Skin Colour Database

R1-56

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Terms of Reference

1. To assemble a database of skin colours, to include spectral data and measurement method.
2. To report on the variation in colour between different ethnic groups, genders and body locations.

1 Introduction

This reportership was established in response to the increasing demands of multi-disciplinary applications of human skin colour. The objectives are to assess existing human skin colour databases by comparing the data taking into consideration the measurement method. From the results of this analysis, it should be possible to assess whether a reasonable comprehensive skin colour database already exists or whether a new database needs to be generated by the combination of existing skin colour databases. To aid the decision, the variation in skin colour between different ethnics groups, gender and body locations are assessed.

2 Measurement method for human skin colour

For human skin colour, the methods used to make colour measurements can be divided into those based on contact measurements and those based on non-contact measurements.

2.1 Contact Measurements

The measurement of the colour of human skin using a contact method is made by placing the instrument on to the selected area of skin, or the selected area of skin against the measurement port of a portable instrument, and making the measurement using light from the source that is an integral part of the instrument. Three types of instruments can be identified, a reflection spectrophotometer, a tristimulus colorimeter and a Mexameter [1]: these are introduced below.

2.1.1 Spectrophotometer

A spectrophotometer is widely used to measure the spectral reflectance of human skin within the visible spectrum from which CIE XYZ tristimulus values can be calculated based on any of a number of CIE illuminants and CIE observers. A light source is built into the instrument and the consistency of measurement is controlled by device characterisation using a calibrated white tile.

2.1.2 Tristimulus colorimeter

A tristimulus colorimeter can also used to measure skin colour directly in terms of CIE XYZ tristimulus values by making measurements using three or four filters that mimic the colour matching functions of a defined CIE observer and using a specified light source in the instrument. This type of instrument cannot measure the spectral reflectance.

2.1.3 Mexameter

For the Mexameter, light emitting diodes arranged circularly emit radiation at three defined wavelengths and photo detectors measure the light reflected by the human skin. A melanin index and an erythema index are computed from the intensity of the absorbed and the reflected light at different wavelengths. This type of instrument is widely used for skin disease diagnosis. It cannot be used to measure CIE XYZ tristimulus values and spectral reflectance.

2.2 Non-Contact Measurements

For non-contact spectral measurement, human skin can be measured by use of either a spectroradiometer [2] or camera imaging system [3, 4] both requiring a controlled lighting environment.

2.2.1 Spectroradiometer

A spectroradiometer is used to measure the spectral power distribution (SPD) of human skin under a defined, stable lighting system. The spectral reflectance of skin can be calculated based on the SPD of the light source and that of the skin sample. Based on this SPD, skin colour in terms of CIE XYZ tristimulus values can be calculated.

2.2.2 Camera imaging system

Examples of camera-based systems include imaging systems developed using conventional digital cameras, those using 3D cameras, and those using hyperspectral cameras. As for spectroradiometry, a defined, stable lighting system is required; mathematical algorithms are also needed to transform the data in the digital image of the skin sample into CIE XYZ tristimulus values or spectral reflectance values.

2.3 Summary

For contact measurement of the colour of human skin, the spectral reflectance can be measured directly using an instrument with a built in light source. However, due to the pressure of the instrument on the skin, a colour shift may be generated between the measurement so obtained and the actual colour of the skin. The measurement repeatability should be investigated in order to at least partially quantify this effect. The aperture size is also need to be carefully selected for skin colour measurement since skin colour is not uniform. A decision must also be made as to whether to include or exclude the specular component of the reflected light.

For non-contact skin colour measurement, the stability and uniformity of the lighting system used to illuminate the skin sample can significantly affect the measurement and therefore needs to be carefully evaluated. Since the human face is not a flat surface, shadows can be generated for different lighting systems. The measurement distance can also significantly affect the measurement results.

For all spectral measurements, the spectral wavelength range, the spectral measurement interval, the use of filtration to control any fluorescence effects that could significantly affect the results, all need to be defined.

3 Skin Colour Database

In the last two decades, skin colour databases have been established by different researchers to meet multi-disciplinary applications. Only databases of spectral data are summarised in this report.

