, the results showed that uniformity perception was affected to some extent by the gradient patterns. While simple patterns of linear change showed almost the same trends, complex patterns, such as bath-tub or radial change, stimuli whose central area was brighter than its peripheral area had higher uniformity than those with the reverse pattern. These results indicate that the polarity of luminance on central area of the stimulus, whether it is higher or lower than average value, can also be the factor for uniformity perception. This finding is supported by our supplementary experiment, in which subjects were asked to select non-uniform stimulus out of two

different random patterns of the same magnitude. After conducting hundreds of trials, the average images were calculated, and the luminance of the central area was higher for “more” uniform stimulus. A metric based on the luminance gradient has been proposed previously. When compared with a uniformity index based on the maximum and minimum luminance values, the metric based on the gradient showed a better correlation with the evaluation rates.

The results of Exp.2 indicated that the perception of chromaticity change depends not only on its chromaticities but also on the luminance level. The results showed a MacAdam-like ellipse for the overall behaviors. Our findings were installed to the current metric adopted in IEC, which calculated the non-uniformity based on the colour difference among different colour directions. Compared with values predicted by the existing metric, our new model showed some improvement in its performance.

4. Conclusions

According to the results of our psychophysical experiments, it is suggested that not only the luminance gradient, but also the polarity of the gradient is important in non-uniformity evaluation, and it would be better to introduce a hue dependent factor in angular dependent colour evaluation.

In order to take the human perceptual properties into consideration, psychophysical experiments are essential, and we believe that the models or metrics will get improved with such properties.

OP14

AN ADAPTIVE DISPLAY DIMMING CURVE FOR ENHANCED WORK PERFORMANCE AND VISUAL COMFORT

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Abstract

1. Motivation, specific objective

Self-luminous display devices, such as tablets, are becoming more and more common in our daily life and are also becoming essential devices in office spaces. This study aims to derive a dimming curve for adjusting the brightness of a display based on the ambient lighting, with a goal to enhance the work performance and visual comfort of users.

2. Methods

This experiment was carried out in an aircraft cab. Six high-power LED floodlights were used to produce five different ambient lighting conditions. The observers completed visual tasks on a display, which was set at five different brightness levels under each ambient lighting condition. Thus, each observer completed the visual tasks under 25 combinations of display brightness and ambient lighting conditions, with five in each trial, with a goal to avoid the visual fatigue caused by the long experiment.

For each combination, the observer performed the work performance test, visual fatigue test, and a questionnaire to rate the level of visual fatigue and visual comfort. Electro-oculogram (EOG) data was collected throughout the experiment and the Critical Fusion Frequency (CFF) test was performed before starting the visual task to evaluate the level of visual fatigue. The observers were asked to read the Ann Fermo J correction table. The hit rate, the false alarm rate, and the duration of the reading were recorded. When the observers completed the task, the CFF was carried out again. The difference of CFF before and after the visual task and characterize the visual fatigue. At the end, the observers completed a questionnaire to rate their level of fatigue and visual comfort. The same procedure was followed under each of the 25 combinations of ambient lighting and display brightness.

3. Results

Analytic hierarchy process was employed to comprehensively evaluate the work performance, visual fatigue and visual comfort of the observers under each condition. A dimming curve was derived to illustrate the optimal brightness level of the display under each ambient lighting condition

4. Conclusions

Psychophysical experiment was conducted to investigate the optimal brightness level of displays under different ambient lighting conditions, with a goal to enhance the work performance and visual comfort. A dimming curve was derived using the analytic hierarchy process.

OP15

INVESTIGATION OF GLARE METRICS FOR REFLECTED GLARE ON DISPLAYS

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Abstract

1. Motivation

The world of electronic information displays has moved on a lot in the last few years. There are new technologies and certifications, all aimed at approaching display technology take the next leap forward. People typically watch displays under ambient light sources, even strong direct sunlit, that causes extremely intense perception by reflected light from the display surface. Extremely reflected glare on displays might affect visual performance, fatigue and headache, but there are rare reports to address the applicability of current glare metrics for the reflected glare on display, especially in low glare level. This paper reviewed the popular glare metrics and conducted an experiment to present the applicability of those metrics for predicting glare on electronic displays in indoor environments.

2. Methods

This work investigates three kinds of glossy, matte and light matte displays under 2 ambient lighting conditions. One is the normal condition with indirectly lighting on the target display and the other condition is the reflected glare condition that a set of linear fluorescent lamps is setup behind observers. For all treatments of the experiment, the luminous distributions of displays are measured by an Imaging Luminance Measuring Device (ILMD).

By device-dependent colour transformation, the colour image of the calibrated ILMD can be converted image pixel digital signal ($RGB_{8\text{-}Bit}$) into CIE xyY colour tristimulus. In this study, the luminance of spatial 2D pixels is raw data for calculating glare metrics.

In addition, the surface reflection characteristics of displays are presented by their Bidirectional Reflectance Distribution Function (BRDF). Because the reflected lights of the display incident to eyes are integrated over visual field angles, multi-angle light reflection must be considered with different display surface material, relative incident angle and observer's viewing angle. The measured BRDF of the displays is applied to fix the resultants from the ILMD.

To test the reflected glare on display, the joint effects of display polarity and illumination condition were assessed. There are total of 12 reflected glare conditions will be measured, three displays, two display polarity positive (dark characters on light background) and negative (light characters on dark background) and two kinds of ambient illumination. Six glare metrics are investigated and calculated to predict the reflected glare on displays, they are disability glare model (DGM), threshold increment (TI), deBoer discomfort glare rating (dBDGR), ASSIST discomfort glare (DG), ASSIST deBoer glare (DB) and unified glare rating (UGR) respectively.

3. Results

Background luminance and ambient illuminance are necessary parameters in current glare metrics. Background luminance was calculated for the positive content under normal condition, the results of glossy display, matte display and light matte were 82.9213, 83.4258 and 83.856. Ambient illuminance was measured under normal condition and the target display was closed, the result was 550 (lx). The values of two parameters were applied in current glare metrics.

Current glare metrics was implemented for analysing reflected glare on displays, the analysed results of DGM, TI, dBDGR, DG, DB and UGR were listed sequentially to present the applicability. The positive content were measured under direct linear fluorescent lamps condition, the glossy display results were 0.0004, 9.3477, 8.9429, -399547.3206, non and 7.7827, the matte display results were 0.0003, 24.6011, non, -1201452.633, non and 9.0424, the light matte display results were 0.0003, 2.3064, 9.2989, -111879.1874, non and -0.1511. All results were compared interactively, TI, DG and UGR present the similar trends, the dissimilar trends were found in DGM and dBDGR, DB cannot be calculated. DGM, dBDGR and DB was inappropriate to analyse reflected glare.

Results revealed that TI, DG and UGR present the similar trends which were appropriate to analyse reflected glare when the positive content was under direct linear fluorescent lamps condition. Another aspect, some issues were disclosed. The glare values of DG and UGR were over regular upper limited value, and the glare values of TI were extremely too close to showing a difference among 12 reflected glare conditions.

4. Conclusions

This paper explored the applicability of current glare metrics for reflected glare on displays. Some metrics present the similar trends, but the values are out of the prediction range. Results revealed that most glare metrics were not suitable to predict the reflected glare on modern displays. It is expected that there are more researches to address and to re-model the reflected glare assessment in the future.

OP16

CONTRAST RATIO STUDIES OF A LED-FLASHED TRAFFIC SIGN AT A FOGGY ROAD

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Abstract

1. Objective

LED lighted road in fog is a new challenging issue for road safety, especially for the recognition of traffic sign. This subject is quite complex because of many variables such as concentration of fog, distance between observer and traffic sign, passive or active type of traffic sign, and projection of headlight would influence the visibility. To systematically study the problem, we used an image luminance measuring device (ILMD) to capture the luminance images of a commercial traffic sign under various controllable conditions in an experimental road. We analysed the luminance images with contrast ratio on the ROIs of the traffic sign.

2. Methods

A left-turn traffic sign with flashed-LED function was placed at roadside of an experimental 2-lane road, which was lighted with LED or high pressure sodium (HPS) luminaires. Various levels of foggy environments were generated by several water mist machines along the road. The distance (d) of the traffic sign from the first pole of lighting was varied as 10 m, 20 m, and 30 m. A headlight was additionally used to project low or high beam to the traffic sign.

Under these experimental conditions, many of luminance images of the road were captured for the analyzations of the visibility, which was defined as area Michelson contrast ratios (C) between the sign area, paint area, and background. The luminance images of road were measured with a calibrated ILMD with 10-22 mm focal length. The ILMD was placed at distance of 30 m between the nearest pole, and the height of the ILMD is 1.5 m.

3. Results

The contrast ratio of paint area of the traffic sign to the surround background (C_{pb}) was defined as an index of influence of fog. The smaller C_{pb} means the more concentrated foggy environment, and vice versa. The average contrast ratio of paint area to signal area (C_{ps}) can be evaluated as visibility of the traffic sign in the fog level of C_{pb}.

As both flashed-LED function and headlight off, in clear weather, C_{ps} for the LED lighting case is varied from 0.62 at d =10 m to 0.27 at d = 30 m. This may be originated from the weak vertical illuminance at intermediate position between light poles. For the HPS case, however, C_{ps} for the LED lighting case is varied from 0.67 at d =10 m to 0.49 at d = 30 m. The better contrast ratio of HPS than LED luminaires at intermediate position meets the visibility experience for some drivers.

In foggy environment, as flashed-LED function off, C_{ps} for the LED lighted case is well proportional to C_{pb} with factor between 0.78 and 0.83 for all distances and headlight status (off, low beam, and high beam). For the HPS lighted case, the factor is between 0.76 and 0.84, which is close to that of LED. This feature may be caused from the nature of a passive, reflected traffic sign.

In foggy environment, as flashed-LED function on, C_{ps} is approximately linear with C_{pb} for all headlight status. However, the slope (S_{pb}) and intercept (C_{pb0}) are dependent on the type of luminaire and position of the traffic sign. For LED luminaire, (S_{pb}, C_{pb0}) are (0, -0.27), (1.13, -0.93), and (1.63, -0.96) for d =10 m, 20 m, and 30 m, respectively. The positive S_{pb} and negative C_{pb0} means that in some conditions of fog concentration and headlight status, the visibility is contrarily lowered. This feature suggests more careful drive in these conditions because of bad recognition.

4. Conclusions

In this work, we have measured a traffic sign by an ILMD under various conditions to study the visibility of a LED or HPS lighted road in artificial fog. We defined contrast ratios C_{pb} and C_{ps} as the level of fog

and index of visibility of the traffic sign, respectively. The analyses on the experimental results show that C_{ps} of passive state of the traffic sign is about $0.8C_{pb}$ for all varieties of luminaire and headlight. While C_{ps} of active state is linear with C_{pb}, and the intercept and slope are fairly dependent on position and type of luminaire.

Session PA2-2
Adaptive, intelligent and dynamic lighting in exterior environment
Thursday, April 26, 15:20–17:00

OP17

PEDESTRIANS SUPPORT SYSTEM USING VISIBLE LIGHT COMMUNICATION

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Abstract

1. Introduction

Currently, more than 200 thousand people are in low vision condition in Japan. People in low vision are visually impaired but not completely blind. Their conditions are various, e.g., double or blurred vision, vision distortion, or peripheral vision loss. With the development of the technology, more and more people with low vision use computers and smartphones. Therefore, they are able to find a route to their destination beforehand and, Global Positioning System (GPS) is able to guide them to destinations. However, the accuracy of GPS walking assistance deteriorates in the shadow and inside of buildings. Furthermore, the maps does not indicate any steps and obstacles on the route, and also there could be many difficulties on the road such as barriers for construction works. Written notices or safety cones with vivid colours/ high contrast colours are often used to indicate caution. They are enough for people with normal vision, however they may not be easy to see by people with low vision, particularly in the night. It is important to make more accessible environment for everyone. Information using light and audio message could be more appropriate for people with low vision. However, constant audio message from a speaker could disturb people with normal vision and residents. Therefore, we are developing a pedestrian support system for people with low vision. The system utilizes Visible Light Communication (VLC) with Light-Emitting Diodes (LEDs). VLC is wireless communication using light in the human-visible wavelength ranged from 380 to 780 nm, and is a communication technology which can be incorporated into existing illumination. The directionality of LEDs is suitable for controlling the communication areas. Therefore, by using this system on streets, pedestrians with low vision can not only get helps from the light but also get audio information or caution anywhere they need including shadow and inside of buildings where GPS cannot reach.

In this study, the hearing and questionnaire survey was carried out to understand life style, difficulties in life and also to know needs of people with low vision, particularly during walking outside. From their need, the VLC system was proposed to be incorporated into illuminated bollards which were short, vertical posts placed on the road to control traffics or indication for people with low vision, and also tactile paving with illumination which is guidance, warning tile blocks for visually impaired people. We also proposed styles of receivers which have functions to receive the VLC signal from the light. By connecting receiver to smartphones, pedestrians are able to listen audio information.

2. Methods

The hearing and questionnaire survey was conducted in order to understand the difficulties of people with low vision particularly when they go out, and also their life style and fashion style such as types of bags they use, whether they use smartphone and so on. Based on their answers, the systems: hardware and software, were proposed. The prototypes of VLC system were made. One of them was a system incorporated into illuminated bollard. In order to find appropriate light, visual assessments were carried out by participants with normal vision and low vision. Different colours of LEDs (white or yellow) and luminescent patterns (the number of flash, flash pulse-width, etc.) were compared in terms of glare, flickering, sharpness, tiredness, surround visibility, preference, etc.

3. Results

From the results of the visual assessment, although the differences were found between participants with normal vision and low vision, some of the light found to be suitable for both normal and low vision people. Considering the characteristics of the light, white LED lights whose flash pulse-width of 1.25 ms, flash rate of 3.5 Hz was selected for the bollard. The data signal is superimposed on the blinking light emission of the bollard. The data is transmitted during one flash pulse. The data rate is 125 kbps so that a sufficient volume of data can be transmitted within the time period of the pulse. Because pulse-position modulation (PPM) is a technique that achieves very good average-power efficiency, 4-PPM is used as the signal modulation of the VLC transmitter.

From the results of the hearing and questionnaire survey, it was found that many people with low vision used smartphone therefore a few different types of receivers were proposed which have functions to receive the VLC signal from the light and play audio information.

4. Conclusions

A pedestrian support system for people with low vision were introduced. The system utilizes Visible Light Communication (VLC) with Light-Emitting Diodes (LEDs). VLC is wireless communication using light in the human-visible wavelength range. In this study, the ideas for the system such appropriate lights and receiver are proposed. The support system is still under development. This system will not only used for people with low vision, this could be extended to use for normal vision people to access information such as direction, tourist guide and advertisement.

OP18

NEW EMPIRICAL DATA FOR PEDESTRIAN LIGHTING: EFFECT ON RECOGNITION ABILITY ON REAL 3D FACIAL EXPRESSION

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Abstract

1. Introduction

With the technology development of LED lighting, the energy consumption of road lighting in many countries might be reduced by using better lighting. Road lighting need to be provided for pedestrians to ensure a safe walking environment and to meet their visual needs without any unnecessary energy consumption. Recognition of facial expression is an important part of interpersonal judgement, which is considered to be a critical visual task of pedestrians. Past studies investigating the effect of lighting level and SPD on facial expression mainly used 2D photos as visual stimuli in the lab-based experiments. There might be a systematically deviation on the results than in realistic scenario where human faces are presented as a 3D visual object. In this study, the ability of 3D facial expression recognition under different lighting conditions was tested, aiming to obtain the visual performance curve that can be used to provide scientific basis in formulating road lighting standards that are more suitable for LED lighting source in the future.

2. Methods

Laboratory experiments were performed to test the abilities of 3D facial expression recognition under 15 lighting conditions. Three spectral power distribution (SPD) equivalent to high pressure sodium (HPS), metal halide (MH) and LED with high scotopic/photopic ratio (LED-SP), as well as five lighting levels (0.33, 1.00, 3.33, 10.00 and 33.33 lux) were used. The SPD was modulated using a multi-channel and full-spectrum LED cube. Terracotta heads with four 3D facial expressions (angry, happy, surprise and sad) were placed in the self-developed electro-mechanical platform. The platform can display one of the expression in a counter-balanced manner, and can collect responding data onto a connected laptop.

Tasks will be performed by 30 young participants (15 male and 15 female). Participants were asked to identify the 3D expression under all 15 different lighting conditions, and to press one of the four corresponding keys on a keyboard as response. Correctness and reaction time of the response were recorded as raw data. Each test participant carried out all 240 possible trials (3 SPDs, 5 illuminances, and 16 trials). The order of the trials was counterbalanced to avoid order effect. In the task, practice trials were used to confirm understanding and familiarity on the task.

3. Results

The score of each trial is the frequency of correct response among the 16 times 3D facial expression recognition. The initial results show that when illuminance increasing from 0.33 lux to 10.00 lux, the score of recognition under LED-SP was also increasing from 2 to 10 points, and performance is no longer increasing when the illuminance is higher than 10 lux. In addition, the initial results also show that when illuminance was 33.33 lux, the score of trials under each SPD was similar, about 10 points. The score under LED-SP was the highest among three when illuminance was 0.33 lux and the performance under MH was the best when illuminance was 1.00 lux and 3.33 lux. Note that the initial results are based on only two participants. More results with statistical analyses will be included in full paper.

4. Conclusions

This study analyses the ability of 3D facial expression recognition under lighting for pedestrians, obtaining the response curve of pedestrians' visual reaction ability and lighting condition by experiments. It was found that higher illuminance can help pedestrians recognize people’s expression more easily, while it does not get better effect when the illuminance reaches a certain level. The effect 3D-versus-2D on the ability of facial expression recognition will be analysed in full paper.

OP19

ADAPTIVE LIGHTING IN MOTORIZED TRAFFIC ROAD: REAL INSTALLATIONS SHOW THAT IOT TECHNOLOGIES CAN SUPPORT THE CORRECT USE OF STANDARDS

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Abstract

1. Motivation, specific objective

In the world of Smart Cities and IoT, traditional pre-programmed street lighting dimming systems are perceived as obsolete. Capable of measuring three essential parameters for outdoor areas lighting control (traffic, weather conditions, and road surface luminance), a new generation of sensors is providing, at reasonable costs, opportunities for new approaches in both design and maintenance of road lighting installations.

The standard EN 13201-1:2015 and CIE TR 115:2010, introduced specific chapters about new approaches of *Adaptive Lighting*: both lighting designers and Municipalities will be now able to operate real time PLMS (Public Lighting Management Systems) through sensors installed within their territories, with benefits in terms of energy saving and increased road safety. The new Italian standard UNI 11248 sets a number of parameters (dimming speed, maximum dimming levels, number and periodicity of samples, calculation parameters, control strategies, etc.) to ensure, in different real time measured conditions, maximum driving safety. The Italian standard introduces two adaptive lighting strategies: the TAI (Traffic Adaptive Installation), where only the traffic volume is measured and the FAI (Full Adaptive Installation), where even weather conditions and road surface luminance are measured. When FAI is being deployed and safety conditions are guaranteed, UNI 11248 allows a downgrade up to 3 lighting classes, corresponding often to 75% dimming of the luminous flux required by the initial lighting class.

Even if these standards are requiring specific real-time measurements, more and more municipalities seem to be attracted by simpler Adaptive Lighting systems, able to detect only occupancy or movements. Clearly, according to standard for motorized traffic roads, this approach should not be considered. Such simple Adaptive Lighting systems well fit, with good results, in parks, gardens, or pedestrian area. On motorized traffic roads, the main driver visual task is obstacle identification, which is proportional to traffic flow and not to lane occupancy or movement.

One reason that didn’t help Adaptive Lighting Systems diffusion was related to lack of technological advanced sensors, which did not give the possibility to install, on road, reliable traffic flow monitor and weather sensors coupled with luminance sensors.

Today, with the help of computer vision technology, this is possible. Unfortunately, sensor cost and limited analysis area are negatively influencing a broader diffusion.

2. Methods

Thanks to EU program LIFE, an innovative approach has been designed and applied in the city of ROME, within EUR district, with the project LIFE-Diademe.

Today, the IoT technology (Internet of Things) is allowing to install, on each lighting pole, low cost sensors, able to detect luminance, traffic flow and weather conditions. All these parameters can be measured in a more accurate way and, above all, in a wide urban area. Within the LIFE-Diademe project, 1000 devices have been installed on 1000 lighting poles, to measure, in a selected area, relevant parameters for Adaptive Lighting. For obtaining a wide records of typical road lighting situation, the tests considers urban contests representing different type of traffic: residential, offices, shops, Public Administration, University, etc.

On-site expert systems analyse streets data and, thanks to the 3 basic evaluated parameters, they adapt street lighting levels in real time mode (measurement and dimming time is executed every minute).

3. Results

To set the base line, a complete lighting measurement campaign has been executed for the 1000 lighting points through EUR Rome. For different pre-set light levels, visual luminance, lighting point luminance, street light uniformity (transversal and longitudinal), pedestrian zone lighting levels and power absorbed by each control panel has been collected.

Then the new LIFE-Diademe system has been installed.

First data about behaviour of the system are showing an approximate energy saving of about 30% compared to pre-programmed dimming cycles, and 50% compared to no dimming. These data are comparable with other Adaptive Lighting installations – designed according to standards – where the most significant result is that in most of the urban roads, for 90% of the time, traffic flow is less than 10% of road nominal capacity.

Thanks to new IoT concepts, data about air quality, noise and pole inclination will also be collected from each lighting point.

4. Conclusions

The LIFE-Diademe project experience will run for one year. This permits to collect a reasonable sets of data. After this period, a new lighting measurement campaign will be performed and, consequently, a Life Cycle Assessment (LCA) and a Life Cicle Cost Analisis (LCCA) analysis will be carried out, in order to asses results, in terms of energy saving, safety, waste reduction, and, finally, sustainability.

OP20

INFLUENCE OF ADAPTIVE STREET LIGHTING ON LED LUMINAIRE LIFETIME

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Abstract

1. Motivation, specific objective

In adaptive control of street lighting luminaires, their light output is based on the demand of illumination. When there is no traffic, the luminaires are dimmed, but brightened when vehicles or pedestrians appear. This type of lighting control saves energy and reduces light pollution.

LED luminaires should withstand the effects of periodic dimming. However, ongoing dimming and brightening of the luminaires causes thermal stress to the LEDs. Thermal cycling is used in hammer testing to accelerate degradation of the electronics so thermal stress may also shorten the lifetime of luminaires. On the other hand, dimming the LEDs reduces the current through LEDs, decreases the junction temperature, and thus extends the lifetime. The net influence of the contradictory effects is worth studying.

The CIE Research Strategy topic on Adaptive, Intelligent and Dynamic Lighting includes the following research questions: Which types and levels of dynamics are acceptable in a lighting installation? What are the energy and operational costs and benefits of adaptive lighting? The experimental observations in our work contribute to answering these questions.

2. Methods

In our study, we have aged inside at the ambient temperature of (25 ± 3) ℃ a batch of 20 LED street light luminaires from two manufacturers A and B in conditions addressing the effect of adaptive control. The types of the luminaires were chosen to be suitable for highway use. In the ageing test, five luminaires from manufacturer A and five luminaires from manufacturer B are switched on continuously for 9 hours and off for 3 hours. The other sub-batch of 10 lamps is operated in such a way that they are switched on for 30 seconds at full intensity and then dimmed to 20% of the full intensity for 30 seconds. The 30+30 seconds dimming and brightening sequence is continued for 9 hours, after which the luminaires are switched off for 3 hours. The 3-h switched off period is used to cool down the luminaire to simulate the natural cooling during daytime when the street lights are not on.

To study the ageing difference between the periodically dimmed and continuously driven luminaires, their electrical and photometric properties are measured regularly every three to six months. During the starting period, more frequent measurements were made. The measurements are carried out in an integrating sphere for the relative spectral radiant flux, luminous flux, electrical power, and luminous efficacy. When comparing the results for luminous flux and luminous efficacy between different measurement rounds, the relative measurement uncertainty is less than 1 % at 95 % confidence level.

3. Results

Our experiment on ageing the street light luminaires takes place since April 2014. During the first 2 years of ageing, the luminous flux and efficacy of the luminaires gradually increased 2 % to 5 % depending on the sample and manufacturer. During the same time interval no differences could be observed in the optical or electrical parameters between the groups of the periodically dimmed and continuously driven luminaires. Thereafter the situation changed systematically for luminous flux and luminous efficacy.

After 3.5 years of ageing, the periodically dimmed luminaires of manufacturer A show, on the average, 3 % smaller luminous flux than the continuously driven luminaires. The luminous flux values of both groups of five samples are clearly separated, as the spread within a group is well below 1 %. For the luminaires of manufacturer B, a similar clear effect is seen with an average difference of 2 % between the periodically dimmed and the continuously driven luminaires. The group of continuously driven luminaires contained five samples, whereas two periodically dimmed luminaires of manufacturer B were

removed from the analysis, because their flux had suddenly dropped to 70 % of the initial value. All other luminaires are still above 96 % of their initial luminous flux.

For luminous efficacy, similar separate groups of periodically dimmed and continuously driven luminaires were observed as for luminous flux. The changes in luminous flux explain the changes in luminous efficacy. Some trend of grouping in correlated colour temperature values can also be observed. However, the results are not yet conclusive enough to say that there would be a difference in the colour temperature change of periodically dimmed and continuously driven luminaires.

For the predicted 70 % lifetime, an extrapolation can be made on the basis of the presently available data with the result that the lifetime of the continuously driven luminaires would be at least one year longer than the lifetime of the periodically dimmed luminaires. It remains to be seen whether smooth decay of luminous flux or discontinuous changes, as observed for the two periodically dimmed luminaires of manufacturer B, will be the dominating mechanism limiting the lifetime of the luminaires.

4. Conclusions

We have selected the periodical dimming and brightening of the luminaires in such a way that it maximizes the thermal stress in the luminaires in order to be able to study the ageing effects experimentally. In actual street lighting applications the probable number of dimming cycles per given time interval would be much smaller. Nevertheless, our data will give the first published results on the effect of the number of dimming cycles on the predicted luminaire lifetime and can potentially be used to optimize the control of adaptive lighting in order to minimize energy and operational costs.

OP21

POTENTIAL OF ENERGY SAVINGS IN TRAFFIC-FLOW CONTROLLED STREET LIGHTING SYSTEMS

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Abstract

1. Motivation, specific objective

Street lighting is a public service provided to inhabitants and visitors of our cities, towns and villages. Besides safety functions street lighting or urban lighting in general is important for creation of pleasant night-time atmosphere and beautification of night-time environment. Different approaches are used for illumination of roads, boulevards, footpaths, squares, parks, central zones, industrial zones and residential areas. Future development of urban lighting now relies on the advanced LED technology and aims to build free-to-control smart lighting systems as an essential part of smart cities. Lighting is losing its independence from other infrastructural subsystems and tends to integrate with traffic, telecommunication, utility services and others. Those interactions are in particular significant that have direct influence on setting of target lighting parameters: weather conditions, visibility level, traffic conditions (density, volume, speed), user presence and demand, composition of users etc. Traffic flow belongs undoubtly to those requiring special attention.

LED technology brought to urban lighting a number of benefits: high luminous efficacy, tailored optics, free choice of colours, dynamic control. Conventional light sources had very limited control possibilities: typical scheme offered a reduced (usually halved) lighting level during night-time hours with low traffic. Dimming, if any, was controlled centrally by means of e.g. voltage regulators. Controlling of LED luminaires offers unlimited freedom: switching or dimming has immediate response and does not affect negatively to lamp's lifetime. Instead of central dimming, thanks to wireless network systems control of individual luminaires is easy. This is the technical precondition to provide lighting on demand – where and how much it is needed in terms of place and time. However, still there is lack of methodology how to describe the actual visual needs of drivers, cyclist, pedestrians or other users, and to define and setup the right lighting parameters to them.

In consequence of lacking methods, not smart-ready luminaires and first of all due to inherited lighting networks with mixed types of lamps, lighting systems are not optimally controlled and it is still a common practice to operate the lighting on full level throughout the night. It is obvious that there is huge potential of energy savings when comparing the state-of-the-art with what from the optimally designed lighting system can be expected. This paper is focused on lighting control based upon detection of traffic flow and its contribution to reduction of energy demand to lighting. Special regard is given to residential areas where the biggest reduction of lighting is supposed.

2. Methods

Energy consumption of road lighting depends on installed power, duration of time in operation and lighting control which implies the variation of power in time from both short-term and long-term perspective. The latter can be e.g. the effect of constant light output (CLO) control or due to maintenance of luminaires. Variation of power over time can be expressed by means of lighting control profiles. Standard control profiles are used to calculate then the energy consumption. Most of parameters are predictable, however, in systems with detectors probability functions must be used and energy demand of a lighting system has to be determined by estimation.

On the other hand, detection of moving cars or presence of persons has to be linked to area of luminaires which should react by increasing the light level locally, taking into account direction of movement and possible continuation by turning left or right at the crossings. Here further assumptions like the relevant road length, time of drive trough, light levels, time of sustaining light levels etc. have to be taken into account and probability of the overlapping of illuminated areas has to be estimated, too. The paper aims to describe situations for the most common lighting tasks in urban lighting and to specify the parameters for description of lighting profiles.

The paper also aims to introduce collection of data acquired from traffic detectors installed at different sites of road sections in poles of traffic lights. Counters are installed mainly on major roads, residential areas are not covered. Here for monitoring of traffic flow camera based devices are currently installed and installation of more advanced systems with image analysis is in preparation. Objective is to acquire figures of traffic flow in different periods of time for better imagination on detection probabilities and traffic density needed to derive the corresponding lighting class according to the Publication CIE 115.

In addition to energy consumption, energy performance of lighting system can be expressed through the couple of compound numerical indicators PDI and AECI as per EN 13201-5. AECI in particular incorporates the lighting control and will be dealt in the paper.

3. Results

Results presented in the paper comprise presentation of data on traffic flow at different sites of a capital city and a disctrict-size town on major roads and in residential areas. For different applications including main streets – arteries and radials, webbed streets of a residential area, settlement units, etc. standard schemes with lighting control profiles and descriptive parameters will be provided. For case studies, energy saving potential will be estimated.

4. Conclusions

Smart lighting is lighting adaptive to different external conditions, integrating additional functions, providing light on demand – increasing thus the comfort to the user and the same time cosiderable reducing energy demand in comparison to steady-state passive lighting systems. Implementing lighting control with traffic flow detectors may discover huge potential of energy savings and to help to preserve natural resources and the environment. Additional benefits are in reduction of obtrusive light, protecting the nocturnal life.

Session PA2-3
Colour and vision (1)
Thursday, April 26, 15:20–17:00

OP22

KANSEI EVALUATION OF COLOUR IMAGES IN VARIOUS COLOUR GAMUTS USING DIFFERENT RED PRIMARIES

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Abstract

1. Motivation, specific objective

Along with the development of advanced display technology, high resolution and super-wide colour gamut are spreading to our everyday life. ITU-R BT.2020 (Rec. 2020) was established in 2012 for SHDTV broadcast [1]. Its RGB primaries are equivalent to the monochromatic wavelengths of 630nm, 532nm, and 467nm, considering the expansion of laser display although it needs for a while. On the other hand, DCI-P3 has been already implemented in upper models of wide display and mobile phones. Its blue primary is the same as sRGB, green primary is close to 545nm but slightly inside the spectral locus, and red primary is equivalent to the monochromatic wavelengths of 615nm. The wide gamut area, 25% larger than sRGB, is mentioned as the advantage of DCI-P3 [2].

However, in ordinal conditions, and for ordinal observers, KANSEI property of colour images on a display is more important than how wide the colour gamut is. KANSEI is a Japanese word meaning a mental sense of subjectivity, being a higher order function of the human brain. It is interpreted in English as sensitivity, feeling of emotion, or psychological feeling. Preference, naturalness, and impressiveness, etc. are often used as the KANSEI evaluation words. In the previous studies, we investigated the best blue and green primaries from KANSEI evaluation point of view. For blue primary, 470nm is the best as a total, probably because appearance of bluish region (the sky and the sea in the test stimuli) looked nearly unique-blue [3]. For green primary, it was difficult to conclude specific wavelength as the best green primary. It seemed that the most favored colour appearance of green is highly object dependent [4].

In this study, we investigated the best red primary that gives the highest performance in KANSEI evaluation. In the field of visual assessment of lighting, appearance of red object is a key factor of scene evaluation [5,6]. The longer the wavelength, the deeper the red appearance, i.e. less yellowish. It would be interesting to examine whether the longer wavelength primary results the better KANSEI evaluation performace, or there exists some optimum primary that gives the best score.

2. Methods

In the experimental method, test colour images were displayed on the screen using two projectors, one is for the variable red primary, and the other is for the green and blue primaries. Interference filter (IF) of λp = 610nm, 620nm, 630nm, or 640nm was inserted in front of the lower projector to achieve different red primaries. White point of different red primary conditions was set nearly the same by inserting appropriate ND filters in front of the projectors 1 and 2.

Five adjective pairs, deep-pale, beautiful-dirty, like-dislike, impressive-mundane, and natural-unnatural, were used in the KANSEI evaluation. Observers were instructed to evaluate each test image by indicating a score on a seven-point scale (-3 to 3) between two bipolar adjectives. Group1 and Group2 of the test images, each group contains 15 images, same as those in our previous studies, were used [3,4]. So far, 13 observers in their twenties with normal colour vision participated the evaluation experiment.

3. Results

Results of Group1 and Group2 were basically similar to each other. Among the 15 test images, results of “red”, “red-blue”, “red-green”, and “multi-colours” images which include red or reddish objects, indicate significant effect of different red primaries. The red primary of 610nm shows the worst in the results of “Impressive vs Mundane,” and “Deep vs Pale,” evaluations, while 630nm and 640nm show high scores. As a total, 630 nm shows the best. Contrary to that, 610nm shows the best score in “Natural vs Unnatural”

evaluation, while 630 nm and 640nm show low scores most of the cases. Neither systematic, nor significant effect is observed in the results of “Beautiful vs Dirty” and “Like vs Dislike”.

4. Conclusions

It is interesting that nearly opposite tendency is found in different evaluation words pairs. The red primary of 630nm, which is the BT.2020 primary, provides deep colour and impressive feeling, but less natural, and observers do not like them. 640nm shows very similar results. On the other hand, The red primary of 610nm, which is the closest to the DCI-P3 primary, does not give a deep red and impressive, but it appears more natural for most observers. This raises the question that the result of which evaluation word should be taken as the first priority to design colour gamut of display. In addition to that, analysis of pixel distribution of chromaticity is needed as we have done in the previous studies on blue and green primary.

OP23

INFLUENCE OF FREQUENCY, WAVEFORM AND COLOUR ON THE VISIBILITY OF THE PHANTOM ARRAY EFFECT

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Abstract

Temporally modulated light can give rise to three temporal light artifacts (TLAs), being flicker, the stroboscopic effect and the phantom array effect, also known as ghosting. The phantom array effect which is the focus of the current study, is defined as “change in perceived shape or spatial positions of objects, induced by a light stimulus the luminance or spectral distribution of which fluctuates with time, for a non-static observer in a static environment.” For instance, when making a large eye movement (saccade) over a small light source directly in an otherwise dark environment, such as a backlight of a car at night, which light output is temporally modulated with a square periodic waveform, the light source is perceived as a series of spatially extended light spots. The phantom array effect is visible in a frequency ranged up to about 2500 Hz, which means that it can occur at frequencies above the critical flicker frequency, i.e. 80 Hz.

In this paper, we present a perception experiment, in which we studied the influence of frequency, waveform and colour of light output of a LED source on the visibility of the phantom array effect. The results can be used to help finding an optimal balance between temporal light quality and design of driving electronics; the latter one having an impact on cost of LEDs, their efficiency, physical space and lifetime.

Two small LEDs were mounted in front of a black panel, with a vertical distance of 80 mm from each other. There were two white dots, positioned 550 mm horizontally to the left and right of the LEDs that served as fixation points. Subjects were seated at 1.5 m in front of the LEDs, resulting in a viewing angle of 40° between the two fixation points, and a 0.17°of each LED. During the experiment, subjects were asked to make rapid saccades over the LEDs and between the fixation points. The experiments used 2-alternative forced choice method. One of the LEDs generated a constant light output (DC) and the other modulated light (AC), in random order, and subjects’ task was to indicate which LED produced the phantom array effect. The visibility threshold, defined as the modulation depth at which participants could detect the phantom array effect with a probability of 50%, was measured using a weighted 3 up 1 down staircase method. Each staircase always started with full modulation depth. Additionally, a few practice trails were included before the actual start of the experiment, to familiarize the subjects with the task.

This study consisted of 2 sessions. In session 1, visibility thresholds of temporally modulated light with a sinusoidal waveform and a square waveform with 50 % duty cycle were measured, at six frequencies, including 80 Hz, 160 Hz, 300 Hz, 600 Hz, 900 Hz and 1200 Hz. The colour of light was white. In session 2, visibility thresholds of sinusoidally modulated light waveforms, at three frequencies of 100 Hz, 900 Hz and 1800 Hz, and with three different colours, being white, red and blue, were measured. Due to methodological limitations, session 2 was divided into three sub-sessions; in each sub-session one colour was tested. The luminance of the LEDs in both sessions was 1400 cd/m^2. 10 subjects participated in both sessions, 6 males and 4 females, with age ranged between 22 and 27.

Results of session 1 show that, the visibility thresholds of both sinusoidal and square waveforms follow a U-shape function of frequency. The thresholds are the highest at the lowest frequency of 80 Hz, having modulation depth of 59% for sinusoidal, and 39% for square waveforms. Then, the thresholds decrease, reaching a minimum at around 600 Hz, having modulation depth of 23% for sinusoidal, and 18% for square waveforms. Above the frequency of 600 Hz the thresholds increase, reaching modulation depth of 46% for sinusoidal waveform and 26% for square waveform at frequency of 1200 Hz. Furthermore, we found that, the visibility of the phantom array effect, measured in the current study, could be predicted using the results of spatial contrast sensitivity function (CSF).

Next to that, the visibility thresholds of square waveforms are smaller compared to sinusoidal waveforms of the same frequency, which means more readily visible phenomenon with square waveforms. In earlier studies of flicker and the stroboscopic effect, researchers have already revealed that, knowing the threshold of sinusoidal waveforms, it is possible to predict the threshold for square waveforms by dividing it by the amplitude ratio of the fundamental frequency of square and sinusoidal waveforms. Since the phantom array effect is partly produced also by periodic fluctuations of light, we want to check whether this prediction also works with the phantom array effect. Thus, the ratio of the visibility threshold of a square over a sinusoidal wave at the same frequency were calculated. Results show that, the ratio is smaller than the inverse of the amplitude ratio. This could be explained by the fact that, in some situations, higher harmonic Fourier components, which subjects were sensitive to, also played important roles. Based on what were found, we hypothesize that the threshold of a given waveform depends on the amplitudes of all Fourier components.

Results of session 2 show that, visibility thresholds measured for blue light are significantly higher than thresholds measured for red and white light, while no significant difference was found between latter two. Comparable to results of session 1, a U-shape dependence on frequency was measured for all the three colour conditions.

To ensure that the light has a high temporal quality, the occurrence of unwanted TLAs, including the phantom array effect, needs to be prevented. The results of the current study help to understand when this effect is visible, by showing its dependency on frequency, waveform and colour.

OP24

A STUDY OF VISUAL TARGET VISIBILITY IN MESOPIC VISION BASED ON ELECTROENCEPHALOGRAM

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Abstract

When driving in dark environment, the loss of visual attention may cause traffic accidents, thus the visibility of detailed targets on road is important for driving safety. Research on environmental factors affecting visual target visibility can contribute to road safety.

This study aims to explore changes of brain activity when subjects recognize visual target in mesopic vision. Furthermore, the impact of contrast and eccentricity of visual stimulus on electroencephalogram (EEG) signal, reaction time and detection rate is discussed.

A visual Go/Nogo experiment is conducted in the study. Scenes with visual stimulus (a 20cm*20cm grey square) and dark road background were used as Go trails, while single dark road background scenes without visual stimulus were used as Nogo trails. Go trails consisted of 9 types of stimulus, including 3 contrast levels (achieved by adopting square targets with different grey levels) and 3 eccentricities. The 9 types of stimulus were represented 60 times for each in randomized order. Subjects were asked to step the pedal as quickly as possible once they detected the stimulus, and to refrain from responding if no stimulus was detected.

Before the experiment, subjects went through a 5-minute adaptation to get used to the dark environment. In the experiment, 600 trails, consisted of 540 Go trails (3 contrast*3 eccentricity*60 repetitions=540 trails) and 60 Nogo trails were displayed. These 600 trails were split evenly into 4 blocks. In each block, 135 Go trails (3 contrast*3 eccentricity*15 repetitions =135 trails) and 15 Nogo trails randomly appeared for 1000ms for each preceded by a variable inter-stimulus interval (ISI). The duration of each ISI was randomly selected from 1500ms to 2500ms. There was a 60-second rest period among blocks to prevent fatigue.

Two digital projectors were used in this experiment, with one displaying the dark road background, and the other displaying visual stimuli target. Dark road background was a uniform road with 3 lanes in constant low light environment with average luminance of 0.95cd/m2. A 20cm*20cm grey square used as the visual stimulus was presented on the road with 3 levels of contrast (expressed in Weber contrast between square target and road background: 0.1, 0.2, and 1.6) and 3 eccentricity (expressed as visual angle: -3.8°, 0°, and 3.8°corresponding to left, middle, and right lane). In the experiment, 10 volunteers (6 female, 4 male) were recruited from Southeast University in Nanjing, with their age ranging from 22 to 27(mean=23.6, SD=1.56). Subjects were seated in front of a 295cm*220cm screen in a dark laboratory. The viewing distance was 1.65m.All the subjects had (corrected to) normal visual acuity over 1.2.E-prime software was used to generate experimental program and collect response time of each trail. Only response made within 200~1000ms duration after the onset of visual stimulus was recorded as correct response. Neuroscan amplifier system was used to record EEG signal with 11 electrodes according to International 10–20 System during the whole experiment.

