ICC Medical Imaging Working Group
FDA Face-to-face meeting
FDA White Oak Conference Center
10903 New Hampshire Ave.
Silver Spring MD 20993
USA
20 June 2014 • 09:00 (EDT)

The meeting was called to order at 09:00 pm (EDT) by Craig Revie, chair of MIWG, with the following attendees:

Nick Anderson, FDA/CDRH/OIR/DMGP
Shyam Kalavar, FDA/CDRH/OIR/DMGP
Cheng Zhang, FDA/CDRH/OIR/DMGP
Bruce Drum, FDA/CDRH/ODE/DOED
Robert Ochs, FDA/CDRH/OIR/DRH
Quanzeng Wang, FDA/CDRH/OSEL/DP
Kyle Myers, FDA/CDRH/OSEL/DIAM
Nicholas Petrick, FDA/CDRH/OSEL/DIAM
Brandon Gallas, FDA/CDRH/OSEL/DIAM
Andreu Badal-Soler, FDA/CDRH/OSEL/DIAM
Chih-Lei Wu, FDA/CDRH/OSEL/DIAM
Wei-Chung Cheng, FDA/CDRH/OSEL/DIAM

Rich Amador, Canon U.S.A., Inc.
Chris Bai, BenQ Corporation
Pinky Bautista, MGH PICT center
Vipul Baxi, Omnyx Integrated Digital Pathology
David Clunie, Bioclinica & PixelMed
Brian Cote, Eizo Corporation
Scott Forster, Roche Ventana
Phil Green, Gjøvik University College, Norway
Bas Hulsken, Philips Healthcare Incubator
Po-Chieh Hung , Konica Minolta
Francisco Imai, Canon U.S.A., Inc.
Bryan Kennedy, KARL STORZ Imaging
Stephen Lansel, Olympus
Changjun Li, Liaoning University of Science and Technology

Takashi Matsui, Eizo Corporation
Efrain Morales, KARL STORZ Imaging
Allen Olson, Leica Biosystems
Craig Revie, Fujifilm Corporation
Christye Sisson, Rochester Institute of Technology
John Sweeney, BenQ Corporation
Dave Wyble, Avian Rochester, LLC
Kaida Xiao, Technical Consultant
Albert Xthona, Barco NV
Masahiro Yamaguchi, Tokyo Institute of Technology

On-line attendees:
Bamba - EIZO
Yoshida - EIZO
James Chang
William Fischer
Yves Vander Haeghen
Andy Masia
Michael Montalto
William Fischer
Yves Vander Haeghen
David Clunie
John Penczek
Hong Wei

After self-introductions Mr. Revie reviewed the agenda for the meeting as follows:

1. FDA Interactive Session
    - Calibration slide for histopathology
    - Medical RGB colorspace –mRGB
    - Coloreye model
    - Framework for multispectral imaging
    - Best practices for digital color photography in medicine
    - Color support for mobile devices
2. Simulation of skin color
3. Next steps for each work item

1. FDA Interactive Session
The goal of this session was to briefly summarise each area of activity in MIWG and provide an opportunity for interaction and discussion with participants from the FDA.

Each of the MIWG areas of activity was briefly introduced:

1.1 Calibration slide for histopathology
Mr Craig Revie summarised the motivation and goals of this activity [see attached]. Calibration methods developed by several of the vendors were reviewed, and the Project Sierra calibration assessment slide developed by FFEI was described.

1.2 Medical RGB colorspace –mRGB
Mr Albert Xthona presented a summary of work on displays [see attached]. He described the problem of display instability and the need for standards. A visualization architecture, specifications and reference implementation were needed, and this should be developed and promoted in conjunction with other groups such as AAPM and IEC. Mr Xthona emphasised that it was important to be able to convey the same appearance on different displays, and have metrics to evaluate this.

1.3 Coloreye model
Ms Christye Sisson presented a summary of work on calibrating retinal fundus cameras [see attached]. She described the main goal in terms of evaluating consistency between different fundus cameras, and showed results of imaging the same eye with different cameras at RIT. Ms Sisson showed results of applying a correction to the captured images which significantly improved color consistency. She described the planned next phase of the work.

1.4 Framework for multispectral imaging
Professor Masahiro Yamaguchi presented an outline of work on multispectral imaging [see attached]. He described potential applications for multispectral imaging, showing the example of color unmixing to obtain relative dye amounts. He proposed the adoption of ICC v4 and v5 solutions, including the Material Connection Space proposed for v5.

1.5 Best practices for digital color photography in medicine
Dr Phil Green presented a summary of progress on best practices guidelines for medical photography on behalf of Dr John Penczek [see attached]. Work had been done to determine the magnitude and sources of color errors between rendered RGB images and in-situ measurements of a test chart, and a draft outline of the guidelines developed.