3.1 SOCS data

In 2003, the International Organisation for Standardization published an international standard: *Graphic technology - Standard object colour spectra database for colour reproduction evaluation (SOCS)* [5]. This standard "provides a database of typical and difference sets of existing object colour spectral data that are suitable for evaluating the colour reproduction of image input devices. It also includes the spectral reflectance and transmittance source data from which these data sets have been derived." Six distinct groups of human skin colours are recommended for use based on the SOCS data.

3.1.1 SHISEIDO Data

The SHISEIDO data were provided by Shiseido Company Limited, Japan. In total, 3900 human skin samples from 1311 subjects were measured using contact spectral measurement with an instrument geometry of d:0° (specular component excluded), respectively. The measurements were conducted in Bangkok, Kuala Lumpar, Taipei and Tokyo using only female Asians. For each subject, three body locations; the forehead (or the zygomatic region – the upper cheek, forward of the ear), the cheek and the neck were measured and the cheek was measured again when the foundation was applied.

3.1.2 KAO Data

The KAO data were provided by the Kao Corporation, Japan. 2187 skin samples from 461 Japanese female were measured using a contact spectral measurement with an instrumental geometry of d:0° (specular component excluded), respectively. The face, with and without applied foundation, was measured using the forehead, the zygomatic region and the cheek. In addition, the skin colour of the arm and the neck were measured.

3.1.3 OOKA Data

The OOKA data were collected in 1998 on the Ookayama campus of the Tokyo Institute of Technology, Japan. 63 Japanese subjects (53 male and 10 female) were measured at three different body sites (forehead, zygomatic region and cheek) using three non-contact spectral measurement devices and two contact measurement devices.

3.1.4 KAWASAKI Data

The KAWASAKI data were collected in 1998 at the NEC Corporation, Kawasaki, Japan. The skin colour of 84 subjects including 80 Japanese (64 male and 14 female), 1 Taiwanese male, 1 Chinese male, 1 Canadian male and 1 Finnish male, were measured at three body locations (forehead, zygomatic region and cheek) by the three non-contact spectral measurement devices (spectroradiometers), and at almost identical positions by two contact-type spectral measurement devices.

3.1.5 OULU Data

The OULU data were collected at OULU University, Finland and are part of the University of Oulu physics-based (UOPB) face database. These data include the skin colour data of 101 Caucasian (78 male and 23 female), 8 Negroid (male) and 10 Asian (3 male and 7 female) subjects. Measurements were made using a contact type device and the instrument geometry was d:8° (specular component excluded). Unfortunately, the measured positions on the faces were not clearly recorded. Three measurements were taken per person: one from each cheek and one from the forehead.

3.1.6 SUN Data

The SUN data were provided by the Color Research Laboratory at Sun Chemical, USA. Skin colours were measured in Carlstadt for 41 subjects including 14 Negroid subjects (5 male and 9 female), 20 Caucasian subjects (15 male and 5 female) and 7 other ethnics groups (6 male and 1 female. For each subject, four body locations (forehead, zygomatic region, neck and hand) were measured by a contact spectral measurement device and the instrument geometry was d:8° (specular component excluded).

3.1.7 Typical skin colour recommendations

Based on these six sets of data, ISO/TR16066 recommends six typical skin colour groups:

- Bare North Asian skin,
- Foundation-applied North Asian skin,
- Bare South Asian skin,
- Foundation-applied South Asian skin,
- Bare Caucasian skin, and
- Bare Negroid skin.

Five samples were selected from each group and these correspond to the average and the extreme colours of their distributions in CIELAB space.

3.1.8 Discussion

The SOCS skin colour data sets described above cover a relatively large number of human skin colours for different genders, ethnics groups and body locations. However, because the data were collected in different laboratories for different applications, there are some limitations to their future use. Firstly, for skin in different ethnics groups, although the data sets include measurements from a large number of Japanese and Caucasian subjects, measurements for other ethnics groups are relatively limited. Secondly, there is much more data for female subjects than for male subjects. Finally and most importantly, the skin colour measurements were made using different colour measurement instruments with different measurement settings. This makes comparison between different data sets problematic. Although some normalisation and interpolation are conducted for each set of data in order to reduce the differences between them, this cannot be an entirely satisfactory process. The details of instrument differences affecting to skin colour measurements for the SOCS data are described in Appendix A.