The detection rate (DR) and reaction time (RT) of different contrasts and eccentricities were calculated for statistical analysis. DR was the percentage of trails with correct response in 60 trails. RT was the average correct response time in 60 trails. Repeated measure ANOVA showed that the influence of contrast was significant on both DR and RT. DR increased, and RT decreased significantly when contrast increased. While the influence of eccentricity was not significant. This may because the eccentricity used in the experiment was too small to show the difference. Furthermore, literatures suggest that the influence of the eccentricity is smaller in mesopic vision than photonic vision.

Results of EEG signals were prepossessed into event-related potential (ERP) signals and group averaged according to contrast, eccentricity and response. Obvious P300 component was observed in Go trails with correct response, while absent in Go trails with no response and Nogo trails. Considering that P300 component is widely accepted as an indicator to reflect the allocation of cognitive resources

in earlier studies, the peak amplitude and peak latency of P300 was selected for analysis in the study. Repeated measure ANOVA showed that contrast influenced the amplitude and latency of P300 significantly. At central locations, such as Cz, CPz and Pz, the amplitude of P300 increased and the latency of P300 shortened significantly when contrast increased. The enhanced amplitude indicated increased allocation of cognitive resources, thus could explain the increased DR, and shortened latency was consistent with decreased RT. Same as DR and RT, the influence of eccentricity was not significant on ERP signals either.

In conclusion, the study showed that P300 component directly related with visual target visibility in mesopic vision. It was influenced by contrast between the visual stimulus and background significantly.

OP25

STRUCTURAL MATERIAL EFFECTS ON DISCOMFORT GLARE IN THE DARK CAB

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Abstract

1. Motivation, specific objective

Lighting condition is one of the most essential elements of locomotive cab, where various recognition and detection tasks and delicate operations are carried out. Discomfort glare not only influences the security of the high-speed transportations, but also damages the operator's eye health, which is an urgent problem to be solved in the ergonomics design of lighting environment for locomotive cab. This study aims at exploring the effect of structural material on discomfort glare evaluation in locomotive cabs.

2. Methods

This paper summarizes the common structural material including chromaticity coordinate, reflectance and refractive index as a reference. Firstly, an integrated optical simulation in consideration of lamps, displays and indicator lights was conducted to evaluate and quantify glare indicators using various different materials. Secondly, ergonomics experiments were conducted to verify the relationship between discomfort glare and the reflectance and refractive index of materials by comparing the subjective visual feeling and visual search performance under different samples, all the tests in the dark cab were measured by instrument of high accuracy.

3. Results

It was found that discomfort glare in the dark cab can be improved by adjusting the reflectance and refractive index of materials inside, including direct glare and veiling reflection on the windshield and visual display terminal(VDT). The diffused and light-coloured coating material can extend space visually and improve discomfort glare. The brightness of veiling reflection on the windshield and VDT can be approximately 20 times lower than the existing typical windshield and visual performance significantly improves($P=0.001<0.05$). Further, a multiple correlation relationship between discomfort glare and reflectance and refractive index can be built.

4. Conclusions

All the results will provide an effective method for reducing discomfort glare level and improve lighting condition, which can provide anti-glare design proposals, alleviate the visual fatigue of the driver and create a comfortable low-glare working environment.

OP26

THE INFLUENCE OF ADAPTING FIELD EXTENT ON CHROMATIC ADAPTATION

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Abstract

1. Motivation, specific objective

Chromatic adaptation is a perceptual phenomenon that keeps the colour appearance somewhat constant across the changes in the colour of the illumination environment. To predict the adaptive colour shift, over the years, many Chromatic Adaption Transforms (CAT) have been developed based on Corresponding Colours (CC). In the CAT02 transform, the equation predicting the degree of chromatic adaptation factor D, is only related to the luminance of adaptation field.

Recently, Smet et al. investigated the impact of the illumination chromaticity on D and developed a new model. He also found that the effective degree of adaptation was much less than 1 even under a high luminance background. This could be explained by the limited size of the adaptation field present during the experiments. Although the field of view might be an important factor in chromatic adaptation, few studies have been carried out on this topic. The goal of the present study is to investigate how the extent (field of view) of the adapting field influences the degree of adaptation and to develop an improved model.

2. Methods

Memory Colour Matching (MCM), a method which has more advantages over traditional asymmetric matching methods, has been used to collect corresponding colour sets for varying extents of the background (adapting field) illuminated by a number of neutral and coloured illuminations. Observers will be required to adjust the colour appearance of the presented stimuli until it matches the target colour in their memory. In the experiment, the stimulus background is a white 3D stage, providing the adaptation field, with several white, grey and black objects. The test stimulus is a 3D grey (spectrally flat) cube centrally positioned in the background scene. A calibrated data projector will be used to provide independent, but easily controlled, illumination on the background and the stimulus. The spectral radiance of the background and cube will be measured with a tele-spectroradiometer after suitable calibration.

Only one target colour, the neutral grey will be used in this experiment. The following thirteen adapting fields will be selected: illuminant A, EEW and D65, and the most neutral white found by Smet et al.; Planckian radiators of 2000K, 4000K, 12000K and infinite K together with five high chroma sources (Red, Yellow, Green, Blue, and magenta). They include 4 neural sources and 9 moderately to highly chromatic sources which covered a large range in colour space. The background luminance will be 150 cd/m2. Also, there will be 6 levels of field of view of the background: 0°, 10°, 20°, 40°, 60° and 80°, from no adaptation field to a quite immersive environment.

During the experiment, the observers will be asked to adjust, after a 45 seconds adaptation time, the apparent colour of the cube to neutral grey by navigating in the CIE 1976 u'v' space using a keyboard. They then need to rate their satisfaction of their colour match on a 0 (not satisfied at all) to 10 (very satisfied) scale. To minimize starting bias, each experiment will be repeated 4 times with 4 different chromaticity starting points of the grey cube. The starting chromaticities is distributed evenly in hue. The mean value of the 4 memory colour matches for each background and illumination conditions will be used for further analysis and model testing and development. The illumination (background) colours and starting points will be presented randomly within a single experiment session. The extent of the adapting field (background) will be randomly varied for each session to avoid order bias. Ten observers (5 male and 5 female), all with normal colour vision as tested by the Ishihara 24-plate test, will participate in the experiments. Overall, 2640 estimations will be made: 1 stimulus target x 10 observers x (13 illumination conditions x 4 starting points x 5 background sizes + 4 starting points x 1 viewing fields). Note that only dark illumination will be applied for obtaining the memory colour without adaptation field (0°).

3. Analysis

Firstly, observer uncertainty and variability (intra- and inter-) should be investigated. The MedCDM (Median colour difference with the mean) in terms of u'v' colour difference can be used to quantify the uncertainty. In addition, observer variability will be also assessed by the Standardized-Residual-Sum-of-Squares (STRESS). Note that intra-variability for each illuminant condition will be evaluated with observer's own memory colour which was repeated 4 times corresponding to 4 starting points.

For each field of view except 0°, 156 (13 x (13-1)) sets of corresponding colour sets could be derived from the 13 illumination conditions (background chromaticities). Firstly, the performance of the CAT02 transform will be evaluated by calculating the colour difference between the CAT02 predictions and the visual result, with the degree of adaptation calculated from the CAT02 D-formula.

Secondly, to minimize the prediction error (colour difference), the D value needs to be optimized for each field of view and illumination condition. It can be expected that the D will increase as the field of view is extended. The performance of an optimized CAT02 could be compared with the original CAT02 to check if there is a significant improvement. Also, the relationship between D and field of view of the adapting field will be discussed. The aim is to develop a new model for the degree of adaptation with the consideration of background luminance, chromaticity and field of view.

Session PA3-1
Integrative lighting and health (2)
Friday, April 27, 11:10–12:30

OP27

A LIGHT THAT CAN IMPROVE SLEEPING QUALITY IN TERMS OF HORMONE CONCENTRATION

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Introduction

Experiments were conducted to develop a sleeping light that can create cozy and relaxing atmosphere and to improve the sleeping quality at night. The results showed that people feel more relaxed and sleepy in a low saturated Red-Yellow light than a phase of daylight.

Experiment

The experiment was conducted in a windowless office-like room. Two light conditions were used in the experiment. Both had an illuminance of 180 lux. and had similar circadian stimulus (CS) of 0.16 and about same energy excited by blue LED. One was the 2700K pink-coloured sleeping light, denoted as SP. The other was a 5000K white light as a phase of daylight, designated as SW. Ten participants experienced each lighting condition for three continuous days. Below is the experimental procedure:

19:45 ~20:00 to adapt in a dim light (<10 lux)

20:00~20:05 to collect saliva sample and to answer questionnaire

20:05~21:00 to be free to read the books brought by themselves

21:00~21:05 to collect saliva sample and to answer questionnaire

21:05~22:00 to read their own books

22:00 to collect saliva sample and to answer questionnaire before leaving the office

Next Morning to fill the sleep log

Note that the sleeping activities were recorded using wrist watch.

Five testing methods were used in the experiment: Critical Flicker Frequency (CFF), fatigue questionnaire, Karolinska sleepiness scale (KSS), Pittsburgh Sleep Diary (PSD) and salivary hormones (melatonin and cortisol) concentration.

CFF was used to measure eye fatigue. A smaller CFF reading indicates a more exhausted eye.

The fatigue questionnaire contains ten scales, including tired eyes, sore eyes, irritated eyes, dry eyes, burning eyes, double vision, blurred vision, headache, dizziness and neck/shoulder/back pain. Each scale had a range from 0 to 4, where 0 means no feeling and 4 means strong feeling.

The KSS ranges from 1 to 9, where 1 = “very alert,” and 9 = “very sleepy, fighting sleep, an effort to remain awake.”

The Pittsburgh Sleep Diary (PSD) is a dairy with a set of questionnaires to be completed at bedtime and awake time. The bedtime ones relate to the events of the day. The awake time ones reflect the sleeping period and contain questions like bed and awake times, sleep continuity parameters, sleep quality, wakeup mood and wakeup alertness.

Participants’ saliva sample were collected using the Sarstedt Salivette® Cortisol, code blue system (SciMart, St. Louis, MO). Melatonin ELISA kit (IBL, German) and enzyme immunoassay kit (R&D Systems, Minneapolis, MN) were used to determine melatonin and cortisol concentrations in the samples.

Results

The ANOVA results revealed that for the fatigue questionnaire, two lights did show significant difference for the ‘dry eyes’, for which subjects felt their eyes were drier under SW than under SP. Although the results from the other tests were not significant, there is a trend SP outperformed SW, i.e. participants did show higher wakeup mood, wakeup alertness and better sleep quality under SP than SW.

However, both cortisol and melatonin concentrations supported that SP had significantly better sleep effect than SW. Salivary cortisol level under SP showed a significant lower concentration at 22:00 than those at 21:00 and 20:00, While under SW, salivary cortisol level at different time points did not have significant differences. Note that a lower cortisol level means less stress.

The salivary melatonin results also showed that SP significantly outperformed SW. Under SP, salivary melatonin at 20:00 was significantly lower than that at 21:00 and 22:00, while under SW, only salivary melatonin at 22:00 was significantly higher than that under 21:00. And salivary melatonin level at 21:00 and 22:00 under SP were both higher than that under SW although the difference was not significant.

In summary, the present results from most of the tests suggested that SP outperformed SW to show a positive effect on creating relaxing atmosphere and to feel a higher sleepiness.

OP28

EFFECTS OF COLOUR TEMPERATURE ON HEART RATE, BLOOD PRESSURE, AND ELECTROENCEPHALOGRAPH UNDER RESTING STATE

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Abstract

1. Motivation, specific objective

Previous studies reported that light not only influence the subjective feelings but also change people's physiological parameters. Optical radiation with a high CCT may suppress the melatonin level at night, which affects human circadian rhythm. At the same time, light, especially blue light, may also increase heart rate. This paper aims to investigate the psychological and physiological effect of colour temperature on young people by characterizing heart rate, blood pressure and electroencephalograph (EEG).

2. Methods

Twelve young subjects were recruited for the experiment. During the experiment, the heart rate, blood pressure, and EEG signals were recorded under each lighting condition, with a goal to evaluate the physiological effect of lighting with different colour temperature.

A colour tunable LED lamp was used to produce illumination with different CCT levels (i.e., 2700K, 4000K and 6500K) and a vertical illuminance of 50 lux at the eye level. The three lighting conditions were presented in a random order and each lasted for more than 10 minutes. In addition, the subjects completed subjective evaluations, using six pairs of words to describe the feelings under each lighting condition. Both CES-D and PSQI questionnaires were taken in advanced to assess subjects' health conditions. The EEG signals were analysed in both time and frequency domains.

3. Results

Subjective evaluation showed that high colour temperature lighting produced higher brightens. The 2700K lighting provided the warmest feeling, and it made subjects more relaxed. The 4000K lighting was the most cheerful.

The heart rate and blood pressure had small fluctuations with significant individual differences. None of them showed significant interaction with colour temperatures.

As for questionnaires, nearly half of the 12 subjects had problems with both depressions and sleep qualities. Thus, subjects were divided into two groups to compare their EEG signals. EEG signal from 60 to 180 seconds was picked up and analysed. Subjects with bad health conditions had higher value of alpha wave and the fluctuations were greater. Subjects with good health conditions had lower and more stable alpha wave. There were significant differences between the two groups. Alpha wave decreased under all light conditions, especially 2700K, which had a more significant drop of alpha wave. The frequency domain analysis of EEG showed that alpha wave moved toward a low frequency range when light changed from high CCT to low CCT.

4. Conclusions

In terms of psychological effects, young people were more likely to choose low colour temperature and neutral white when they relaxed. As for physiological parameters, heart rate, diastolic and systolic blood pressure didn't show significant interaction with colour temperature ($p>0.05$). Health conditions could influence EEG value, considering the facts that EEG signal in resting state was higher and more unstable for people with depression or bad sleep quality. Alpha wave in time domain analysis decreased in the before-sleep resting state. 4000K and 6500K had similar reduction of alpha wave. 2700K gave greater reduction of alpha wave value. In frequency domain analysis, alpha wave tended to move towards a lower frequency with low CCT.

OP29

USING LIGHT TO FACILITATE THE MOBILITY OF LOW VISION PEOPLE

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Abstract

1. Motivation

According to the most recent review conducted by the World Health Organization (WHO) from 2000 to 2010, the number of people of all ages referred to as “low vision” are estimated to 246 million. Two thirds of this population are over the age of 50 and were not concerned by any visual deficiency when they were younger. Concurrent with the increase in the average age of people, growth in the number of persons with visual impairment is unfortunately expected.

A visual impairment can affect the ability to perform simple activities of everyday life as walking safely at home, pouring water in a glass or easily finding familiar and household objects. The quality of life can be dramatically altered and it can be impossible to maintain independence in a safe manner. Yet loss of independence is a predominant concern of the older adult.

Nowadays, existing visual aids are mainly based on all-optical devices even if a few electronic apparatus are available for prescription. Visual aids are specifically designed for magnification for near, magnification for distance and visual field defects. Primary aids for orientation and mobility are canes. They are used by visually impaired travellers to detect obstacles as well as changes in ground surfaces such as drop-offs and sidewalks.

Quite obviously, due to the constraints in their use and due to their lack of portability for some of them, the existing visual aids for low vision do not match the patient’s concerns. Consequently, the challenge is to improve both the usability and the efficiency of equipment in order to facilitate the mobility and the socioeconomic independence of the low vision population.

Such a double improvement is the scope of a pilot project we are currently developing. Our objective is to propose an assistive lighting system to help low vision persons for independent navigation. Our approach attempts to make use of residual vision of patients by exploiting light characteristics to enhance edges of objects forming a real scene. The paper we propose will present and focus on our first studies and results in relation with the psychophysical experiments carried out to determine what light features could be relevant to facilitate the autonomous mobility of low vision people.

2. Method

In our concern in developing a mobility aid for visually impaired people, we considered from different published results that an edge enhancement approach could be an efficient basis for a first pilot study. Then we carried out a psychophysical experiment to study the effectiveness of such an approach.

The experiment consisted in asking participants wearing simulated impairment glasses to walk in a room through a series of obstacles of two types: floor and hanging obstacles to reach a “kitchen” counter in order to make two cups of tea.

The ambient light was produced by fluorescent tubes with a colour temperature of 4000K and the average illuminance at eye level was roughly 300 lux. Ribbon LED tapes were stuck on the edges of each obstacle. All ribbons were set up to obtain white light at about 4000K with an illuminance higher than 300 lux at 1 meter from the source. Objects on the “kitchen” counter were illuminated by the side with vertical fluorescent tubes.

Three groups of 15 observers each with normal vision wearing simulated visual impairment glasses participated in the experiment. Three types of simulated impairments were selected: tunnel vision, central scotoma and blur vision. All participants were naïve and they were familiarized and adapted to the simulated visual impairment glasses during a preliminary training. Then, they received the following instructions: “Walk naturally from the entrance door to the illuminated table at the back of the room.

Avoid any obstacles on the way, try not to contact them. Make two cups of tea. Take one tea bag out from the box, put in the teapot, pour water from kettle into the teapot (mark is provided), bring the teapot to a “dining” table (located 1 meter from the kitchen counter), bring two cups to the table and rinse water from the teapot into the first tea cup and the second tea cup (mark is provided). After that, go back to the entrance door by avoiding obstacles.”. As the observers received a long instruction, they visualized the steps of activities on a monitor before starting the experiment.

The ribbon LED tapes were switched on during the mobility walk course and switched off during the kitchen activity. Then, the return mobility walk course was performed by the participants with raw obstacles (no edge enhancement). Only the “kitchen” counter was illuminated by the side, the “diner” table was lit only by the ambient light.

3. Results

Time to complete the walking course, walking speed (m/s) and numbers of body contact with any object were measured. Parameters such as confusion or repeated instructions were also considered.

Statistical analysis shows that there is no significant differences between the walking speeds when the LED tapes were switched on and switched off for tunnel vision and central scotoma. For the blur vision, the walking speed is decreased when the LED tapes are switched on. For the three groups, the number of body contacts with obstacles increases when their contours are not enhanced by light.

Except for blur vision group who complained about uncomfortable glare produced by the lighting system of “kitchen” counter, participants performed more easily the first part of tea cup making than the second part located on a table only lit by the ambient light. Moreover smaller deviations between the actual level of liquid compared to the expected one were measured for the “kitchen” counter.

4. Conclusions

The first experiment carried out to study the effectiveness of object contour enhancement based on illumination techniques provided interesting and promising results which confirmed that light could be efficiently used to facilitate the autonomous mobility of low vision people. This motivated new experiments with low vision people to extend the study with the scope to develop smart lighting systems designed as a mobility aid for visually impaired people.

OP30

EXPERIENCE OF LIGHT IN COMPARISON WITH RETINAL RESPONSE TO RADIATION

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Abstract

1. Motivation, specific objective

The tools available for defining light quality are based primarily on the knowledge of the eye's sensitivity to light intensity, which is a very limited definition of the visual function. When photons hit the eye's retina, a reaction is created which the visual perception system transforms into a basic and automatic sensory experience, and the visual impression created is interpreted both on an emotional and cognitive level. The processes are largely unconscious but in principle simultaneous. Although they represent different aspects of vision, it is in fact not possible to separate them if the goal is to create a basis for good light environments.

Knowledge and awareness of the effects of light on man is steadily increasing. One term that is increasingly used is human centric lighting. It focuses primarily on the effects of light on hormone levels and the circadian rhythm, and how lighting facilities can be planned and controlled based on that knowledge. Man is guided by biological, physiological and sensory functions and is at the same time a social and cultural creature, who also has specific needs and preferences at the individual level. A definition of light quality needs anchoring in all of these levels.

The study is conducted as part of a multidisciplinary research project. The overall objective is to develop definitions and concepts for light quality, as well as a basis for methods and tools for design and evaluation of light environments. Methods from different research disciplines are used in the studies carried out in the project. Sensory analysis, originally developed in the food and beverage industry, has well-established methods for using human sensory abilities as measuring instruments and quality assessments for products such as wine or different foods. The field of environmental psychology studies the interaction between humans and the environment and has among other developed methods for examining people's experience of a spatial context. The research project is being carried out in close collaboration with a number of companies in the lighting industry. Through an iterative process during a number of meetings and workshops, a collection of concepts for visually experienced light quality has been defined. The concepts are validated through the research studies carried out in the project, of which the study presented here is one. In this study, the results are also compared with an analysis of how the eye's receptors respond to the radiance of the light environments assessed.

The purpose of the study is to compare an investigation of how light environments are perceived visually with an analysis of the radiation and its impact of the photoreceptors. The aim of the study is to contribute to a tool based on a definition of light quality that is anchored in a holistic perspective on light experience.

2. Methods

The project's definition of light environment is that it consists of the three factors *light*, *colour* and *space* that together determine how the light quality of a room is experienced. Three methods are used in the study. Two of them investigate the perceived light quality and the third is an analysis of the response of the receptors to the radiance of the examined environments.

The study is conducted with a number of scale models of environments that have different combinations of light and colour schemes. The designs of the models are identical and consist of different volumes and structures resembling furniture, but the rooms should not be associated with any specific function. The colour schemes have varying degrees of contrast and reflection and are illuminated according to different lighting principles, ranging from even lighting to varied. A selection of the concepts defined within the project describing visually perceived light quality is assessed by 25 subjects through semantic differential scales. Some examples of the concepts assessed for each model are: *diffuse, distinct, intense, varied* and *monotonous light*, as well as the *perceived light level*. Based on a few open questions, the subjects also describe in their own words the quality of light in each of the models, and whether they experience them as appealing or not.

The method for analysing the receptors response to the light environments radiance is done using photographs of the models, similar to a luminance analysis. A software calculates how the four different receptors of the eye, the three types of cones and the rods, respond to the radiance and the result is presented in logarithmic curves. Contrast is of greater importance to the photoreceptors, as well as for whole visual system, rather than the amount of light radiation and the experience of brightness as an isolated factor. The reason why radiance is used instead of luminance is precisely to exclude the photometric units' correction to the visibility curve. The method, developed by a biologist, has so far only been used in outdoor environments.

A relatively large number of environments with different light situations have been analysed using the method. The logarithmic curves describe the receptors response to respectively short-wave, medium-wave and long-wave radiation, as well as a median value. As expected, they show quite different results for a natural light environment like a beach in daylight, compared to a nightly urban environment dominated by motley artificial light, or an environment illuminated with a low pressure sodium lamp. The starting point of the method is that the function of the eye is developed and adapted to the type of light and contrast conditions found in natural environments. The method allows you to read if a light environment differs from it. The method could thus also provide a basis for optimizing artificial light based on the function of the eye.

3. Result

The results of the three methods are relevant both individually and in comparison with each other. The scale models have been designed with both common and more extreme light and colour settings, and with varying degrees of contrast and brightness. The radiance analysis is compared with the material from the previous outdoor environments study to identify similarities and differences. The subjects' assessment of the scale models light quality and their preferences are also set against the results of the radiance analysis to identify possible correlations. Throughout the study, the concepts of light quality as defined in the project can also be validated in a first round.

4. Conclusions

The aim is that the results of both the sub study and the entire project will culminate in definitions and scales that describe light quality based on both visual and emotional values that can be used as a tool both in research and practice. It is also hoped that the result will ultimately be able to contribute to raising awareness of light and light experience.

Session PA3-2
Solid-State Lighting (SSL) technologies
Friday, April 27, 11:10–12:30

OP31

JUNCTION TEMPERATURE OF SMART LIGHTING LUMINAIRES OBTAINED WITH PULSED DIMMING

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Abstract

1. Motivation, specific objective

After the invention of blue light-emitting diodes (LED) and phosphor-converted white LEDs soon after, the lighting industry has been striving towards LED based light sources and smart lighting for reducing the energy consumption. The main parameter affecting the efficiency of LEDs is the junction temperature. One commonly used method for measuring the junction temperature is the forward voltage method that uses short current pulses with synchronous forward voltage measurement over the LED junction. The current pulses are kept short enough so that they do not heat the junction. However, in many of the LED products, the electronics is inaccessible and the forward voltage method cannot be used. Another method based on a contact measurement using a thermocouple may change the thermal properties of the system due to the small size of the LED junction. In addition, due to the strong temperature gradients, a thermocouple may underestimate the junction temperatures. Thus, a non-contact optical method is needed for measuring the junction temperature of an LED junction. In principle, the electroluminescence (EL) spectrum of an LED depends on the junction temperature and it is possible to model the spectrum with junction temperature being one of the fitting parameters.

In our previous studies, we have developed spectral models for InGaAlP, GaAs, and InGaN light-emitting diodes. These models are based on quantum mechanical principles; the EL spectrum of an LED is described by the Maxwell-Boltzmann distribution for the high-energy side and the effective joint density of states (DOS) for the low energy side of the spectrum. The spectral models developed bring the theoretical semiconductor physics and the actual measured properties closer together as the junction temperatures of the actual LED based light sources can be monitored spectrally for their junction temperature.

The spectral models developed require one spectrum of an LED at a known junction temperature to calibrate the parameters describing the effective DOS. Moreover, in our earlier studies we noted that especially the spectral properties of InGaN LEDs vary among LED individuals. Thus, the DOS parameters determined for one LED component do not necessarily describe the DOS of another LED individual. These variations arise from the high dislocation density of InGaN that is not easy to control during the manufacturing process. The InGaAlP LEDs are significantly more homogeneous in this respect, but to obtain the best accuracy, the calibration of the model parameters should be performed separately for each LED component.

2. Methods

In this work, we study the possibility of obtaining an LED spectrum at a known temperature by pulse-width-modulating the LED. Spectra are measured at varied duty cycles, and the results are extrapolated to the duty cycle of 0% to obtain a spectrum resembling the junction temperature equal to the ambient temperature. We study the effects of frequency and duty cycle on the junction temperature. Spectral measurements of pulse-width-modulated LEDs can be carried out by averaging over various pulses, or by synchronizing the measurements to the modulation. Also the effects of different heat sinks on the EL spectra obtained are investigated. The final goal of this work is to obtain a reference spectrum at room temperature that would be useful especially with smart lighting, where dimming is carried out by pulsing LEDs. Such a reference spectrum can be used to obtain the effective DOS by dividing the spectrum with the Maxwell-Boltzmann distribution.

The setup that is used for carrying out this study consists of a high quality function generator (Agilent 33521A) with the available duty cycles of 0,01 % – 99,99 % and frequencies up to 30 MHz, a custom-made pulsed voltage-to-current converter to drive LEDs and a high-quality array spectroradiometer

(Konica Minolta CS-2000) to measure the EL spectra. Different LED holders are used to see their effects on the spectral measurements.

3. Results

We have investigated how the pulse-width dimming affects the junction temperatures and the EL spectra of white and green InGaN, and red InGaAlP light emitting diodes. Our studies show that with red InGaAlP LEDs, the junction temperature is directly proportional to the duty cycle. However, it appears that with the InGaN blue LEDs the relationship may not be that simple, but their spectra blue-shift less towards shorter duty cycles compared with AlGaInP LEDs. Our approach is to extensively measure all the scenarios and find links to the underlying physics of the observations.

In theory, the EL spectrum at the room temperature is obtained by extrapolating the duty cycle to 0%. To validate this statement, we have measured the reference EL spectra of DC driven LEDs, calibrated with the forward voltage method and compared the extrapolated spectra with the reference spectra of the same LEDs.

We have also found a validation method for the non-synchronised spectral measurements of pulsed LEDs. The problem with such measurements is that with the short duty cycles, the ambient stray light and the finite rising and falling edges of the current pulses start to dominate measurement, distorting the EL spectrum measured. Thus, such distorted spectra have to be discarded from the analysis. We have found that a straightforward method for evaluating whether the distortion in the spectra is dominant is to check whether the normalised spectra intercept at a temperature invariant energy value. This intersection point formed by the spectra at different temperatures, over a sufficiently narrow temperature range, is a property existing in every LED component.

4. Conclusions

This work studies the effect of the pulse-width-modulation on the junction temperatures and the corresponding EL spectra of LED luminaires. The findings of this and future work can be used for creating an optical method based on pulse-width-modulation to obtain the EL spectrum at room temperature. Such a reference spectrum can then be used to calibrate the parameters of spectral models for junction temperature determination. The goal is to monitor the junction temperature of the LED luminaires optically when using the smart lighting where dimming is carried out by pulsing the LEDs.

OP32

NON-INVASIVE MEASUREMENT OF PHOSPHOR TEMPERATURE FOR PC-WLEDS

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Abstract

1. Motivation, specific objective

Solid-state light source has played the most important role in modern lighting, in both the outdoor and the indoor applications. Among the lighting applications, phosphor-converted white LED (pc-WLED) is the key light source owing its advantages in low cost, fast response, high efficiency, good colour performance and acceptable reliability. Generally, the pc-WLED contains a yellow (or green with red) phosphor layer covering a blue die to emit white light in wide CCT (correlated colour temperature) range with acceptable CRI. The performance of a pc-WLED can be judged by the efficiency, colour accuracy and reliability. The reliability, i.e. lifetime evolution of these factors is related to heat flow and temperature distribution in the package volume. In our previous study, we found that the hottest spot in the package volume could be located at the top of the blue chip or in the phosphor layer which is a package with remote phosphor. High temperature in the package volume of a pc-WLED could cause thermal quenching in phosphor, and resulting in colour drift as to induce blue light leakage, efficiency droop and lifetime shortening. Thus, the thermal effect is an important factor in managing the lifetime of a pc-WLED. Generally, the junction temperature of the LED die is regarded as an indicator to show the thermal condition in both the research and the industrial products. But, the junction temperature of the LED die is not strongly correlated with the temperature in the phosphor layer. The temperature across the phosphor layer or volume needs more watch and thus there is an intense demand in monitoring the phosphor temperature. However, there is no effective way to detect the phosphor temperature for pc-WLEDs. Then, the thermal dynamics of the phosphor layer/volume in a pc-WLED lacks of useful support.

2. Methods

To detect the phosphor temperature in the experiment, an IR camera takes images of the conformal-coated phosphor on a blue die that is attached on a board. Since the phosphor layer is thin, the surface temperature by the IR camera can be used to indicate the phosphor temperature. The emission spectrum is caught by a spectrometer in free space or in an integrating sphere. The final approach is based on the feature band of the spectrum. A Gaussian function is used to fit the feature spectrum so that the equivalent peak wavelength and the bandwidth can be obtained. The experiments are done with different wavelength of the pumping blue light, different phosphor concentration, different thickness and with or without lens encapsulation. Both the fitting peak wavelength and bandwidth from the detected spectra are fitted with simple quadratic functions respectively. Then the fitting functions are used to predict the phosphor temperature in a real pc-WLED.

3. Results

Advanced analysis of the spectra with different blue emission and different phosphor concentrations are executed to find a more effective way to build up a single and simple function. A basic thinking is that it could bear less cross-talk for the crossover range of the short and long bands in the emission spectra away from the blue light. The spectra from 580 nm to 800 nm are almost identical in all cases under the room temperature. The spectra from 580 nm to 800 nm can be regarded as the feature band of the whole spectrum. The feature band for different phosphor temperature shows possibility to clearly reflect the temperature effect. Therefore, only one fitting is necessary in that process. We can apply a Gaussian function to fit a part of the emission spectrum along the feature band for different phosphor temperature. The peak wavelength as well as the bandwidth is a good factor to indicate the phosphor temperature. Various experiments were done to collect enough data to evaluate the consistency of the fitting factors, where various pc-WLEDs pumped by different blue dies in different phosphor concentrations. The most interesting part is that the fitting single Gaussian function is applicable to the package with or without lens encapsulation. We find that the bandwidth part is more accurate than the peak wavelength part because the bandwidth gets higher sensitivity in temperature. The proposed detecting model is to build up a database to obtain the featured quadratic functions for describing the relations between the fitted peak wavelengths or the fitted bandwidth of the feature band and the phosphor temperatures. The

conformal coating package without lens was used to build the database. Then the pc-WLEDs were encapsulated with a silicone lens. The database was used to indicate the temperature of the phosphor layer. The lens encapsulation blocks possible air convection of the phosphor layers and the temperature will be higher than the package without lens encapsulation. It is worth noting that the phosphor temperature as a function the injection current can be adopted only for the same thermal dissipation design.

4. Conclusions

A novel scheme for precisely detecting the phosphor temperature of a pc-WLED. The detection model can be adopted to different blue dies, different phosphor concentrations, different phosphor thickness, different CCTs and with or without lens encapsulation. The study starts from checking the emission spectra by the phosphor, and divided the spectrum into two sub-bands. The peak wavelength and the bandwidth have well correspondence to the phosphor temperature. Furthermore, the two correspondence can be well fitted by simple quadratic polynomials respectively. Using the two functions, we can detect the phosphor temperature at various conditions, including changing the blue die, phosphor concentration, the phosphor thickness, different CCT, and with or without lens encapsulation. The only restriction is that the phosphor must be the same. The features are diverse for different phosphors in principle. So, the coefficients in the empirical scheme will need to fine tune, individually. However, the method and the procedure should work still well. Meanwhile, this empirical scheme is based on the stable properties of the phosphors. The empirical scheme won’t expect to correctly predict the phosphor temperature after the phosphors become in ageing. During the ageing stage, the temperature of the phosphors might not become one of the most important issues. The proposed novel scheme based on spectrum fitting provides an effective way for remotely detecting phosphor temperature of a pc-WLED. Scientifically, we have successfully demonstrated well correspondence between the yellow spectrum and phosphor temperature from a white light spectrum with large cross-talk. In the real application, this study provides a very effective way to monitor the phosphor temperature. This accomplishment can help the sold-state lighting industry to develop more trust-able light source with high reliability, high colour stability and high efficiency.

OP33

LIMIT OF LUMINOUS EFFICACY AND PACKAGING EFFICIENCY IN PC-WLEDS

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Abstract

1. Motivation, specific objective

Phosphor-converted white LED (abbreviated as pc-WLED) is a solid-state light source which emits white light based on a blue die covered by yellow or green-red phosphor]. Such a light source has been intensively applied to general lighting owing to its advantages, including high energy efficiency, fast response, acceptable colour rendering, and low cost. The property in high luminous efficacy enables pc-WLEDs to replace most light sources in general lighting and even in special lighting. The use of high-efficiency pc-WLEDs becomes one of the important topics in global energy saving. With no doubt, a pc-WLED could save energy due to the light emission mechanism in a semiconductor with p-n junctions. A well design with a suitable substrate such as low-cost sapphire makes a pc-WLED to perform luminous efficacy as high as 150 lm/W operated at 1 watt. Furthermore, a high quality GaN template could even rise the internal quantum efficiency (IQE) as high as 88% or potentially even higher. Also, well-developed chip process and die shaping could effectively increase the light extraction efficiency to a level of 90%. Combination of the IQE and LEE, the state-of-the-art external quantum efficiency of a blue die for a pc-WLED could reach as high as 80%. However, it is lack of detailed analysis for packaging efficiency to decide the limit of luminous efficacy of a pc-WLED with a certain spectrum. In this work, we present a study of packaging efficiency for several kinds of pc-WLEDs to figure out the possible limit of packaging efficiency. Then, we further consider the photopic spectral luminous efficiency function of human eye on pc-WLEDs according to the specific spectrum. In corporation with the state-of-the-art EQE, we study and discuss the potentially reachable luminous efficacy of a pc-WLED with different colour performance.

2. Methods

The study of the packaging efficiency is aimed to figure out the potentially highest efficiency so that people knows which the improvement space is for the current pc-WLEDs. In this study, several typical packaging structures are applied. The diameter of the encapsulation lens is 6 mm in all types. The blue dies are selected with a name of EZ700 by CREE. Yellow YAG phosphors with different diameter are used to achieve white light incorporated with a blue die in the experiment while Green YAG and Red Nitride phosphors are used in the simulation. The limit packaging efficiency can be analysed through examining the packaging loss budget through simulation with Monte Carlo ray tracing incorporated with the precise phosphor model that we developed. The practical packaging loss mainly comes from the geometry loss including the absorption in the bottom layer of the board and the absorption in the active layer of the blue die. To make fair comparison, we adjust the phosphor concentration and thickness to achieve similar particle number of the phosphor so that the CCT is controlled at 6500K ±100K.

3. Results

To estimate the limit of luminous efficacy of a pc-WLED, the scenarios are focused on the effect by the PkE, the CCT, and the LER. The first scenario is that there is no geometry loss and phosphor quantum loss, so Stokes loss is the only factor counted in the packaging efficiency. The second scenario is a more practical case, where the phosphor quantum loss is counted, and the geometry loss is also applied according to the lowest loss. If Stokes loss is the only loss in packaging level, it is possible to use green YAG phosphor to perform a limit of luminous efficacy of a pc-WLED as high as 300 lm/W, but the colour appearance might not be white, and the CRI could be below 30. If 4% of phosphor quantum loss and CCT-dependent geometry loss are counted, the practical limit of luminous efficacy of a pc-WLED for greenish white or yellowish white is about 260 lm/W for very low CRI and is about 240 for CRI around 60. For the yellow phosphor, it is possible to reach the limit of luminous efficacy of a pc-WLED in a range from 200 lm/W to 250 lm/W of a well-defined CCT around 6000K to 6500K and CRI around 70. To increase the CRI to 80 or even above, two phosphors must be used. Then, the limit of luminous efficacy of a pc-WLED in a range from 160 lm/W to 200 lm/W with a well-defined CCT around 4000K to 5000K. It means that better colour performance will dramatically sacrifice luminous efficacy.

4. Conclusions

We investigate the PkE in seven types of pc-WLED to figure out what the most efficient is among them. In order to know the details of the PkL, we analyse the PkL budget, which contains Stokes loss, phosphor quantum loss, and geometry loss. The Stokes loss depends on the blue spectrum and the spectrum of the down-conversion. The geometry loss is more complicated, and it relates to the phosphor, the reflective surface in the packaging volume and the absorption of the active layer of the blue die. The simulation shows that phosphor particle size could induce different backward scattering, and so does the geometry loss. Based on the analysis above, we try to estimate the limit of luminous efficacy of a pc-WLED with Type VII structure. In the calculation, we will obtain the limit of luminous efficacy of pc-WLEDs. The limit of practical limit of the LED will be sacrificed in obtaining higher CRI. To approach the optimal luminous efficacy and the optimal CRI in the same time always put us into a dilemma. For various applications in the daily life, it might be a good strategy to keep a minimal requirement on CRI first, then to optimize the luminous efficacy as possible. That will bring us as higher luminous efficacy but will not lose CRI too much in any specific application. In summary, the study of the PkE clarifies the PkL budget of a pc-WLED, so that the limit of the luminous efficacy and illumination luminance efficacy can be estimated. It will be much helpful for the people in the field related to pc-WLED to figure out what/how luminous efficacy can be achieved and what/how the people can do in the next.

Session PA3-3
Colour and vision (2)
Friday, April 27, 11:10–12:30

OP34

EXPERIMENTAL EVALUATION OF DIFFERENT BRIGHTNESS PERCEPTION MODELS BASED ON HUMAN PUPIL LIGHT RESPONSES

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Abstract

1. Motivation

The spectral dependence of the pupil mechanism has a higher sensitivity in the short wavelength range possibly due to the intrinsically photosensitive retinal ganglion cells (ipRGCs). Various research studies have shown that if there are quasi-monochromatic stimuli at a constant luminance calculated by the $V(\lambda)_{2^\circ}$ function, then the pupil diameter exhibits wavelength dependence. Further studies with quasi-monochromatic stimuli have shown that this effect disappears when using the luminance calculated by the $V(\lambda)_{10^\circ}$ function. However, the time dependence of the ganglion cells' adaptation process has to be taken into account, as well. The weighted contribution of ipRGCs in the pupil mechanism increases over time and reaches its saturation after 300 seconds of exposure time. Therefore, regarding the evaluation and modelling of the pupil mechanism, the temporal variation of the pupil diameter has to be considered, as well.

In this work, we investigate the accuracy of current brightness models to predict pupil diameter in comparison to classical 10° and 2° photopic luminance. The aim of this work is to find out whether it is possible to establish a correlation between brightness perception and pupil response by adding a time component to the brightness model.

2. Specific objective

The first step is to check the hypothesis whether pupil response can be described in terms of the luminance signal. For this purpose, luminance is calculated with both the $V(\lambda)_{2^\circ}$ and the $V(\lambda)_{10^\circ}$ functions to check if - in the shorter wavelength range - an increased sensitivity ($V(\lambda)_{10^\circ}$) can represent a better description of the pupil mechanism. When determining the pupil diameter, the pupil's response is divided into a long- and a short-term phase and these phases are examined separately. This separate consideration is probably necessary due to the time-dependent adaption process of the ipRGCs in pupil control.

Next, brightness models from literature are used to evaluate the pupil's variation in diameter. The null hypothesis is that a correlation between the perception of brightness and pupil diameter can be assumed. To check the null hypothesis, only the pupil's response in the long phase is considered. Thus, the maximum component of the ipRGCs can be determined in the brightness model equation. The minimum component of the ipRGCs in the model is represented by the short phase pupil response.

As a result, it is expected that an optimized time-dependent brightness model will be derived. In addition to subjective evaluation using questionnaires or brightness adjustment, objective parameters such as pupil response will allow us to design an extended brightness model.

3. Methods and results

A stable 11-channel LED light source is used in a box chamber with diffusely reflecting walls to provide different stimuli with the same luminance (measured on the bottom of the viewing box), but different R, S, ipRGC and L-M weightings. Six different stimuli are presented, each with an exposure time of 330 seconds. A reference stimulus (4000 K) is offered as an anchor between the stimuli for 330 seconds, in order to avoid influences from pre-stimulation. The main stimuli are presented randomly in order to avoid systematic influence effects. Three different luminance levels 266±1 cd/m^2, 25±0.1 cd/m^2 and 1.6±0.005 cd/m^2 with homogeneous illumination on the bottom of the chamber are investigated. The two lower levels are achieved with spectrally neutral shadow masks below the luminaire.

The head position of the subject is fixed by a chinrest so that each subject has a constant viewing angle of 33° x 36°. The subject's gaze position was nearly fixed with a target inside the experimental setup.

The pupil diameter is recorded with a sample rate of 40 Hz and the Eye Tracker System Tobii Pro x3-120.

4. Results

Based on the currently available results, the first null hypothesis which says that the pupil's response depends on 2° photopic luminance could be rejected. These first results are based on five subjects aged between 25 to 31 years. All subjects had corrected visual acuity of 20/30 or better. Normal colour vision was tested with Ishihara plates. The pupil's differences of the right eye $|\Delta d_{pupil}|$ between the anchor stimulus and the main stimulus (that contain various amounts of R, S, ipRGC and L-M signals) were evaluated. These values vary between $|\Delta d_{pupil}| = 0.3$ mm and $|\Delta d_{pupil}| = 0.8$ mm. There was no significant variation of these pupil difference values among the two luminance levels 25 ± 0.1 cd/m^2 and 1.6 ± 0.005 cd/m^2.

In the detailed manuscript, further investigations (mentioned in the "Method" section), will be described. This will include at least 30 participants by the time of the paper submission in order to provide statistically robust results.

OP35

MODELLING BRIGHTNESS IN TERMS OF ROD, S-CONE AND IPRGC SIGNALS BASED ON A NEW VISUAL EXPERIMENT

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Abstract

1. Motivation, specific objective

In lighting practice, a wide range of luminance levels (from low mesopic up to high photopic luminances) and different light chromaticities can be found. This results in very different spatial brightness impressions of the viewed scene which cannot be described by the quantity luminance (in cd/m^2) alone as often pointed out in literature. A new, alternative descriptor quantity for brightness was proposed recently. This quantity combined numeric descriptors of rod (R), S-cone (S) and ipRGC signals depending on luminance level. Optimum model coefficients were estimated based on a previous study.

In the meantime (as it was indicated previously), a series of new visual brightness experiments with different multi-LED spectra were conducted at four different luminance levels (measured on the bottom of the viewing box: 266±1 cd/m^2; 25±0.1 cd/m^2; 1.6±0.005 cd/m^2 and 0.34±0.004 cd/m^2). The aim of the present paper is to show and model these new visual brightness results in the above mentioned physiologically relevant R-S-ipRGC-framework introduced previously. In the new experiments, observers assessed the brightness of stimuli of different spectral content but the same luminance at each one of the four luminance levels.

The quantity *luminance* (in cd/m^2 units, in the conventional sense; for the sake of practical applications, alternative models of the luminance signal like *V** were not considered) was used to keep the signal of the luminance channel (roughly: a linear combination of the L and M cone signals) of the stimuli (to be assessed visually) constant at each luminance level. The signals of the other channels, R, S, ipRGC, L-M (hence the chromaticity of the equi-luminant stimuli) were varied systematically. The hypothesis that brightness impression changes significantly with the R, S, and ipRGC content of the stimuli was corroborated. The objective of the present contribution is to show the optimum exponent and the weighting of the R, S and ipRGC signals as a function of luminance level to show the way towards a new R-S-ipRGC-based brightness model (which also includes luminance dependence) intended for practical applications. Another hypothesis is that latter brightness model can better predict pupil response than luminance alone. This is intended to be investigated in a parallel paper at the present conference.

2. Method, results and discussion

Two different methods were applied: 1. category rating at the 0.34 cd/m^2 level and 2. brightness discrimination procedure at the other three levels (266 cd/m^2; 25 cd/m^2; and 1.6 cd/m^2). The CIE best practice guidance was studied carefully before designing the procedures to avoid bias effects: 1. for category rating, the response range was anchored, 6 categories (even number) were used, the number of stimuli (6) equalled the number of categories (6) and these six stimuli were presented six times in differently randomised orders; and 2. for discrimination: the 20 stimuli to be compared with the reference stimulus were shown twice in two different randomised orders and the order of the test and reference (left/right) was changed in between in order to avoid position bias.

In the category rating procedure (0.34 cd/m^2 measured on the bottom of the viewing box), 29 observers of normal colour vision rated each one of the six stimuli by the aid of six categories (6 points: the brightest; 1 point: the darkest). After 20 minutes of dark adaptation, the stimuli were presented for 1 minute after each other in a random order. Six such random orders were used and the sum of the points of all 29 observers x 6 repetitions determined the rank order of the light source. This rank order could be best predicted by the standalone rod (V') signal. The weighting of the other components, S and ipRGC, did not contribute to the model. Observers were completely immersed in the viewing booth (their position was fixed by a chinrest) and were asked to rate the brightness of the homogeneous bottom. The six stimuli were produced by optimising the LED driving values of a stable, six-channel LED light

engine to provide six very different R, S, ipRGC and L-M signal distributions among the six stimuli at the fixed luminance level of 0.34 cd/m^2.

In the brightness discrimination procedure, 37 observers of normal colour vision compared the brightness of 20 different stimuli (provided by a stable 11-channel LED light engine) with a reference stimulus (a stable, high-quality one-channel white multi-phosphor LED at 3800 K) in two adjacent viewing chambers. As mentioned above, two series were carried out at each luminance level (266 cd/m^2; 25 cd/m^2; and 1.6 cd/m^2) with two different randomised orders and different positions of the two light sources (left/right, right/left). The two lower levels were achieved by spectrally neutral shadow masks. The position of the observer's head was fixed by a chinrest so that each chamber covered a viewing field of 33° x 36°. After 15 minutes of initial adaptation, observers viewed every pair of stimuli for 1 minute. Observers were taught to view both stimuli binocularly by slowly looking back and forth between them (mixed adaptation) and give their answer by assessing the homogeneous viewing booth bottoms.

The 11 LED channels were optimised to obtain 20 stimuli at the same luminance (measured on the bottom of the viewing box) but with very different R, S, ipRGC and L-M signal distributions (hence also different chromaticities). The peak wavelengths of some of the 11 LED channels coincided roughly with the peak sensitivity wavelength of the above mechanisms. First, observers had to tell which side of the double-chamber viewing booth was brighter (forced choice) and then also tell how much brighter, 0 being almost equally bright (difference almost invisible), 1 being a little bit brighter (very small difference), 2 being a bit brighter, 3 being explicitly brighter and 4 being explicitly brighter (a big difference is visible). If the reference was brighter then this number was multiplied by -1 during the evaluation. The sum of these numbers from every observer in the two repetitions determined the rank order of the twenty light sources. This rank order could be best predicted by the model equation in the following way: 1. L-M signals were excluded from the prediction; 2. the exponent of the signals equalled 0.5; 3. rod contribution equalled zero; 4. at 266 cd/m^2, the ratio of the ipRGC and S-cone weighting factors equalled ipRGC:S= 1.2:1.0; 5. at 25 cd/m^2, this ratio equalled ipRGC:S= 15.0:1.00; while at 1.6 cd/m^2, this ratio equalled ipRGC:S= 17.4:1.00. The role of the ipRGC signal and its relationship with pupil behaviour will be discussed in the final paper together with the performance of existing brightness models from literature.

OP36

A CROSS-CULTURAL STUDY OF COLOUR EMOTION FOR INTERIOR LIGHTING

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Abstract

1. Motivation, specific objective

The term “colour emotion” has been used by several recent studies to describe a research area investigating the relationship between colour and affective quality of the colour itself (e.g. colour patches) or of the environment/product (e.g. a real-scale lit environment or simulated images). Recent development in this area, however, has involved investigations into emotional responses using methods similar to these studies. It is also agreed in the CIE TC 1-86 technical committee that the use of “colour emotion” will help broaden both the scope of the subject area and the applications in related industries.

The most important finding in this area was perhaps the underlying factors of colour emotion scales. Principal components identified in these studies suggest at least three common underlying factors: *hue-related* (e.g. warmth, warm/cool, colour heat, temperature), *lightness-related* (e.g. soft/hard, potency, colour weight) and *chroma-related* factors (impact, dynamism, clear/greyish, activity, colour activity, colour impact). And It seems clear that colour emotion responses are somewhat culture-independent, showing consistent patterns across the regions.

Most of studies were based on flat colour patches either shown on a cathode ray tube (CRT) display or shown in a viewing cabinet, situated at a darkened room of each experimental site. Little is known, however, as to whether these findings can also apply to interior lighting. LEDs have become a dominant light source and can easily manipulate light colours to create an atmosphere. Can the relationship between light colour and the observer’s response be also consistent and predictable, just like what has been discovered in the conventional colour emotion studies?

2. Methods

To answer these questions, the present study used four Philips Color Blast RGB LED lamps to light an entire experimental room, 3.5m (width) by 2.5m (depth) by 2.3m (height) in size, decorated like a fashion store to provide a context. Observers were asked to rate the room in terms of 4 scales “liking”, “brightness”, “tension” and “dizziness”. This was followed by rating of the observer’s own facial skin using a mirror in the room in terms of 5 semantic scales “like/dislike”, “smooth/rough”, “natural/unnatural”, “young/old” and “feminine/masculine”.

There were 40 light colours used in this study, consisting of 25 white lights and 15 coloured lights. Note that all the 40 light colours had the same luminance value, 300 cd/m2 and that the general colour rendering index (Ra) of the 25 white lights varied between 21 to 60. The 25 white lights were selected to cover 5 Duv levels, -0.02, -0.01, 0, 0.01 and 0.02, and to cover 5 CCTs, 3000K, 3500K, 4000K, 5000K and 6500K. The 15 coloured lights included 5 hue regions, red, yellow, green, blue and purple, and 3 levels of purity based on Illuminant E. Thirty observers, 15 females and 15 males, from National Taiwan University of Science and Technology with various nationalities, participated in the experiment. All observers had normal colour vision. During the experiment, each observer was seated at the room and was asked to wear a grey coat in order to avoid any influence of their clothes colour on the experimental results. For each light colour, the observer was asked to rate the room as well as his/her facial skin using the 9 scales described above after the eyes were fully adapted to the lighting condition. The observer was asked to focus on the wall right before him/her when rating the room but could look around to better appreciate the appearance of the room.

Thirty observers, including 12 Taiwanese and 18 non-Taiwanese, participating the study. The non-Taiwanese observers were from Europe, South America and South Asia.

3. Results

For perceived room characteristics, it shows that Taiwanese observers consistently gave higher rating for “Liking” and “Brightness”, and lower rating for “Tension” and “Dizziness” than non-Taiwanese

observers did. For perceived brightness of the room, Taiwanese observers tended to feel the brightest for white lights at 6500K with a negative Duv, while the results for non-Taiwanese observers did not show such a tendency. For the liking for the room, the highest rating for Taiwanese observers was white lights at 6500K, and for non-Taiwanese observers the highest rating was for those at 5000K.

For perceived facial skin characteristics, it shows that “natural” was most similar between the two observer groups. There is more variation between the two observer groups in “smooth”, “young”, “Masculine” and “liking”. Under blue and yellow lights, non-Taiwanese observers felt that their faces were less smooth than Taiwanese observers. Under purple and red lights, non-Taiwanese observers felt younger than Taiwanese observers. Taiwanese observers preferred their skins under a yellow light, while non-Taiwanese observers preferred their skin under a purple light.

Although there is some difference between Taiwanese and non-Taiwanese observers, the Pearson correlation between the two kinds of observers for characteristics indicated that had significant correlation, except for “feminine/masculine”.

4. Conclusions

The results show that the “colour emotion” for room and facial skin characteristics were similarly agreed by observers of each region in a lit environment. There might be other experimental biases for each dataset collected, such as individual observer’s professional background, age, gender and his/her own definition of colour emotion. To clarify this will require further investigations into the impact of individual difference on colour emotion in a specific context, where the results may reveal how such an impact can influence real-world lighting design applications.

OP37

HUMAN VISUAL RESPONSES TO PAINTING AFFECTED BY LIGHTING CONDITIONS

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Abstract

1. Motivation, specific objective

Lighting as an environmental and architectural element can influence our perception, emotion and behaviour and is extensively applied to interior spaces, where layering lighting plays an essential role in creating a comfortable and appealing atmosphere. There is an increasing demand from the industry for understanding how the combination of accent and ambient lighting can affect the occupant's visual perception in terms of comfort and attractiveness.

To see how such an issue can be properly addressed, the present study used a small room where a 3D polyhedron object served as a visual task, lit by LED lamps of the typical 3000K colour temperature and various lighting installations. A panel of observers participating in the study were asked to assess the 3D object as well as the experimental room in terms of a set of semantic scales. The psychophysical methods were used to quantify the visual responses.

2. Methods

The present study used a small experimental room, 3.5m (width) by 2.5m (depth) by 2.3m (height) in size, where a 2D painting was displayed to serve as a visual task for the observers. The three walls were grey in colour. The wood veneer floor appeared dark brown. The 2D painting was 41cm (width) by 31cm (height) in size, fixed on centre of a painting distance 1.68m from the ground.

A panel of 30 observers, 15 males and 15 females, with normal colour vision took part in the study, individually conducting visual assessment in the room. During the experiment, each observer was asked to stand in the middle of the experimental room to assess an oil painting in terms of "visibility of details in texture" and "intensity of reflective light", "clearness" and "Liking", followed by assessment of the entire room in terms of "brightness" and "comfort".

An LED ceiling track light (1080lm, 14.8W), with a beam angle of 60 degrees, was used for the accent lighting. The light was located at either of two positions under the ceiling middle. The first position was right on top of the observer, providing a horizontal incident light angle of 0 degree to the painting, as can be seen in the top view of the room. This is called T1 in the study. The second position of the ceiling track light was located to the left side of the observer, with a distance of 1m, providing a horizontal angle of 45 degrees to the painting. This is called T2.

The ambient lighting was provided by indirect lighting from the background wall behind the painting. The background wall was lit by three linear LED light bars, called W in this study, recessed in the ceiling to down light the background wall. Each light bar (36.9W, 1360lm) was 1m in length. All lights used in this study had CCT = 3000K.

There were two light settings in this study. The first setting was that W and T1 were all switched on and were dimmed by changing the currency at the same rate, by 4 steps: 100%, 66%, 33% and 0%. The second setting was that W and T2 was switched on and was also dimmed using the 4 steps described above. The sequence of the dimming settings was randomised in the experiment for each observer.

3. Results

Experimental results show that for W all switched on and dimmed at the same rate, the observer responses were found to have different tendencies between T1 and T2. When T2 was on, the observers tended to see less reflective light, to like the painting more and to feel that the painting was more clearly presented than when T2 was on. This suggests that T2 had a more negative impact than T1 on the painting, the former having a horizontal incident light angle of 0 degree to the painting, and the latter 45 degrees.

Regarding the effect of W, the most preferred light setting was when W provided a medium luminance contrast for the painting, the ratio of vertical illuminance for the painting to the background wall being 3:1. This was when the painting felt most visible in details of texture, the painting being liked most, and the room being rated the most comfortable.

4. Conclusions

The findings described above reveal interesting insight into how the effect of ambient lighting on the visual response can be influenced by the position of lamp providing the accent lighting. The findings can help develop useful guidelines of lighting design for related applications.

Session SE1
Seminar LOC invited papers (1)
Friday, April 27, 09:00–10:40

SP02

APPEARANCE SIMULATOR OF FLUORESCENT OBJECTS UNDER DIFFERENT LIGHT SOURCES

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Fluorescence is a luminosity phenomenon where a material is first excited by light radiation in a specific wavelength region, and then the excited state relaxation emits light radiation in another longer wavelength region. This wavelength shift called Stokes shift causes a compelling visual effect. In fact, because of fluorescent emission, the fluorescent surfaces appear brighter and more vivid than the original object colour surface. Therefore, objects containing fluorescence are widely available in our daily life. Fluorescent materials are used in painted objects, papers, plastics, clothes, and all sorts of things that we may come across each day. Another usefulness of fluorescence is increasing whiteness perception in human vision. The material is called fluorescent whitening agents, which absorb light in the UV and violet wavelength range of incident light, and emit light in the blue wavelength range. This emission effect enhances the appearance of colour of the original fabric and paper by causing a whitening effect.

The fluorescent characteristics are described in terms of the bispectrality radiance factor. The radiance factor is a function of two wavelength variables: the excitation wavelength of incident light and the emission/reflection wavelength. The bispectral radiance factor can be measured using two monochromators normally. The two-dimensional characteristics of the measurement results are summarized as a Donaldson matrix, which is an illuminant independent matrix representation of the bispectral radiance factor of a target object. Therefore the appearance of a fluorescent object surface is determined by the Donaldson matrix of the fluorescent material and the spectral-power distribution of a light source that illuminates the object surface. However, when two or more fluorescent objects are located closely, the surface appearances often change. This is because an object surface is illuminated by fluorescence emitted from the nearby object surfaces as an indirect illumination, which causes light reflection and fluorescence excitation on the target object.

The present paper describes appearance simulator to reconstruct the appearance of fluorescent objects under different illuminants. We consider the appearance reconstruction problem not only for a single fluorescent object, but also for multiple fluorescent objects influenced by the mutual illumination and fluorescent objects with surface texture.

First, we present an effective method to estimate the bispectral Donaldson matrices for fluorescent objects in a scene by using a spectral imaging system. Multiple ordinary light sources with continuous spectral-power distributions are projected sequentially to the object surfaces without controlling the illuminant spectral shape. The Donaldson matrix is modelled as a spectrally high dimension array with 71×60 dimension where the excitation range is defined in (350, 700 nm) including UV wavelength range and the emission range is defined in (400, 700 nm) of visible wavelength range. The estimation problem is solved as an optimization problem to minimize the residual error of the observations acquired by the spectral imaging system. We estimate the three spectral functions of reflectance, emission, and excitation constituting the Donaldson matrix, in a direct way without using basis functions.

Next, we model the mutual illumination phenomenon between two fluorescent objects. When multiple objects are located closely, the phenomenon called interreflection or mutual illumination is observed on the object surfaces. In such a case, the illumination consists of at least two distinct parts: the direct illumination from a primary light source, and the indirect mutual illumination created by light coming from the other object surfaces. The mutual illumination affects the appearance of the object surfaces. When the mutual illumination is assumed to be based on only one reflection/emission between two surfaces, the spectral composition of the mutual illumination is determined by the multiplication of the two Donaldson matrices of two objects. In fact, the spectral composition of the observed image is composed with four components of (1) diffuse reflection, (2) diffuse-diffuse interreflection, (3) fluorescent self-luminescence, and (4) interreflection by mutual fluorescent illumination. The observed image of mutual

illumination is then modelled by the sum of multiplication of the spectral component functions and their location weights on the surfaces.

Third, we describe appearance reconstruction of fluorescent objects under different illuminants. Suppose a single fluorescent object without mutual illumination. Then, realistic images of the fluorescent objects under arbitrary illuminations can be rendered using the estimated Donaldson matrix at each pixel and the illuminant spectral-power distribution of a target light source. In the case of fluorescent objects with mutual illumination, we use the two estimated Donaldson matrices for appearance reconstruction including the mutual illumination effect. The spectral composition of the observed image of the two objects is composed with the four components. The estimated component images are used to render the images of the same fluorescent objects under different light source. Thus, the realistic appearances of the fluorescent objects with mutual illumination effect can be reconstructed by combining the component images.

We note that most material surfaces are not always smoothed but have some uneven texture such as irregularities, roughness, and patterns. Therefore, we also consider the extended problem of appearance reconstruction of the fluorescent objects with textures by surface geometries and roughness. We show that the observed spectral image are modelled by a multiplication of two factors of the spectral functions depending on wavelength and the location weights representing the texture information of the surface. The surface appearances of the textured fluorescent object under arbitrary illumination can be reconstructed by combining the two component images.

In experiments, the feasibility of the proposed appearance simulator is demonstrated using several scenes of fluorescent objects having the mutual illumination effect and the surface texture. We compare the appearances of the reconstructed images on a display device to the observations under real light sources under different light sources.

SP03

COLOUR DEPTH: A KEY FOR UNDERSTANDING THE RELATIONSHIP AMONG COLOUR SYSTEMS, COLOUR TONES, AND COLOUR EMOTIONS

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Abstract

1. Background and objective

Colour depth is the concept forgotten away in present colour study, especially in CIE. However, colour depth is an important human sense in colouring industry such as dyeing and printing industries, and one of the most important colour parameters. Because the colour depth corresponds to colourant concentration and/or percentage. Recently, following on the development of colouring industry, colour depth has been paid attention again.

On the other hand, lightness is normally used as one of three attributes for colour systems. However the lightness is different from colour depth. For example, vivid yellow has high lightness same to light grey such as L*=80, but the vivid yellow has very high depth colour similar to dark grey and black colours such as L*=20-40. Usually, colourists working in colouring industry, especially in dyeing industry, need to check colours with the viewpoint of colour depth relating to colourant concentration. Therefore, there are some gaps between attributes of the colour systems and senses of colourists working in colouring industry.

In this paper, we would like to confirm the importance of colour depth. We would also like to consider the relation among colour systems and colour emotions, using colour depth.

2. Numerical expression of colour depth, and its history

We have an important standard relating to colour depth. It is 1/1 Standard Depth of ISO 105 A01, and additional 2/1, 1/3, 1/6, 1/12, 1/25 depth level standards. Its original standard was produced in the 1920s, around 100 years ago.

The first numerical expression of colour depth was suggested by Godlove, around 70 years ago. The colour depth value is called as Godlove's A. Judd and Wyszecki introduced the concept of dyer's colour system including colour depth and dyer's brightness in their book 'Color in Business, Science, and Industry'.

After that, Gall's B, Rabe's θ, Teraji's DL*, Sato's D and some other colour depth values were suggested to express colour depth numerically. Using the formulae to calculate the colour depth values, we can instrumentally measure the colour depth of coloured materials. However, those colour depth values are calculated using attributes different colour systems, such as Goddlove's A and Teraji's DL* based on Munsell Colour System, Rabe's θ based on DIN Colour System, and Sato's D based on CIELAB.

3. Colour depth and colour system

CIELAB, Munsell and some other colour systems have three attributes such as hue, lightness and chroma. On the other hand, three attributes of the dyer's colour system introduced in the book of Judd and Wyszecki are hue, colour depth and dyer's brightness. In addition, the attributes of NCS colour system are hue, nuance, blackness, chromaticness and whiteness. The attributes of PCCS colour tone system are hue and colour tone.

Generally the Y-axis for displaying colour system and colour solid is made into lightness. When the Y-axis is changed into colour depth, what will change? We will be able to find a new concept for colour system, colour tone system, and colour solid. The colour solid will be conical.

Colour depth is very similar to the whiteness of NCS colour system. However, they are a little bit different. Colour depth is a sense corresponding to the concentration of colourant, and can be simply understood as the distance from white cloth/paper. The whiteness of NCS is a sense corresponding to the percentage of white, and can be simply understood as the distance from white.

Colour tone system such as PCCS system is useful for colour design. Using colour depth and dyer's brightness, colour tone system is also understood as more logical and instrumental-measurable system.

In order to understand the relationship among colour systems, colour depth will be one of important keys.

4. Colour emotion

Colour systems based on three attributes are useful. However, we feel various senses through colours which are called as colour emotion. Some of colour emotions correspond to physical properties. What sense for colour emotion corresponds to physical property?

Roughly saying, lightness corresponds to illuminance. Colour depth corresponds to concentration of colourant. Colour heaviness corresponds to physical weight. Colour warmness/coolness corresponds to temperature.

There are not only the colour emotions corresponding to physical properties, but also colour emotions not-corresponding to physical properties such as colour preference. The various colour emotions are made in our brain. Therefore, we can make various colour systems using the various colour emotions.

Using the concept of colour depth as a key, we will not be able to understand only the relationship among colour systems, but also colour tones and colour emotions. Moreover, we will notice new colour descriptions.

SP04

COLOUR APPEARANCE FOR VIRTUAL REALITY SYSTEM DISPLAY

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Abstract

1. Motivation, specific objective

Recently, virtual reality systems are an emerging area in display industry. Head mounted displays are commonly used for virtual reality systems with a mobile device as the main screen. Convex lens are fixed in front of the eyes to stimulate a wide viewing angle and stereoscopic contents. Previous studies have applied colour appearance models such as CIECAM02 on various displays. This paper purpose is to find out the surround conditions of the VR system in perspective view based on CIECAM02.

2. Methods

Three types of displays were used for the colour appearance experiment. The Virtual Reality (VR) system display was Samsung Galaxy Gear with Galaxy 6 attached and the mobile display (Mobile) was Galaxy 6 itself. 65 inch UHD TV (UHD) was used to stimulate wide view angle from viewing at a near distance. The surround conditions for viewing all three displays was dark surround conditions. Therefore, the surround variables for calculation in CIECAM02 was dark surround conditions.

The first part of this paper was a colour appearance experiment using single colour patches. Colour patches for the experiments was performed by the same data set in pervious colour appearance experiment. The visual data lightness and colourfulness colour attributes were accumulated by psychophysical experiment magnitude estimation. The CIExyY was measured with a spectro-radiometer. The measured data was used for the input data for CIECAM02. The surround conditions variables were ‘dark surround condition’ in calculation CIECAM02. This was due to no extra illuminant other than the display itself for all three conditions. Then the colour attributes lightness (J) and colourfulness(M) is compared with the visual data lightness and chroma (colourfulness).

3. Results

Lightness: Lightness for the CIECAM02 was plotted against the accumulated visual data sets. The straight line is the 45° line and shows the perfect match among the data sets. It is well known that lightness is relatively more sensitive to the luminance level of the surround condition than the other colour attributes. However, assuming different surround conditions among the three displays, the lightness data sets did not show distinguishable difference among the displays.

Colourfulness: Colourfulness was plotted against CIECAM02 colourfulness(M). Besides from the mobile data sets plotting, most of the VR and UHD data points are positioned under the 45-degree line. This indicates that the visual data is estimated higher than the calculated colourfulness of CIECAM02. Assuming that CIECAM02 estimates well for normal dark surround conditions of 2-degree stimulus size configuration such as the Mobile conditions, the wide viewing angle of VR and UHD effects the colour appearance for colourfulness. Larger viewing angles tends to higher up the perceptual colourfulness. Also this means the surround conditions are darker than normal dark surround conditions such as Mobile viewing conditions. This is due to the Hunt effect for transmissive media.

4. Conclusions

CIECAM02 is structured with dark surround as zero based with higher illuminance levels up to brighter surround conditions. We have found out that a stimulus on a larger viewing field can occur to darken the surround condition and effect the stronger colourfulness for single colour patches and higher luminance contrast for complex images.

SP05

MATERIAL APPEARANCE MANAGEMENT TECHNIQUES WITH AFFECTIVE MONITORING

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Abstract

1. Motivation, specific objective

Recently, an electronic commerce such as online shopping becomes more active with powerful progress of high-speed network and computer science. Especially, the development of computer graphics (CG) technique and rendering engine have a great contribution for the advancement of electronic commerce. An excellent representation of commercial product excites consumer's interest, and an accurate representation with high quality makes possible the commerce transaction in the virtual world.

An accurate reproduction for material appearance is the most important factor for commercial value of product as the quality control of electronic commerce. The mischief is that the appearance has no responsibility for the representation on various kind of display device. Appearance matching method should be developed for the further electronic commerce growth.

Therefore, in this paper, we propose a device independent reproduction method to match the appearance of surface graininess by the control of CG image. We derive the uniform perceptual space about surface graininess by experiment of magnitude subjective evaluation. By controlling the height and distribution of bump profile in CG image according to the maximum luminance, the proposed method can make a perception of surface graininess equal in each display device.

To derive a device independent reproduction model, it is necessary to conduct a subjective evaluation experiment on the graininess evaluation image. However, long time experiments have fatigued subjects and there are responses that can't concentrate on the experiment. Therefore, we evaluated concentration on tasks to build psychophysically-based model of graininess perception for device independent graininess reproduction system. We measure the concentration of the subject when conducting subjective evaluation experiments for deriving the model. Then we use only the concentrated responses for deriving the model.

2. Methods

In the experiment to obtain the subjective evaluation values, the magnitude estimation method was used to quantify the graininess perception. The graininess model obtained by multiple regression analysis for the above values can be used to calculate curved surfaces where the graininess objects are observed as the equal appearance. This surface can be used for device independent graininess reproduction process to match the graininess under the displays with various maximum luminance. The appropriateness of the physically-based model is affected by the experimental situations. In this paper, we focus on the concentration on the experiment by subject. It is easily understood that the obtained subjective data is not reliable when the subject did not pay attention to the task. We measured heart rate variability by the electrocardiogram attached on the arm of the subject. The high frequency (HF: 0.15-0.4Hz) of the heart rate variability reflects the respiratory sinus arrhythmia affected by action of the respiratory and parasympathetic. Meanwhile, the low frequency (LF: 0.04-0.15Hz) represents the Mayer wave originated in the action of both sympathetic and parasympathetic. In this paper, we calculated LF/HF as the index of concentration on the task. As a result of preliminary experiments, it is defined that responses with LF / HF> 1 are concentrated, and responses less than 1 are not concentrated. To investigate the improvement of the model accuracy, we focused on the value in the coefficient of determination of the equation.

3. Results

We derived the equation by a multiple regression analysis for the data obtained by the magnitude estimation experiment. The coefficient of determination (R^2) was 0.763 for this equation. A is the depth for ruggedness (Amplitude), S is the size of grain, and L is the maximum luminance value corresponding

to the maximum pixel value in the image. *G* is the dependent variable related to the perceptual graininess. Using this model, we obtained the equal perception level on each graininess. This model can be utilized to make us equal perception for graininess by manipulating the physical parameters such as *A*, *S* and *L* along the model. Therefore, when we select the value of *A* or *S* along the same surface according to the arbitrary maximum luminance of display, the device independent reproduction for graininess can be acquired.

Next, multiple regression analysis is performed on evaluation data on graininess obtained by subjective evaluation experiment while measuring electrocardiogram. At this time, a calculation algorithm was created so that the determination coefficient of the model equation becomes the largest value. This is a combination of A, S, which are three parameters dealt with in the graininess object, from the 10th power to the 10th root to derive a model equation with the largest coefficient of determination. First, we derive equation calculated using all data. The coefficient of determination was 0.518 for this equation. Next, the model calculated by excluding the response in the non-concentrated state, that is data at LF / HF < 1, is derived. The coefficient of determination was 0.6372 in this equation. Comparing the determination coefficients of all data model and only concentrated model, the coefficient of determination with concentration model was increased compared to all data model.

4. Conclusions

In this paper, we produced a psychophysically-based model of graininess perception for device independent graininess reproduction model. This model was used to match the graininess perception under the displays with various maximum luminance, and derived using only the concentrated response by measuring the electrocardiogram. We found that it is necessary to consider the concentration on the task by the subject to obtain the appropriate psychophysically-based model. The generated objects for the same graininess along this model were observed as the equal appearance with high accuracy.

Unfortunately, this model is evaluated in the only cases that the graininess object has a limited amount of luminance. The limitation of our model should be explored by the additional evaluation. Moreover, our model is only evaluated by using the object of plane surface. There are many kind of objects with complex shape in the world. In our future tasks, it is necessary to achieve the more practical scale implement of appearance matching for the progress of electronic commerce.

Session SE2
Seminar LOC invited papers (2)
Friday, April 27, 09:00–10:40

SP07

IMPACT OF AGEING CHANGES IN HUMAN VISUAL SYSTEM ON DISCOMFORT GLARE SENSATION AND PRINTED TEXT READABILITY

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1. Introduction

CIE 227:2017 provides guidelines of lighting requirements for normal healthy older people. However, this technical report also suggests larger individual deviations in evaluations of discomfort glare and readability of printed texts among older people than those among young people. Such general lighting guidelines may not be useful for an older person whose visual function differs from that of the normal healthy older people. Therefore, it is important to provide additional lighting requirements to fill the gap between the individual visual function and the averaged.

Unfortunately, the Unified Glare Rating (UGR) system (CIE, 1995) does not take the ageing effect on glare sensation into account. Luminance contrast of each light source against its background is an important factor in UGR. As the luminance contrast increases, the degree of discomfort also increases. With age, light scatter in eyes increases, and therefore the luminance contrast of the light source against the background is reduced. Then, the degree of discomfort may also be reduced. However, light scatter may directly raise the degree of discomfort by increasing the apparent size of the light source. Due to such conflicting mechanisms, studies showed mixed results with regard to the effects of age on discomfort glare.

Readability of printed letters is mainly influenced by the size and luminance contrast of the letters and adaptation luminance of observers. Most readability models were developed based on young observers' responses. However, with age, lens density increases while pupil size decreases. These ageing changes result in lower retinal illuminances and therefore lower adaptation luminances. Since light scatter in eyes also increases, luminance contrast of printed letters may also be reduced with age.

To investigate which factors may cause such large individual deviations, this study examined relationship between individual visual characteristics and discomfort glare sensation / printed text readability. In this study, young and older subjects evaluated discomfort glare and printed text readability after being examined their visual characteristics in this study.

2. Methods

This study conducted (1) measurements of visual characteristics, (2) discomfort glare evaluations and (3) readability evaluations. In this study, six young subjects (20-23 yrs.) and 18 older subjects (65 - 80 yrs. in age) participated.

(1) Visual characteristics measurements: Ophthalmologists measured visual characteristics such as visual acuity, pupil size, density of crystalline lens, and effective (clear) lens area for the subjects. The optical characteristics were measured by using a cross section image photographing device (ESA-1000, NIDEK). The contrast sensitivity was also measured by using a commonly used device and procedure (CSV-1000E, Vector Vision).

(2) Discomfort glare evaluation: The experiment used an experimental setup, composed of a 0.63 m wide, 0.63 m high, and 0.15 m deep glare box and a dimmable flood light. The glare box contained 15 dimmable LED luminaires, and had a square opening with a translucent acrylic panel. The square opening provided a glare source to subjects. The dimmable flood light was used to maintain the background luminance as about 40 $cd \cdot m^{-2}$ for all experimental conditions.

The independent variable was the size of the glare source; i.e., the sides of the square glare source were 2 cm and 60 cm. The borderline of comfort and discomfort (BCD luminance) of the glare source was measured for each of the two sizes.

In the experiment, each subject sat on a chair at a distance of 0.8 m from the glare source whose luminance was set to 100 cd/m^2 as the lowest luminance. After adapting to the brightness of the glare source, the subject gradually increased the luminance by rotating a knob of a dimmer until the subject started feeling discomfort. Then, an experimenter measured the luminance of the glare source as a BCD

luminance. Then, the experimenter set the luminance of the glare source to 35 000 cd/m^2 as the maximum luminance. The subject gradually reduced the luminance by rotating the knob until the subject stopped feeling discomfort. Then, the experimenter measured the luminance of the glare source as another BCD. Finally, those BCD luminances were averaged for each of the subjects.

(2) Printed text readability evaluation: The experiment used a 1.2 m high, 1.4 m wide and 1.2 m deep target presentation box whose interior surfaces were illuminated by four dimmable fluorescent lamps. The box had an opening through which a subject looked at a target posted on the opponent interior wall. The target was a 140-letter Japanese paragraph. The independent variables of the experiment were luminance contrast (0.90, 0.72, 0.65 and 0.35), letter size (32, 21, 14, and 10 points), and target luminance (600, 200, 70, and 20 cd/m^2).

In the experiment, each subject sat on a chair in front of the box and looked at the target which was set to one of the experimental conditions, through the opening of the box. The subject evaluated the degree of readability by using a nine-point readability scale.

3. Results

(1) Discomfort glare evaluations: The results of the discomfort glare evaluations showed a similar tendency to Akashi et al. (2017). The results found that for the small glare source people who have clearer lenses and larger pupils, and therefore larger retinal illuminance values tend to have lower BCD luminance values. On the other hand, for the larger glare source, people who have larger effective (clear) lens areas seem to have higher BCD luminance values. However, people with very small effective lens areas also appear to have high BCD luminance values.

(2) Readability evaluations: First, we investigated the relationship between each of the visual characteristics and the readability evaluations. We found a high correlation between contrast sensitivities and readability evaluations. Therefore, we divided all the participants into two groups based on subjects' contrast sensitivities and developed new readability models. The models clearly showed that people with high contrast sensitivity can read letters even with low luminance contrasts, but that people with low contrast sensitivity cannot read letters with low luminance contrasts. Finally, we developed a readability model for various luminance contrasts, letter sizes and adaptation luminances.

SP08

QUANTIFICATION OF EXTERNAL LIGHTING ON HUMAN CIRCADIAN SYSTEM IN METROPOLISES AT NIGHT

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Abstract

1. Motivation, specific objective

Since the discovery of ipRGC in the retina in 2003, more and more efforts have been made to investigate how light affects human health, especially circadian system at night. Meanwhile, policy makers are revising relevant standards, with a goal to reduce light pollution and light nuisance caused by external lighting. Past studies, however, mainly focused on the visual comfort and glare caused by external lighting. This study aimed to quantify the effect of external lighting on human circadian system through a series of site measurements in two metropolises (i.e., Hong Kong and Shanghai), which has never been studied.

2. Methods

Illuminance and spectral power distribution (SPD) were measured at 222 locations, with 152 locations at three commercial business districts (i.e., Causeway Bay, Tsim Sha Tsui, and Mong Kok) in Hong Kong and 70 locations at three business districts (i.e., Lujiazui, Xujiahui, and Nanjing Road) in Shanghai. At each location, four sets of measures were taken using a calibrated irradiance spectroradiometer, which was vertically placed at the eye height (i.e., ~1.6 m above the ground), with two along the road and two perpendicular to the road, to characterize the amount and the spectral content of light arriving at pedestrians' eyes. All the measurements were taken after 7 pm on non-rainy days, so that no daylight or high reflections were included. Based on the illuminance and SPD measurements, both equivalent melonopic lux and Circadian Stimulus (CS) were calculated for each location.

Computer simulation was carried out to investigate whether it is possible to reduce the impact of external lighting on human health, in terms of CS value, by producing metameric light stimuli with optimized SPDs using a seven-channel spectrally tunable LED lighting device.

3. Results

The average vertical illuminance in Hong Kong and Shanghai were 164 and 56 lx, with a standard deviation of 168 and 64, respectively. 98% of the measured light stimuli had chromaticities within a D_{uv} range ± 0.03 and a Correlated Colour Temperature (CCT) range of 1900 and 30000 K.

The external lighting in the two metropolises generally had negative impacts on human health. The average CS values were 0.15 and 0.07 in Hong Kong and Shanghai respectively, both of which were higher than 0.05, a threshold value for affecting human circadian rhythm at night. Specifically, 68% and 46% of the stimuli at measurement points in Hong Kong and Shanghai had CS values beyond 0.05.

The computer simulation indicated that the CS value can be reduced by 9.2%, 18.7%, and 28.3% when the illuminance level was reduced by 10%, 20%, and 30% respectively. In contrast, spectral tuning can reduce the CS values by 22.9% on average by holding the chromaticities and illuminance as measured. For the stimuli with a CCT between 2800 and 3400 K, spectral tuning was found to effectively reduce CS values by 65% to 80%.

When the light stimuli had chromaticities on the Planckian locus, CS was found to be related to both CCT and S/P, at a same illuminance level. When CCT was beyond 4000 K, the stimuli with higher CCT tended to have higher CS, and S/P was positively correlated to CS for those with same CCT. Similarly, the stimuli with higher S/P had higher CS, when CCT was 2000 and 3000 K. For the stimuli at 4000 K, there was a discontinuity at S/P of 3.2. CS were lower than 0.08 for those with S/P below 3.2, but were higher than 0.18 for those with S/P beyond 3.2.

For the light stimuli with CCT beyond 4000 K and chromaticities off the Planckian locus, the metameric stimuli with higher S/P tended to have higher CS. Positive correlation was found between CCT and CS

for those with same D_{uv}; while negative correlation was found between D_{uv} and CS for those with same CCT values. A similar negative correlation between D_{uv} and CS was found for the 2000 K stimuli. When the 3000 K stimuli had D_{uv} other than -0.01 and the 4000 K stimuli had D_{uv} other than +0.01, a positive correlation between S/P and CS was found for the metameric stimuli. The 3000 K stimuli with D_{uv} of -0.01 and the 4000 K stimuli with D_{uv} of +0.01 had similar discontinuity at S/P of 1.7, and had the lowest CS values. The discontinuity for the on- and off-Planckian stimuli were due to the drop of circadian sensitivity for the yellowish stimuli.

4. Conclusions

A series of field measurements of illuminance and SPDs were taken at six commercial business districts in two metropolises, with three in Hong Kong and three in Shanghai. It was found that the illuminance and the spectral content of the external lighting in the metropolises would affect human circadian system, especially in Hong Kong. Specifically, 68% and 46% of the measurement points in Hong Kong and Shanghai had CS values beyond the threshold of 0.05. The computer simulation suggested that spectral tuning can be more effective in reducing the negative impact on circadian system than decreasing illuminance levels, especially for a certain range of CCT levels. The stimulation results also revealed the possibilities of using CCT, S/P, and D_{uv} to roughly estimate the impact of light stimuli on human circadian system, which can be easily used by lighting specifiers and users.

Session SE3
Seminar LOC invited papers (3)
Friday, April 27, 09:00–10:40

SP14

INFLUENCE OF CORRELATED COLOUR TEMPERATURE AND DUV OF ILLUMINATION ON VISUAL IMRESSION OF A LIGHTING SPACE

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Abstract

1. Motivation, specific objective

Advances in LED technology have opened new possibilities of lighting design using coloured light. Colours of illumination close to the blackbody locus are often described by single parameter; correlated colour temperatures(CCT). However, colours of the light having the same CCT should appear more or less different if their deviations from the blackbody locus are different. The value of Duv provides information on the distance and direction of a colour deviation from the blackbody locus on the CIE 1960 uv colour coordinate. It is important to consider both CCT and Duv to know how colours of the lighting appear and how it influences on our visual impressions of the lighting space. The aim of this study was to examine effects of CCT and Duv of illumination on our visual impressions of the lighting space.