3.2 Other Skin Colour Data

As the SOCS data cannot comprehensively represent human skin, skin colour database are continually developed in order to meet different research and industry requirements.

3.2.1 Sheffield Data

The Sheffield data were provided by Xiao et al. from the School of Clinical Dentistry at the University of Sheffield, UK [6, 7]. A Konica Minolta CM2600d spectrophotometer was used to make contact measurements at nine body locations of 448 subjects. The measurements were made in the UK, China and Iraq. The skin colour data were used to evaluate the advanced manufacturing techniques for facial prostheses.

3.2.2 RIT Data

The RIT data were provided by the Munsell Color Science Laboratory, Rochester Institute of Technology, USA [8]. Non-contact measurements were made at 16 body locations of 34 subjects using a Photo Research SpectraScan 704 Spectroradiometer.

3.2.3 L’Oreal Data

The L’Oreal data were collected by L’Oreal Recherche in France [9, 10]. A non-contact measurement system, the Chromasphere, was developed to provide a constant lighting condition. Skin measurements of 1000 female subjects, within four ethnic groups, were measured using a Photo Research PR-650 Spectroradiometer. This database was used to develop cosmetic products.

3.2.4 Kanebo Data

The Kanebo data were collected by Kanebo Cosmetic, Japan [11]. Contact measurements were made of 200 female subjects within two ethnics groups using a Konica Minolta 2600d spectrophotometer. This database was used to develop cosmetic products.

3.2.5 SpectroMatch Data

The SpectroMatch data were provided by SpectroMatch Limited, UK. Contact measurements were made of 250 subjects using a Konica Minolta CM-2500d Spectrophotometer. This database was used to derive the colour reproduction of soft tissue prostheses.

3.2.6 SCIEN Data

The SCIEN data were collected at the Stanford Center for Image Systems Engineering, Stanford University, USA. A non-contact hyperspectral imaging system was used to measure the spectral reflectance of the face of 100 subjects.

3.3 Summary

In addition to SOCS data, a number of databases of spectral measurements of human skin have been collected from different locations. However, there no skin colour database could comprehensively represent human skin in different ethnics groups, gender and aging. There is difficulty to combine existing skin colour database since different measurement methods, measurement instruments and measurement settings were employed for different skin colour database. There is no research to be conducted to evaluate their measurement difference caused by various measurement techniques and therefore and there is no any post processing exist to reduce these measurement differences.

4 Skin Colour Variation

Skin colour variation cannot be investigated without a comprehensive skin colour database. It has been found that the difference between skin colour samples for individuals can be very large (more than 30 ΔE^*_{ab}) based on the Sheffield data [7].

5 Conclusion and Recommendation

In this report, existing skin colour databases and their measurement methods are summarised. It is suggested that none of the presently available skin colour databases can comprehensively represent the human skin of different ethnics group, gender, age and body location. The measurement method for human skin colour is not unique and different methods were applied to establish skin colour data. Consequently, existing skin colour databases are difficult to compare and unite and hence skin colour variation cannot be comprehensively investigated using these data. Skin colour difference between individual is known to be significant.

It is recommended that a new Technical Committee be formed to define a unique measurement method for human skin colour and to establish a comprehensive human skin colour database.

Terms of Reference

1. To investigate the uncertainty of skin colour measurement and to recommend protocols for skin colour measurements.
2. To develop a technique to combine existing skin colour database.
3. To recommend a skin colour database covering different ethnic groups, genders, age and body location.

The uncertainty in skin colour measurement can be investigated using the available data: this should lead to a better measurement protocol. It is to be hoped that at least some of the presently available data can be incorporated into a future database, although it is recognized that new data will be required.

6 Acknowledgment

Professor Michael Pointer provided his guide and consultancy for this report. I would like to acknowledge his contributions to R 1-56.