2. Methods

This study was conducted at a laboratory of Kyoto University. The size of an experimental booth was 3.0m x 3.0m and 2.4m high. The colour of lighting in the booth could be set precisely by tuning the colour of nine LED downlights attached on the ceiling. We set 52 test colours of the light covering the wide range of the area along the blackbody locus. The illuminance at the center of a table placed on the floor was set 100 lx for all conditions. Subjects viewed the interior space illuminated by one of the lighting conditions and evaluated visual impression of the lighting for nine items; brightness, comfort, spaciousness, activity, warmth, naturalness, stimulating, preference and suitableness.

3. Results

The results of the study were firstly plotted on the CIE 1960 uv colour coordinate to see the effects of CCT and Duv. Visual impressions of comfort, naturalness, preference and suitableness were found to have higher evaluation close to the blackbody locus, indicating influence of Duv. Visual impressions of warmth and stimulating were significantly influenced by CCT.

4. Conclusions

The results of this study provided the information how the visual impression of the light changes along the wide range of the blackbody locus. This would provide a scientific basis to consider effects of the CCT and Duv of lighting and to create new lighting design suitable for our living environment. The results will also be discussed considering practical applications.

Session PS1
Presented Posters (1)
Friday, April 27, 13:40–14:25

PP01

AN OPTICAL FILM-BASED DAYLIGHTING SYSTEM WITH HIGH DAYLIGHTING PERFORMANCE AND LESS DISCOMFORT GLARE

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1. Motivation, specific objective

At present, lights are constantly on in the daytime in many buildings, and it is hard to say that solar light energy is effectively used from the viewpoint of energy utilization. In the office, it is said that the lighting energy accounts for about a quarter of the total electricity consumption, and it is a social requirement to reduce electricity consumption by using daylight.

In response to this request, various daylight utilization techniques have been proposed. We propose a daylighting optical film and a new daylighting system using it as a means of using natural light. We aim at achieving a daylighting system which realizes high daylighting performance and suppressed discomfort glare simultaneously. The system will contribute to the reduction of the lighting energy as well as the improvement of living comfort and wellness of persons in buildings.

In this study, we introduce the outline of the new daylighting system and investigate the performances including daylighting efficiency, discomfort glare, and lighting energy reduction through a whole year.

2. Methods

2-1. Outline of the daylighting system

Our daylighting system is installed on the upper side of windows of a room. It consists of a daylighting optical film and tetra lateral frame, and it has a shape of thin flat plate. The daylighting film is a kind of prism lens with diffuser. It is a few micro meters in thickness. The film is optically designed by ray-trace simulation. It reflects incident sunlight to the ceiling of a room and minimizes downward light leakage. Diurnal and annual motions of the sun are taken into account in the optical design. So, the daylighting system illuminates a room with indirect light throughout a year, and it does not give unpleasant glare to persons in a room.

2-2. Evaluation environment of the daylighting system

In order to verify the performance of the daylighting system, we constructed an experimental room in Kashiwa City, Chiba prefecture, Japan. The size of the room was 7.2 m in width, 9.0 m in depth, and 2.65 m in ceiling height. The windows were facing south-southeast and had a width of 6.4 m. The specification of the window was a single plate glass without heat reflective coating. There were condominium buildings in front of the room with elevation angle of 19 degrees. The daylighting system was installed at the position of 0.65 m from the ceiling and the window's lower part was shielded with fully closed blind to evaluate the daylighting system. The desktop illuminance was measured by illuminometers (Konica-Minolta, T-10A) at the height of 0.75 m from the floor. We also measured luminance distribution around the window (Radiant Imaging, Inc., Prometric PM-1423F) to evaluate discomfort glare.

2-3. Calculation of lighting energy saving performance

Lighting energy reduction rate of the daylighting system was calculated from the desktop illuminances. First, we measured the desktop illuminance of the room every one meter and every 15 minutes from 8 to 17 o'clock. Then, we calculated the lighting reduction rate at each time as R_{15min}. In the calculation we assumed that lights are turned on to compensate the daylighting system for keeping 500 lux in the entire room. Next, we conducted this measurement and calculation throughout a year, and the annual lighting reduction rate was calculated by accumulating R_{15min}.

3. Results

3-1. Illuminance and glare index of the experimental room

In the daylighting system experimental room, a bright light environment was realized throughout the year. Sunlight was introduced by the daylighting system effectively, and the whole room was filled with

soft diffused sunlight. In a winter sunny day, for an example, the desktop illuminance at the back of the room showed 300 lux from 11 to 15 o'clock only with the effect of the daylighting system. The desktop illuminance level was enough for ambient lighting of office rooms. And around the noon it reached over 500 lux at a maximum. Glare level in the room was evaluated by PGSV and less discomfort glare was confirmed. It was suppressed under 1.2 except just in front of the windows. The daylighting system realized high desktop illuminance and glare suppression simultaneously.

3-2. Lighting energy saving performance

The lighting energy saving performance of the system was evaluated by making a map of R_{15min} for a year. Higher R_{15min} values were obtained especially during the period from autumn to spring equinox as the daylighting film was optically designed to introduce sunlight deeper in the winter season. For example, lighting energy reduction rate of a sunny day reached 45 % in summer and 75 % in winter while that of a cloudy day showed around 20 % in both seasons. As a result of accumulating R_{15min} with taking into consideration of 365 day's weather, the annual lighting reduction rate was 42.9 %. The data indicated the daylighting system had a potential of over 40 % cut-off of lighting energy under the experimental room condition.

4. Conclusions

An optical film-based daylighting system was implemented in an experimental room and its performance was evaluated. The data obtained in the room showed high desktop illuminance and less discomfort glare simultaneously through a whole year. The system had a potential of over 40 % lighting energy cut-off a year under the experimental room condition.

PP02

Depreciation of Room Surfaces Reflectance and their influence on Maintenance Factor of Lighting Systems

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Abstract

1. Motivation, specific objective

Maintenance Factor (MF) is the key parameter used in any design and measurement of lighting systems. Its role is to adjust the calculated or measured value of target lighting parameter (illuminance or luminance) with respect to the end of maintenance cycles (i.e. time when the maintenance is to be carried out) so that anytime the lighting level satisfies the given requirement. Once the lighting system is put to operation, ageing and environmental influences are responsible for depreciation and continuous decrease of illuminance or luminance or in systems with CLO control continuous increase of power consumption. Depending on lamp type or luminaire type some of the changes can be eliminated by maintenance (e.g. relamping, cleaning of optical parts) and some must be related to the end of life (non-recoverable losses due to ageing of optical parts, luminous flux depreciation and mortality of non-replaceable LEDs).

Maintenance Factor for interior lighting systems is dealt in the Publication CIE 97:2005 and for exterior lighting systems in the Publication CIE 154:2003. Methods for determination of the maintenance factor are, however, decades older and neither reflect the current level of technology nor the current quality of environment. Update of the both technical reports is in terms of reference of the new joint technical committee (obviously JTC 12).

Full structure of the maintenance factor comprise luminous flux maintenance factor (LLMF), lamp survival factor (LSF), luminaire maintenance factor (LMF) and room surface maintenance factor (RSMF). For exterior applications, LSF and RSMF are not used, the latter due to inexistence of walls and ceiling outdoors. However, novel approaches tend to propose establishment of this component back to MF for tunnel lighting, underpasses and similar applications.

This paper deals specifically with the RSMF component of the maintenance factor. Loss of reflectance of the walls, ceiling and floor undoubtedly has influence on target lighting parameters and extent of this influence depends on many factors like room shape factor, initial (or nominal) reflectances, luminous intensity distribution of luminaires and cleaningness of the environment. As the problem is very complex, to determine this component for a given room or space with careful consideration of all the factors is almost impossible. Currently available methodology is too simplified and inaccurate. It is also not possible to consider different luminaire types installed in the same room or space.

Proposal of a new method is based on exclusion of RSMF from the maintenance factor, or in other words, separation of the maintenance factor to the part associated with individual luminaires and the part associated with surfaces. New surface factor will be directly incorporated in the value of reflectance. Accuracy of this approach is in sole estimation of reflectance decrease. How luminous flux from luminaires hits these surfaces and how their reflection affects lighting parameters on the target area, is matter of ordinary lighting calculations. Thus, tables for different room shape factors and luminaire types (expressed through the direct flux fraction) can be avoided.

Aim of this paper is to present the new proposal for determination of the RSMF component as a self-standing surface factor associated directly with surfaces, taking into account environmental conditions and depreciation of reflectance in time under these conditions.

2. Methods

Depreciation of the reflectance of walls is being monitored in different applications (usage pattern, environment) with focus on (but not only) office rooms and class rooms. Up to now, 2-year data have been collected. Samples of 600 x 600 mm are placed on walls and taken for measurement of reflectance after stated periods of time. The known shape of depreciation curve is typical for a knee short after installation and with long time of steady-state value of reflectance. To save time and to cycle

measurements more frequently it is practical to capture the knee bend and to terminate the depreciation right after steady-state is reached. Reflectance is measured in laboratory condition by the luminance/illuminance method assuming that the surface is ideally diffuse. Additional measurements are carried out for real surfaces in rooms with known time of the last paint renovation. Aim of the measurements is to study the nature of depreciation of common paints and to derive a table of values for the surface factor.

Influence of the depreciation of room surfaces reflectance on target lighting parameters is studied on model calculations for different shape factors, luminous intensity curves, arrangement of luminaires and illuminance levels. Model calculations are carried out with the Dialux calculation software.

3. Results

Proposal of a new method for determination of the maintenance factor split to luminaire associated and surface associated components will be explained in details. The paper will focus on the surface factor component.

The paper will publish results of the measurement of surface samples in different applications. Depreciation curves will be confronted with the currently available figures in CIE 97. New values for direct adjustment of reflectances instead of calculated or measured lighting parameters will be proposed.

Results of model calculations will be analysed. Based on analyses, benefits of the novel approach will be confirmed.

4. Conclusions

Results presented in the paper will show a justification for the new approach of separation of the surface factor from the maintenance factor, leaving it associated with luminaires only. Depreciation of the reflectance of room surfaces still need to be investigated with respect to the quality of environment which itself is the subject of further research. It was found out, for example, that depreciation of reflectance is uneven and it is related with circulation of air in rooms which carries dust and other pollutants – therefore contamination of wall centres will differ from corners. Good selection of real installations and/or artificial deposition of dust and dirt on samples will be essential. Further measurements should continue to provide wider set of data. More precise monitoring of air quality and possibly monitoring of air flow should also take place.

PP03

THE OPTIMIZATION OF A SMALL OFFICE LIGHTING BASED ON THE DYNAMIC TAGUCHI METHOD

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Abstract

All along, people are constantly looking for the best lighting, hope that lighting can become the best aid in life. To achieve good lighting, the necessary conditions include the type of lighting, appearance, quantity, illumination, colour temperature, luminous efficiency, etc. For most users, the lighting is comfortable, harmless, and contributes to the execution of the event, which could be regarded as appropriate lighting.

People today spend at least eight hours a day on work, the lighting of the working environment is very important, its profound impact on the user's physical and psychological, and performance on the effectiveness of the work. In Asia, office is usually designed as a light steel frame ceiling, so the most common lamps are the grille light steel lamps. This type of luminaries can make the office to achieve the basic illumination, and suitable for general paperwork. But for some users with highly focusing work, e.g. need a long time in using computer, reading, calibrate, typing, or mapping, uneven desktop illuminance and over dark office space (some are too bright), will cause the user to physical and psychological fatigue easily.

In order to improve the above problems, our team focuses on the user’s health and comfort, by using Taguchi Methods and Robust Parameter Design to conduct experiments of office lighting. The experimental results will be a parameter that optimizes the lighting. It will help the development of the lamp manufacture, space lighting design has a better understanding and application.

This study selected a small office as an experimental field. There were 10 observers, 5 males and 5 females participated in the experiment, aged between 25 and 35 years old, daily working hours at least 8 hours. About the experimental design, spatial planning includes signal factors and control factors. The signal factor is colour temperature and illuminance. The control factor is to change the wall colour and spatial uniformity. In addition, the physiological parameters of electroencephalography and heart rate variability were measured as non-subjective evaluation of this experiment, questionnaire scale as subjective evaluation, and analysis of the physician's physiological changes, psychological feelings at the same time.

The results of the experiment show that, in terms of colour temperature, during the implementation of the task, the observers in the task of light with colour temperature of 5300K felt more spiritual. For the overall space comfort and the degree of natural, are also prefer to the light with colour temperature 5300K. At the part of the illumination, the majority of observers in the task of 300lx light, felt tired easily which was compared with the 500lx light. The results of comprehensive experiment, the most suitable parameters conditions of this small office are colour temperature 5300k, illumination 5001x. In the future, lighting-related industries, including lighting manufacturers, interior designers and architect, could be used as a reliable basis.

PP04

EXPLORING THE COLOUR APPEARANCE IN HDR TERRITORY

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Abstract

1. Motivation, specific objective

Our eyes performed remarkably well to be able to perceive a wide range of luminance levels from bright sunlight (10^8 cd/m^2) to the dark light (10^{-6} cd/m^2). So, during the bright sunlight, all objects are perceived to be bright, colourful, vivid. On the contrast, they appear to be dim, dull. In many applications, there is a need to simulate real viewing environment, e.g. to simulate outdoor scene, to monitor traffic conditions.

In the imaging industry, the era of HDR devices have arrived. Almost all cameras nowadays equipped with HDR capturing capability no matter is mobile or DLSR technology. For the arrival of digital cinema and TV industries, displays have expanded its colour gamut range, contrast, peak white luminance, high resolution, fast frame rate. The new technologies such as OLED, QLED, have been greatly advanced over the years. However, many challenges have been raised in the recent workshop in CIC2017 conference with a title of 'Visual perception and emerging technologies in cinema: perspectives from academia and the industry'. A consensus has been achieved, i.e. a lack of model of colour vision that can predict the perception of brightness, colourfulness, hue, contrast for natural images. The present most advanced CIECAM02 was developed to predict the colour appearance under different typical viewing conditions, considering chromatic adaptation, brightness adaptation, background and surround effect. However, it does not cover extreme photopic and low mesopic ranges. Without this, industry is struggling to develop standards for faithful reproduction of colour and contrast, to avoid visual discomfort that is enhanced image content might induce.

With the above in mind, there is a strong need to design and build a HDR light systems to carry out colour appearance research under extreme photopic and low mesopic ranges. This paper describes the performance of such a lighting system.

2. Methods

A lighting environment has been achieved. It located in a room including 2 cubicles, one to accommodate the HDR lighting system and the other to accommodate a high-performance display such as OLED. Each cubicle had a size of 2x2x2.65 m^3. The walls in the two cubicles were painted with a white and a black colour, having reflectance values of 0.861 and 0.035 (or L* 94 and 22), respectively.

The HDR Lighting system including 14 illuminators, each had a 11-channels of LED covering from 415nm to 660nm wavelengths. They located in the different positions of the cubicle: 4, 3, 3 and 4 for the top, left, right and bottom, respectively. The goal is to achieve a high dynamic range environment illuminated by a large range of the white lights. Also, it should meet high colour quality measures such as CCT, Duv, MI, Ra of the CIE daylight illuminants and those in the Blackbody locus. The spectral power distributions (SPD) will be difficult to be exactly reproduced due to limited 11-LED channels. However, their SPD curves should agree reasonably well. Most importantly, they should achieve a high vertical uniformity on the wall.

3. Results

The results to simulate a CIE illuminant D65, and 4000K and 3000K in the Blackbody locus are reported here. For D65, it had a luminance ranged from 2453 to 59.6 cd/m^2, which were measured by a Konica Minolta CS-2000A tele-spectroradiometer. To achieve lower luminance, a custom made shading plates with 3x3 Φ10mm holes were installed for each illuminator. The lowest luminance was 1.6 cd/m^2. Hence, for D65 tested, a contrast of 1500:1 was obtained. When measured using a Konica-Minolta CL500A on the wall, an illuminance of 8539.9 lux was achieved. It also had a CIE Metamerism Index (MI) less than 0.20 which is categorized as Class A for D65. For 4000K in the Blackbody locus, it had a luminance ranged from 1337 to 58.6 cd/m^2. The lowest luminance was 1.7 cd/m^2 covering with the shading plate. For 3000K in the Blackbody locus, it had a luminance ranged from 1135 to 51.7 cd/m^2. The lowest

luminance was 1.5 cd/m^2 covering by the shading plate. Root mean square (RMS) calculated between the measured and standard SPD was also reported to evaluate the goodness fit of spectral match. These were 0.05, 0.07, 0.09 for 6500, 4000 and 3000K the respectively. For all the three illuminants tested, CCT kept within ±20K, Duv of ± 0.0015, CIE Colour Rendering Index (Ra) >96. They can be considered high colour quality of illuminants.

Radiant Prometric imaging photometer was used to obtain a luminance map. Luminance uniformity on the wall was calculated from luminance map and was defined by CIE as the ratio of minimum luminance to average luminance. For all test lights, luminance uniformities on the wall were above 97%. CS-2000A and Prometric pointed to the middle of wall and was 1.5m away from the wall.

4. Conclusions

In conclusion, a multifunctional HDR LED lighting system has been established to provide a high dynamic range (1500:1 for D65), great spatial uniformity (>97%) and accurate colour quality. It can be used to carry out colour appearance research, colour quality evaluation in the digital cinema and HDR TV studios, calibration of digital camera devices, cross-media colour reproduction and colour management. A series of experiments have been planned.

PP05

RESEARCH ON THE APPLICATION BENEFITS OF THE LED LIGHT SOURCE BASED ON THE ROAD LIGHTING SYSTEM FOR THE SMART CITY ---IN TIANJIN REGION AS AN EXAMPLE

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Abstract

With the development of China's social economy, the number of the smart city is constantly on the rise as a result of the Chinese government's advocacy. The lighting system of the smart city plays an irreplaceable role in the lighting of the city nightlife. Intelligent lighting provides the protection of night life for urban residents, at the same time, it also enriches the life of the public and facilitate the work of the various amateur activities of the public.

Based on the investigation and discussion of the lighting system in the smart city of Tianjin, this paper analyses the existing problems of the road lighting system and summarizes the solutions。Relying on DIALUX software to build the urban road model foundation space including the main roads, the secondary roads and the branches to simulate the urban lighting system. Get a series of chart relations by adjusting the height of the LED light source, the distance between the light source and the performance parameters, including the metering result and related light distribution curve, the light intensity data table, the vertical coefficient combination chart, the pseudo colour map illumination and the 3D virtual reality map, the brightness effect chart and so on. Analysis the data, using the DIALUX Lighting computing Wizard to find out the best application strategies for each kind of the light source. Establish the contrast light source, and combine with the new light source parameters, based on the best application strategies, using the ORIGIN software to analysis and simulate the data, at last calculate the relevant benefits, including the economic benefits, the energy benefits and the environmental benefits report.

Keywords: smart city; lighting system; benefit

1. Motivation, specific objective

a. Investigate the road lighting system in Beijing Tianjin Hebei region， then analysis the existing problems and find out the measures to be solved.

b. Using the DIALUX software to evaluate the three kinds of the road space model, including the main road, the trunk road and the branch road. At last find out the best application strategies for each kind of the light source.

c. Based on the best application strategies, we will figure out the three evaluation result, including the economic evaluation result, the energy evaluation result, and the environmental evaluation result.

2. Methods

The research methods include the literature review, the field Investigation, the computer simulation experiment, the comparative analysis, the numerical analysis and so.

3. Results

The road lighting system in Tianjin was investigated, and the light environment simulation was carried out by using DIALUX software. Compared with the traditional light source, the application benefit of the optimal LED light source was obtained.

4. Conclusions

Based on the best application strategies, we will figure out the relevant benefits, including the economic benefits, the energy benefits and the environmental benefits report.

PP06

A STUDY ON HIGH EFFICIENT AND ENERGY SAVING LIGHTING SYSTEM FOR JIUZI ANCIENT TOWN IN CHINA

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Abstract

According to the statistic published by Chinese National Tourism Bureau, during the holiday from 1st October to 7th October 2017, the number of tourists who travelled in the mainland China reaches 663 millions, and it has 11.96% jump if compared to last year, and the total income reaches RMB 549 billions! Statistic also showed that there is a tremendous increase of the number of the tourists who paid a visit to Ancient Town. There is a trend that the people who stay and work in city areas (such as metropolitan cities like Beijing, Shanghai, Shenzhen and Guangzhou) who are willing to spend their holidays and stay overnight (or even several nights) with their family members in the ancient town. The ancient town not only able to attract tourist from local but also foreign visitors. This paper focuses on the theme of high efficiency and energy savings and summarizes the creative realization work (by proper tailor of light rays and also careful colour selection) of the beautification and night landscape lighting of the Hui-style Ancient town in China- Jiuzi Ancient Town using high power LEDs. The night landscape lighting in Jiuzi Ancient town not only serves aesthetic value, economical value and environmental value on tourism, but also creates a primitive and quiet atmosphere at night and a perfect harmonization with the historical architecture. The key issues of this study work are the appropriate luminance distribution, luminance contrast, the smart use of colour to meet the aesthetics need of old ancient town, integrated application of LED lighting science and technology, creating comfortable and peace illuminated environment of old architectures, applying green lighting and controlling light pollution.

Keywords: night landscape lighting, high power LEDs, high efficiency, energy savings, luminance distribution, luminance contrast, green lighting, light pollution

PP07

COMPARISONS OF FOUR DIFFERENT DESIGNS OF LED FREEWAY SIGNS

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Abstract

1. Motivation, specific objective

LEDs have been widely used in lighting applications, including traffic signs and traffic signals. Making traffic signs self-luminous with LEDs is considered promising to improve legibility, especially in combating severe weather such as heavy rains or fogs. However, the design of LED traffic signs has no universal specifications yet. This study evaluates four custom-designed LED freeway signs, including three self-luminous ones as LED lightbox, LED backlight and regional LED backlight, and one non-self-luminous sign with external LED lighting. Participant observation studies are performed to investigate which design would have the best visual quality.

2. Methods

Due to the space limitation of the experimental site, the dimension of each signage is one-sixth of the real freeway signs. The observation distance is set at 25 m, which corresponds to a legibility distance of 150 m.

Pilot experiments on the three self-luminous signs are performed to find their optimal luminance ranges. Each sign is hanged by itself with ambient illuminance of 2.8 lux. We light the sign from dark and gradually increase the luminance. The observer is asked to notify the experimenter when starting to recognize the content on the sign, and notify the experimenter again when starting to feel glary. Then, the sign luminance is gradually decreased from maximum to dark, and the observer will notify the experimenter twice, one for not feeling glary and the other for not recognizing the content. The procedure is repeated for 4 times, and the total duration for each observer is about 30 minutes.

Once the optimal luminance for each self-luminous sign is found, the four LED freeway signs are hanged together to compare their visual quality. Their positions from left to right are arranged by a Latin square to eliminate the position effect. Hence there are 4 position arrangements. The observation study uses the within-subject design, that is, each participant will experience all the position arrangements. The observation time for each position arrangement is 5 seconds. After the observation, subjective ratings are collected from the participants, including visual comfort, legibility, preference and forced-choice ranking. Each participant completes the experiment in 4 days, experiencing one position arrangement in a day, and the total duration is about 30 minutes.

Based on the results of pilot experiments, the luminances of LED lightbox, LED backlight and regional LED backlight are set at 256, 214 and 324 cd/m^2, respectively. The illuminance on the non-self-luminous sign with external LED lighting is set to 400 lux, complying with the national regulations. The ambient illuminance is 2.8 and 6.0 lux in two separate formal experiments.

Totally 40 participants joined the experiments, including 8 for each self-luminous sign in the pilot study, and 8 for each formal experiment. The participant must be more than 20 years old, has normal or rectified vision with a decimal acuity value of 0.9 or higher, has no cataract or other eye diseases, and possesses a valid driver's license.

3. Results

In the pilot experiments, the optimal luminance range for LED lightbox being clear and not glary is 206-308 cd/m^2, and the midpoint is 256 cd/m^2. The optimal range for LED backlight is 39-393 cd/m^2 with the midpoint at 216 cd/m^2. The optimal range for regional LED backlight is 105-543 cd/m^2 with the midpoint at 324 cd/m^2. The midpoint values are then utilized in the formal experiments.

In the formal experiments, the subjective ratings on four dependent variables, including visual comfort, legibility, preference and ranking, are analysed by repeated-measures one-way ANOVA. With the

ambient illuminance of 2.8 lux, the three self-luminous signs have no statistical differences in the aspects of visual comfort, legibility, preference and ranking. The self-luminous signs are significantly better than external LED lighting in legibility, preference and ranking. For visual comfort, LED backlight and LED lightbox are significantly better than external LED lighting, while regional LED backlight shows no statistical difference from external LED lighting.

With the ambient illuminance raised to 6.0 lux, the self-luminous signs are all significantly better than external LED lighting in the aspects of visual comfort, legibility, preference and ranking. LED lightbox and regional LED backlight have no statistical differences in the four aspects. Regional LED backlight is significantly better than LED backlight in visual comfort, legibility and preference. LED lightbox is significantly better than LED backlight in legibility, preference and ranking.

Subjective ratings in the two experiments are also analysed by independent-samples t-test. The results show that regional LED backlight is highly susceptible to the ambient illuminance. Since the green background in regional LED backlight is not lit and relies on the ambient illumination to provide brightness, a small variation in the ambient illuminance would result in tremendous change to the contrast between green background and white text. This consequently influences the visual performance of regional LED backlight and changes its ranking from first to third when the ambient illuminance is raised.

4. Conclusions

Four different designs of LED freeway signs are compared in their visual comfort, legibility, preference and ranking. The designs include three self-luminous ones as LED lightbox, LED backlight and regional LED backlight, and one non-self-luminous sign with external LED lighting. The results of participant observations show that self-luminous signs provide superior visual quality than the non-self-luminous one. In addition, LED lightbox and regional LED backlight have no statistical significant differences in the experiments. However, regional LED backlight is more sensitive to ambient lighting. LED lightbox and LED backlight both light up the whole signage area and provide similar visual sensations to the participants. When the ambient illuminance is raised, the subjective scores of LED lightbox in legibility and preference are significantly better than those of LED backlight. Therefore, among the four LED freeway signs evaluated in this study, we suggest LED lightbox as the prior design. Investigations on other designs of self-luminous traffic signs such as LED dotted matrices are in progress. Field studies on the freeway are currently in the planning stage.

PP08

VISIBILITY AND GLARE STUDY OF LED-EMBEDDED SIGNS

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Abstract

The purpose of this study was to investigate the evaluation of visibility and glare with different LED-embedded signs under same luminance level. The interaction of planar light source luminance, spacing of point light source array and viewing distance were investigated. Accordingly, the optimized luminance and arrangement of LED array lighting can be obtained.

1. Motivation

In recent years, the technology of high-luminance light-emitting diode (LED) has a great breakthrough. LED has been used in lighting applications, but also widely applied in traffic signs, so that the applications of LED light source can be carried forward. Nowadays, the standards of the LED traffic sign control in Taiwan is still not well-defined, the growing of LED lighting abuse may affect the passers-by, driving conditions, and light pollution at night. Therefore, this study had investigated in clarity and perception of glare with a LED embedded traffic mark by the data of psychophysical experiment and proposed recommendations methods.

2. Method

To obtain the main factors affecting the clarity in the preliminary experiment, con-trol variables included the size of the LED light source, LED light source spacing and complexity and luminance with different fonts. The reference luminance specification of Illuminating Engineering Society of North America and Bureau of Energy, Ministry of Economic Affairs were followed in this research, so the luminance of LED light source is set to 20 ~ 500 cd/m2.

According to the preliminary results, the further discussion and comparison with LED embedded traffic mark used in the national highways was mentioned. Besides, by the evaluation of subjective feelings of clarity and perception of glare, we obtained the combination of different sizes and spacing of the LED light source. Thus, the luminance of single LED light source for LED embedded traffic mark was suggested to re-define as 100~300 cd/m2 according to the analysis results.

3. Summary

This study presents the related formula of evaluation score, and the formula is related with density and luminance. The definition of clear is as follow: if the clarity score is more than five points, then means observer felt clear, and likewise, when the score of perception of glare more than five points, it means observer has feeling glare. The conclusion can be used as a reference in LED signs in the future.

PP25

EXPLORING THE PREFERRED LUMINANCE OF VDT AND INDICATOR LIGHTS IN AIRCRAFT COCKPIT FOR AUTOMATIC DIMMING

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Abstract

1. Introduction

Modern all-weather aircraft flight requirements complex conditions in the daytime and night time. Visual environment of the cockpit is one of the most important factors that affects the safety of flight. The rapid change of ambient illuminance directly affects the visual performance of the pilot. When the change of ambient illuminance, the pilot need to manually adjust the light, which will increase task burden, visual fatigue and disperse attention. Cockpit automatic dimming system is a promising solution to this potential risk. For example, when ambient illuminance changes and captured by light sensor, if the luminance of VDT and indicators lights can simultaneously adjust to a comfort level, it will increase the visual performance and ensure a comfortable visual environment. Prior to the application of such automatic dimming system, the relationship between ambient illuminance and preferred luminance of VDT and indicator lights. The aim of this study is to collect such data for automatic dimming of aircraft cockpit.

2. Methods

An experiment was conducted in laboratory where lighting parameters can be well-controlled. Ten young participants (average age of 25 years) were recruited. They were asked to dim the computer display showing a picture of cockpit attitude indicator (VDT task) and an area light source covered by a hollow panel with indicator (indicator lights task). Test subject are free to set the luminance to the most comfortable level that they preferred. The dimming tasks were completed under eight ambient illuminances: 1.00, 3.33, 10.0, 33.3, 100, 333, 1000 and 2048 lux. All ambient lighting condition were using the spectrum D65 defined by CIE. The colour of indicator lights was using night-vision compatible green regulated by standards. The preferred luminance of VDT task and indicator lights task set by test subjects was recorded as raw data.

3. Results

The results show that with the increase of the ambient lights, higher luminance of VDT and Indicator lights is preferred. However, the curve obtained between them does not follow a linear relationship. When the curve is extrapolated to higher and lower range, it is clear the preferred luminance of either VDT or indicator lights follows a power function (R^2>0.99).

The preferred luminance of VDT is found to be lower than that of indicator lights. For VDT, the average preferred luminance of VDT is about 20 cd/m^2 when ambient illuminance is 10 lx, 33 cd/m^2 when 100 lx, and 58 cd/m^2 provided 1000 lx. For indicator light, the average preferred luminance of indicator light is about 47 cd/m^2 when ambient illuminance is 10 lx, 120 cd/m^2 when 100 lx, and 331 cd/m^2 provided 1000 lx.

4. Conclusions

It is found that when ambient illuminance increases, the preferred luminance of the VDT and indicator lights is higher, and it follows a relationship of power function. By using the dimming curve obtained by the experiment, the automatic dimming system of the cockpit can be optimized and the pilot's work efficiency can be improved. The results of this study can provide empirical data for the automatic dimming lighting system for aircraft cockpit.

Session PS1
Presented Posters (2)
Friday, April 27, 13:40–14:25

PP09

MATERIAL APPEARANCE MANAGEMENT WITH RELIGHTING USING LIGHT FILED CAMERA

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Abstract

1. Motivation, specific objective

We are surrounded by various light sources, and the detected colour of the object is changed depending on the light sources. Human can perceive the correct colour under arbitrary colour of light source by colour constancy. However, it cannot be correctly perceived when the object is taken by camera and observed under different illuminates. Therefore, in the most of digital camera, auto white valance function is on board to estimate the colour of light source and compensate the colour of image to the standard light source. Based on this estimation, we can reproduce the colour of object under different light source.

We are also surrounded by various shapes of light sources. The shape of specular reflection on the object is changed with the changing shape of light source. Human can perceive the reflectance property correctly under various shape of light source. However, it become difficult to perceive the reflectance property correctly, when the captured images is observed under different shape of light source. Therefore, it is required to reproduce the appearance of reflectance property under different shape of light source based on the estimation of reflectance property. This can be named as auto appearance balance.

For acquiring the reflectance property, various researches have been performed in the field of computer vision and computer graphics. Gloss is observed around the angle of mirror-reflection. To record this property, it is necessary to measure the reflectance by changing the incident and existent angles. Generally, digital camera is used as sensor, small light is used as light source for this measurement.

However, in this method, dense sampling is required, and the size of the instruments and the amount of measurement time are large. Then, this is difficult to be practically used. Therefore, simple method is proposed by limiting the object as known shape and homogeneous reflectance property. Inoue et al., proposed to measure the specular reflection point spread function (SR-PSF) by using single image. Wang et al., also proposed to measure the blurriness of light source image. In their method, step-edge lighting is performed by displaying the white and black pattern. The reflectance property is estimated from the degree of blurriness of the edge pattern.

As is mentioned above, from the point of practical use, it will be effective to use blurriness of the shape of specular reflection which is the image for the shape of light source.

However, in the general imaging condition, the blurriness will be changed depending on the position of the camera focus. Specially, in the high gloss object, since the degree of blurriness is strongly changed by the position of focus. Therefore, it is difficult to estimate the reflectance property from the general imaging condition.

2. Methods

In this paper, therefore, we propose to use light field camera which can re-focus the image after taking the image for estimating the reflectance property. Since the light field camera can capture the light field in single captured image, we can obtain re-focus image by simple calculation in the captured image.
We use light field camera to estimate the reflectance property by choosing the image where the light source is focused on the object. We also performed gloss reproduction under different lighting conditions based on this analysis as auto appearance balance function.

3. Results and Discussion

In this research, we performed the estimation of reflectance property from multi-focus images. We used light field camera to estimate the reflectance property by choosing the image where the light source is focused on the object. We successfully estimated the reflectance property from the captured light filed

information for various type of materials. We also successfully performed gloss reproduction under different lighting conditions based on this analysis as auto appearance balance function.

The proposed method is performed under the limited conditions. It is necessary to consider the various conditions such as distance between light source and object surface, distance between Lytro and object surface, types of light source and so on. In this research, we also assumed that the shape of object is plainer. If the object is not plainer, it is necessary to consider the curvature and transform the geometry into plainer shape. In this research, we analyse the change of gloss in spatial domain. Frequency domain is expected to be used as was implemented by Romeiro et al. where it is not necessary to consider the inclusion of edge pattern. Perturbation in the edge is treated as noise in this research. However, meso-structure is included in this noise pattern. Therefore, by analysing the noise, it is expected that meso-structure can be measured, and in the gloss reproduction, it is necessary to consider the shape and meso-structure of the surface for accurate reproduction.

4. Conclusions

In this research, we propose to use multi-focus images for estimation of reflectance property. Light field camera is used to acquire the multi-focus images. By using estimated reflectance property, we reproduced the gloss under different shape of light source

PP10

A STUDY ON THE STAIR ILLUMINATION METHOD CONSIDERING THE ELDERLY

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Abstract

The first purpose of this study is to clarify the influence of light environment on user's evaluations of stairs such as visibility and easiness of moving up and down. By measuring illuminance, brightness, and subjective evaluations of stairs of stations, it shows that illuminance and brightness of the lower view angle influence greatly on subjective evaluations. Taking that result, we conclude that lighting set in handrails of stair can illuminate most efficiently.

The second purpose is to clarify the influence of variation of lighting height. Intended for elderly people and young people, we conducted an experiment. As a result, variation of height of handrail lighting does not influence on subjective evaluations greatly. However, the evaluations in the environment of handrail lighting tend to be higher than that of ceiling lighting. In addition, it shows that elderly people can feel security in the environment of handrail lighting.

1. Motivation, specific objective

Current Japan faces a serious ageing society, and the elderly population that is 65 or over is 25% of the total population. Furthermore, by showing the lowest fertility rate in the world for several years, the future outlook is also dark. According to the Cabinet Office's Annual Report on the Ageing Society: 2016, the proportion of elderly people will be 30% of the total population in 2020 and will be 40% in 2060, which is a very serious situation.

Recently, with the advancement of barrier-free design, escalators and elevators are being actively installed in order to make it easier to move up and down stairs. However, due to limited space and number of installations, the frequency of using the stairs is still high. Therefore, it is important to consider the safety and comfort of the stairs.

In this research, we propose an illumination method focused on the safety and visibility of the stairs, and the main purpose is to verify the performance mainly of the elderly.

2. Methods

In this research, "LED handrail illumination" was produced as a lighting method that simultaneously satisfies "safety", "visibility", and "power saving" at the stairs.

The composition of the experiment-pattern is based on a comparison of the performance of ceiling lighting and handrail lighting. In the case of handrail lighting, divide the brightness (50 lx, 100 lx, 200 lx) and installation height (500 mm, 800 mm, 1,100 mm) into three stages. In the case of ceiling lighting, a single pattern of 200 lx was adopted, and a total of 10 patterns including 9 patterns of handrail illumination were constructed as experimental conditions.

The composition of subjects was 20 people in the "young people" group of 20 to 30 generations who are general users, 20 people in the “elderly” group (age 65 and over) assumed to be vulnerable people, total 40 people.

In the case of impression evaluation, a similar illumination environment was presented to 40 subjects based on the bipolar 7-stage evaluation scale. Evaluation criteria were evaluated separately for "evaluation at stop" to evaluate by standing at the ascent and descent, "evaluation at after movement" to evaluate after actually moving, and final "comprehensive evaluation".

3. Results

There is a clear difference between the evaluation results of both groups for the "look up" evaluation result of "evaluation at stop". In the case of the "young people" group, there was a tendency to evaluate

"ceiling lighting" very brightly and glaringly. In the case of the "elderly" group, there was a tendency to evaluate both ceiling lighting and handrail lighting brightly, and neither was dazzling.

As a result of the "evaluation at after movement", the "young people" group highly evaluated "ceiling lighting", and the "elderly" group tended to highly evaluate "handrail lighting". In addition, there was a tendency that shadows became anxious under the condition of ceiling lighting.

As a result of the comprehensive evaluation, the judgment of both groups greatly differs in the evaluation of "luxury". The "young people" group evaluates the "luxury" of the ceiling lighting very low, while the "elderly" group feels the same level of luxury as the handrail lighting on the ceiling lighting.

In order to investigate the influence of the light environment on users, correlation analysis was carried out using the result of the physical quantity measurement in the laboratory and the result of the impression evaluation by the subject.

In the case of the "young people" group, the correlation between "brightness", "glare" and physical quantity is high. As a result of the correlation analysis with "the average luminance of the upper half" and "the average luminance of the lower half" of the luminance image, in the case of "brightness", "glare", it was evaluated depending on "the average luminance of the upper half".

The correlation analysis result of the "elderly" group has a lower correlation with "vertical illuminance" than the "young people" result, and the correlation with "floor illuminance" and "average luminance" It is getting higher. In particular, the correlation analysis result with "the average luminance of the upper half" and "the average luminance of the lower half", the correlation with "the average luminance of the lower half" over all the evaluation items is high, The main visual object is considered to be the lower part of the space, that is, the step part of the stairs.

4. Conclusions

Based on the results of the experiment, it is thought that the impression of the space can be enhanced by the illumination method that lightens the step part of the stair even in the environment of similar illuminance. In particular, it is considered that "glare" and "uneven illuminance distribution" can be improved by installing "handrail illumination".

Although the subjects of viewing when using stairs are different, in both groups comfortably evaluating the environment of "handrail lighting".

Such "handrail illumination" is considered to be applicable when there is no ceiling, when the ceiling height is very low or very high, and the installation position of the lighting is limited.

Moreover, by utilizing the line light source illuminating the wall surface, it is considered that the light environment becomes more even and safe.

PP11

ASSESSING ROAD SAFETY CONCERN FOR LIGHT-EMITTING-DIODE-BASED AUTOMOTIVE HEADLIGHT GLARE

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Abstract

1. Motivation, specific objective

There are more than 1.25 million people die each year as a result of road traffic crashes according to World Health Organization (WHO). Unsafe vehicle is the biggest risk factor for those accidents occurred. Automotive lighting is a key component for driving safely at night. However, the enhanced light emitting diode (LED) headlight caused discomfort and disability glare may actually worsen the situation. The awareness of this concern needs to be addressed and more research needs to be done along with the rapid growth of LED lighting applications.

2. Methods

We studied the technical, ergonomics, and regulation aspects of the vehicle headlight publications. Besides the general consideration of energy efficiency, service life, and optical performance of LED headlight, we also deeply analysed the human factor connections on this subject.

3. Results

We compared the impact of LED headlight on driver's visual responses to traditional light source used in most automotive lighting applications. The result showed that LED headlights are recognized for producing a stronger, brighter and sharper beam by its light generating mechanism. This bright beam can cause disability glare for 2-5 seconds for normal eyes, and up to 15 seconds for some particular impairment eye conditions. It is important to avoid directing this beam at oncoming drivers or pedestrians, especially the sport utility vehicles (SUV) regardless the high- or low- beam is used.

The narrowband spectral output of coloured LEDs produces highly saturated colour appearance and white phosphor-converted LEDs produces higher correlated colour temperature (CCT) lights. These are some of the LED lighting characteristics could augment the glare effect while driving. We also learned that the performance requirement for automobile head-lightings are largely adapted from the Society of Automotive Engineers (SAE) and other similar industry organizations. Certain minimum or maximum luminous intensity toward different angles are specified in the requirements. The goal of those standards is to ensure the lighting system provides sufficient illuminous level for the drivers but reducing glare to other drivers. However, some low-priced models ignore the significant effects of glare and increase potential risks for road safety.

4. Conclusions

LED sources are different from conventional automotive lighting applications. The visual performance can be largely influenced by photometric, colorimetric, and temporal properties of LED light sources. The spectral distribution of phosphor-converted white LEDs (blue InGaN with YAG phosphors) exhibits large amount of short-wavelength (blue) light to reduce visual performance while driving. Our results suggest that the glare caused by LED automotive headlights could trigger serious road safety issues, and therefore should be studied more intensively. The vehicle safety standards should also be evaluated regarding this hazardous effect. The users should be more aware of this effect before switching to LED headlights.

PP12

INVESTIGATION OF PHYSICAL ENVIRONMENT OF ATRIUMS IN LARGE PUBLIC BUILDINGS IN BEIJING, TIANJIN AND HEBEI PROVINCE

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Abstract

The construction of large and medium-sized public buildings in cities shows an accelerated trend of development with an increasing amount. In the core of large-scale public buildings, the space of the atrium quality rises in a diversity way. At the same time, it also exposes the problems of poor comfort and high energy consumption in space and physical environment. This article narrative to the large-scale public buildings and the physical environment of the atrium of the subjective and objective investigation of the user's comfort feelings in Beijing-Tianjin-Hebei region.

The objective investigation mainly focuses on the large-scale public buildings with typical atrium space. Measuring the atrium interior space scale, illumination, brightness, wind speed, temperature and humidity and decorative materials reflectance data for a unified time. Also researching on the several simultaneous measurements of the outdoor environment at the same time. Through the collation of measurement data and comparison with related standards, this paper attracts the typical atrium space model and the physical environment of the main reference parameters and illumination, brightness distribution and temperature and humidity changes.

According to the subjective survey that the users includes staffs and visitors, the questionnaires contain the atrium intuitive perception of space and the atrium acoustic environment, light environment, thermal comfort and subjective evaluation and make recommendations. Finally, 618 effective questionnaires were obtained. The results of the questionnaire showed that 87% of the respondents gave two “very good” and “particularly good” evaluations on the spatial scale morphology. This report mainly focuses on the degree of quietness in the acoustic environment of the atrium and whether the external noise is shielded brightness and softness in the environment. Meanwhile, the degree of hot and cold in the hot environment and the air circulation have a higher concern are also referred.

Keywords: Atrium space, Physical environment, Space model, Reference parameters

PP13

INVESTIGATION ON THE LIGHT ENVIRONMENT OF CHINA'S ACTIVE WIDE-BODY AIRCRAFT

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Abstract

The quality of light environment in aircraft cabin is a key element that affecting the comfort level of passengers. Currently, the typical models of China's existing wide-body aircraft include the Boeing b777-300ER, A330-300, and Boeing787-9, with varied degrees of differences in the light environment in each model. In this paper, investigations on the influencing factors of cabin internal comfortability have been carried out based on the abovementioned three types of cabin lighting configurations for wide-body airliners. The tasks performed during the investigation include the measurements of indicators, such as cabin illuminance, luminance, colour temperature, colour rendering properties, surface reflection coefficient, etc. as well as the research on the relationship of space and types of lighting, and the features of the lighting control interface concerned. The data measuring of the thesis selects four typical stages as samples---taking off, smooth operations, food delivering and dining and aircraft landing. Through comparisons and analysis on three models of aircraft based on obtained statistics, the thesis illustrates and affirms merits of Boeing787-9 in terms of lighting environment conditions. Meanwhile, defects of lighting environment of China’s existing wide-body aircraft still exists, such as low illumination of working surface, glaring light from passenger reading lights, relatively low colour rendering index, outmoded switching equipment, etc. Through vertical comparison among indexes of lighting environment in buildings and parallel comparison among high-speed trains, the thesis will make out series suggestions on measures to upgrade lighting environment conditions of existing wide-body airliners to achieve its goals of providing a more comfortable light environment for passengers.

PP14

RESEARCH ON DESIGN STRATEGY OF GLARE PREVENTION AND CONTROL OF GLASS CURTAIN WALL CONSTRUCTION

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Abstract

1. Motivation, specific objective

The glare formed by the sunlight reflection of large glass curtain wall has become a major source of light pollution in the city during the day. The strong glare has increasingly threatened the daily life and traffic of adjoining areas. Glass curtain walls, built in different shapes, have featured by their wide impact scope, high glare intensity and localization. However, studies on its effect, especially on the control strategy, is relatively few. Only some reference standard is not enough. This paper tries to complete the system research in this field.

2. Methods

In order to study how to prevent the formation of high-intensity reflective glare by adopting design measures in the architectural design stage, this paper analyses various influencing factors of reflected light from the causes of reflected light, analyses the influence mechanism of reflective glare, and then summarizes the control at the design level Regular method of reflecting light. Here based on the glass curtain wall harmful reflection glare factor classification, through the glass curtain wall building model, the calculation of time and location selection, and special circumstances discussed, the impact of various factors were targeted computer simulation experiments and analysis of statistical simulation data. Finally get control of the general rules of the design and prevention of harmful reflection of glass curtain wall. Combined with design process, with urban, building and curtain construction factors considered, the strategy and guideline of glare control of glass curtain wall had been proposed. The typical model of glass curtain wall building was established. By controlling the single factor variables, the influence factors were simulated by computer one by one, and the experimental results were obtained. Quantitative evaluation and comparative analysis method were used to summarize the influence and regularity of various factors of reflection glare. Finally, by inducing the experimental results and regular methods, the design strategy of prevention and control of reflected light pollution in urban glass curtain wall buildings is put forward.

3. Results

By analysing each factor through the data chart and the actual case study, the influence characteristics of each specific factor controlling the design of the control and prevention of the harmful reflection of the glass curtain wall are obtained, and the different influence indexes of the specific factors are subdivided. The factors of geography are divided into four index items of geographical latitude, season, time and weather. The surrounding environment is divided into four parts: building and afforestation, multiple glass curtain wall buildings together affect the surrounding light sensitive points distribution and the surrounding glare-sensitive spots. The flat form is straight plane, a convex plane and a concave plane 3 categories; shape into a complete facade face, with a lateral window, with the window vertical grid-like spacer 4 and the like; cross-sectional shape into perpendicular to the ground, inclined obliquely upward and downward 3 categories; the curtain wall size is divided into two aspects: the absolute height of the curtain wall and the curtain wall area; and the influence of different reflective materials and the shielding member form on the reflection glare is analysed.

4. Conclusions

Based on the above research, this paper proposed a new method for reflection glare prediction, that is, the concept of Boundary of Reflection Retention Time Area (BTA), which is "Boundary of Reflection Retention Time Area with accumulated residence time of reflective light in glass curtain wall", is convenient for computer simulation Data quantification, accurate evaluation of the characteristics of reflective glare provides a method basis. Finally, combining with the architectural design flow, from the aspects of urban planning, site design and building zoning standards in the sensitive areas of glare, the

influence laws of the reflected glare in different latitudes, the orientation selection of the glass curtain wall building monomer design, the plane form, the facade form, the section form material selection and the like, and the shutter member disposed wall size level, and reflective walls technical level wall panels, curtain wall glass is proposed to control the reflected light architectural design theory and design requirements. This paper conducted a quantitative research on the reflected light of the glass curtain wall, which not only proposed the basic data and research methods for the study of the curtain wall building, but also provides some reference for further design practice.

PP15

ALTERNATIVE METHOD FOR LUMINOUS INTENSITY DISTRIBUTION ASSESSMENT

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Abstract

1. Objective

There are few methods to compare full luminous intensity distribution (LID). Current methods provide metric of the distance between LIDs but their formulation does not define an exact limit than can be considered acceptable in order to evaluate if two LIDs are indeed of the same luminaire. Therefore, it is necessary to formulate a method to determine if two LIDs can be considered of the same luminaire.

2. Methods

Proposed methods that already exists does not take into account perturbation of the data due to uncertainly of measurement. Current indexes that have been already used, provide a number to define a perfect match between LIDs (for example, 0 or 100 to define perfect match), but two LIDs from the same luminaire at the same laboratory will not get this perfect match due to uncertainty.

In this work, we proposed a method in which we include uncertainty as a perturbation of the data. Every single value of the LID is perturbed with a multiplicative random variable with normal distribution whose parameters are defined by the user according to the actual experimental conditions.

In general, to compare the shapes of two objects, these must be translated, rotated and uniformly scaled in order to make them as alike as possible. In order to do so, we use *Procrustes Analysis* before comparing LIDs. The Procrustes analysis require an orthogonal coordinate system, therefore a change of C/γ coordinate system to Cartesian coordinate system is necessary.

Once we have performed the best alignment between LIDs in the Procrustes sense, we use the Hausdorff distance as the metric selected to measure dissimilarity between the two aligned and scaled objects. To make sure that calculated Haussdorf distance represent the best fit, a nonlinear optimization process is performed. Using a rotation matrix, the optimization process find the x,y,z axes and rotation angles that minimize Haussdorf distance.

In order to estimate the random variations of the LIDs, due to uncertainty, we use a Montecarlo approach. In this regard, it is necessary to repeat the complete process described above (perturbation, procrustes analysis, nonlinear optimization of Hausdorff distance) with different perturbed data.

After a determined number of iterations (1000 in our case), we get a histogram of Hausdorff distance. From this histogram, we can get the expected error and the maximum error for the metric with the standard deviation defined to perturb the data. This maximum error is defined as the maximum acceptable error for comparison between the reference LID and another LID.

3. Results

We use the proposed methods with 2 different LIDs of the same luminaire taken in the same laboratory. One is taken for reference and the Haussdorf histogram was calculated with normal distribution of $\mu=0$, $\sigma=0.01$ (1%). The process of procrustes analysis and optimization of Haussdorff distance was calculated between the LID's. Here we show that the proposed method enable us to determine whether the two LIDs belongs to the same luminaire.

4. Conclusions

Proposed method allow to establish an expected H(P,Q) an a maximum H(P,Q) acceptable. The showed result allow to determine which LID has a dissimilarity of 1% of error or more. It is possible to define different histograms related to different percentage of error, which enable to establish a confidence interval of 99% or 95%. We expect to get a mean and maximum error by apply this method with other metrics to compare LID.

PP16

MAIN UNCERTAINTY CONTRIBUTION FACTORS ANALYSIS OF GLARE MEASUREMENT USING ILMD

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Abstract

Glare is an important index to evaluate the lighting quality, and has attached closed attention both in industry and academia. Publications, such as CIE112, CIE 115 and CIE 117, CIE 140, have been released to set up models of glare indices in various lighting environment. In addition, CIE JTC 7 is studying a corrected model to evaluate discomfort glare caused by non-uniform light sources. However, the lacking of guidance or standards in the aspect of the physical measurement hinders the wide application and comparison of the glare indices. CIE TC 2-86 is established to study the glare measurement using imaging luminance measurement device (ILMD), which allows users to calculate the glare indices based on measured luminance distributions, and it is considered to be a better solution than spot luminance meter, because the former has much higher speed, and can deal with complex shaped or non-uniformed sources.

But the performance of the ILMDs varies very much, for example, some use fisheye lens and some use standard lens, and the detector could be CCD or CMOS, and it will influence the accuracy of the glare measurement. CIE TC 2-59 is dealing with the characterization of ILMD, and many specifications have been listed in the draft, including V(λ) mismatch, UV and IR response, linearity and etc., but not all these are sensitivity to the specific measurement of glare. In this research, we investigate three important factors, i.e. linearity, uniformity, and distortion, of different types of ILMDs, including commercial cameras, and professional ones with standard lens and fisheye lens, and the typical spec. will be listed in the full paper. It is known that the glare indices have complicated calculation formulas, and we can hardly tell the uncertainty contributions directly. So we further use the numerical simulation to study the sensitivity coefficients of the factors to the measurement uncertainty of UGR and TI in typical lighting environment. And the linearity, uniformity and distortion requirement of an ILMD can therefore be proposed properly so as to acquire acceptable accuracy of glare indices. The full paper will introduce the simulation method as well as the results in detail.

PP26

EXPLORING THE OPTIMISTIC DAYLIGHTING DESIGN METHOD: IS COMPUTATIONAL SIMULATION ACCURATE ENOUGH?

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Abstract

1. Introduction

The accuracy of computational simulation as daylighting design method is limited when applied on large space public buildings, especially those are used for long hours, e.g. airport terminal. A precise daylighting design of an airport terminal via simulation is usually unrealistic to be carried out due to its complexity. Many factors other than functional requirements also need to be considered, including visual comfort and energy efficiency. Computational simulation is commonly used in the lighting design of the airport terminal, but it failed to illustrate the actual illuminance completely. The purpose of this study is to evaluate the discrepancy between simulated parameters and those measured on-site in daylighting design for airport terminal. Daylighting design parameters based on physical scaled-model will also be collected in an artificial sky laboratory. The departure hall of Zhengzhou airport, a recent accomplished project, was selected as case study.

2. Methods

Both simulation and on-site measurement were taken for comparison. The computational building model of Xin Zheng International Airport T2 Terminal was built by Google SketchUp® and Rhino® software. Daylighting model was provided by Radiance® software. Calculation and analysis were performed in Autodesk Ecotect® Analysis 2011 software. On-site measurements of horizontal illuminance were taken within a three-day period: 8am to 4pm from 10th to 12th in October, 2015. The weather of these three days was all clear day. There were in total 23 measuring points that are evenly distributed within the departure hall. The height of measuring point is 1.2 metres away from the ground level as a common requirement in guidelines. Experiments of physical scaled-model is undergoing.

3. Results

For the given 5 measuring points for outdoor daylighting, the computational simulation data and the on-site measurements were compared between groups. The average outdoor horizontal illuminances from sun and sky measured on-site was higher than the results obtain from simulation. The discrepancy between simulation and on-site measurements was about 13.6%. It was noted that this discrepancy was significantly large (32.7%) for the data collected at 8:00-9:00 on 12th October 2015.

For the given 23 measuring points, the computational simulation data and the on-site measurements were compared between groups. The average indoor horizontal illuminances measured on-site was also higher than the results obtain from simulation. The discrepancy between simulation and on-site measurements was about 125.4%. It was noted that this discrepancy was significantly large (166.0%) for the data collected at 8:00-9:00 on 12th October 2015.

4. Conclusions

In summary, results of computational simulation cannot accurately describe the actual illuminance level of airport terminal. Therefore, a more precise simulation technique of daylighting design is needed. The availability of LED makes physical simulation based on artificial sky technology more precise and better prospective as a tool of scientific research. The accuracy of physical and computational simulation in daylighting design of airport terminal will be further investigated.

Session PS1
Presented Posters (3)
Friday, April 27, 13:40–14:25

PP17

EFFECT OF AMBIENT LIGHTING CHROMATICITIES ON PERCEPTION OF NEUTRAL WHITE OF A TABLET

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Abstract

1. Motivation, specific objective

In recent years, computer tablets and colour tunable LED lighting are becoming more and more popular. The degree of chromatic adaptation of human visual system when viewing computer tablets under different lighting conditions, especially under those with chromaticities off the Planckian locus, merits careful investigations. It can help a better adjustment of tablet display for enhanced user experience and visual comfort. This study aims to study the effect of ambient lighting chromaticities on degree of chromatic adaptation by investigating the perception of neutral white of a tablet.

2. Methods

Psychophysical experiment was conducted using an 11-channel spectrally tunable LED lighting device to produce ambient lighting with different chromaticities. The lighting device was placed above a viewing booth, whose dimensions were 60 cm x 60 cm x 60cm and interiors were painted using Munsell N5 spectrally neutral paint. A 45° viewing table was placed at the center of the viewing booth, on which an iPad Air 2 was placed to create a 0°:45° viewing geometry.

Seventeen ambient lighting conditions were created, including one dark condition, seven conditions with chromaticities on the Planckian locus (CCT = 2500, 2700, 3000, 3500, 4000, 5000, and 6500 K), and nine conditions with chromaticities off the Planckian locus (Duv = +0.02, -0.02, and -0.04 for 2700, 3000, and 3500 K). The lighting conditions were calibrated to produce a high CRI value and an illuminance level of 1000 ± 30 lx on the viewing table using a Minolta T-10 illuminance meter and a JETI 1211 spectroradiometer.

The black iPad was adjusted to produce 76 stimuli, whose chromaticities were uniformly distributed in CIE u'v' colour space and luminance levels were at 235 ± 10 cd/m^2 measured using an Xrite i1 Pro. Only one stimulus, covering the entire display, was presented each time.

Sixty-three colour-normal observers (44 males and 19 females), as tested using the Ishihara Color Vision Test, between 18 and 27 years of age (mean = 21, std. dev. = 1.9) evaluated the colour appearance of the stimuli on the display under various lighting conditions by fixing their chin on a chin rest. Each observer evaluated 264 stimuli under three lighting conditions, with 86 stimuli (76 stimuli + 10 repeated stimuli for intra-observer variation) under each ambient lighting condition and each ambient lighting condition was evaluated by 10 or 11 observers. After observing a stimulus for 5 seconds, the observers first made a judgement about whether it can be classified as white, which was a forced-choice, and then made a magnitude of estimation about whiteness level, with 0% for purely chromatic and 100% for pure white. The 86 stimuli were presented in a random order. It took around 45 minutes for each observer.

3. Results

The average STRESS value of the inter- and intra-observer variations were 37.6 and 30.8.

When there was no ambient lighting, the observers rated the stimulus at 7500 K with a D_{uv} of 0 as the whitest. When the ambient lighting conditions had chromaticities on the Planckian locus, the observers generally rated the stimuli at higher CCT levels with chromaticities on the Planckian locus as the whitest. (i.e., the stimuli from 5567 to 8966 K with D_{uv} of 0 were rated as the whitest under the ambient lighting from 3000 to 6500 K). Under both 2700 and 2500 K ambient lighting conditions, the stimulus at 6408 K with a D_{uv} of -0.01 was rated as the whitest.

Under the ambient lighting with chromaticities above the Planckian locus (i.e., D_{uv} of +0.02), the observers generally rated the stimuli at higher CCT levels with chromaticities on the Planckian locus as the whitest (i.e., the stimulus at 5567 K with a D_{uv} of 0 was rated as the whitest under the 2700 K ambient lighting; the stimulus at 6408 K with a D_{uv} of 0 was rated as the whitest under both 3000 and 3500 K).

Under the ambient lighting conditions above 3000 K with chromaticities below the Planckian locus, the whitest stimuli rated by the observers generally converged towards the Planckian locus. For the 3000 and 2700 K conditions with chromaticities below the Planckian locus (i.e., D_{uv} of -0.02 and -0.04), the whitest stimuli generally had similar levels of D_{uv} as the ambient lighting but at higher CCT levels.

4. Conclusions

Psychophysical experiment was conducted using a spectrally tunable LED lighting to investigate the perception of neutral white of a tablet being viewed under ambient lighting conditions with various chromaticities, especially under some ambient lighting conditions with chromaticities far away from the Planckian locus (i.e., D_{uv} of -0.04). Contours of iso-neutral white of a tablet were modelled for each lighting conditions. The findings generally suggested a lower degree of the chromatic adaptation under the 2700 and 2500 K ambient lighting conditions with chromaticities on the Planckian locus and under the 3000 and 2700 K ambient lighting conditions with chromaticities below the Planckian locus.

PP18

A VISUAL EVALUATION OF COLOUR DIFFERENCES BETWEEN 3D OBJECTS

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Abstract

1. Motivation, specific objective

3D scanning and 3D printing are more and more widespread. Colour 3D printers are also available for rapid prototyping and small amount productions in the market. It is expected to be a normal work in a 3D Print Shop in the future. However, 3D objects are more complex than 2D images in their visual perception. Human vision would adjust visual appearance of the objects according to not only spectral reflectance of the objects but also the lighting geometry, surface property, viewing geometry, texture, micro structures, translucence and reflection of the surround. Colours can change by those conditions. Bad object reproduction would cause disputes. How to measure the colour differences of 3D object therefore is very important for future applications. In addition, many 3D prints only have virtual original which are created by 3D modally software and its image appearance is normally simulated on a display. However, very few study focus on the image differences between 3D objects. CIE recently lists 3D printing is one of ten major applications in the future. Related standards must be established for the new applications. The aim of this study is to under the basic visual phenomena of viewing coloured 3D objects. It includes a series of psycho-visual experiments to quantify visual colour differences of 3D objects shown under a standard light booth.

2. Methods

A colour printer was calibrated by ICC colour management system to print colour samples on both plain and glossy papers. And the samples were folded as cylinders and cubes for visual assessment. 8 colours including red, green, blue, cyan, magenta, yellow, dark grey and light grey were used as reference samples. And the colours were perturbed colorimetrically in CIELAB space to result in lightness, chroma or hue differences to the reference samples. Ten participants were asked to fully adapt to the dark surround in front of the standard light booth with a diffused D65 simulator under 800 lux illuminance for two minutes. After the adaptation, the participants were asked to use grey scale estimation method to quantify visual colour differences between the reference object and its colour perturbed counterpart.

The visual results were compared with the estimation of CIEDE2000 to see which aspects cannot be predicted successfully by the sophisticated colour difference formula.

3. Results

The initial results show that lightness differences was overestimated by the CIEDE2000 and the visual colour differences of glossy samples are smaller than the plain samples. Hue is most important as lightness and chroma are easily affected by viewing geometry. The effect is more significant for glossy surface.

4. Conclusions

Our visual results support that the colour differences of 3D objects cannot be predicted accurately by the estimation of the plan surface. It has some interesting features. To fit the visual data, the lightness and chroma of CIEDE2000 must be further scaled. And the scaling has a relation to the glossiness of the surface. We noticed the viewing geometry also has some impact on the results. The viewing geometry therefore must be standardized for comparing colour 3D objects. The optimal viewing geometry should be studied next for the visual comparison of 3D objects.

PP19

CHROMATIC INDUCTION AFFECTED BY SHAPE

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Abstract

1. Motivation, specific objective

In most researches on colour appearance, uniform colour patches in a square shape are commonly used. However, in everyday life, colours are often seen in various shapes. There are many factors that induce the change of colour appearance. One important factor is a background on which the colour is presented. The sample colour is induced by its background colour and/or brightness in the direction opposite to the background colour. This phenomenon is called simultaneous contrast. Difference in the shape of colours may be affected by simultaneous contrast differently. The colour of the background might induce more changes on the colour sample having a certain shape than the others. This research thus investigated the effect of shape on the induction level of the background colour.

2. Methods

Different shapes of a grey sample were displayed against a colour background on an LCD monitor and the effect of shape was determined by the differences in colour perception between the grey sample in different shapes and the matching colour in a square shape displayed on a grey background. Six shapes including circle, square, diamond, isosceles triangle, triangle and hexagon were tested with four colour backgrounds: red, green, yellow and blue. These background colours were prepared to have the same apparent lightness as the grey background on which the matching colours were presented, so that the main influence of the background is its chromatic induction effect. Note that the test colours in different shapes were the same grey colour. All different shapes had the same height and width.

Visual assessments were conducted in a darkened room, where the monitor screen was divided into two halves: the left side showed the grey sample on the colour background, and the right the matching square on the grey background. Observers' task was to match the colour on the right to the left by adjusting RGB values of the colour square. The experiments were divided into four sessions according to the background colour. Each session contained six shapes of the grey sample shown one after the other in a random order for each observer. Forty observers participate in the experiments, where they did the matching for each shape and completed for all background colours. They adapted to the viewing envirnoment for one minute for each experimental session.

Colour measurements were made for the grey sample and its corresponding colours, as well as the background colours, under the same viewing conditions as visual experiments. The colours were measured in terms of CIE XYZ tristimulus values with a spectroradiometer. The XYZ values were then transformed to CIE L*, a*, b* values using the monitor white point.

3. Results

When the test colour (grey) and its corresponding match were in a square shape, the changes in colour appearance were induced by the background colour. In order to investigate the effect of shape on colour changes, the results from the square shape were used as the reference colour and were compared to the results from different shapes. If there is no difference between the matches of the square shape and the other shape, the given shape has no contribution to the change in colour appearance of the test colour. The results showed that shape had an impact on colour appearance of the sample in a way that it could change the intensity of simultaneous contrast. The diamond always reduced the effects of simultaneous contrast. In other words, the diamond made the background have less effects on colour appearance of the sample. In this study, the diamond cancelled out all the effects of simultaneous contrast, so the same sample appeared the same on different backgrounds. Overall results showed that the haxagon and circle increased the colour changes of the sample due to the background colour, while the triangles slightly decreased the changes.

4. Conclusions

The impact of sample shape on simultaneous contrast was investigated in this study. It was found that different shapes yielded different degrees of colour changes. Circle induced more changes than the other shapes. The descending order of shape contribution to the colour changes was as follows: circle, hexagonal, square, triangle, isosceles triangle, and diamond.

PP20

SPECTRALLY VARIABLE SOURCE BASED ON SPATIAL CONTROL OF WHITE-LIGHT BEAM

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Abstract

1. Motivation, specific objective

A light source whose spectral distribution can be varied to any desired shape would be a useful tool in the colour and vision experiments. With the advance of LEDs, such a spectrally variable light source can be easily realised by mixing different types of commercial coloured LEDs. However, for a high resolution control of spectral distribution, say in the step of 10 nm or less, additional dispersive components are required to separate the spectral components. Simultaneous control of optical power at all the spectral components is the challenging issue for realisation of the high-resolution spectrally variable source. In this work, we present our concept for a spectrally variable source, which controls the spectral distribution through the spatial light modulation. The feasibility of the concept is also experimentally demonstrated for the proto-type setup.

2. Methods

The proposed source consists of a super-continuum source, a Powell lens, a linear variable bandpass filter, a spatial light modulator, and a set of (cylindrical) off-axis parabolic mirrors. The super-continuum source emits a white-light collimated beam through a single-mode fibre. The Powell lens, often referred to as a laser line generator, forms a beam fanned out in the horizontal dimension, which is then collimated by using a parabolic mirror. The white beam in the horizontal line shape is then bandpass-filtered to a “rainbow” beam by transmitting through the linear variable bandpass filter whose centre wavelength depends on the spatial position. Each spatial position on the beam is now assigned to each spectral band of different wavelength. A spatial light modulator, or a spatial mask pattern in the simplest case, positioned behind the filter can then control the spectrum by changing the transmittance at different positions. The spectrally filtered beam is then focused by using another parabolic mirror to a target plate or into an optical fibre.

3. Results

The spectral variation through the spatial modulation is first demonstrated by using simple masks with specific patterns as the spatial modulator. For example, when we use a mask with one hole, the monochromatic light is emitted whose centre wavelength is determined by the position of the hole on the linear variable bandpass filter. We could also vary the spectral distribution under the PC control by using a LCD-based spatial light modulator. For various target spectra, we tested the performance of the proto-type spectrally variable source.

4. Conclusions

The experimental results of the proto-type setup show the feasibility of the concept for the compact and programmable spectrally variable source for the colorimetric applications. The ideas how to improve the performance such as the spectral range, spectral resolution, and dynamic range of variation are also discussed.

PP21

PILOT STUDY ON THE IMPACT OF MESOPIC VISION ON THE PURITY PERCEIVED BY HUMAN EYES

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Abstract

1. Motivation, specific objective

Mesopic vision is an important vision state that needs to be studied, a number of scenes, such as roads in the night, tunnels, are in the mesopic vision luminance range. Although a lot of studies have been conducted under mesopic vision in recent years, most studies are about photometric performance, which means only a few studies are concerned with colorimetric performance under mesopic vision. Both photometric and colorimetric performance are important and interrelated for light sources, and their performance under mesopic vision would be different. However, it remains uncertain to what extend the colorimetric performance was influenced under the mesopic vison state. In this study, we try to find out how the purity feeling of colours changes with varying luminance under mesopic vision. Moreover, this study could provide some guidance about colour perception trend in the mesopic vision.

2. Methods

We use colour management monitors with neutral density filters (NDFs) in a dark room to simulate mesopic vision luminance state. This experiment evaluates two independent variables: luminance and hue. The luminance levels are 0.5, 0.3, 0.1, 0.05, 0.03 and 0.01 cd/m^2, respectively, which are within mesopic vision luminance range. The LCD display were divided into two sides, and the sample colours in the left side of the display while the referential colours in the right. Each colour (including referential colours) was displayed in a 10-by-10 cm^2 respectively, while the rest of the display was blocked. Since the luminance of displays couldn't match the luminance of the mesopic, we used NDFs to reduce luminance of the left-side display where the sample colours were presented and made the luminance down to the luminance level we needed. In this way, we simulated six different luminance levels of mesopic, and in each level, we did the repeat experiments on colours with different hues. The colours we chose included red (dominant wavelength, 640nm), yellow (dominant wavelength, 583nm), green (dominant wavelength, 522nm), cyan (dominant wavelength, 486nm), blue (dominant wavelength, 453nm). Therefore, There were 30 experimental conditions [6 (luminance levels) * 5 (colour hues)].The referential colours we used have the same hue of the sample colour, and were presented in the right side with luminance of 5cd/m^2 which means that was displayed in the photopic vision luminance range. Then we adjusted those reference colours to a certain purity sequence, and every two adjacent colours have the same purity difference. To make sure the purity intervals between two adjacent referential colours are stable, a colorimeter was used to measure the value of each colours' purities. One of the referential colours have the same purity value of the sample colour.

Twenty college students (12 males and 8 females) between 19 and 27 years old (mean age, 22.4 year; SD, 1.9 year) participated in the experiment. All had corrected visual acuity higher than 0.8 and normal colour vision as tested by standard isochromatic charts.

A matching task was conducted to evaluate the influence of mesopic vision on colour purity feeling. In each luminance level of mesopic, participants were asked to observe the sample colour and choose one of the referential colours that they considered had the most similar purity with sample colour. The time participants took to make a choice also been recorded and may use to evaluate the degree of difficulty of colour recognition in the mesopic vision.

3. Results

The analysis shows that the participants generally chose a less saturated colour than the sample colour as the matched colour that they considered have the same saturation with the sample colour. And under the lower luminance level condition, participants tended to use more time to make sure their choices. One thing to mention, we noticed that participants made choices closer to the actual colour in the test groups where colour had shorter dominant wavelength.

4. Conclusions

The mesopic vision does have a significant effect on the colour purity identification, and in the different levels of luminance in the mesopic vision, the influence changes but not much. The lower the luminance level is, the harder it is for people to discern colours. Furthermore, in mesopic vision, people would generally underestimate colour' purity. Differences in colours' hues will also affect the purity feelings. Through the experimental results, it indicated that colour have short dominant wavelength can be better identified by people in the mesopic vision.

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PP22

A COMPREHENSIVE DISCUSSION ON COLOUR STABILITY OF PHOSPHOR CONVERTED LEDS

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Although people mostly talk about „LED lighting“, it would be more accurate to call these devices „LED and phosphor“, since the phosphor is actually generating more than half of the photons that we end up seeing. Among all the materials that constitute a phosphor converted LED, the phosphors are therefore of particular importance with respect to the white light quality in terms of colour stability and colour consistency of white LED light sources. Product-to-product variations of the correlated colour temperature (CCT) values influence the colour consistency, e.g., due to the problems of depositing exactly the same amount of phosphor upon fabrication. The colour stability is affected by variations of the CCT values for a given luminaire upon the operation at different currents (temperatures) or by materials degradation over lifetime. Variations of the CCT values upon operation of a luminaire at different currents are mainly caused by a temperature dependent variation of the luminescence intensity of the phosphor. Generally, the quantum efficiency (QE) and therefore the luminescence intensity of a phosphor decrease with increasing temperature.

The US Department of Energy has defined some research goals in regard of colour stability of phosphors (down converter materials). As state of the art for 2014, green (yellow) emitters have a quantum efficiency of 95% with a reduction of the QE in between 25°C and 150° C of 10%. The research goal is to increase the quantum efficiency to 99% till 2020 and to lower the temperature dependent reduction of the quantum efficiency to 5% (in the above mentioned temperature interval). Although in the meantime (as of 2015) the state of the art value for the quantum efficiency has increased to 98%, the state of the art reduction of the quantum efficiency is still 10% in between 25°C and 150°C.

Based on combined optical and thermal simulations, in this contribution we give a comprehensive overview on the colour shifts that can be expected for phosphor converted LEDs upon variation of the drive current due to temperature dependent reduction of the quantum efficiency of state of the art phosphors as well as future phosphors with improved performance values, delamination processes that occur in the LED package as well as colour shifts due to the differences in the thermo-optical coefficients of the materials constituting the phosphor layer. From these studies some suggestions for further improvement are drawn and compared with the research goals as defined by the US Department of Energy.

PP23

A COLOUR GAMUT INDEX AND COLOUR-SHIFT INFORMATION BASED ON CIE 13.3

The CIE general colour rendering index, R_a, as defined in CIE 13.3-1995 “Method of Measuring and Specifying Colour Rendering Properties of Light Sources”, is widely adopted and used by the lighting industry, in regulatory documents and in international and regional standards and specifications. R_a represents an average shift in colour appearance for a set of eight specific CIE-1974 test-colour samples (TCS) under a test light source in comparison to a reference illuminant having the same correlated colour temperature (CCT) as the test light source. However, neither the general colour rendering index nor the special colour rendering indices, R_i, provide information on the direction of the colour shifts. One light source with a specific spectral power distribution (SPD) may reduce the colourfulness for specific TCS, while another light source, with the same CCT but a different SPD, may increase the colourfulness for the same or other TCS, even though both light sources may yield identical R_a values. Information on the average magnitude and direction of the colour shifts, as well as for the individual test-colour samples, would be valuable in addition to R_a and R_i. The CRI-R_a alone, originally designed to measure colour fidelity, cannot accurately predict acceptability of a white-light source for a specific application, because chroma changes and hue-angle shifts also contribute to the appreciation of the appearance of the objects’ surface colours.

In 2017, the CIE published a research report “CIE 224-2017 - CIE 2017 Colour Fidelity Index for accurate scientific use” describing a scientifically more accurate fidelity index (R_f), developed by CIE TC 1-90. This colour fidelity index also does not address the need for objective information on colour rendition properties beyond fidelity. Furthermore, as mentioned in the report, R_f, is not recommended as a replacement of the general colour rendering index, R_a, for the purpose of rating and specification of products nor for regulatory or other minimum performance requirements. Consequently, R_a will continue to be used till a new set of CIE colour rendition measures is developed and widely accepted by the lighting community. Meanwhile, there is an urgent need for additional colour rendition properties, which can be easily added to CRI calculation (CIE 13.3-1995) and can be used together with CRI-R_a. The concept of using a system based on, at least, two index values, e.g. colour fidelity and colour gamut, was already proposed in 2004, but so far not yet standardized by CIE.

This paper provides additional colour rendition properties for characterizing white-light sources, which can be used in conjunction with the general colour rendering index (CIE 13.3-1995). It presents the content of the Technical Note that will be published as output of reportership DR1-68 “A Gamut Area Measure and Colour-shift Graphic, based on CIE 13.3-1995”, together with some examples how the additional information can be used. The Technical Note will include a CRI-based colour gamut index and a colour-shift graphic as well as chroma indices and hue-angle changes for all individual TCS. The described properties can be used till a new set of CIE-defined colour rendition measures, to eventually replace CRI-R_a, is developed and widely accepted by the lighting community.

The colour gamut index, G_a, and the colour shift graphic are computed with the same set of CIE 1964 U*V* coordinates as for computing the general colour rendering index. G_a can therefore be used in conjunction with R_a and provides information whether the colour gamut for the test source becomes smaller ($G_a < 100$) or larger ($G_a > 100$) compared to the colour gamut for reference illuminant. Typically, a G_a value > 100 indicates, on average, a more colourful appearance of objects’ surface colours. The colour-shift graphic enables an easy visualization of the actual colour shifts for the first eight CIE-1974 TCS.

The change in colour gamut, represented by G_a, does not reveal information on the colour shifts for the individual TCS. The colour-shift graphic only presents a global indication of the direction of the colour shifts for the 8 TCS, but not their values. Some studies have found that specific object colours (or memory colours) are important when judging the attractiveness or naturalness of a lit environment. Therefore, it is important to also quantify the colour shifts for the individual TCS. CIE 15:2004 “Colorimetry” describes several uniform colour spaces for computing correlates of lightness, chroma and hue from which the colour shifts can be characterized. It was decided to compute the chroma-, C_i, and hue-angle changes for each of the TCS with the CIE 1976 L*u*v* (CIELUV) colour space, because

this one is closest to the CIE 1964 UCS. The C_i value is less than 100 when chroma for the test light source decreases (TCS appears less colourful) in comparison to the reference illuminant, and is greater than 100 when chroma increases (TCS appears more colourful). The chroma indices may be important parameters to be used in conjunction with the special colour rendering indices, R_i. For instance, C_9 represents the chroma change for the strong red TCS (#9). For skin-tone rendering, the hue-angle change for TCS #13 may be an important property to consider.

It should be noted that no minimum requirements or target values are provided in the Technical Note, because that is subject for further research.

The results of a user study will be presented to demonstrate the additional value of the newly defined colour rendering properties.

PP24

OPTIMIZATION OF BIMODAL QUANTUM DOTS CONVERTED WHITE LEDS FOR HIGH COLOUR RENDITION

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Abstract

1. Motivation, specific objective

The most widely used white light-emitting diodes (LEDs) are based on the integration of traditional phosphors on blue InGaN/GaN chips today. Although traditional phosphors can produce a white spectrum with high luminous efficacy (LE), it is still a challenge to achieve high colour rendering at the same time.

Because of its tunable and relatively narrow emission and its small overlap of emission and absorption spectra, the new-generation phosphor materials, quantum dots (QDs), enable us to foresee the solution to the problem of traditional phosphors.

Bimodal QDs is a kind of special QDs, and there are two strong emission peaks in the spectrum power distribution. Although, optimization of unimodal QD-WLEDs for radiation luminous efficacy had been studied with the constraint of CCT and CRI in specified range in previous studies, few work were about optimization for bimodal QD-WLEDs. It would be more applicable to make photometric optimization of CCT tunable QD-WLEDs, together with excellent colour rendition.

In this work, the optimization for maximizing colour rendition properties of CCT tunable QD-WLED based on a blue chip, unimodal and bimodal QDs was developed under the constraint of a reasonable range of CCT and LE. The optical parameters of QDs were carefully designed to achieve high-quality QD-WLED. After that, we compare it with traditional phosphor-coated WLED and unimodal QD-WLED.

2. Methods

To work out the complex optimization problems, we conducted a combined examination of the photometric and colorimetric performance by transferring photometric and colorimetric performance to chromaticity diagrams.

We used MATLAB 2013a (Mathworks, Natick, Massachusetts) to calculate the LER and Ra contours of the QD-WLEDs on the gamut-area formed by the chromaticity of it. Then, by establishing a coordination system for three dimension of x- y- Ra or x- y- LER, contour maps of LER and Ra were drawn on the CIE 1931 XYZ colorimetric diagram.

The variation trends of different contours are quite distinct with no intersection, even the contour lines on the LER maps are parallel to each other. Hence, they can be used for predicting the variation trends of the performances with varying chromaticity coordination. In order to express the variation trends, we performed a bivariate polynomial fit of the contours. It was satisfying that the functional models all had an adjusted R2 value of 0.9999 to the contours.

With all these work done, we made a tradeoff analysis of the functional models of LER and Ra.

Considering that different monochromatic QDs exert different influences on the calculations of LER and Ra, which then directly influence the variation trends of the contours, we set comparison assembles whose bimodal QDs was replaced with a unimodal QDs. Then compare the results of comparison assembles to that of the QD-WLED we chosen.

3. Results

We finded that the QD-WLED we chosen, which is based on a favorable bimodal QDs and two unimodal QDs excited by a blue chip, outperformed the assembles. In addition, the result shows that colorimetric performances of the optimal QD-WLED are better than that of the traditionnal pc-WLEDs under the same condition of LE.

4. Conclusions

By using a favorable bimodal QDs and two unimodal QDs excited by a blue chip, we can more easily produce a CCT tunable QD-WLEDs with both excellent colour rendition and high luminous efficacy than using all unimodal QDs excited by a blue chip.

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Poster Session

Friday, April 27, 14:50–16:20

PO01

ILLUMINATION CONTROL MODEL FOR COMFORTABLE INDOOR READING

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Abstract

1. Motivation, specific objective

In this era of human centric lighting, the development of lighting technologies not only focus on raising luminous efficiency and lowering production costs, but also the development of intelligent lighting and modulation database to create desirable lighting environment for different situations. This study considers the working or reading scenarios of general public in the office, school, etc. Psychophysical experiments are carried out for different combinations of correlated colour temperature (CCT) and task illuminance. An ergonomic control model based on the subjective perceptions is then established to define the satisfactory operating range of comfortable office lighting.

2. Methods

Two operating factors are evaluated, including CCT at three levels (3000K, 4500K, 5700K) and task illuminance at four levels (200, 450, 700, 1000 lux). These combines to 12 lighting conditions, arranged by a Latin square to eliminate the ordering effect. The experiments use the within-subject design, that is, each participant will experience all the lighting conditions. The procedure for each lighting condition includes 5-min rest with eyes closed, 2-min measurement for the flicker fusion frequency (CFF), 15-min target word searching in randomly-ordered upper and lower English letters, 15-min target word searching in Chinese essays, 1-min questionnaire and 2-min CFF measurement. The participant will experience 3 lighting conditions in a day and complete the whole experiment in 4 days. The total duration is about 480 minutes.

The CFF difference before and after experiencing the lighting condition serves as the indicator for the objective visual fatigue. The word finding efficiencies represent the objective task performance. Subjective perceptions are obtained from 16 questions in four aspects: visual preference, visual comfort, physiological fatigue and subjective task performance.

Totally 46 participants joined the experiments, including 10 in the pilot study for adjusting the procedure and questionnaire, and 36 for the formal experiment (male: 18, female: 18, mean age: 22.6±2.5). Statistical analyses of the experimental data are conducted in SPSS. The indicators that are statistically significant are used as the basis for the establishment of luminaire control model.