7 References

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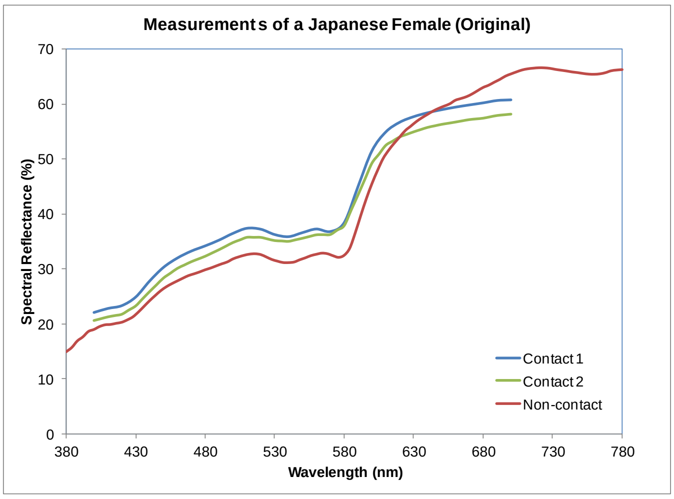
Appendix A. Instrument difference to spectral measurement in SOCS data

In the SOCS data, spectral reflectance of six groups of skin colour data were measured by eight different instruments and the specifications of these instruments can be found in Table A1. It can be seen that measurement wavelength region, wavelength interval and measurement geometry for different instrument can be very different. The measurement distance (between human skin and measurement instrument), uniformity of lighting (for avoiding shadow) for non-contact measurement and aperture size for contact measurement could also affect the measurement results for human skin significantly. However, they were not specified in the SOCS data.

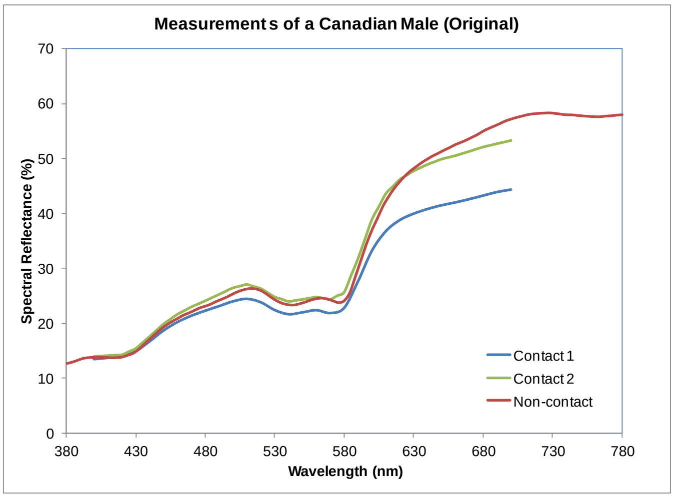
Table A1. Specification of Instruments applied for SOCS data

Instrument	Type of Measurement	Measured range (nm)	Wavelength interval (nm)	Measurement Geometry
04	Contact	400 – 700	10	d:0° (SEI)
w05	Contact	400 – 700	5	d:0° (SEI)
06	Non-contact	380 – 780	5	45°/0°
07	Non-contact	380 – 780	5	45°:0°
08	Non-contact	380 – 780	4	45°:0°
09	Non-contact	380 – 780	4	45°:0°
15	Contact	400 – 700	10	d:8° (SEI)
16	Contact	400 – 700	10	d:8° (SEI)

Figures A1(a) and A1(b) are plotted to illustrate the spectral measurement results achieved using different instruments for the skin (cheek) of a Japanese female subject from the OOKA database and a Canadian male subject from the KAWASKI database, respectively. It can be clearly seen that slightly different spectral measurements are obtained for the different instruments for the same skin sample.



(a)



(b)

Figure A1. The original spectral measurements for human skin using different instruments.

(a) Cheek of a Japanese female subject from the OOKA database.

(b) Cheek of a Canadian male subject from the KAWASKI data.