3. Results

The results of two-way ANOVA show that the word finding efficiency for English character detection is the only significant factor in the objective assessments. The factors that are statistically significant in the subjective assessments include: in visual preference the brightness perception, the colour preference, the colour perception (reddish or blueish) and the overall lighting preference; in visual comfort the eye pain, blurred vision, difficulty in reading and the overall visual comfort; in physiological fatigue the overall physical comfort; and in subjective task performance the word recognition speed, reading speed, ease of concentration and endurable work duration.

After identifying the factors that are statistically significant, mathematical rating models of these factors are constructed as functions of CCT and tack illuminance via fitting the experimental data to polynomial equations. The coefficients of determination (R^2) range from 0.834 to 0.997, indicating that the models can well predict the average ratings of participants. A luminaire control model for indoor working and reading activities is then established based on these factors with user-adjustable weighting coefficients. Factors highly correlated (Pearson's correlation coefficient, r >= 0.95) are grouped together to reduce the number of weighting coefficients. The relative magnitudes of the weighting coefficients represent the user-defined importance of individual factors. For instance, if overall visual comfort is considered more important, we can assign larger weight to this factor. Different weight combinations would yield the illumination control models for various scenarios. Once a particular model is chosen, a higher rating

from the model implies a more satisfactory lighting environment. The location with the highest rating is the optimal operating point, and we suggest the operating range as the region within one standard error from the highest rating to account for user variations.

4. Conclusions

This study evaluates the psychological and physiological influences of indoor reading illumination in relation to two operating factors: the correlated colour temperature and task illuminance. The results show that the two factors have significant effects on several aspects of visual preference, visual comfort, physiological fatigue and task performance. By utilizing the fitted rating models associated with the dependent variables that reach statistical significance, an illumination control model with adjustable weights is constructed to define the satisfactory operating range for comfortable and efficient reading.

PO02

ATTENTION COMPARISON OF DIFFERENT OFFICE LIGHTING SCENARIOS BY BRAINWAVE MEASUREMENTS AND EMPIRICAL MODE DECOMPOSITION

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Abstract

1. Motivation, specific objective

Artificial lighting is an indispensable part of our daily lives. When it comes to working environments, we generally think that brighter illuminations are better for us to see clearly and avoid long-time excessive stress of our eyes. In this study, we try to see how lighting affects the brainwaves and concentration. Psychophysical experiments are performed to collect participates' brainwaves while working under two different lighting setups. Possible indicators of attention levels are extracted from the brainwaves by using empirical mode decomposition (EMD) followed by fast Fourier transform (FFT). We then use binary discrimination tests on several brainwave bands to compare the effectiveness of attention indicators in classifying different lighting scenarios.

2. Methods

The experiment comprises two 10-min lighting sessions, with a 3-min rest session in between. Two lighting conditions are involved, one being 5500K and 1000 lux and the other being 2700K and 200 lux on the task surface. During the experiment, a brainwave receiving device, MindWave™ Mobile, is used to collect participants' electro-encephalography (EEG) signals at forehead with 512 Hz data rate. Participants are required to perform reading tasks during each lighting session, including 5-min Chinese target word searching and 5-min English target word searching. The order of the two lighting conditions is interchanged for every other participant.

To extract participants' attention levels, we need to process the raw EEG signals into proper frequency bands. The alpha and beta waves, which in turn correspond to the frequency ranges of 8 to 12 Hz and 12 to 38 Hz, are most related to rest and attention, respectively. Since EEG signals are inherently nonlinear and non-stationary, we use EMD to decompose the signals into intrinsic mode functions (IMFs) before analysing their frequency content by FFT. The FFT spectra of different IMFs would contain information at distinct frequency ranges, which may provide greater capability in differentiating the attention levels under different lighting setups.

We focus on the change in alpha and beta waves whose activities would arise during the reading tasks. Once the FFT spectra of IMFs are obtained, we choose a few candidates for constructing the attention indicator. IMF4 for alpha wave and IMF3 for beta wave are cherry-picked, and their frequency intensity in the alpha and beta bands are summed respectively into the band powers. After processing 7 participants' data with moving block bootstrap, we build up the histograms of alpha and beta band powers and turn them into probability distribution functions (PDFs). Binary discrimination tasks are then performed to generate the receiver operating characteristic (ROC) curves for evaluating the attention indicators.

3. Results

The resulting PDFs show that the power spectra in alpha band exhibit no apparent differences between two lighting setups, but have significant change between working and relaxing. The relaxing power spectrum has obviously higher alpha band power than the other spectra in the reading tasks. On the other hand, the differences in beta band between two lighting setups are more apparent with relatively higher power in setup 2, which is a darker lighting environment. This can be interpreted that people need to be more concentrated in setup 2 to deal with the same task.

Furthermore, the ROC curves from the binary discrimination tests represent the difference between a pair of PDFs, such as PDFs associated with the working and relaxing statuses or with the two lighting sessions. A pure guessing line is an oblique straight line with a slope of 1, meaning no difference between the two PDFs in the ROC analysis. The ROC curve for working and relaxing is far above the guessing line, indicating the proposed data processing method has high sensitivity in differentiating the

working and relaxing statuses. The ROC curve for working under respective lighting setups is close to the guessing line, yet still above the guessing line most of the time, implying the method has potential in discriminating attention levels under different lighting conditions.

4. Conclusions

A brainwave processing method composed of EMD, FFT, and statistical classification tasks is developed for evaluating users' attention levels under different lighting conditions. Preliminary experimental results have shown the proposed method has high sensitivity in differentiating the working and relaxing statuses. Further investigations on other IMFs and frequency extraction methods other than FFT are in progress.

PO03

THE GREY RELATIONAL ANALYSIS OF PSYCHOLOGICAL AND PHYSIOLOGICAL EVALUATIONS FOR VISUAL FATIGUE IN THE OFFICE LIGHTING

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Abstract

People have extended working hours with rapid change of social change today. Some studies find the long working hours and high use of eyes would have physical and mental conditions be in long-term fatigue and further increase the risks of emotion, sleep problems, and low work efficiency. How to improve the office workers' state is the most important issue. Therefore, we propose 12 lighting environment with different colour temperatures, illuminations and peak wavelengths of blue lights and analyse the physiological and psychological impacts for visual fatigue. In addition, Grey relational analysis is applied to analyse the correlations between physiological and psychological evaluation to control and stabilize the quality of experiment

In this study, the parameters acquired with subjective and non-subjective evaluations are different. The factors in the questionnaire scale are numbered 1~6, while the heart rate variability and brain waves measuring factors present the second decimal place. In this case, all series need normalization to have the factors appear in 0~1 and the series show comparability for further calculation. The normalization equation could be substituted according to the properties of data.

Grey Relational Analysis find out the correlations between s subjective and non-subjective evaluations, but also verifies the accuracy of the experiment and enhance the clarity of the experimental result. Such results would greatly help the research and development of healthy and comfortable lighting systems.

PO04

PARAMETRIC DESIGN APPLICATION IN INTELLIGENT LIGHTING

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Abstract

1. Motivation, specific objective

Intelligent lighting is an important part for smart city construction. The intelligent lighting system is convenient in management and control, good at conserving energy and simplifying operation. The parametric design process makes smart lighting more flexible and adaptability in building space. Design of such parameterized lighting new methods for grid management, distributed lighting uniformity enhancement is realized. Parametric design application is one of creativity tools and is used in exploring complex and order space combinations. In our study, we try to simulate the interaction between people and lighting environment in indoor spaces. The optimal configuration of lighting can be doped out by complex parametric algorithm rather than simple linear relation. The configurations is content with needs of the human physiology and psychology. These parametric setting are based on spatial and spectral properties of light systems. The flexible conversion between parameters and graphics make default parameters into influence factor to reach different purpose such as art scene and desired lighting environment.

2. Methods

At present, there are many different methods for parametric design. We adopt the rhino and grasshopper to make parametric design. The 'battery', namely a kind of virtual arithmetic unit, is an important component in grasshopper, and can be compiled using Python. Batteries, in grasshopper, assemblage in order to carry out graphic editing, data visualization and interference calculation.

In the study, we firstly set up a scene, then change the location of lighting fixtures in space grid by random distributions. We further set the light output of the lamps, and collect data for uniformity of illumination. Then, we compare multiple data sampled in workplace to obtain optimal solution. The steps are as follows:

1. Establishing a flow chart constituted by multiple batteries. The batteries control the size of space grid, location of lighting devices and how luminaries affect grid.

2. Setting the battery parameters including distance between two lamps, the influence range of lamp and the count of lamps.

3. Extracting random seed from input port.. Random seed can control location point and is used to change coordinate frequently.

4. Extracting the location point of lamp about eight times at least according to graphic changing in grasshopper,

5. Importing the experimental results in the interface of grasshopper into ECOTECT and performing physical performance calculations, after they are feedbacked into rhino and changed into suitable format.

6.Building a 3D space model in ECOTECT, whose plane has the same size with space grid in length and width, and extracting data after finish operation, after setting the rooms height and luminous of light.

7. Analysing data by the software. In this way, it is easy to obtain the optimal illumination uniformity program under the same number of lamps.

On the other hand, we can also compile the battery about lighting parameters trough python to operate and simulate on the grasshopper interface directly. By this means, we can control the change of the plane grid by the luminous flux of the lamps and realize the illumination data visualization on the grasshopper.

3. Results

The results also need to be simulated repeatedly, so that the optimal uniformity can be achieved through multiple experiments. By simulating in Ecotect, the sampling data can be analysed including illumination valve, global illumination and vector quantity of illumination.

Under the premise of the same illumination, the artificial lighting with nonlinear distribution is better at the uniformity of interior lighting environmental and the result of appearance outstanding comparing to traditional artificial lighting. Using the rules of illumination uniformity calculation to measure whether the the degree of uniformity of luminous environment is promoted or not. The results are positive.

4. Conclusions

Parametric lighting systems can sense and feedback. Integrated with statistics, the effects of lighting can be quantified to satisfy the requirements of different people and different application.

Applying parametric design in the smart lighting system contributes to energy conservation and will reduce the barriers to implement custom design. By dividing a complex system into several simple logical data questions, we can achieve desired results.

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PO05

INVESTIGATION OF AFFECTIVE FACTOR EVALUTION METHODOLOGY FOR WHITE LIGHTS

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Abstract

1. Motivation, specific objective

The lighting quality study is intensively ongoing to satisfying user-preference and physical/emotional wellbeing requirements, leading to meeting the demands of human-centric illumination. Many researchers use adjective words for learning the influence of illumination change on user emotion and satisfaction, however, the study of evaluation methodology itself for these factors is limited. There are two approaches in the affective-factor (emotion) evaluation that are verbal and non-verbal methods. The affective factors are various from one-dimensional ones such as warm or cold to complex ones such as stylish or beautiful. It is very much difficult to measure variations in the complex affective factors using non-verbal method i.e., physiological tool.

The evaluation components for lighting quality include visual comfort, visibility, user-required affective factors, workability etc. that are different up to the architectural use of space and behaviour types of users. All of these components contribute to overall user satisfaction. Our affective factors are composed of stimuli through five senses (sight, hearing, touch, smell and taste), subjective feelings, behaviour types, and individual long-term experiences. We therefore need to understand the deviation between user-required 'affective factors' formed from long-term experiences and 'those' influenced by visual pathway against the illumination change. This study attempts to figure out this deviation and to determine the affective factors significant for human-centric illumination development.

2. Methods

The verification experiment is designed targeting office lights using verbal method. Physiological tools are partly also applied. The adjective words are collected from the relevant studies and promotional materials (109 words) and lighting experts who are involved in the development of smart lights (71 words). These are classified with exclusion of repetitive words using Kawakita Jiro method, resulting in final 23 adjective words. The 23 adjective words are quantified using a 5-point qualitative category scale against 16 illumination conditions: four illuminance levels of 200, 300, 500, 750 lx, and four CCT values of 3,000, 4,000, 5,000 and 6,000 K. The illuminance and CCT ranges are determined in which the observers' affective factors are varied. The nine office behaviours are chosen: document work, computer work, and night overtime in general office, presentation with projector, writing on the board, and discussions in conference room, refreshment, relax, and chatting in lounge. The 23 adjective words are separated to be the empirical affective factors that office users expect to have in each of nine behaviours based on 45 office workers' long-term experiences. The affective factors that are proved to be influenced by illumination changes from the visual experiment are then compared with the categorized empirical affective factors.

3. Results

It is examined using cross tabulation analysis whether the empirical affective factors required in each of nine behaviour types are significantly different. Its results show that these factors are different up to the behaviour types of office workers ($p<0$ in chi-square test). The cluster analysis is then conducted to categorize the nine behaviour types according to the similarity, resulting in four categories. The 1st and 2nd categories correspond to the affective factors required in general office and in conference room respectively. The 3rd and 4th groups are relevant with alive actions of refreshment and chatting, and calm behaviour of relaxing respectively in lounge. The empirical affective factors separated in each of these 1st – 4th categories can be related with offering focusable environment for the 1st, appeal for the 2nd, activity for the 3rd, comfortable and friendly state for the 4th.

The changes in the 23 affective factors are quantified through visual experiments against the 16 illumination surround variations. By applying factor analysis to the quantified results, the 23 affective

factors are divided into three groups that can be expressed in terms of workability (maybe related with general-office lighting conditions), activity (conference room), and relaxation (lounge). The internal consistency using Cronbach's α is examined for the affective factors belonging to each of these four groups. The resulting Cronbach's α values are 0.94, 0.97, and 0.96 for each of these three groups, suggesting that the affective factors are well classified.

The empirical affective factors are formed from long-term experiences when users do specific actions in office spaces. It is discovered which ones amongst those are not influenced by visual pathway in the illumination condition changes. For example, the users expect 'easy-to-concentrate', 'clear', 'pleasant', 'stable', 'quiet' when they do document and computer works. A low Cronbach's α value of 0.55 is obtained by internal consistency analysis for these five adjective words based on the visual quantification results. By eliminating two adjectives of 'stable' and 'quiet', higher Cronbach's α value of 0.94 is given. On the other hand, these two affective factors show high internal consistency with other words for relaxation in lounge. These analyses indicate that a part of the empirical affective factors are not influenced by visual stimuli, but this is dependent on the user behaviour type. Through internal consistency examinations, are determined the significant empirical affective factors that are verified to be changed by varying illuminance and CCT properties.

The observers are asked to choose one of the 16 illumination variation cases that is the most suitable lighting condition for each of general office, conference room and lounge. Their answers are examined using correspondence analysis. Its outcome in the form of graphical representation shows that observer prefer different conditions of illuminance and CCT according to the three sub-spaces in office: 750 lx and 5,000 – 6,000 K for general office, 300 – 500 lx and 4,000 K for conference room, and 200 lx and 3,000 K.

4. Conclusions

The affective factors for the development of lighting products are selected from other application (fashion, architecture, etc.) cases in the most of previous studies. To realize human-centric lighting, it is important to learn user-expected affective factors targeting lighting field. The user-required affective needs for the illumination are shaped by diverse factors: growing environment, culture, gender, etc. for a long time, and mental state and visual stimulation at that instant. The present study, therefore, introduces the verification results whether such user-required affective needs correlate with the affective responses occurred immediately by visual perception against varied illumination.

PO06

OPTIMIZATION METHOD FOR LED LIGHTINGS CONSIDERING CCT, ILLUMINANCE, AND CRI

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Abstract

1. Motivation

In these days, white LED light sources prevail in many lighting applications such as indoor general lighting, outdoor lighting, and automotive lighting. Different light applications and lighting source types require different lighting quality and luminance level. For example, required CRI in indoor office lighting and in commercial retail store lighting is different. Colour temperature is one of the most important parameters to control lighting according to human activities and required mood. In addition, multi-chip LED packages with three or four different colours in a single package are commercially available from many LED suppliers. Therefore, it is important to control various aspects of lighting parameters of the full colour LED according to lighting applications. In this paper, we present an optimization method for the control of LED lighting colour temperature (CCT) with high colour rendering index (CRI) in CIE 1931 spaces.

2. Methods

We conducted two experiments: one is using multi-chip LED (red, green blue and white), the other is using 1 narrow band individual LEDs (red, green, blue, cyan, and amber) and a wide band white LED. For the optimization of LED lighting spectrum according to required CCT or CRI parameters, we need spectral distributions of each individual LED light source. So, we measured individual LED's spectral distribution and Illuminance data using spectrometer. We uses the Gurobi optimization tool in Matlab, and the lighting control parameters can be solved by finding optimal integer values for the pulse width modulation control.

To find control parameters with required lighting characteristics, we first optimized CCT by minimizing distance to the target black body locus in CIE1931 colour space. That black body xy coordinate (x_{cct}, y_{cct}) in is computed from the target CCT. Then, the CIE1931 xy point is converted to XYZ coordinate value using target illuminance value. Optimization is proceeded in this homogeneous coordinate. Second, we consider CRI to constrain the optimization solution to have high CRI values by minimizing the distance to the spectrum distribution with reference white locus. CRI was closely connected to the daylight spectrum distribution similarity of reference white. That spectrum of reference white is combined two illumination model that CCT≤5000K use black body model, CCT≥5000k use CIE D illumination. Finally, PWM value of each individual LED was computed and controlled from the optimization result.

3. Results

We applied the optimization method to two different colour LED combinations. Optimization results can be explained by three parameters: CCT, illuminance, and CRI. In case of multi-chip 4-colour LED, we can optimize CCT from 3000K to 7500K with CRI larger than 80 and less than 95. We can optimize CCT from 2500K to 7500K and CRI is above 90 when CCT ≥ 3000K in case of combination of 6-colour LED.

4. Conclusions

In this paper, we present an optimization method for high quality LED lightings. This simple optimization method provides given target CCT and illuminance with high CRI. The proposed method can be used for any other combination of LED. For the high quality LED lighting source, and for better control of LED lighting source according to the target application, we need further development of the control of several different lighting parameters independently using optimization methods.

PO07

COLOUR BARRIER-FREE ILLUMINATION USING MULTISPECTRAL LIGHTING SYSTEM

Motivation

Colour deficient observers (CDOs) in a certain proportion of general population live with colour normal observers (CNOs) together in the same living environment. In recent years, several nonprofit organizations in the world, such as Color University Design Organization (CUDO) in Japan, has devoted to create varied friendly environments to CDOs. Several methods have been announced that they could improve colour discrimination for CDOs, like colour-blindness corrective glasses, and colour-blindness correction app. However, these methods are still limited. Light technology should be a potential solution to helping CDOs. Tamura et. al. (2014) proposed a colour barrier-free illumination consisting of white, red, and blue LEDs for deuteranopia-type defects. However, the colour temperature and colour render property of the illumination were unclear. In this study, we apply tunable multi-spectral LED spectra with different correlated colour temperatures (CCT) to improve colour discrimination abilities of colour defects.

Methods

In this study, the deficient types of CDOs are diagnosed by Ishihara test, D-15 test, and anomoloscope. A total of ten CDOs, including five deutan observers and five protan observers, participate in our experiment. A Telelumen multi-LED system is used to produce the varied test sources in this study. The test samples, i.e., printed Ishihara test book and the caps in D-15 test, are to check the colour discrimination abilities of CDOs under the illuminating of each test source. The accuracy ratios of the above two diagnosing methods are analysed to confirm the efficacy of each test source.

Two kinds of experiments are designed in this study. In Experiment 1, a series of of daylight metamers are produced by a multi-LED system in terms of 7 CCTs of 2000K, 3000K, 4000K, 5000K, 6000K, 7000K. The experimental result is examined to determine which spectrum of test sources is better to improve colour discrimination abilities of the CDOs for deutan and protan observers. All of the test sources are set to the same illuminance level of 300 lux. The experiment is conducted in the darkroom. Considering colour adaption, progressive CCT changing is adopted, then the subjects have enough time to adapt to the assigned light condition.

Based the result in Experiment 1, the spectrum of the test source with the best performance would be used in Experiment 2. We add the each of the four narrow-band colour lights of red, yellow, green, blue (corresponding to 660nm, 595nm, 525nm, and 475nm peak wavelengths, respectively) into the best spectrum obtained from Experiment 1. A total of 15 spectrum combinations of test sources are used in Experiment 2. i.e., 15 kinds of test sources are produced, which combine the daylight metamer with the best performance in Experiment 1 with all possible combinations of red, green, yellow and blue lights. Experiment 2 is designed to further examine which spectrum of the updated test source is better to improve colour discrimination for deutan and protan observers.

In addition, the efficacy of each test source designed in Experiment 1 and Experiment 2 are also inspected by the computerized simulation methods, such as colour-vision simulation proposed by Brettel et al. (1997), IES TM-30-15 fidelity index (2016), and CIE 2017 colour fidelity index (2017).

Results

The experimental result shows that the suitable CCT of the illuminant depends on the type of CDOs, i.e., protan or deutan. Currently, the diagnosing result of 5 deutan observers in our study shows that the best performance of the lighting condition is the CCT of 2000K. Besides, the spectrum combinations of 2000K daylight metamer and 4 colour lights can be designed, and be successfully formed by a multi-LED system for testing deutan and protan visions in Experiment 2. The preliminary result of Experiment 2 for 4 deutan observers indicates that the spectrum combinations containing green light cannot provide any help for raising colour discrimination abilities of the deutan observers. Besides, it can be seen that all of the spectrum combinations except for the spectra containing green-light component indicate there is a tendency to improve colour discrimination abilities well for deutan visions. However, more colour-defect observers are necessary to examine its reliability in the future.

4.Conclusions

Our preliminary result shows that the daylight metamer with a CCT of 2000K can effectively improve colour discrimination for deutan observers. Other further verification will be performed using the colour-vision simulation proposed by Brettel et al., IES TM-30-15 fidelity index, and CIE 2017 colour fidelity index. The complete result will be presented in full paper.

PO08

LIGHT POLLUTION IMPACT STUDY OF DYNAMIC DOT MATRIX LED SIGNS IN TAIPEI AND HSINCHU

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Abstract

New type of dynamic dot matrix LED advertising signs have the characteristics of high brightness, fast response, high color saturation, with flicker and diverse contents, which get the attention of human eyes but also easy to cause glare and flicker hazards.

In this research there are two kinds of dynamic dot matrix LED advertising signs, which commonly used by current domestic business, including peacock-tail lights, octagon-shape lights. Three peacock-tail lights, and three octagon-shape lights were studied and located in Taipei City and Hsinchu City, respectively.

Through the statistical analysis of monitoring data (luminance, vertical illuminance, horizontal illuminance), we get the appropriate photometric measurement parameters for glare and flicker evaluation. In summary, flicker evaluation criteria and luminance measurement method of outdoor LED dot matrix dynamic advertising signs will describe in this paper, which might be a good reference for light pollution control.

Keywords: dynamic dot matrix LED advertising signs, glare, flicker, visual discomfort, photometric measurements, luminance, light pollution

1. Motivation

According to a survey conducted by the Environment Administration Taiwan (EPA Taiwan) 2011~2017 research projects, it has been found that the light pollution caused by the scintillating light source in the Taiwan metropolitan area is quite serious and the impact on the perception of the Taiwan people has been carried out for more than 6 years. In the 2011 to 2014, the main research object is focusing on LED advertising billboards (also known as multimedia billboards), which have higher portion of public petition cases in Taiwan.

We proposed a glare-luminance recommendation table respective to de Bore rating, which has been confirmed by outdoor subjective questionnaires survey of LED advertising billboards for 461 people with 1,385 valid questionnaires in 2015 project.

In 2016, the outdoor LED billboard field experiments of flicker perception were done in Taichung. For a better control of the flicker impact by LED billboards, it is suggested to use a maximum value of FFM_90^{th} under 31~33 (the value suggested in 2015) for LED billboard with maximum luminance between 1,100 cd/m² and 4,299 cd/m².

In 2017, the experiments of LED octagon-shape light and LED peacock-tail light have conducted for BCD of light pollution in partially controlled outdoor field. The questionnaire included the maximum glare and the maximum flicker. The independent variables included 3 luminance levels, 3 frame rate of LED combo lights, and 4 patterns. There were 20 participants involved and total of 4,320 data were recorded. The results will be published in another article.

In 2017, three LED peacock-tail lights and three LED octagon-shape light located in Taipei and Hsinchu downtown area were studied, respectively. The light pollution impact of those LED combo lights will be reported in this study. While, a proposed objective flicker measurement method and improvement measures of LED combo light will also discuss.

2. Methods

The experimental set-up were composed by a luminance meter, a illuminance meter, and a flicker measurement device (FMD). Where a Konica-Minolta LS-100 luminance meter was used for monitoring

the luminance of LED billboard, and a Konica-Minolta T-10 illuminance meter was used for monitoring the environmental vertical illuminance and horizontal illuminance. The measurement height is set as the average pedestrian standing eye height, which is 1.5 m. While, a Flicker Measurement Device (***FMD***) was used to detect objective flicker of LED combo lights. In this study, we use DILMD as a ***FMD*** and using **FFM_90th** to detect the flicker characteristics of LED combo light.

3. Results and Summary

There are 778 light pollution petition cases in the 22 counties and cities in Taiwan, there are 7 cities have more than 10 and less than 100 petition cases, they are New Taipei, Taoyuan, Taichung, Tainan, Kaohsiung, Hsinchu City, and Chiayi City, while Taipei City has more than 500 petition cases.

Advertising category of light source with a total of 467 petition cases (60% in total) were found to be the most complaint one for the people in Taiwan. Too bright and flashing were the two major factors of discomfort. Light pollution may interfere most people's homes and even affect sleep, light pollution may affect traffic safety or caused the interference of pedestrians.

This study conducted a total of 6 case studies of monitoring the luminance of LED billboards, vertical and horizontal illuminance in New Taipei metropolitan area.

For example, LED billboard located at crossroads of Sec.2, Yonghe Rd. and Sec. 1, Zhongshan Rd., from the MRT station about 100 meters, near the office buildings, quite a lot of traffic vehicles and pedestrians. The LED billboard maximum luminance of 2,049 cd/m² is quite high, a 58 % chance of finding a luminance greater than 1,000 cd/m² (recommended by the CIE Urban Area) from luminance statistics, so the LED billboard has a considerable light pollution influence on the environment, because of its location at the crossroads, it may cause a greater impact on drivers and passers-by.

Farglory Museums is located in Xintai 5th Rd., Xizhi Dist. which belong to industrial area, near the office buildings, the LED billboard maximum luminance of 234 cd/m² is not high, so it is very low light pollution impact on the surrounding environment.

Banqiao Bus Terminal is located in Banqiao District of the Sec. 2, Xianmin Blvd., close to the Xinfu Rd. and Sec. 2, Xianmin Blvd. intersection, facing office buildings, the LED billboards maximum luminance of 926 cd/m², with a probability of 1.6 % higher than the 800 cd/m² (CIE suburban recommended value). Therefore, this LED billboard has little light pollution impact on the surrounding, but because of its location close to the intersection, it may cause little impact on drivers and passers-by on the Xinfu Rd.

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PO09

USING MULTI-LED SYSTEM TO INCREASE VIVIDNESS OF TEXTILES

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1. Motivation

Because of LED technology advances, the LED lighting has shown large improvement in all these aspects and gained popularity. General museum lighting is designed according to its high colour-fidelity colour render index, which is based on the general colour rendering index (CIE-Ra) with simple average of CIE-Ri values (i=1~8) for the 8 colour samples. However, it could be not enough to bring the viewers more vivid sensation for the artwork. Therefore, the aim of this study is to utilize a multi-LED system to produce a series of specific illuminants for achieving colour-vividness effect of the textiles, if the designed illuminants can invoke the viewers vivid sensation when illuminating on the textiles with different colour combinations.

2. Methods

A pair of Telelumen® multi-LED devices are used in this study, which have 16 narrow-band LED channels across the visible spectrum to generate lights to match the Spectral Power Distribution (SPD) of the illuminant. One is the reference illuminant and the others are 8 test source. In this study, the lighting conditions of reference illuminant and test sources are set identically, and they are the CCT of 4000K and the illuminance level of 300 lx.

To explore the colour-vividness effect of the textiles illuminated by the illuminants, the spectra of test sources and the textile samples are manipulated. Therefore, four kinds of manipulated factors are designed, including hue-emphasizing spectrum, vividness-effect spectrum, sample's pattern and sample's colour combination. Here, hue-emphasizing spectrum factor contains 4 main colour hues of red, yellow, green and blue, which is designed to add the assigned peak-wavelengh of the spectra in the test source. Vividness spectrum factor contains colour vivid and colour fading effects, which make the spectrum of the test source have a capabiliy of showing colour-vividness effect. Sample's pattern contains two patterns of 'leaf' and 'flower' on the textiles. And sample's colour combination contains two types of colour relationships on the textiles based on opponent colour or neighbor colour theories.

All of the test samples are illuminated in a lighting cabinet, which is divided into two compartments to accommodate reference illuminant and test source. There are two identical contents for each test sample. Eight subjects take part in the experiment (4 males and 4 females). Observers are asked to view the two identical test samples illuminated by the pair of test source and reference illuminant separately, which are located at right and left sides in a viewing cabinet respectively.

The psychophysical methods are designed to evaluate degrees of preference for lighting qualities, including the questionnaires of vividness, preference and clarity. The rating scores are answered by the observers for each specific experimental condition according to the comparison scale via a 6 categorical-point scale. In total, 1152 assessments are accumulated (4 hue-emphasizing spectra × 2 vividness-effect spectra × 2 sample's patterns ×3 sample's colour combinations x 8 subjects x 3 questionnaires) in this study.

3. Results

The correlation coefficients in the pairs of either of vividness, preference and clarity were analysed. The analysical results indicated that the correlation coefficients are 0.79 in the pair of vividness and preference, 0.78 in the pair of preference and clarity, and 0.82 in the pair of clarity and vividness. Furthermore, all of the test sources will be analysed according to the calculations of IES TM-30-15 fidelity index (R_f), gamut index (R_g), and CIE 2017 colour fidelity index (R_f). More details will be reported in the full paper.

4. Conclusions

The aim of this study is to develop an intelligent lighting system applying in museums. When the illuminants with the special SPDs illuminate on the painting or textiles, the colour-vividness effect of the object can be emphasized. The analytical result indicated there are high correlations in the pair of either of vividness, preference and clarity. It is concluded when an observer watches the textile sample under the illuminant with colour-vividness effect, then he (she) can feel vividness, preference, and clarity simultaneously.

PO10

NON-SUBJECTIVE AND SUBJECTIVE EVALUATIONS OF CONCENTRATION OF OFFICE WORKERS IN LIGHTING CONDITIONS WITH DIFFERENT BLUE LIGHTS

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Abstract

To more definitely understand the effect of lighting on humans, the ergonomic study on health lighting has been discussed. Our research team has preceded the ergonomic study on the influence of led lighting with different proportions of blue-light wavelengths on humans. Both subjective and non-subjective evaluations were implemented for obtaining the influence of different lighting conditions on human. The subjective evaluation result revealed that most participants presented concentration, pleasant and being excited, while the non-subjective evaluation showed that participants were enhanced the sympathetic activity indicator and the indexes of brain waves and reduced the parasympathetic activity indicator. However, the correlations between subjective evaluation and non-subjective evaluation were not mentioned.

For this reason, Grey relational analysis is applied to analyse the correlations between subjective evaluation and non-subjective evaluation to control and stabilize the quality of experiment, expecting to reduce the variation between subjective and non-subjective experiment results and enhance the accuracy of experiment through such correlations. Furthermore, it is expected to establish a reliable model for the development of human-centric lighting in the future.

PO11

OPTICAL DESIGN OF THE NON-BILATERAL SYMMETRICAL ELLIPTICAL REFLECTOR WITH NEAR INFRARED LED APPLIED IN NON-INVASIVE BLOOD GLUCOSE MEASUREMENT

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Abstract

1. Motivation

The measurement of the blood glucose concentration is very important for daily life of a diabetes patient. However, the traditional blood glucose measuring technology often obtains blood glucose concentration information by puncturing the fingers. The invasive method often makes patient feel pain, full of mental pressure, and also often causes the wound infection. Hence, the optical non-invasive blood glucose measuring (ONBGM) technology has been rapidly paid attention recently. Generally, the near-infrared (NIR) light source usually is utilized as the light source in the ONBGM owing to the information of the blood glucose concentration can be greatly enhanced by the stronger absorption of the NIR light in the blood. In order to detect the information of the blood glucose, a light source chip and a detector are usually assembled very close to each other and both close to the skin. The informations of blood glucose can be detected by the back-scattering light from the skin of the fingers which is directly passed through by the light from the light source. Unfortunately, the small size of the detector and the omnidirectional of the back-scattering light cause the great energy loss in collecting light. Moreover, some heat issues about the conditions that the light source chip is very close to the skin could produce some interferes in measurements of the blood glucose. Hence, in this study, a reflective system composed of a non-bilateral symmetrical elliptical mirror (NSEM), a light source chip and a detector is proposed and designed. To avoid the troubles of the heat and the circuits mounting of the light source chip and the detector, they are assembled at the two sides of the system. The simulations and related results about the ONBGM with the reflective system are calculated and analysed in below details.

2. Methods

At the beginning of the optical simulations, the optical model of the skin which consists of an epidermis, a dermis, and a subcutaneous fat layer must be built in the simulations. In simulations, the light paths from the light source chip treated as a lambertian emitting surface are traced by ASAP program. The size of the light source chip and the detector both are 1mm*1mm. In addition, the related optical parameters of different layers in the skin must be considered in the optical model of the skin, such as the absorption coefficient (μ_a), the scattering coefficient (μ_s), the anisotropy factor (g), and the refractive index (n), respectively. In order to predict the paths of the scattering light, the Henyey-Greenstein scattering model are utilized to calculate the energy distribution of the scattering light in the human skin. To increase the energy that the detector can receive, a reflective optical module consisting of the NSEM and a light source and a detector is used to focus the emerged light from the light source to a focal spot on the skin of the fingers, and simultaneously collect the back-scattering light from the skin to the detector. To achieve the purposes of better heat dissipation and circuit layout, the light source and detector are assembled at both sides of the module. The NSEM can even reduce the proportion of the light which directly transfers to the detector but does not enter the skin, the so-called the stray light. In this study, the shape and size of the NSEM are optimized by analysing the overall optical efficiency. In addition, the tolerances of locations of the light source chip and the detector are also analysed by simulations.

3. Results

According to the simulation results about the optical efficiency, the ONBGM with the NSEM can provide better performance in optical efficiency. The optical efficiency of general ONBGM without any other optical module is about 3%, however, the optical efficiency of NSEM with side light source and detector

applied in ONBGM is about 9.6%. Therefore, the optical efficiency of NESM with side light source and detector is about three times higher than the general ONBGM. The main reason is that the NSEM can effectively collect the energy of the side light source chip. In addition, the NSEM can also avoid most of the light emerged from the light source directly enters to the detector but never propagate into the skin. Hence, the NSEM will increase the collecting efficiency of the back-scattering light emerged from the skin and improve the overall optical efficiency further.

4. Conclusions

In this study, the design of the NSEM with a side light source chip and a detector used in the ONBGM is proposed to improve the optical efficiency of the traditional optical module. In order to evaluate the performance of the ONBGM with two different optical modules, the Henyey-Greenstein scattering model is used to build the optical model of the skin first, and the optical efficiency of the ONBGM with specific optical module is analysed by the simulations. According to the analysed results, the optical efficiency of the ONBGM with the NESM is about three times higher than the conventional ONBGM. This is because of the NSEM can effectively collect the light emerged from the side light source chip to the skin and avoid most of the light emerged from the light source directly enters to the detector but never propagate into the skin. Hence, the overall optical efficiency can be improved further.

PO12

ANALYSIS OF TOLERANCE IN CONCENTRATION OF VOLUME SCATTERING DIFFUSER AND COLOUR CONSISTENCY IN AN ANTI-GLARE WHITE LED LIGHTING

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Abstract

1. Motivation

Nowadays, White Light Emitting Diode (WLLED) has been widely used as a light source in lighting and display applications. However, in pursuit of high LED light output efficiency, people pay more and more attention to the quality of light colours, such as colour rendering index, colour gamut or colour consistency of mass production. And the internal components related technologies of white light LED, including phosphor coating, lens design, heat sinking treatment, etc., may change the original white light characteristics.

In addition, in the process of using the light source in lamps, such as volume scattering diffuser (VSD) for backlight modules and lighting fixtures, which has the effect of reducing glare and increasing the light divergence angle, but it will have a problem that the variety of colour temperature, which refers to the colour of the light incident on our human eye after the function of the lamp and the VSD is different from the colour originally emitted by the light source. People to discriminate the colour of light is subjective, and the discrimination between colours is different among different people. Therefore, in this study, to describe the variety of the colour temperature and the luminous flux of white light caused by the VSD in the anti-glare lamp and further analyse the tolerance of the fabricating parameters of the VSD.

2. Methods

In simulations, a WLLED anti-glare lamp that is mainly composed of a top plate with a hole, a cylindrical side wall and the WLLED which is installed at the bottom of the lamp. The designed VSD is put on the top of the lamp and covers the hole of the top plate. The light source is CREE-XPE2, the original CCT value are 6110K and 3125K respectively. In experiment, the acrylic particles whose average particle diameter is 2 μm are mixing with the Epoxy resin to make our VSD. The variations of the white light path and the spectrum because of the light scattering into the VSD are calculated by the colourful variation model which is studied in previously work. Then the WLLED anti-glare lamp is combined with the VSD, and the corresponding measuring results measured by the integrating sphere is analysed and compared with the simulation results. In order to observe the influences of the concentration of VSD and the reflectivity on the colour temperature variation of white light, the concentration of the VSD is changed gradually from 1% to 10%, and the reflectivity of the lamp is changed to 0%, 20% and 95% respectively. Finally, the MacAdam ellipse is utilized to analysis the tolerance about the change of concentration in VSD when the colour perception of anti-glare WLLED lamps is consistent for most people.

3. Results

After our experiment, we find out that whether 6110 K or 3125 K white light sources, both of their CCT value is drop dramatically with the increasing concentration from 0% to 2%, more stable with the increasing concentration from 2% to 4%. Then, the CCT value is drop gradually with the increasing concentration from 5% to 10%. The maximum ΔCCT of the 3125K and 6110K white light LEDs, are 219K and 836K, respectively. And the ΔCCT of the lower colour temperature is smaller than the ΔCCT of the higher one. In addition, when the reflectivity of side wall of our anti-glare WLLED lamp is increasing, the oscillation of the colour variation is smoother when the concentration is less than 5%, and drops more abrupt when the concentration is more than 5%.

In order to comprehend fabricating tolerance of the VSD, the colour consistency could be analysed by David Macadam's ellipse, whose inside colour coordinates represent different colour, but are not distinguished by most people. For these two different colours of WLLED lamps, according to the analysing results of the 1-step and the 4step Macadam ellipses, with increasing concentration, the colour coordinates are almost move towards top-right direction. In addition, the colour coordinate is outside the

1-step (4-step) Macadam's ellipse for the 0% and the 95% reflectivity lamp while the concentration exceeds 0.17% (7%) and 0.6% (4%).

4. Conclusions

In this study, the optical model that the colour variation of the white light which is produced by light scattering in VSD is proposed, and applied in an anti-glare white light LED lamp. According to the simulation and the experimental results, with increasing concentration, the CCT value is drop dramatically from 0% to 2%, and more stable from 2% to 4%, then, is drop gradually from 5% to 10%. In addition, with the increasing reflectivity of the side wall of the lamp, the oscillation of the colour variation is smoother when the concentration is less than 5%, and drops more abrupt when the concentration is more than 5%. Finally, according to the comparing results of the 1-step (4-step) Macadam ellipse and the colour coordinate moving, for the purpose that the colour perception of anti-glare WLLED lamps is consistent for most people, the fabrication tolerance of concentration of the VSD used in the anti-glare WLLED lamp whose reflectivity is 0% and 95%, must be controlled within 0.17% (7%) and 0.6% (4%).

PO13

VISIBILITY OF ROAD MARKINGS ON A LED-LIGHTED FOGGY ROAD

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Abstract

1. Objective

For rapid growth of the LED luminaires in road lighting, it would be seriously considered the visibility of the road in bad weather, such as fog and haze. This is optically due to the substantial presence of particles in the atmosphere that absorb and scatter light, and may significantly degrade the visibility. To study this subject, the contrast of road markings in man-made fog weather were systematically measured and analysed. It was performed by on-site measurements of luminance images at an experimental 2-lane road. The distance–dependent contrasts of various markings in these luminance images were calculated and analysed to get physical parameters such as effective sky luminance (p_e) and effective extinction coefficient (k_e).

2. Methods

The measurements were performed at an experimental 2-lane road at southern Taiwan. A set of LED luminaires were mounted on the typical lighting poles at the road. The height of the luminaire, width of each lane, and distance between the luminaires are 10 m, 3.8 m, and 43.8 m, respectively. Various levels of foggy environments were generated by several water mist machines along the experimental road. Many of luminance images of the road were captured for the analyzations of the visibility.

The luminance images of road were measured with a calibrated image luminance measuring device (ILMD) with 10-22 mm focal length. The ILMD was placed at distance of 30 m between the nearest pole, and the height of the ILMD is 1.5 m. The luminaires used in this study are LED, high pressure sodium (HPS), and metal halide (MH) in order to compare the influences of visibility between them in foggy road.

3. Results

We selected ten road markings at various distances (d_1) in the luminance images to quantitatively study the fog and distance dependent visibility. Michelson contrast ratios (C) of the markings were calculated with the average luminances of bright and dark areas across the markings. Because the contrasts (C_0) of each marking in presence of clear weather are different, we further defined the relative Michelson contrast ratio ($C_R=C/C_0$) to obtain parameters corresponding to the visibility of each luminance image.

With Koschmieder's model of luminance as function of distance, the effective sky luminances and effective extinction coefficients of each luminance image can be obtained by curve fittings on C_R and d_1 of the selected road markings. These parameters are statistically distributed in a range of the p_e-k_e plot. For the LED lighted situation, the average, maximum, minimum, and standard deviations of k_e are respectively 0.0333, 0.0538, 0.0090, and 0.0142, and those of p_e are respectively 0.841, 1.115, 0.626, and 0.155. The distribution of p_e-k_e of the HPS and MH lighted situations are similar to LED.

By covariance analyses between p_e and k_e, the averages of (k_e, p_e) for LED, HPS, and MH lighted foggy road are (0.0304, 0.87), (0.0300, 1.02), and (0.0477, 1.05), respectively. Because C_R is about inversely proportional to p_e, and exponentially decay with k_e, the visibility will be better for smaller p_e and k_e. These data mean that the visibility of LED lighted foggy road is better than those of HPS and MH in the experiments.

4. Conclusions

We have quantitatively studied the visibility of a man-made foggy road based on the on-site measurements of luminance images. The statistical distribution of effective sky luminance and effective extinction coefficient are used to study the performance of the foggy road lighted with various types of luminaire. The comparison results show that the visibility of the road with LED luminaires is somewhat better than those by HPS and MH lightings. These analysis processes as well as experimental data are

expected to provide a contribution for the development of LED road luminaires used in abnormal weathers.

PO14

CALIBRATION OF TOTAL LUMINOUS FLUX, SPECTRAL RADIANT FLUX AND CORRELATED COLOUR TEMPERATURE OF LED LAMPS BY INTEGRATING SPHERE

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Abstract

1. Motivation, specific objective

Tungsten lamps have been widely used by calibration laboratories as reference standards lamps. When the filament heats up, it produces heat and light from wavelengths throughout the visible spectrum which has similar characteristics from a Planckian black body in the spectral distribution. In the consumer market, incandescent light bulbs are gradually phased out in recently years owing to the evolution of more energy efficient with extended operating life lamps, including halogen lamps, compact fluorescent lamps (CFL) and light emitting diode (LED) lamps.

LED lamps are solid-state devices which are rugged, have much longer operating life and have much better efficiency than tungsten lamps. As LED lamps have different spectral power distribution from tungsten lamps, a technical committee has been set up under CIE to study the use of the LEDs as reference light sources. The committee will also decide a reference spectral for LED standard lamps named as Illuminant L.

To support the calibration demands from the local industries, the Standards and Calibration Laboratory (SCL) of Hong Kong has developed the calibration of total luminous flux, spectral radiant flux and correlated colour temperature for LED lamps and tungsten standard lamps.

2. Methods

At the SCL, the calibration of the total luminous flux follows the principles described in Section 6 of CIE 84-1989. An integrating photometer, which consists of a 1.65 meter diameter integrating sphere and a photometer, is used to compare an unknown flux generated by a unit under test (UUT) light source against a known flux generated by a reference light source. Correction for self-absorption of the lamps is calculated by the ratio of the flux of an auxiliary lamp with the reference and UUT lamp installed inside the integrating sphere respectively. Spectral mismatch correction, which is also known as the colour correction factor, is also included in the calculation of total luminous flux. The parameters include the spectral power distribution of the UUT lamp and the reference lamp, the relative spectral responsivity of the photometer detector, the spectral reflectance of the sphere coating and the CIE spectral luminous efficiency function for photopic vision ($V(\lambda)$).

In the calibration of spectral radiant flux, the spectral radiant flux of a UUT light source is compared against a reference light source using a spectrometer. The integrated light signal is coupled by an optical fibre to a double monochromator equipped with a PMT detector and a current to voltage amplifier for measuring the spectral power distribution. Similar to the total luminous flux measurement, the correction for self-absorption of the lamps is calculated by the ratio of the spectral power distribution of an auxiliary lamp with the reference and UUT lamp installed inside the integrating sphere respectively.

The power supply to the lamps supports either AC or DC mode with supply current up to 13 A and 10 A respectively. Supply voltage and current can be accurately controlled by digital multimeters which measure voltage and current quantities by 4 wire method and by using a current shunt respectively.

In the calibration of correlated colour temperature, the spectral power distribution of the UUT light source and the CIE 1931 standard observer colour-matching functions (x, y, z) are used to calculate the (X, Y, Z) tristimulus values by numerical summation of the wavelength range from 380 nm to 780 nm in every 5 nm interval. The chromaticity coordinate of the UUT light source is then transformed to the CIE 1960 (u, v) diagram and is determined by using a cascade expanse minimum searching method to locate the nearest point to the blackbody locus.

3. Results

The developed calibration range for total luminous flux is from 20 lm to 10,000 lm, with the best measurement uncertainty of 2.2%. The calibration range of spectral radiant flux is from 365 nm to 850 nm for 10 μW/nm to 200 mW/nm, with the best measurement uncertainty from 2.3 % to 3.9 %. The calibration range for correlated colour temperature is from 2700 K to 3100 K, with the best measurement uncertainty from 26 K to 30 K.

The measurement uncertainty components are extensively evaluated. The measurement model was validated by GUM framework in accordance with the JCGM 100:2008 “Evaluation of measurement data – “Guide to the expression of uncertainty in measurement” and JCGM 101:2008 “Supplement 1 – Propagation of distributions using a Monte Carlo method”.

4. Conclusions

The calibration system of total luminous flux, spectral radiant flux and correlated colour temperature for LED lamps with AC power supply and tungsten standard lamps with AC/DC power supply using integrating sphere is setup at the SCL. The calibration service can support the demands in LED lamps and standard lamps testing from the testing and certification industry in Hong Kong.

PO15

WAVELENGTH CALIBRATION OF A SPHERE-SPECTROMETER MEASUREMENT CONFIGURATION

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Abstract

1. Motivation, specific objective

The photometry and radiometry's LED measurement facility sphere-spectrometer measurement setup for total flux measurements was recalibrated to achieve lower claimed uncertainties. The reason for unnecessarily high uncertainties was because the manufacturer calibrated the system previously as a result the traceability chain was lengthy.

2. Methods

The wavelength calibration was performed using a partial flux measurement configuration with the integrating sphere – array spectrometer system and pencil style wavelength sources. The calibration was performed on an optical rail to enable easy moving of lamps for better signal. Three calibration lamps were used, namely mercury, xenon and krypton.

3. Results

The krypton PENCIL lamp could not be used as its peaks were too close to one another in the wavelength region of interest and as a result we only used the mercury lamp and xenon for UV, Vis and NIR lines (250 nm to 1 100 nm). Measurements before the calibration showed a maximum difference of 0,2 nm in wavelength and those after the wavelength calibration show a difference of less than 0,1 nm. Verification of results was done using a HeNe laser.

4. Conclusions and future work

The wavelength calibration was a successful exercise resulting in a 50 % reduction in wavelength inaccuracy. We are continuing with the next stage of the sphere-spectrometer calibration that is performing a spectral sensitivity calibration (traceable to our spectral irradiance standards) and ultimately performing an absolute calibration using our standard LEDs. This exercise of performing an full inhouse calibration is aimed at reducing the traceability chain of our measurement set-up which should also result in reduced uncertainty contributors and a better understanding of our system as it will be well characterised.

PO16

WHITE LIGHT LED SPECTRAL OPTIMIZATION IN UNDERWATER ILLUMINATION

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1. Motivation

Multiple of oceanic creatures live with natural light in the shallow sea area, many reports point out that the spectral energy of natural light varies with the depth of transmission in seawater, and the short wavelength of light can pass a longer distance than the long wavelength. The current applications of underwater lighting such as photography, archeology, military, entertainment and so on, hence they will have the problem of colour deviation when taking the photos, which is due to the absorption coefficient of seawater. However, for improving the absorption, Zhang Fa-Quan, et al. has tried to enhance the overall intensity of lighting and find the strongest output for monitoring system. But they didn't consider about the absorption of seawater on different wavelength characteristics, it still causes too much unnecessary lighting energy. Therefore, considering the absorption coefficient and the influence of the particles in seawater, a real seawater model will be established in the optical simulation in this study, and the spectral absorption of transmitting through seawater will be described below.

2. Method

According to the different season, area, depth, parameters of seawater are extremely complex and variable with different conditions. In order to simplify the conditions, all the parameters which we imported in the seawater model were dominated by common or average. During the simulation, refractive index and absorption coefficient equation that provided from Robert Foster are utilized to establish the seawater model. The temperature and salt concentration parameters were also considered in the equation. The correlated parameters of seawater which researched from Marcel Babin et al. used by the study.

According to the attenuation of different wavelength light in references, we used the visibility equation which proposed by Otto Klemm et al. to calculate the particle concentration. It was 3.11g/m3 at a visibility of 9m. In order to observe the actual degree of absorption of real light more clearly, an Equal-Energy White Light (EEWL) source spectrum for simulating the seawater absorption at different wavelengths, were proposed to calculate the transmittance of seawater. Furthermore, the spectral attenuation of white LED at 6000K of CCT can be also easily calculated by the seawater transmittance.

3. Results

The EEWL spectral attenuation toward the normal direction in the seawater, could be simulated by the seawater model and recorded the spectrum changes from the distance was 1m to 10m, respectively. Hence in the lateral direction, the scattered intensity of EEWL, where the recorded distance was 1m to 5m. After analysing the spectral attenuation of EEWL, the spectral transmittance with different depth of seawater could be deduced. And as in the attenuation result of above, the spectrum of a white LED that decayed from the distance 1m to 10m in the normal direction and scattered from the distance 1m to 5m in lateral direction respectively.

The simulation results above showed the highly positive relationship of spectral energy decay, seawater extinction coefficient and scattering. And the spectral energy dacayed of a 6000K white LED is obviously under seawater illumination.

4. Summary

In this paper, we figure out that the illumination spectrum will decrease with transmitting through seawater. The reason is caused by the extinction coefficient and the Mie scattering. With the simulation, the results can quickly let us realize the variation of a common white LED light source passing in the seawater. Therefore, to prevent the colour missing when taking any photos or filming the vision underwater, colour compensation for reducing the true colour of underwater illumination is necessary in the future.

PO17

COLOUR DEVIATION SENSING AND COMPENSATION METHOD FOR MULTI-SPECTRAL LED LIGHTING SYSTEM

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Abstract

LED intelligent lighting could create a suitable lighting environment by dimming for users in different occasions. However, under the long-term current driven, the effects of electricity and heat from LED Lighting would reduce optical power output and lead to inconsistent light source decay, which results in colour difference. In this study, utilizing low-cost RGB colour sensor as the device to measure light source output and perceive colour. After calibrated common mixed colour temperature on black body locus, the sensor could get average $\Delta u'v'$ of 0.0015 and average illuminance error of 9.45 lux under various illuminance within the range of 2000K-7000K to detect differences of colour source output. As the outcome of light source is beyond expectation, the system can adjust automatically and keep producing light source output effectively by compensating light source via closed-loop control. In order to eliminate the limitations caused by the response spectrum with the ambient light, we propose two different methods for supplementing light through collecting the light source with different lighting conditions, thereby generating decision tree, and results show the errors of tristimulus indicate that maximum errors are respectively 0.92% and 4.02%.

1. Motivation

In recent years, with the development of solid-state lighting technology, the application of intelligent lighting has been gradually attention. In the past, the points of traditional lighting often focused on the performance of light efficiency and colour rendering, but now, intelligent LED lighting products can be connected through the sensing device, according to the needs of users or the environment, automatically adjust the light colour, the lighting system has become more intelligent. However, the colourful performance and dimmable design of LED will be affected by the high heat generated with long operating time, resulting in the drifting of light colour and instability of brightness. In order to solve this problem, we use low-cost RGB colour sensor to import the energy ratio of various colours in the colour sensor to the appropriate colour correction model, minimizing the brightness and colour perception errors of LED, and through the feedback control system to accurately compensate for the situation of light decay.

2. Methods

The experiment used LED lighting source mixed by the tristimulus value of the linear combination on red, green, blue and white light, through the pseudoinverse matrix to get the exact solution for colour light intensity control and achieve the target tristimulus value. According to the colour temperature from 2000K to 7000K on black body radiation locus to correct. Measure the three stimulus values of different light on 800Lux, and use the linear regression method to find the matrix corresponding to the sum of the least squares errors.

Through the relationship between RGB channels, the light sources were classified and a decision tree was set up to judge the ambient light source. The corresponding correction matrix was obtained by linear regression for various light sources, it could increase the accuracy of converting RGB to XYZ coordinate space. After the classification and correction of the ambient light by the colour sensor, according to the principle of additive colour mixture, two compensation modes were provided by LED lamps in different lighting environments: (a) Compensation with external source colour temperature, (b) Compensation with target colour temperature setting. By setting the target illuminance value, the external colour sensor firstly determined the external ambient light source, and then calculated the illuminance by two compensation modes.

3. Summary

By the integration of various components to form a smart lighting system, the light source was set to achieve the average Δu'v '= 0.001 and the average ΔY = 0.70 lux after considering the resolution of the PWM control. After confirming that the light source could output accurately, the output of the light source was set with the chromaticity coordinate of 2000K-7000K on the black body radiation locus, and calibrating the colour sensor. In the case of a colour sensor that satisfied the high contrast output of the light source, there was only an error of average Δu'v '= 0.0015 and average ΔY = 9.45 lux as compared with the colour sensing of the spectrometer. With the calibrated colour sensor, the system could judge by the feedback signal of colour sensor and compensate for each light source by the control method of the closed circuit. From the results of the three colour temperature(3000K,5000K and 6500K) in 800Lux, the average illumination error were 2.2lux, 5.6lux and 5.3lux, and the colour temperature error were only 5.9K, 12.2K and 11.9K. For the two different compensating modes by the influence of ambient light source, the errors of tristimulus value showed that the maximum error of the first mode was 0.92%, and the maximum error of the other mode was only 4.02 %.

PO18

IMPROVEMENT OF THE COLOURFUL UNIFORMITY BY THREE DIFFERENT MEDIUMS OF THE PACKAGING LENS IN THE WHITE LIGHT LED

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Abstract

1. Motivation

Light-emitting diodes (LEDs) has been developed rapidly in recent years. Hence, LED also has been widely utilized in daily life, such as indoor lighting, outdoor lighting, special lighting, monitor and backlight, etc. With the development of LED, the requirements of good performances in high light luminous efficiency and high quality of light distribution are both paid more attention.

Generally, a transparent packaging lens is assembled to protect the chip in the white light LED (WLLED) and causes the specific spatial light distribution. In addition, the phosphor layer coated on the chip is often used in exciting the white light in the WLLED. However, the non-optimized phosphor layer coated on the chip and the colourful dispersion that the white light is split into many different wavelength beams at the interface in the packaging lens both cause the poor colourful quality of the light pattern. The former had been recently studied and solved by optimizing the shape or the recipe of the phosphor coating, however, the latter still cause the colourful halo on the edge of the light pattern even the phosphor coating is optimized. In commercial, although the colourful halo due to colourful dispersion often could be improved by roughing the surface on the packaging lens, the poor performances in collimating light and the reproducibility of the rough surface still is inconvenience for using in lighting applications. Hence, in this study, an axisymmetric and cylindrical packaging lens composed by three transparent materials is proposed to compensate the colourful dispersion. The shapes of the three materials have been calculated to reduce the colourful halo effect at the edge of the light pattern, and the simulation results are analysed in this study.

2. Methods

In order to compensate the colourful dispersion of the packaging lens, an axisymmetric and cylindrical packaging lens which is constituted by three different materials is proposed. Moreover, except the bottom and top surfaces are the planes, the shapes of other interfaces inside the packaging lens are calculated to reduce the colourful dispersion by Snell's law. The lower interface is provided to split the white light emerged from the phosphor layer coated on the chip into the multiple monochromatic lights, and the higher interface is utilized to refracts the multiple monochromatic lights and re-converges to a same focal point on the top surface. Finally, the multiple monochromatic lights on the top surface are all refracted to the same direction. In simulations, the shape of the packaging lens whose radius and the height are respectively 1.75mm and 2.6mm, is cylindrical. The refractive indices of the lights with all wavelengths of the three different mediums are considered in calculations. A square lambertian emitting surface whose size is 1mm*1mm is used as the phosphor layer coated on the chip and assembled at the bottom of the packaging lens. The light paths inside the packaging lens is calculated by ASAP optical simulation software. Finally, the colourful dispersion can be analysed and evaluated by the dispersion extent in angular value which is obtained by comparing the intensity distribution of the blue (480nm) and the red (632.8nm) light at different normalized intensity.

3. Results

According the simulation results, except that the normalized intensity is 0.4 and 0.7, the dispersion extent in angular value for other normalized intensity are obvious reduced. Especially for the normalized intensity is zero, that corresponds to the edge of the light pattern, the dispersion extent in angular value even can decrease from one degree to zero degree. Hence, the result represents that the packaging lens composed by three different transparent materials can effective improve the colourful quality in spatial distribution at the edge of light pattern.

4. Conclusions

In this study, an axisymmetric and cylindrical packaging lens composed by three transparent materials is proposed. The bottom and the top surfaces of the packaging lens are set as the planes. The shapes of other interfaces in the packaging lens are designed to reduce the colourful dispersion. In order to comprehend the order of the colourful dispersion at the edge of light pattern, the intensity distribution of the blue light is compared to that of the red light, and the dispersion extent in angular value at specific normalized intensity are analysed. According to the simulation results, the colourful dispersion can be obvious reduced by designing the shapes of the interface among the materials in the packaging lens. Especially for the normalized intensity is zero, that corresponds to the edge of the light pattern, the dispersion extent in angular value can even be completely eliminated. The result represents that the colourful dispersion at the edge of the light pattern is induced by single medium packaging lens, however, can be significant reduced by designing the shapes of the interfaces inside the packaging lens which includes three different mediums.

PO19

VISUAL EVALUATION OF 3D COLOUR VOLUME

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Abstract

1. Motivation, specific objective

The colour gamut volume is colour reproduction capability of a display in a three dimensional colour space. The ICDM (Information Display Measurements Standard) introduced and recommended colour gamut volume based on using CIELAB to measure the 3D colour gamut volume. CIELAB is simple and effective in calculating the colour volume with perceptually uniform space. The several studies have been studied about perceptually uniform colour space for HDR displays. They show that CIELAB is not suitable for HDR displays. To calculate the L*a*b* of sample colour the reference white is set to the display max luminance. In recent year, many displays are able to reach a max luminance of up to 1000 cd/m^2. In this case, CIELAB does not reflect the luminance difference. Therefore, it is necessary to study other uniform colour spaces that can replace CIELAB.

CIECAM02 is colour appearance model based on various experimental result in human colour vision. CIECAM02 can be used to predict the relative colour appearance attributes and the absolute colour appearance attributes. The absolute colour appearance attributes, brightness (Q), colourfulness (M) and hue (h) could be able to reflect the luminance difference. This absolute colour space can be denoted by Qa_Mb_M. Dolby has suggested a colour space IC_TC_P as a HDR encoding colour space. In this space, sample colour is normalized with max luminance of 10,000 cd/m^2. In this study, the colour gamut volume of a display is visually evaluated to find out a better colour space than CIELAB for colour volume calculation.

2. Methods

Psychophysical experiment was conducted to investigate the performance of uniform colour spaces in predicting perceptual colour gamut volume. Four test images were selected and simulated on 27-inch LCD monitor. These test images covered colourful image, bright image, night image and colour pattern. All the test images were rendered by adjusting colour gamut (100% sRGB and 95% sRGB), white luminance (100% sRGB and 95% sRGB), and black luminance (0.37, 1 and 3 cd/m^2). For each test image, 18 sets of experimental images (= 2 colour gamut size x 3 white luminance x 3 black luminance) were prepared.

Twenty university students (10 females and 10 males) with normal colour vision participated the experiment. Before starting the experiment, the subjects had a training session to fully understand the concept of colour volume. To represent the colour volume of image, the term of ‘rich’ (‘pungbuhan’ in Korean) was used. After that, they sat in front of the LCD monitor in dark room and adapted to the grey (40% grey level of the max luminance of the monitor) screen for about three minutes. When the subjects were fully adapted, a pair of test images was presented and they judged which image looks richer in colour using pair-comparison method. Each pair were randomly chosen form combinations of 18 rendered images. The number of the pair was 153 (= 18 x (18-2)/2) for each test image, therefore, the total number of observations was 12,240 (= 153 pairs x 4 images x 20 subjects).

3. Results

Experimental results show that the perceived colour volume is affected by all three factors. Especially, the difference according to the colour gamut size was the largest. The perceived colour volumes were also affected by changes in white luminance.

For each simulated images, the colour volume was calculated using L*a*b* (CIELAB), Qa_Mb_M (CIECAM02: brightness Q, colourfulness M) and IC_TC_P. The calculated colour volume was compared with the perceived colour volume result. Experimental results show that CIELAB calculates the colour gamut size change well, but it does not predict the change with luminance. On the other hand, Qa_Mb_M

and IC_TC_P show good performance in both colour gamut and luminance variation. The performance of Qa_Mb_M data shows a higher correlation coefficient, $R^2 = 0.973$, than for the IC_TC_P data, $R^2 =0.958$.

4. Conclusions

The colour volume was visually evaluated as a term of rich in colour. This concept of psychophysical experiment works well. Current colour appearance model, CIECAM02 is suggested for colour volume calculation. This model shows better performance compared with visually evaluated colour volume data. Absolute colour appearance attribute Qa_Mb_M of CIECAM02 should be used to evaluate the colour volume. Moreover, using the existing CIE colour space will be more acceptable for the display industry. This experiment has limitations using the SDR display. Further study on HDR display conditions will be necessary.

PO20

IMPROVED CIECAM02 MODEL TO PREDICT HUMAN BRIGHTNESS PERCEPTION UNDER HIGH SURROUND LUMINANCE LEVELS

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Abstract

The purpose of this study was to evaluate lighting quality of LED light fixture based on human visual perception. In this paper, we first present statistical analysis results of the perceived brightness and visual comfort under different LED stimuli and surrounding lighting conditions. Thereafter, an evaluation model is established and the rendered image is proposed to represent the information about absolute visual brightness for LED light fixture.

1. Motivation

With the popularity of LED light fixture in general lighting application, investigation of the visual perception of LED lights in a lit room under different surrounding luminance level is an important practical consideration, especially when LED light fixture has annoying hotspot problem and glare effect. In addition, following on the product diversification of LED light fixtures, it become more complex in terms of the change and influences of visual perception and sensation, as well as even direct affect the response of human psychology.

To prevent these problems, it is necessary to develop an analysis platform for quantitative evaluation of quality of LED light fixture. Based on this platform, ultimately, we hope to provide LED users with energy saving, visual comfort and novel visual experience.

2. Method

In this study, the relationships between the objective luminance and two metrics: subjective perceived brightness rating scale (PBRS) [4] as well as visual comfort rating scale (VCRS) [5] for existing LED light fixtures were collected utilizing physical and psycho- physical measurements. The equipment used in this physical measurement is TOPCON imaging luminance meter with wide field of view (up to 1/12.5) and high dynamic range (0.005 to 100,000 cd/m2). The luminance of light fixture and background can be measured simultaneously. Thus, each of the luminance contrast can also be calculated from measurement data.

3. Result

According to the purpose of this research, we establish an evaluation model with modify CIECAM02 colour appearance model to obtain more accurate brightness prediction for the LED light fixture. it was observed that the new model could more accurately predict our visual results than the original one. In order to figure out the difference between two models, these data were further divided into two groups: SR>1 (over-bright to bright surrounding luminance level) and SR≤1 (average to dark surrounding luminance level). The SR is surround ratio defined as ratio of luminance of surround and maximum luminance of stimuli. When SR≤1, these estimation results both appear almost close to predicted brightness of each model. However, when SR>1, the brightness predicted by original CIECAM02 model was not correlated to our psychophysical data well. It means that our new model predicts the perceived brightness very well under various surrounding conditions from dark to over-bright.

Based on the new brightness-matching model, a rendered image can further be processed to predict the perceived brightness for a LED light fixture. Meanwhile the information of visual comfort also can be obtained through the relationship between PBRS and VCRS. Figure 6 shows the example of image process converting the measured luminance image into perceived brightness image under different ambient lighting level. Also, it provides predictive information about PBRS and VCRS.

4. Summary

In summary, based on imaging luminance measurement and psychophysical experiment, the CIECAM02 brightness equation has been modified for PBRS and VCRS prediction on LED light fixture

under various lighting conditions. For further applications, the estimation and prediction of the LED lighting environment may be necessary, in which case more human or environmental factors should be considered in a practical lit room.

PO21

A STUDY ON IDENTIFICATION OF OBJECTS BY INTRODUCING COLOUR CONTRAST BASED ON METAMERISM PHENOMENON

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Abstract

1. Motivation, specific objective

The metamerism phenomenon, in simple terms, is the same colour with different spectral compositions. At present, the study of the metamerism phenomenon is mainly to avoid or weaken this effect, namely to reduce the colour difference or colour contrast between objects. Relative studies have shown that increasing the colour contrast between objects helps to improve the speed of identification, but this result has not been well applied. The identifiability of low saturation objects weren't good enough under low illumination conditions, this work will explore the differences between a group of metameric and normal light sources in colour display effect of chromatic objects, such difference may also affect the observer in identification speed.

2. Methods

In this experiment, two colour samples were used to replace the objects illuminated by a light source A and a light source B, respectively. The A and B are the light sources of metamerism. The two colour samples made up three groups, the first set of colour sample simulated the actual colour rendering effect of the object illuminated by the light source A, the second set of colour sample simulated the actual colour rendering effect of the object illuminated by the light source B, and the third colour sample's upper half illuminated by the light source A, the lower half illuminated by the light source B. The colour samples were controlled by the programs set up in virtual reality devices, then the subjects put on the equipment to react to the colour samples in the field of view. At the same time, the subjects' responses would be recorded and analysed.

There were two factors in the light source A and B: colour temperature and the type of monochromatic light sources. There were two levels of colour temperature factor: 4300K and 6000K. The factor of synthesizing light source have two levels of RGB and RYC. Among them, 4300K and 6000K were typical colour values of automobile lamps, the illuminated objects were typical colour samples. A total of 50 subjects, including 25 men and 25 women, aged between 18 and 30, had corrected visual acuity of more than 0.8, people that visually impaired were excluded by examination.

3. Results

Results show that subjects responded faster to the third set of colour samples, those colour samples can be distinguished clearly from further afield, too. That is to say, subjects had faster recognition speed and shorter reaction time for a group of metamerism light sources.

4. Conclusions

The application of the metamerism phenomenon is helpful to improve the colour contrast of the illuminated objects, thus helping the observer to identify quickly. In addition, the colour objects illuminated by a group of metamerism light sources were more likely to attract the attention of the observer under the same conditions.

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PO22

SPARKLE ESTIMATION OF METALLIC SAMPLES USING A LOW-COST SYSTEM

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1. Motivation

How to quantify material appearance becomes more and more important as new materials and new finishing methods are available for industrial designers to choose for enhancing visual appearance of a product. However, some appearance attributes such as Sparkle and Graininess are not easy to be measured and quantified.

Previous studies used multi-angle colour spectrophotometers (such as BYK-mac) to describe the material appearance. But they are expensive and its sparkle related indices are not clearly defined by the venders and researchers. To reduce the cost of the appearance measurement and to better understand the properties of the indices, the proposed study uses a low-cost Merck ‘‘Goino Vision Box’’ with a camera to obtain multi-angle image appearance of metallic samples. The results will be analysed and to predict the reading of the BYK-mac. On the other hand, a psychophysical experiment was conducted to correlate the sparkle related visual appearance to see if the visual data can be predicted accurately by the low-cost system.

2. Methods

Goino Vision Box is a multi-angle (11 angles) vision box. We put a fiber-optic source to any of the angle to illuminate the material sample and use a camera with multiple exposures to get a High Dynamic Range (HDR) image for estimating the sparkle luminance of the sample.

The Goino Vision Box was characterized by 0 lux calibration and using a perfect diffuser and ColorChecker to quantify the colours measured by the camera. To compare the reading of BYK-mac, appearance parameters such as graininess, Sg, Si and Sa with sparkle angles (15˚, 45˚, 75˚) were measured. 32 metallic samples were tested. They have four different grade of sparkle.

In terms of the Goino Vision Box, two light conditions (uniform light and direction light) were tested. the illumination angle was the same as the BYK-mac. HDR images of the samples are obtained by combining images with different exposure time. The camera was placed in the direction of surface normal.

Observers also performed visual evaluations on those samples with similar viewing and lighting geometry. A total of 12 observers observed the samples with different levels of sparkle from three observation angles (15°, 45°, and 75°) under the two lighting conditions.

3. Results

After experiment, we analysed the image for two parameters (Sg, Si, Sa) to found a formula. Then, we compare the readings with BYK-Sparkle (Sg, Si, Sa). The results show highly positive correlation coefficients in sparkle, and the psychophysical experiment that was accessing appearance also had the highly positive correlation coefficients in sparkle.

4. Conclusions

In this study, metallic samples were measured by both the expensive BYK-mac and the proposed low-cost system for sparkle estimation, and the sample also measured psychophysically for comparison. The results show that the proposed low-cost system can be used to estimate the psychophysical data and high-end equipment with HDR image analysis with polynomial fitting.

PO23

PROPOSAL FOR THE NEW FORMULA OF COLOUR RENDERING PROPERTIES TAKING ACCOUNT OF ILLUMINANCE-EFFECTS AND GAMUT-SHAPE-EFFECTS

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Abstract

1. Motivation, specific objective

Ra is not sufficient when colour rendering properties are evaluated at low illuminance because brightness and colourfulness reduced as the illuminance decreases (Hunt effect) even in case of high *Ra* lamps.

In our past studies, we clarified that the subjective colour feelings were influenced by illuminance as well as the spectral power distributions (SPDs) of light sources, and the subjective impression depended on the hue of colour samples, especially on whether the sample contained red. Based on these results, we defined “Colour Quality Index” called Gx to evaluate the new colour rendering properties expressing illuminance-effects and gamut-shape-effects.

Gx is calculated by the ratio between the gamut of the test colour samples under a test light source and that of the reference light source. $Gamut_{Test(E)}$ is the gamut of the test colour samples under a test light source at E lx. $Gamut_{Reference(E)}$ is the gamut of the test colour samples under the fluorescent lamp specially designed for a museum lighting (FL-EDL: *Ra*96, 3060 K) at 700 lx. In addition, the a_Mb_M coordinates (by CIECAM02) under a test light source is calculated with the weighting coefficient Whi which is only defined at reddish and greenish colour.

The purpose of this study is to examine subjectively the importance of red when evaluate colour rendition of objects as well as the accuracy of Gx.

2. Methods

The experiments were carried out using a haploscopic viewing booth, the left was the reference side and the right was the test side in a dark room. The reference light source was the FL-EDL. The illuminance of the test light source was set at 700 lx or 10 lx on the top of the desk, and the reference side was fixed at 700 lx. The observers evaluated the colour impression of the chromatic samples of the test side compared with those of the reference side by the semantic differential method (SD method).

The first experiment used four kinds of the test lamps, the two of them were the fluorescent lamps (*Ra*96 and *Ra*55), and other two were the LED lamps (*Ra*21and *Ra*84). The colour temperature (CCT) of these lamps was approximately 3000 K. The colour samples were the two colour pairs, the mosaic colour sample (composed of 20 colours), and the picture samples. The colour samples were separated in two groups, one was the samples including red and another was those not including red.

In the second experiment, we used eight kinds of the test light sources, the four of them were the same as the first experiment and SPDs of the other four test lamps were composed by the tuneable LED lighting system with 6-chanel (red, orange, amber, green, blue-green, and blue). CCT of eight test lamps was approximately 3000 K, *Ra* was from 21 to 96, Gx at 700 lx was from 64 to 185, and Gx at 10 lx was from 26 to 65. The colour sample was the mosaic colour sample as the same as the first experiment.

3. Results

The first experiment: It was clearly shown that the subjective impression under the four test lamps were different when evaluated the sample including red. On the other hand, the subjective results were not different for the samples not including red under the test lamps.

The observer was additionally asked which colour the most influenced when you judged. In the result, the observer’s judgement for the most influenced colour was “red” regardless of illuminance and the light sources.

The second experiment: It was shown that the subjective evaluation decreased from 700 lx to 10 lx depending on illuminance and were different under the four test light sources with the same *Ra*. It was

suggested that *Ra* could not explain the subjective evaluation under the test lamps with colour quality other than colour fidelity. On the other hand, Gx showed the good correlation with the subjective evaluation under the test light sources and the both illuminance (at 700 lx: r=0.94, p<0.01 and at 10 lx: r=0.98, p<0.01).

4. Conclusions

The subjective colour impression of the colour samples under the various test lamps were influenced by illuminance, the SPD of light sources, and the hue of the colour sample. Red was the most important when evaluated colour rendition. It was suggested that the overall impression of the multi-colour scene was determined by red.

It was clearly shown that the colour quality index Gx was able to predict the subjective evaluation under various lighting condition. We propose that Gx is the new formula of colour rendering properties which can explain illuminance effects (Hunt effect) as well as the hue dependency of the colour sample.

PO24

SMART GARNISH LIGHT/DISPLAY FOR VISUAL ASSISTANCE IN AUTOMOBILE

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Abstract

1. Motivation, specific objective

A glove compartment is located in front of the passenger seat in automobile. The upper part of the glove box is generally covered by high-quality plastic finishing materials. This part is called “Garnish”. We attempt to develop “Smart Garnish” in order to replace the conventional garnish area with lights/displays. Its prospective roles are visual messenger delivering greeting and alerting remarks, interior lights from which users can select the mood option as they prefer etc. The present study introduces the best candidate scenes offering the user-expected interior mood selections and the warning message based on subjective experimental results using automobile simulator.

2. Methods

In the preliminary experiment, 33 stimuli presented on a 24-inch LCD monitor are investigated in order to narrow down hue and luminance values and types of pattern for developing smart garnish. The 30 observers estimated these 33 stimuli using 27 adjective words to determine key perceptual factors that are required by automobile users. As its results, the four key perceptual factors and their representing six adjective words are revealed: (1) Active factor (‘active’ and ‘distinctive’), (2) Brilliant factor (‘brilliant’), (3) Refined factor (‘luxurious’ and ‘simple’), and (4) Warning factor (‘warning’).

To develop a prototype of smart garnish, the preliminary experimental conditions are downsized and the 2nd experiment is conducted using an automobile simulator. The eight-hue (red 19˚, orange 37˚, yellow 89˚, green 139˚, cyan 174˚, greenish-blue 249˚, blue 291˚, purplish-blue 327˚in CIELAB) and three luminance-level (0.25, 0.45, 0.65 cd/m^2) colours and ten patterns are applied. The fused picture of colour and pattern is displayed on LCD display having 1360 (H) x 768 (V) resolution that is designed particularly for smart garnish. For blue colour, lower luminance range (0.15, 0.25, 0.45 cd/m^2) is shown to observers considering that mesopic and scotopic sensitivity shifts to short wavelength region than photopic vision. For ‘Warning’ visual environment, two hue values of red and orange, and four luminance values of 0.25, 0.45, 0.65 and 0.85 cd/m^2 are chosen. All the experiments are carried out in a night driving situation, except the ‘Warning’ case where night and twilight surrounds are simulated. A total of 30 observers assessed six adjective words using a 5-point qualitative category scale and then their preferred combination sets of colours (hue and luminance) and patterns are discovered for the smart garnish offering four interior-atmosphere options from (1) Active, (2) Brilliant, (3) Refined, to (4) Warning. Are also asked three other questions of brightness, visual comfort, and preference.

3. Results

The aim of the present experiment is to find out the most-preferred scene types to be reproduced on smart garnish so that automobile users perceive Active, Brilliant, Refined and Warning visual mood respectively. Once the emergency situation is detected by sensors, the warning visual option can be operated from smart garnish. For actual applications, the appropriate luminance value but enough warning signal will be important in securing driver safety at night. Therefore, determination of appropriate luminance values is necessary for observers to recognize their expected mood at night or to notice warning situation at night or twilight.

Amongst three input attributes of pattern, hue, and luminance, the statistically significant ones are found in the perception of each of (1) – (4) factors. The colour and pattern are determined that observers perceive each of (1) – (4) visual atmospheres clearly, suitable brightness without discomfort, and the most preferred. For Active interior mood selection, the pattern and luminance are found to be significant attributes ($p<0.05$). The greenish-blue hue, 0.65 cd/m^2, and two types of pattern (4 and 7) offer the most ‘active’ mood whereas the red hue, 0.65 cd/m^2, and the pattern of 7 is viewed to have the most ‘distinctive’ mood. For Brilliant mood selection, the pattern and luminance are again found to be critical input components ($p<0.05$). The observers recognize the most brilliant environment from two different

hue values of orange and purplish-blue, 0.65 cd/m^2, and the pattern of 7. For Refined interior mood, the pattern and luminance, and all three input attributes are important in the perception of ‘luxurious’ and ‘simple’ mood respectively. The combination of greenish-blue hue, 0.45 cd/m^2, and the pattern of 8 appears to be the most luxurious whereas that of cyan hue, 0.25 cd/m^2, and the pattern of 1 is observed to be the simplest. For delivering Warning visual message, both orange and red hue, and two types of 9 and 10 patterns are effective to call driver’s attention. The suitable luminance level for producing alerting meaning without discomfort glare is different according to the simulated surrounds of night and twilight. The darkest level of 0.25 cd/m^2 is sufficient at night but slightly brighter range of 0.45 – 0.65 cd/m^2 is required at twilight.

The effect of cautious visual message can be enhanced by adding dynamic flash function. The subjective experimental results show 0.25 seconds of flashing duration is enough for users to grasp emergency situation but acceptable discomfort. For showing welcoming message for users entering a car, the appropriate slope in increasing brightness is found about 0 to 0.5 cd/m^2 for 2.5 seconds. At this increasing speed, observers are satisfied without discomfort.

4. Conclusions

The final goal of this study is to develop smart garnish light/display for replacing the upper part of the glove compartment located in front of the passenger seat or the lower part of the window in the door. The role of the smart garnish is to act visual assistance linked with various vehicle sensors, to provide interior light mood selection, and to supplement driver security and entertainment. The smart garnish can be used for light or display by automobile user demands. This study presents the experimental results applicable the interior light mood functions, visual assistance tools for safety, and delivering messages in smart garnish light/display.

PO25

OPTIMIZING IMAGE APPEARANCE OF AN OPTICAL SEE-THROUGH HMD FOR MIXED-REALITY APPLICATIONS

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1. Introduction

Mixed reality (MR) has been discussed for several decades. The concept of augmented reality is mixing virtual experiences with real world. Recently, it becomes widely known and popular due to the rapid development of devices such as optical see-through head-mounted displays (OST-HMDs). By wearing OST-HMD, users could experience virtual and real world at the same time.

However, there are some problems to be considered while using OST-HMDs. Firstly, when the white point luminance of OST-HMD is too low, the virtual image will be transparent. Secondly, when the luminance of background (real scene) is too high, the virtual image will be unclear for users to see. As a result, the aim of this study is trying to deal with these problems and make MR experience as immersive as possible.

There was a research about optimal parameters of MR image rendering model in our previous study. We proposed five parameters – luminance of the virtual image, luminance of inverse mask, luminance of ambient mask, contrast and saturation of the virtual image. These parameters were evaluated by psychophysical experiment. The scene behind the HMD was simulated by a LCD. However, the dynamic range of a real scene is normally higher than the LCD and the luminance distribution is not uniform, it's necessary to check if a normal low dynamic range (LDR) video camera can estimate the luminance distribution of the scene and compensate the MR image properly. In order to analyse the non-uniform luminance of real scene, we are going to capture that with a video camera. Due to the dynamic range of the camera is not as high as real world, the inverse tone mapping is needed to predict the highest luminance in the scene. As a result, as long as we could get the highest luminance of the background, it would be helpful to decide the image processing parameters of virtual image to enhance the visibility of virtual objects in high luminance conditions.

2. Methods

To evaluate the high luminance part of background, it's necessary to map the captured LDR image to its HDR version. According to the tone curve of LDR image, the saturate parts which are outside the dynamic range is needed to be recovered. In this study, we predict the peak of high luminance value by the average luminance surrounding the saturate areas of the capture image. If the average of luminance is lower, the peak of the curve would be higher relatively, and vice versa. Once the highest value of the test images is predicted, it's convenient to carry out a psychophysical experiment to get the relation between high luminance values and the parameters of virtual objects.

Based on the psychophysical experiment of our previous research, there are also five parameters here to be evaluated. First, the luminance of virtual image is necessary to cover the background preliminarily. However, if the virtual object is so transparent that couldn't cover the background well, it would work if we add an inverse mask with certain value of luminance on it. In addition, the benefit of adding a little luminance of ambient mask would make the mixed scene looks more uniform and natural. Finally, the contrast and saturation of mixed scene will decrease significantly after overlaying the displayed virtual objects with the scene. As a result, the contrast and saturation enhancement parameters are needed to improve the fidelity of the mixed scene.

After estimating the HDR scene, we perform psychophysical experiment to optimize the MR rendering parameters for the HDR environment.

3. Results

Generally, the luminance of virtual object will increase as the luminance of real scene increases. However, it's not easy to cover the highest luminance region of the background. As a result, the ambient

mask is much more necessary, compared with our previous study. Also, the parameters of contrast and saturation of virtual object is much higher.

4. Conclusions

In view of the fact that there are many high luminance parts in real scene, we make an image rendering procedure that take the highlight condition into account. In this study, we derive an optimal MR image rendering model to improve the fidelity of the virtual objects.

PO26

DUAL-BAND VIDEO-BASED MEASUREMENT FOR NONCONTACT PULSE RATE ESTIMATION IN INFRARED

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Abstract

1. Motivation, specific objective

Recently, noncontact methods have been proposed for detecting physiological information using a video camera. The pulse rate is one of the essential vital signs that are used to reflect the physiological health of humans, and it plays an important role in health care monitoring. Pulse rate monitoring can be used to monitor fatigue, concentration at work and drowsiness when driving, and can also help to prevent sudden infant death syndrome, heart attacks or paroxysmal diseases in patients located both at home and in the hospital.