In order to reduce the measurement differences by different instruments for the SOCS data, a normalisation procedure was used based on the measurement of a white, gloss colour sample using each instrument. A ratio, *k*, is used as a normalisation factor and the values for eight instruments are given in Table A2. The newly normalised spectral reflectance data for different instruments were obtained by applying equation 1 to each set with the appropriate value of the constant, *k*.

$$d_{\mathrm{int}} = k \cdot d_{org} \qquad (1)$$

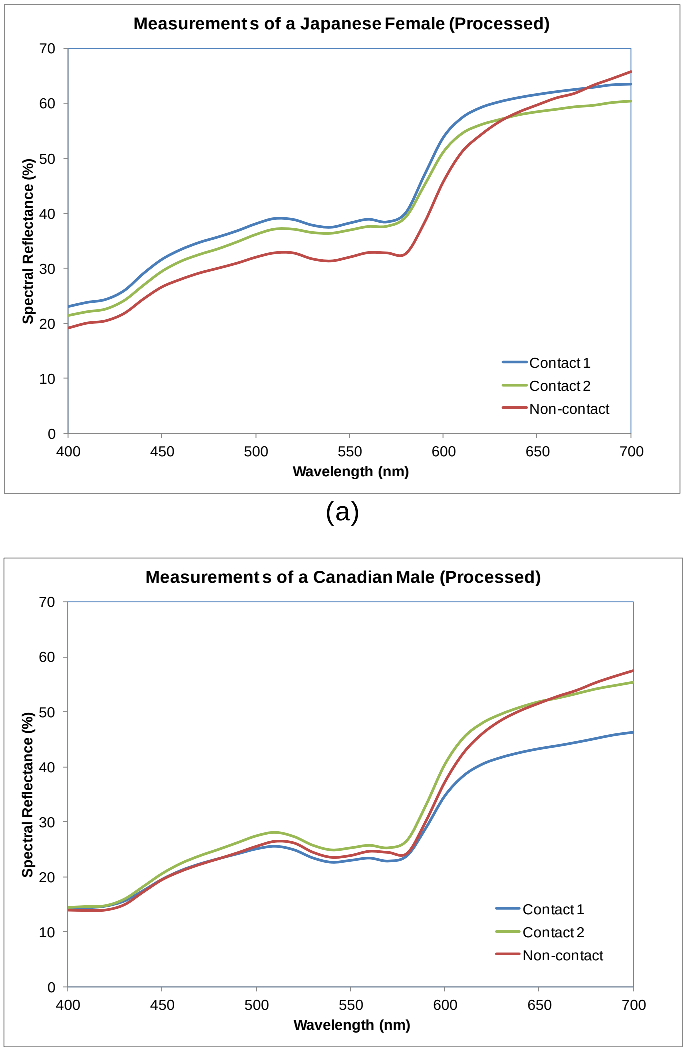
where d_{int} and d_{org} represents the spectral reflectance of object with and without normalisation, *k* represents normalisation factor.

Table A2. Normalisation factor (k) for different instruments

Instrument	K	Instrument	k
04	1.0450	08	1.0005
05	1.0372	09	1.0051
06	1.0004	15	1.0249
07	1.0123	16	1.0197

An interpolation processing was also conducted in order to unify the wavelength range and interval between different instruments. Finally, all measurement results were interpolated to a wavelength range of 400 nm to 700 nm with a wavelength interval of 10 nm.

By applying the normalisation and interpolation, the processed measurement results for the skin of the Japanese female subject and the Canadian male subject were generated and are plotted in Figure A2.



(b)

Figure A2. The processed spectral measurements for human skin using different instruments.

(a) Cheek of a Japanese female subject from the OOKA database.

(b) Cheek of a Canadian male subject from the KAWASKI data.

It can be seen that the measurement difference due to instrument difference is not much reduced. This indicates that the normalisation process based on the measurement of a white, gloss sample is not adequate. This might be due to the following:

1. Surface of human skin is very different to a gloss sample.
2. Skin is not a flat surface. A shadow might be generated when it is measured by a non-contact instrument, whereas there is no shadow effect for contact measurement.
3. The effect of a colour shift due to the pressure of contact measurements.

In summary, for spectral measurement in human skin, different instruments and measurement conditions can generate a significant measurement differences. For SOCS data, although a processing was applied to reduce the disagreement between different instruments, there is still a large uncertainty to combine six groups of skin colour database using current form of recommendation.