In this paper, we propose a noncontact pulse rate estimation method that is robust to fluctuations in illumination based on the use of dual-band infrared video signals. Verkruysse et al. determined that the time-series variations of the intensity of pixel values in the region of interest (ROI) showed strong correlations with physiological information such as the pulse rate or the respiratory rate when they were recorded using an RGB camera. In particular, the green channel showed the strongest features for extraction of physiological information. Kumar et al. developed a noncontact method for extraction of pulse waves and pulse rates that was robust to motion artifacts when using the green channel in a standard RGB camera. After the patients's face was tracked and fitted, the facial region was decomposed into several ROIs to extract the pulse wave from each ROI. A pulse wave with a high signal-to-noise ratio (SNR) was generated by integrating pulse waves extracted from whole ROIs with considering pulse rate ratio. McDuff et al. developed a noncontact method to estimate both the pulse wave and the patient's physiological status through a heart rate variability spectrogram (HRVS) measured using a five-band sensor (16 bits/channel) with red, green, blue, cyan, and orange (RGBCO) bands. Poh et al. developed a noncontact pulse wave monitoring method based on application of an independent component analysis to the variation of the spatially averaged pixel in the ROI in RGB video recordings made under ambient light conditions. They intended to use the RGB video recordings to estimate the patient's physiological status based on an HRVS produced by analysing the R to R wave (RR) intervals in the frequency domain. Kurita et al. proposed a noncontact estimation method of pulse rate and physiological status based on extracting of hemoglobin information from RGB video recordings made under ambient light conditions. They also intended to use the three-colour channel signals to estimate the patient's physiological status via an HRVS in a visible light environment. In the above applications, it may be necessary to measure the face at night without visible lighting while the subjects are driving or sleeping. Conventional RGB video recordings therefore cannot be used in such situations. Garbey et al. proposed a method to measure pulse waves from single-band thermal video recordings of the subject's neck based on spatial averaging of the variations in the pixel values in the ROI. They performed experiments using a single-band mid-wavelength infrared video camera. However, their thermal imaging system required a specific camera and use of a differential blackbody as a calibration device. Hamedani et al. developed a method for pulse rate extraction using a 16-bit single-band thermal video camera. The pulse rate was obtained by magnifying the recorded thermal video using video magnification and spatial-temporal filtering techniques. Zeng et al. proposed a method to estimate both the pulse wave and the pulse rate based on spatial averaging of the pixel values in the ROI of single-band infrared video recordings and then detection of the maximum power spectrum in the frequency domain. While the methods proposed by both Garbey and Zeng can detect the pulse rate without use of visible lighting, they cannot be used in situations where the illumination fluctuates as it does in real environments, such as the illumination when driving. Because the pixel values were affected by fluctuations in the illumination, the measurement results can thus also be affected. To solve this problem

and enable implementation of these methods in the proposed applications, removal of the fluctuations from illumination is therefore essential.

2. Methods

The dual-band infrared video signals can be separated into hemoglobin and shading components by application of a separation matrix in logarithmic space. When the shading component has been separated, the extracted hemoglobin information will then be robust to fluctuations in the illumination. The pixel values of the ROI are spatially averaged over all the pixels in each frame. These averaged pixel values are then used to form the raw trace signal. Finally, the pulse wave and the pulse rate are obtained from the raw trace signal via several signal processing stages, including detrending and adaptive bandpass filtering. In this work, we evaluate the absolute error rate (AER) for the pulse rate between the estimated value and the ground truth, which was obtained using an electrocardiogram.

3. Results

The AER of the pulse rate when using the dual-band infrared video signals shows higher accuracy when compared with the conventional method of Zeng et al. using the single-band infrared video. We also obtained the profile of results when comparing the estimates of the pulse rate and the ground truth with fluctuating illumination. We confirmed from these results that the pulse rate estimates were strongly affected by the fluctuations in the illumination. The results obtained using the proposed method also show that our method provides greatly improved performance when compared with that of the conventional method because the corresponding pixel values of the video recordings have been separated into the hemoglobin and shading components.

4. Conclusions

We proposed a noncontact pulse wave monitoring method that is robust to illumination fluctuations. Separated hemoglobin and shading components were obtained by determining a new basis vector in the colour vector space. Our proposed method showed greatly improved accuracy, with an improvement from 29.56% to 3.73% when compared with the results of the conventional method that used single-band infrared video. We will focus on the estimation of heart rate variability under dim light condition or full darkness as our future work.

PO28

PSYCHOLOGICAL INFLUENCE OF COLOURFUL LIGHT-EMITTING DIODE LUMINAIRE

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Abstract

1. Motivation, integrative lighting and health

Light-emitting diode (LED) lighting becomes the mainstream of lighting products. The construction of colourful LED lighting system can be based on human factor, well-being, and human health including physiological and psychological effects. Automatic change and people-oriented intelligent lighting system achieve the smart life environment. Under normal physiological conditions, the most important factors affecting the physiological clock (circadian rhythm) are the coordination of light and dark changes, movement, diet, and physiological clocks of whole cells. The response curve of circadian stimulus / photometry (CSP) is the definition of circadian action factor (CAF) which is an indicator of physiological light stimulus. However, the psychological influence of colourful LED luminaire is a complex and important issue to study the mental effect of integrative lighting.

2. Methods

The use of intelligent LED dimmable colour lighting, with a variety of adjustable lighting parameters (colour temperature, spectrum), to understand the psychological impact of uniform light environment. The experimental conditions are six different parameters of the light source, which the colour temperature are 4000K, 5000K, 6000K, and each colour temperature with two metamerisms, all colour rendering index (CRI) greater than 70, illumination maintained at 750 - 850 lux, and the non-reflective wall in uniform light environment.

In this study, semantic difference analysis (SD) was used to analyse the psychological responses caused by light stimulation. Two reverse semantic adjectives were placed at both ends of the scale and divided into five levels of adjectives options: very positive (+5), a bit positive (+3), medium (0), a bit negative (-3), very negative (-5).

Six groups of light were randomly selected at the designated uniform light room. The questionnaire was evaluated for different light conditions. The experiment process was interval between 5 minutes with open-eyes under randomly selected group of light when subject filled questionnaire evaluation and 5 minutes with open-eyes under dark room. The whole experiment was about 1 hour, and the temperature and humidity of the environment were recorded.

Ten subjects with age of 20 – 60 years were carried out in this experiment. Independent variables of 9 semantic adjectives were listed as the results section.

3. Results

The brief results were as following.

1. Melancholy / pleasant: all colour temperature are pleasant, CCT = 4000K / CRI = 87 is most pleasant.

2. Not focused / focused: all colour temperatures are focused, CCT = 5000K / CRI = 88 and CCT = 6000K / CRI = 71 most focused

3. Uncomfortable / comfortable: all colour temperature are comfortable, CCT = 4000K / CRI = 87 / CAF = 0.515 is the most comfortable.

4. Not dazzling / dazzling: CCT = 4000K / CRI = 87 is most not dazzling, CCT = 5000K / CRI = 71 is most dazzling.

5. Not tired / tired: all colour temperature are not tired.

6. Awakened / relaxed: CCT = 4000K / CRI = 87 is more relaxed, CCT = 6000K / CRI = 71 is more awakened.

7. Cool / warm: CCT = 4000K / CRI = 87 is warmer. CCT = 6000K / CRI = 86 is cooler.

8. Dark / bright: all colour temperature is bright, CCT = 6000K / CRI = 71 is more bright.

9. Modern / traditional: CCT = 4000K is more traditional.

4. Conclusions

To understand the psychological influence of colourful LED luminaire, we designed the semantic difference analysis and studied with paired T test, Pearson test, and classification tree. The results provided reference lighting parameters for mental demand of designing integrative lighting.

PO29

MAIN PROBLEMS AND SOLUTIONS FOR TEMPORARY EXHIBITION SPACE LIGHTING

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Abstract

1. Motivation, specific objective

From a city point of view, the exhibition building plays a vital role in the regional economic development and the urban construction. Lighting needs of the exhibition space has also led to the rapid development of the lighting industry. Along with the economic and social development and human progress, "people-oriented" lighting environment is coming into life. As a green energy-saving lighting, LED lighting can meet the demand of lighting of the exhibition space well. Having the characteristic of small size, low cost, high luminous efficiency, low-power consumption, fast reaction rate and long life-span, LED becomes a new generation illuminant and has a significant advantage in lighting technology. Thus, the application of LED lighting system in the exhibition space is gradually popularized because of the advantages of high efficiency, long service life, energy saving, fast modular installation, convenient transportation and so on. With the luminous flux and luminous efficiency of high-power LED continues to improve, the advantages of the application of exhibition lighting has been gradually highlighted. More common applications are LED screen, fundamental illume, stage atmosphere creating and so on.

However, due to the lack of domestic relevant specification for exhibition lighting, the neglect of design of exhibition booth lighting and "bandwagon effect "in brightness, resulting in negative effects of light pollution and other problems become more serious. This study can provide theoretical basis for setting relevant norms and standards. In addition, it is of great significance for the further development of LED light source in the exhibition space lighting.

2. Methods

In this paper, the present situation of exhibition venue lighting is investigated. The contents of the survey include: common light source statistics, lighting, illumination, illuminance uniformity. Aimed at main problems of exhibition space lighting, to give solutions from the aspect of saving energy.

3. Results

The main problems in Exhibition Space Lighting include four aspects: the serious light pollution, the enormous loss of energy, the lack of relevant standards and norms and the neglect of exhibition area lighting design. The related solutions are proposed from the following three measures: modular design, glare control and the LED light source application.

4. Conclusions

Generally speaking, in the area of temporary exhibition artificial lighting, there are still a lot of bad phenomena and problems that need to be solved urgently. The effective formulation of relevant standards also need to be attached importance to. With the development of exhibition space lighting technology, more attention should be paid to energy saving, sustainability and economy. For another, as the basic lighting in exhibition space, the application of LED is still very few at present. The use of LED is intended mainly to create artistic effects and improve the display effect, such as the use of LED soft rope light, LED screen and so on. Therefore, the application of LED light source as a green energy in temporary exhibition space lighting needs further research and further development.

PO30

MEASUREMENTS OF PHOTOSYNTHETIC PHOTON FLUX (PPF) AND FLUX DENSITY (PPFD) FOR GREENHOUSE LED IRRADIATORS

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Currently LED irradiators with emission maxima in the vicinity of 400 and 700 nm, that is near the visible region boundaries, are more and more often used in the field of greenhouse lighting. And now the effectiveness of such blue-red irradiators is quantified by photosynthetic photon flux (PPF) and flux density (PPFD) instead of the previously used lighting units. However, in measurements of PPF and PPFD there are some metrological problems, associated with the fact that photosynthetic photon units are off-system units, and there are no reference radiation sources and no international standards.

However in some countries (Russia, USA) there have already appeared national standards, legitimizing a new system of photosynthetic photon quantities. A number of measurement equipment manufacturers started the production of meters for PPFD measurements. Initially existing standard filament lamps could be used as reference light sources, whose light settings could be converted to photosynthetic photon system by a certain method.

In the Test center of VNISI there were conducted a series of measurements aimed at developing the methods of PPF and PPFD measurements and some comparative measurements of photon flux density meters of different manufacturers. A standard filament lamp SIS-40 with a known spectrum and luminous intensity was used as a standard source for obtaining the reference values of PPF and PPFD. The reference PPF and PPFD values for a given lamp were calculated according to a conversion equation.

In the report there are presented the results of the PPFD comparative measurements and the results of PPF measurements that were performed according to the method which was developed in VNISI.

PO31

PROBLEMS ASSOCIATED WITH THE APPLICATION OF CURRENT STANDARDS ON LIGHT POLLUTION AND NEED IMPROVEMENT

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Abstract

1. Motivation, specific objective

People's desire for more pleasant living conditions has grown even more in recent years in Asia. However, along with sharp increase in use of nighttime lighting equipment due to growth in economically active population and changes in people's lifestyles, the ill effects from light pollution have also increased. Many Asian countries have come to recognize light pollution as a serious social problem, and in order to resolve such problems of ecological hazard and energy waste caused by light pollution, they have been coming up with measures – devised based on international guidelines such as CIE 150:2003, IDA/IES MLO(2011), etc., while adapting to their own circumstances – and enforcing them in order to regulate light pollution.

Korea has also been managing its light pollution problem by enacting laws or adopting standards that had been developed based on information – such as recommended maximum values of lighting parameters, calculation and measurement methods – provided in CIE150, a guideline generally accepted and used internationally. However, some standards from such international guidelines are not quite applicable to urban and residential structures in Asia, not to mention significant differences in the source and magnitude of light pollution. This is mainly due to different lighting environment in Korea compared to those in European countries or the United States where such guidelines were put together. In addition, along with the advancement in LED luminaires, use of many new forms of lighting equipment employing new methods continues to rise. In consideration of LED luminaires and new technologies, now is the time when improving these current standards, for calculation and measurement methods as well as effects of light colour, etc., is absolutely necessary.

In this research, we examined installation environment and light pollution effects of street lightings in Seoul. Then, problems arising from applying light pollution prevention standards of CIE and IES were evaluated and improvement methods proposed**.**

2. Methods

Since the enactment of "Light Pollution by Artificial Lighting Prevention Act" in 2012, numerous fact-finding studies, researches, and environmental assessments had been and are being carried out on a national level in Korea. This study is based on data and information available from various sources. These sources include research results our team of researchers had obtained from various commissioned studies carried out over the years on public lightings (street lighting, security lighting, and park lighting), advertisement lightings, and decorative lightings; environmental impact assessment reports prepared by regional government offices; and records from conferences held by the Ministry of Environment, Korea's main governmental department which oversees light pollution management.

3. Results

Urban residential areas in Asian countries, including Korea, are densely populated, and the distances between lighting equipment and property lines in these places are, in most cases, very close. Problems with applying standards created for European and American cities to these Asian cities are as follows.

- According to the study on lighting environment of residential areas in Seoul, the distance between a luminaire and its bordering residence was about 2m in most places. If the back light regulation (B- rating) of MLO is applied, there are almost no instances where the distance between a luminaire and its bordering residence exceeds at least one half (0.5x) of luminaire's installation height, and therefore, only the luminaires of B0 rating would be subject to use. Moreover, the BUG rating of IES does not provide means to control light trespass due to forward light; even though it does identify the speed of forward light, it is only for the purpose of working out the G-rating. Our team of researchers, in efforts to improve

on such system, have developed the HFBS Code for luminaires, which makes it possible to choose luminaires that do not create light trespass during the luminaire selection process. This coding system is currently being used in Seoul.

- When many types of light sources are simultaneously causing trespass light due to complex and concentrated layout of urban structures (ex. public lighting + advertisement lighting), it becomes unclear as to which source is actually liable for causing light pollution.

- In situations where an area in one environmental lighting zone is affected unfavorably by another adjoining lightning zone of different level, either the criteria of lower level zone have to be satisfied or regulations must be set up to protect those suffering damages.

In calculating vertical surface illumination, CIE 150 recommends using computer software with maximum horizontal and vertical grid distances of 5m and 1m, respectively. It was discovered in our study that when CIE-recommended grid distances were applied and software used for calculation, there was as much as 32% discrepancy in maximum illumination values. For this reason, we have included the illumination calculation method in our recommendations on public lighting equipment (street, security, park lightings, etc.) Installation, a part of a research commissioned to us by the Ministry of Environment, and set grid distances at 0.2m, both horizontally and vertically.

As for the measurement of surface luminance of advertisement and decorative lightings, CIE 150 recommends using point luminance method. However, such method fails to clearly distinguish the boundary of the point (area) being measured for average value of the light source surface, and therefore tends to rely on subjective measuring by the measurer. Our investigation has shown that it is difficult to apply CIE 150 standards since, (i) there is a big margin of error for point light sources such as LEDs; ii) LED advertisements or decorations are affected by the colour; and (iii) they generally have their own light emitting parts. In addition, big deviations were noticed depending on types of measuring devices used as well as measuring location and angle. Such standard must be improved.

Korea’s Ministry of Environment recommends using surface luminance system. In order to increase the accuracy of measurements, the measuring point (location of the measurer) has to be within 45^{o} of the angle created between the measuring surface (source of light pollution) and horizontal surface (ground), and set measurement area (polygonal shape) to include points with luminance values that are at least 1/50 of the maximum luminance value measured.

4. Conclusions

In this study, we examined the problems and alternative solutions associated with international standards when applied to Korean lighting environment – unlike the European and US cities where those international guidelines were compiled, Korean cities are structured in a very complex and concentrated manner. Also proposed in this study is the need to improve light pollution assessment methods, in order to cope with increasing use of LED lighting equipment as well as with new technologies.

As LED-based lighting equipment have been introduced and now used regularly, light pollution grievances from people on flickering and coloured light have also risen. We are at a point when additional researches are absolutely necessary.

PO32

INNOVATIVE PUPIL DETECTOR EQUIPMENT

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Abstract

The pupil detector has many problems not only bulky, complex operation and inconvenient to carry, but also equipment costs too high to have one that is difficult to achieve. So that we developed the pupil detector which is low-cost, easy to carry and easy to operate. In order to quickly determine the pupil size, we developed a pupil detector that can stimulate pupil zoom by visible light and enhance the contrast of images by infrared light. Now the team can capture the pupil successfully with an external controller and calculates the actual diameter and the ratio calculation before pupil being stimulated and after. The pupil detector currently has an accuracy of 88.3%.

Motivation

Civilized diseases, cardiovascular disease occurs frequently. The emergency room is the first front in a hospital and often has to face many unexpected situations such as car accidents and accidental injuries. Medical personnel needs to determine the patient conscious. Usually, they use the optical pupil detector to test the patient's pupil size. In current health care system, handheld pupil detector was used to detect the patient's pupil size by medical personnel. Nowadays detection of the patient's pupil in two ways. The first one based on the experience of medical personnel and with a handheld pen on the pupil size picture to do recognition. It could not provide accurate quantitative value. The second way is to use electronic instrument detection, but the instrument is too expensive and bulky. Regard these reasons, we want to develop a portable electronic handheld pupil detector. It could determine the pupil scale quickly and can provide accurate quantitative values for medical personnel to use. It will enhance the convenience of first-line medical personnel and nurses in the future.

2. Methods

We use an external embedded system currently to achieve the size of pupil recognition function. Among them, we completed the optical lens design, image processing and systems, 3D print structure design and functional integration testing. We have to rely on an external embedded system to complete the integration of the overall functional verification. It has been successfully achieved an external controller to capture the pupil and identify the size of the function.

The architecture of pupil detector divided into four parts: optical lens design, image processing, distance measurement system, 3D printing structure. The infrared light source is used to assist pupil to recognition in the optical lens section. First, improve the contrast of human pupil and iris by the infrared light source then stimulate iris by visible light. The identification program is to first identify the auxiliary light using infrared light for the first time and then identify the contraction of the pupil with the visible light and an infrared light source. Get pupil contraction image and then do image processing: The first step is to increase the contrast, the second step is to get the binary image from the image, and the third step is to find the pupil. Finally, the pupil will be marked with a circle. The distance measurement module set on the tip of the pen will detect the distance from the pupil. We calculate the diameter of the pupil before and after stimulation of the absolute diameter size in a proportional relationship between distance and pixels. The last use of 3D printer structure.

3. Results

This study will produce a portable pen-type lamp with pupil identification system. The work items completed in this research including Designing the optical lens with a visible light lens and controlling its light-emitting half-angle within 20 degrees also use infrared to improve the visibility of the pupil which

illuminate the work area effectively and make the fetch clear. After then combined with image processing and recognition system through the development of algorithms. Capture the pupil of the contours correctly, and finally display the data identified in pen LCD screen. In pupil detector light capture pupil image reliability test, the test conditions of the indoor illumination environment illuminance is 250 lux, 5 cm from the eye, in the same parameter environment for reliability testing. We define this test as 60 times with a yield of 80%. If the recognition rate is less than 80% the algorithm stops the test. The test uses the successive test method to record the error point or correct until the yield exceeds 80%. The test result identifies the rate of 88.3%, more than 80% of the standard value.

In the past, the pupil was judged by the medical personnel to make a visual judgment. This may cause mistake sometimes caused by medical personnel in a tight-bodied situation. The output of this project will provide a convenient and easy-to-use system that substantially reduce the burden on medical and nursing personnel.

4. Conclusions

The results of the project will be optimized pupil detector and reduce the size and recognition rate and can carry easily. The medical pupil detector has an image recognition system that captures images through a micro-camera for image processing and performs to display the recognized data on a liquid crystal display screen above the pupil detector. Medical personnel can quickly understand the patient's pupil changes and provide quantitative records to the medical team for the following judgment. When the medical personnel needs to conduct the light reflex examination, a large or small pupil contraction side is slower speed or small amplitude, it may be the optic nerve tumors or other diseases in the early symptoms. This action can’t be controlled. So we found pupil light reflex response worse, the patient may be life-threatening, medical personnel needs to determine whether the patient is unconscious or life-threatening. The first time the standard of judgment will use optical pupil detector to test the patient's pupil size. For the busy healthcare system, many measurement and record-keeping steps can be eased and reduce the time to achieve the best medical treatment Care effect. Now the team can capture the pupil successfully with an external controller and calculates the actual diameter and the ratio calculation before pupil being stimulated and after.

PO33

TRANSMITTANCE HAZE MEASUREMENT FOR HIGH HAZE MATERIALS

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Abstract

1. Motivation

There are currently many products, such diffusers often applied to luminaries or lighting designs, labelled 'high haze' but no standard specifying the measurement method for the material with haze value over 40 %. Five NMIs within the Asia Pacific Metrology Programme (APMP), including CMS/ITRI, MSL, NIM, NIMT and KRISS, applied for the initiative project of the pilot study to investigate high haze samples, and it has been approved by APMP with financial support. CMS/ITRI begins to study some properties of diffusers for the coming pilot comparison of high haze in 2017.

2. Methods

The diffusers with nominal transmittance haze values of over 90 % were adopted. The transmittance haze values were measured according to the current documentary standards (ASTM D1003 and ISO14782), double-beam method and double-compensation method developed by CMS/ITRI.

3. Results

According to the calculation of sphere multiplier in each step in the different methods, transmittance haze (TH), total transmittance (TT) and diffuse transmittance (DT) can be measured accurately by the double-beam method and double-compensation method, but none of them can be acquired right by ASTM D1003. In addition, TH also can be measured accurately by ISO 14782. The analysis of the results shows that the haze measurement depends on the sphere multiplier highly. Compared to the TH by double-compensation method, the TH ratios of double-beam method and of ISO 14782 were very close to 1, and the ratio of ASTM D1003 became close to 1 after the sphere multiplier correction. From the TH data, the differences among various methods at high haze level are similar to those at the haze value below 40%.

It is noticeable that the variations of TT and DT between ISO 14782 and double-compensation method are different in the two types of samples. For the diffuser with haze value around 93 %, the difference between the two methods is less than 0.5 %, while the difference is over 3 % for the diffuser with haze value around 97 %. Whether the samples measured by ISO14782 are more sensitive to their own diffuse properties will be further clarified.

The commercial spectrophotometer with a diffuse accessory is also used commonly to measure transmittance haze. Samples measured by this kind of the instrument can be regarded as those measured by double-beam method, if the reference beam is used during the measurement process. However, TT and DT from the commercial spectrophotometer are larger than the data from double-beam method in our haze measurement system. This is probably due to the size of the incident beam. As the beam size of the commercial spectrophotometer is smaller, the larger part of the scattering light may be captured by the sphere.

4. Conclusions

The discrepancies among different methods highlight deficiencies in current documentary standards. TH, TT and DT measured by current standard documents are highly dependent on the sphere multiplier because of the different configuration of the integrating sphere ports in each step of operation process. Most of the variation among different methods can be accounted for by the sphere multiplier. Other factors will be confirmed with the aim of improving existing standards documents

PO34

COLOUR FADING MODEL OF LEDS FOR CONTEMPORARY PHOTOGRAPHIC MATERIALS

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1. Motivation

It is possible to assess the art work damage by measuring different physical and chemical parameters. One of the most immediate parameter is colour difference, which is a consequence of chemical changes in the material. CIE 157:2004, “Control of Damage to Museum Objects by Optical Radiation”, classified museum collection in 4 groups according to different light fastness. However, these researches were assessed in conventional light sources. Even LED technology was popular broadly; there is no advanced evaluation about colour fading or colour change test for contemporary art works. Recently, The U.S. Department of Energy (DOE)-GATEWAY program supports evaluations and demonstrations of high-performance solid-state lighting (SSL). The result notes that blue-pump LED is generally the least likely product type to cause material degradation at any given CCT. Even the violet-pump LED poses no more risk than a typical incandescent or halogen lamp. However, few studies that have compared the fading rates of various light sources, including LED sources.

2. Methods

The aim of this study is to develop a colour fading model of LEDs applying to the contemporary photographic materials. First, the accelerated ageing test is conducted for three primary colours (cyan, magenta, and yellow colours) on 3 types of photographic materials frequently adopted in modern art: Chromogenic print (C-print), Cibachrome print and inkjet print. They are illuminated by two types of 4000K white LEDs and the 4000K halogen lamp (HA lamp). For two white LEDs, one is blue-pump type with CIE R_a = 96 (BP LED), and the other is purple-pump type with CIE R_a = 88 (PP LED).

The test photographic samples are located in the center of test chambers. The test light sources were installed on the top of chamber. A spectral irradiance meter ISM-Lux is used to measure the ambient illumeinence. Furthermore, the colour differences of test samples before and after the light exposures are measured at 150,000 lx·h for each time. A total of light exposures are performed 13 times. The cumulative exposure is 1,950,000 lx·h. Metric colour differences are evaluated based on CIE1976 $L^*a^*b^*$ formula.

3. Results

Exp. 1: Photographic Ageing Test

This study follows the criterion of “noticeable fade ΔE^*_{ab}=1” stated in CIE 157:2004. When a light source with spectral irradiance distribution $E(\lambda)$ [W/(m^2 ·nm)] was incident on the effective irradiance evaluated of materials ([W/ m^2]), the effective radiant exposure is called *effective radiant exposure* (H_{dm} [W·h/m^2]). The *threshold effective radiant exposure* ($H_{s,dm}$) represents the H_{dm} value that causes a slightly noticeable colour shift of ΔE^*_{ab} = 1.

For the C Print, the ranking of $H_{s,dm}$ is: HA lamp > BP LED > PP LED. For the Cibachrome print, the $H_{s,dm}$ is ranked as: PP LED > BP LED > HA lamp. For the inkjet print, the $H_{s,dm}$ is ranked as: PP LED > HA lamp > BP LED. The result indicated that the HA lamp exhibited a tendency that caused a colour shift in all test samples. Furthermore, inkjet prints were relatively more sensitive to all illuminants, and Cibachrome was more stable than C-print after long-term light exposure. The result indicated that the two white LED lamps exhibited less colour fading compared with the HA lamp.

Exp. 2: Colour Fading Model

In this study, we attempted to design the colour fading model suitable for the test photographic materials. The proposed model is attempted to model colour difference variations in the test materials when they are exposed to the three types of test light sources. The proposal colour fading model of LEDs for the usages of photographic materials for short- or long-term exhibition will be reported in the full paper.

4. Conclusions

This study identified that the CIE157:2004 method based on threshold effective radiant exposure ($H_{s,dm}$) can be applied to the actual ageing test of UV-filtered light sources, including two types of white LEDs (blue-pump and purple-pump LEDs) and one traditional lamp (UV-filtered halogen lamp). The result also presents the colour fading model that can be used in museum LED lighting to predict the colour difference of the contemporary photographic materials (C-print, Cibachrome, and inkjet print) for short- or long-term exhibition. This study provided a revised light dosage classification of modern photographic materials for museums.

PO35

COMPARISON OF PHYSIOLOGICAL RESPONSE BETWEEN LED AND OLED DURING TASK EXECUTION

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Abstract

1. Motivation

Organic light-emitting diodes (OLEDs) have some advantages such as high colour rendering properties, no UV emission, and low heat radiation. It is expected as a next-generation illumination following LEDs. Impression under OLED lighting is different from that under LED. For example, in our experiment using a miniature living room, the subjective evaluation score of "comfort" was higher under OLED illumination than under LED illumination, while the score of "activity" was higher under LED than under OLED. As our results were obtained subjectively, the quantitative evidences, or physiological evidences, were desired. However, few studies have focused on physiological responses. In this study, we recorded the physiological responses during conducting tasks under LED and OLED light source, and investigated whether physiological responses were affected by the light source itself such as LED and OLED, or affected by differences in spectral distribution.

2. Methods

Experiment 1 investigated whether there was differences on physiological responses under LED- and OLED- illuminated spaces. The light sources used in this experiment were commercially available LEDs and OLED panels whose correlated colour temperatures were approximately 4900 K (duv 0.003±0.003). The illuminance was set to be 500 lx at the center of the table. The experiment was conducted in a booth which had white walls, a desk and a chair as a furniture. The light source was set just above the desk. Room temperature and humidity were kept almost constant. Three physiological responses that reflect autonomic responses: nasal temperature, heart rate variability, and brain waves, were measured during the experiments. Nasal temperature was obtained by a thermal image recorded with a thermographic camera. Heart rate variability and brain waves were measured with dedicated equipments. A session of the experiment was composed of three phases: adaptation, task execution, and recovery. The responses both under LED and OLED were recorded successively within a session. The flow of each session is as follows: the subject stayed calm for 5 minutes under the test light in the adaptation phase, then conducted the task such as Kraepelin test in the task execution phase for 10 minutes. After the task execution phase, the subject stayed calm again in the recovery phase for 10 minutes, respectively. This procedure was repeated for another light source after changing the light source. 10 subjects participated in Experiment 1.

Experiment 2 was conducted to clarify whether the differences observed in physiological response were mediated by the difference in spectral distribution of light source. In this experiment, spectral tunable LEDs were introduced to illuminate the table with the same spectral distribution as OLED panels. The illuminance and the correlated colour temperature of each illumination source were 500 lx and 4000 K, respectively. The duration of the adaptation, task execution, and recovery phase of this experiment were 10, 10, and 15 minutes, respectively. In this experiment, a single illumination source was tested within a session. 13 subjects participated in Experiment 2.

3. Results

In this paper, the results obtained from nasal temperature change is introduced, as they showed the most remarkable results. The results of Experiment 1 showed that nasal temperature dropped down in the task execution phase and recovered in the recovery phase in all experimental sessions. This indicated that the nasal temperature behavior can be used as a physiological indicator. We also found the change of the nasal temperature under LED in the task execution phase was significantly larger than that under OLED. This suggested that OLED may reduce the stress as a result of executing tasks than LED.

The results of Experiment 2 also showed that nasal temperature decrease in the task phase in all experimental conditions. However, no significant differences in the change of nasal temperature under LED and OLED were observed. This means that the spectral component of the light source is one of the important factors that affect the physiological response. Physiological indicators other than nasal temperature did not show significant difference between LED and OLED in both experiments.

4. Conclusions

In this study, we showed that there is a significant difference on physiological response during task execution under LED- and OLED- illuminated spaces. This suggests that OLEDs may reduce the stress which was mediated by a task than LEDs do. We also found that there is no significant difference on physiological response in LED and OLED illumination spaces when the spectral distributions were the same. This means the spectral distribution of the light source is one of the important factors that affect the physiological response.

One of the remaining issues is difference in light distribution. While OLED is a diffused light source, LED has some directivities. It will be necessary to investigate whether the differences in light distribution would mediate different physiological responses.

PO36

SMART LED STREET LIGHTING

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Abstract

1. Motivation

New technologies are evolving in such a way that local governments are beginning to realise the benefits to be gained by adopting a 'Smart City' concept that encompasses energy efficiency, sustainability, environmental benefits and information management. LED streetlights are viewed as an integral part of a Smart City concept due to their energy efficiency and adaptability with other smart devices.

The scope of this research is to demonstrate an understanding of the benefits and limitations of utilising smart control technology with public lighting. This includes an investigation into the structure of a smart network and the necessary components to construct such a network. Technical issues such as increased harmonics will also be investigated.

3. Results

3.1 Communication mediums

Wi-Fi has a significant drawback in the large amounts of power consumption. Bluetooth Low Energy (LE) is another alternative and has improved power consumption however the signal range and small number of devices that can be connected are major drawbacks.

Z-Wave and ZigBee have been around for some time now and there are a number of different available devices that utilise these protocols. The two protocols are not compatible with each other but do allow interoperability between different types of devices on a network. Encryption offered is similar to that used by some online banks (AES-128 symmetric encryption).

Potential disadvantages of the Z-Wave protocol include factors such as a slower speed than ZigBee and the fact that it is a proprietary protocol (i.e. owned by a single organisation).

ZigBee is an open standard protocol based on the IEEE 802.15.4 wireless-data specification and this makes it particularly attractive, the small range can be a significant drawback although there is talk of long range low power amplifier modules.

The emerging LPWAN technology has a range highly dependent on the environment or obstructions; this is determined by the link budget (measured in decibels).

As the packets of data get larger the requirement for a more reliable communication medium arises. Gateways usually communicate with the server via cellular networks.

GPRS (General Packet Radio Service) is a packet oriented data service that uses the 2G and 3G cellular networks. This is a possible choice for communication although the 2G network are becoming disabled in many developed nations.

LTE-M is a variation of the Long Term Evolution (LTE) technology currently used in 4G mobile phones. LTE-M has been developed specifically for IoT or machine to machine (M2M) communication. LTE-M will be on the more expensive side of the spectrum, although the data speed and bandwidth may be worthwhile in some cases and it will certainly be cheaper than the alternative 4G/LTE network. LTE-M was designed to meet the low power and long battery life requirements of IoT devices.

Communication over the cellular network will require contracts with cellular providers which will inevitably come at an expense.

It is important to understand that one type of technology cannot be used for every IoT device. Wi-Fi and BTLE will serve communications with personal devices well, other LAN technology will fill in the gaps for short range communication; cellular technology provides options of high data throughput for devices with a power source. LPWAN technology will be particularly useful for nodes to send small amounts of data over long distances a few times per hour from varying environments.

3.2 Power quality implications

The diversion from purely resistive incandescent lighting has been ongoing for some time now, leading to rising concern for the implication on the grid. The source of concern is due to the increasing number of electronic loads being utilised. Electronic loads have been shown to impact distortion of current and voltage waveforms – i.e. Individual or Total Harmonic Distortion (THD) as well as the angle between the current and voltage waveforms – i.e. power factor (pf). The effects of an individual lamp can be seen to be minimal; however, installation in large numbers gives cause for concern.

The use of a passive low-pass harmonic filter can reduce the harmonics level to a satisfactory standard. Diversity factor of THD is a measurement of the combined THD impact from a variety of different loads. A small value of diversity factor indicates that a significant amount of cancellation occurs because of superposition of individual current wave shapes. Results revealed that diversity factor reduced when either different types of LEDs were interconnected or when LEDs and CFLs were interconnected. Connectivity of the same type of LEDs did not reduce the diversity factor.

4. Conclusions

The smart network can be utilised for more than just street lights – the street lights themselves form a large geographic foundation that can act as a ‘net’ to capture a vast range of data. The network can be configured in such a way that other types of devices can be installed, connected, controlled and monitored. These additional devices are simply treated as nodes that become an integral part of the mesh networks and in some cases extend the coverage of the ‘net’.

In order for a piece of plant to have networking capabilities it will require a control module to be installed (or modified) to include a communications module enabling connection to the network via the most practical communication medium. The self-healing aspect of mesh networks is particularly attractive from a reliability perspective however this is only achievable in areas of high node population density. In some cases, it is simply not viable to implement a mesh network and therefore alternative communication mediums should be considered – this will affect the overall costs however the benefits may still prove worth it.

The low power consumption of the nodes is usually achieved by the devices switching into standby mode when not transmitting data – this is a relatively simple concept however when the number of nodes enters the range of hundreds of thousands the data traffic requirements increase drastically. Central Management Systems therefore gain significance and protocols are required to appropriately manage data transmission and prioritise data that is required ‘instantly’ (near real time) over data that is required once a day.

PO37

EFFECTS OF AGE AND GENDER ON VISUAL PERCEPTION OF COMMODITY WITH DIFFERENT MATERIALS IN COMMERCIAL REFRIGERATOR

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Abstract

1. Objective

Customer behaviour is extremely influenced by the perception of surroundings and feelings of well-being in retail store. Lighting parameters (intensity, correlated colour temperature (CCT), and colour rendering index) greatly affect the psychical state of the consumer by changing the perception of surroundings. Studies have been carried out to investigate influences of lighting parameters and the surface colour of commodity on human responses in terms of visual perception. Little was known, however, as to whether and how such responses can be affected by surface material of commodity. This research used LED lights at various CCTs and illuminance intensities in a commercial refrigerator where the observers conducts a self-assessment of visual perception. We explore the correlation between the different surface material of commodity (metal, paper, and plastic) and the satisfaction of visual perception (freshness, quality, and attractiveness) of observers in different age and gender.

2. Methods

This study aims to investigate the influence of age and gender on visual perception with various surface material of commodity in commercial refrigerator using white LED lights. A psychophysical experiment was conducted to examine whether there were age difference and gender difference in assessing visual perception using various surface material of commodity settings. A real commercial refrigerator, 190cm(H)×90cm(W)×60cm(D) in size, was used as the experimental lighting case. The LED light bars developed as the experimental light source were pasted inside refrigerator chamber. The LED light bar was 60cm in length, consisting of 84 chips for warm white (CCT=2800K) and 84 chips for cool white (6500K). A DC power supply was used for driving the LED light bars at CCTs of 5000K and 6500K. For each CCT, three illuminance intensities, 500lux, 1000lux and 2000lux, were used individually in the experiment.

Thirty-two Taiwanese observers (16 males and 16 females) participated in the study. Half of the observers were over 50 years in age and the other half were under 40 years. All observers have passed the Ishihara test for colour deficiency. During the test, each observer stood in front of commercial refrigerator at the experimental dark room. Each observer was asked to watch a lot of different surface material of commodity in front of commercial refrigerator for each lighting conditions described above. For each lighting condition, the observer was asked to assess visual perception on a six-category force choice scale, for example, “very attractive”, “attractive”, “slightly attractive”, “slightly repulsive”, “repulsive” and “very repulsive”. The categorical judgment method was used for data collection.

3. Results

The experimental results show that the surface material of commodity had no significant impact on the observer response by using white LED lights in commercial refrigerator. Experimental results of visual perception were compared between the three surface materials (metal, paper, and plastic). High correlation was found between the three groups, with a correlation coefficient of 0.99 for metal and paper, 0.98 for metal and plastic, 0.99 for paper and plastic. This suggests that there was little surface material of commodity difference in assessing visual perception.

Experimental results of visual perception were compared between the two ages. The results indicates that under each surface materials of commodity, the young and elderly observers agreed well with each other without showing strong age difference. This suggests that there was little age difference in assessing visual perception for surface materials of commodity. Nevertheless, for the surface materials of commodity condition with a metal, the elderly observers felt more satisfied than the young observers.

Regarding the influence of gender on visual perception, the results indicate that gender had significant impacts on visual perception in different surface material of commodity. This suggests that there was strong gender difference in assessing visual perception for surface materials of commodity, especially in freshness and attractiveness. In addition, for the surface materials of commodity condition with a metal and plastic, the male observers felt more satisfied than the female observers.

4. Conclusions

In our study 32 younger and elderly respondents participated with the purpose to reveal the impact of the white LED lights on various surface materials of commodity in commercial refrigerator. The experimental results show that for the effect of surface material of commodity, no significant difference was found in visual perception. For the effect of age, no significant difference was found in visual perception. However, a strong gender effect in visual perception (freshness and attractiveness) was found for surface material of commodity under the metal and plastic.

5. Acknowledgement

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PO38

A REAL-TIME SYSTEM TO ENHANCE LEGIBILITY AND AWARENESS OF TEXT INFORMATION FOR AN OPTICAL SEE-THROUGH HMD

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Abstract

1. Motivation, specific objective

Wearable devices are more and more popular in recent years and optical see-through HMD (denoted as OST-HMD) is likely to be one of the major wearable device for future AR applications. However, in an outdoor environment, bright and complex scene would greatly reduce the legibility of text displayed on the OST-HMD. Orlosky's study shows that users are more aware when using an OST-HMD compared to a smartphone device. We exam text colour and rendering method for the type of applications. A series of visual experiments were conducted to summarize the rules of text placement and text rendering for the applications. The aim is to develop a rendering model to automatically enhance the legibility of text displayed on the OST-HMD in an outdoor environment.

2. Methods

In this study, 3 different masks, text only, transparent text box, and text plus box, were tested. 4 real scenes were tested. Experiment ask 10 participants to answer the legibility and awareness of text information in 9 locations individually by a 7 point Likert scale. Test 1 applied only green colour to the 3 masks as the colour is bright and has higher awareness to most of colours. Test 2 applied yellow text with a magenta box to enhance both awareness and legibility. Test 3 chose colour with maximum colour difference to the background area. We also set 3 different weights to lightness, chroma and hue differences in the Test 3. The colour and complexity of the scene behind the HMD was estimated by a video camera mounted on the HMD. The estimation is limited by the dynamic range of the video camera.

3. Results

Overall results show the Text 2 Mark 3 model is the best one when the background information is unknown. The results of legibility are highly correlated to awareness. To choose a text rendering model for more critical viewing conditions, we evaluate regions with top 25% mean lightness (L*) or top 25% standard deviation of lightness (L*) by the video camera. The result shows the (1:2:1) weighted colour-difference model in Test 3 won the highest scores. However, the computation cost is higher. The cost-effective Text 2 Mark 3 model also is recommended.

4. Conclusions

The results show that the brightness of background image plays very most important role. To make the text visible, its's better to place a text in a dark and uniform area. A transparent text box is more visible than text only mode. The text colour should be bright and the colour is complemental to the background. We have developed a real-time system to verify that the proposed text rendering model can be used to choose an optimal place in the viewing zone of the OST-HMD to enhance the legibility and awareness of the text.