1.6 Color support for mobile devices
Dr Phil Green presented a status update on calibration for mobile displays on behalf of Mr Andy Masia [see attached]. Problems included the lack of support for color management on most mobile device operating systems, and significant differences in color rendering between devices. The group was discussing requirements for mobile displays used in medical imaging (such as calibration, ambient light compensation and neutralizing dynamic controls) and potential architectures to meet these requirements.

1.7 Discussion
1.7.1 Calibration slide. The meeting asked about the stability of stains for whole-slide imaging. Mr Revie stated that fading of Eosin is the main problem, and the FFEI calibration assessment slide uses DABCO as a stabilizer which produces a small color shift. He is also investigating the use of Eosin as a marker to indicate the degree of change. He clarified that the purpose of the calibration assessment slide is to evaluate the accuracy of calibration of a slide scanner. Additionally, a marker could be included on every slide that is scanned as a control. Adding this marker could increase the total scan time unless the digital microscope systems are adapted to handle it.

1.7.2 Medical RGB colorspace. Was the GSDF compatible with color? Mr Xthona stated that implementing both GDSF compliance and color accuracy required technology at the display end and color transforms, these could now be considered feasible. Color difference was assessed using 1976 CIELAB and/or CIEDE2000 metrics. There was interest in how to calibrate a display for research purposes. Mr Xthona

suggested there was a need to calibrate each component in the workflow, and Mr Revie suggested that it would be useful to provide guidance for users on how to accomplish this.

1.7.3 Color eye model. Did the fundus cameras change over time? Ms Sisson stated that the aging of the Xenon flash tube was the primary source of variation. The group had decided to focus on consistency rather than precision/accuracy. It was expected that some user calibration would be needed, but probably not frequently performed in clinical practice.

2. Simulation of skin color

Dr Kaida Xiao presented a summary of work on a skin color database and skin color simulation [see attached]. He had undertaken previous projects on skin prosthesis manufacture, including color management. He showed examples of prostheses. The current approach is to do a visual assessment and manual color mixing. This was costly, time-consuming and relatively inaccurate. More advanced technologies use non-contact measurement and 3D printing to generate prostheses with colors matched to the recipient.

Existing databases skin color were not comprehensive or compatible, being based on different patient populations and different measurement instrumentation.

Dr Xiao described the difficulty of measuring skin, which has different layers which give rise to a complex reflectance, and is not uniform, flat or stable. He described different measurement instruments, and suggested that digital cameras had some advantages although lower potential accuracy.

He showed differences in skin color between ethnic groups, the main difference being in chroma.

Dr Xiao described the applications for a skin color database, which included reproducing skin color, reconstructing skin reflectance and image analysis. He stated that there was a need to a skin color test target, as the Pantone skin color samples do not map well to skin measurements in color or reflectance. A measurement protocol and uniform lighting were needed. Two methods of characterization had been adopted: RGB to XYZ and then to reflectance, and RGB directly to reflectance.

In the discussion it was noted that X-Rite had done work on skin color with an industrial partner who has a large database of skin color measurements. It was also noted that gloss could have an effect on measurement, particularly in dentistry. Polarized lighting was used where this was considered a problem.

3. Next steps

The meeting discussed work on color support for DICOM. Dr David Clunie stated that there were some details to be clarified in DICOM, but relatively little scope for work in MIWG. A particular question was around support for camera RAW images. It was necessary to define the use cases for RAW images and whether RAW RGB could be obtained from different capture systems and whether it would be stored in the image pac file. DICOM would support a dual TIFF and DICOM format. De-identification of patient data was needed when storing on a central server. Camera RAW image data was of potential interest to ophthalmology and medical photography, and Adobe DNG was a candidate for encoding RAW images.

For the model eye activity, Andy Masia of X-Rite undertook to provide help in generating a suitable test target.

The WSI activity agreed a schedule and participant list for testing the Sierra/FFEI calibration assessment slide.

Mr Revie closed the meeting at 12:00pm.

A full recording of the meeting is available at http://www.npes.org/Portals/0/standards/2014-06-20%2009.01%20FDA%20Interactive%20Session.wmv

International Color Consortium

ICC Medical Imaging Working Group

FDA face-to-face meeting

19th and 20th June 2014

ICC MIWG Agenda: Friday

09:00 FDA Interactive Session (Nick Petrick / Craig Revie)

- Calibration slide for histopathology (Craig Revie)
- Medical RGB color space – mRGB (Albert Xthona / Michael Flynn)
- Color eye model (Christye Sisson)
- Framework for multispectral imaging (Masahiro Yamaguchi)
- Best practices for digital color photography in medicine (Phil Green / John Penczek)
- Colour support for mobile devices (Phil Green / Andy Masia)

10:30 Simulation of skin colour (Kaida Xiao)

11:00 Next steps for each work item (www.color.org)

ICC Medical Imaging Working Group

Whole Slide Imaging summary

20th June 2014

Color in Medical Imaging Summit work item

International Color Consortium

Calibration slide for histopathology

- **Problem statement**
  - One reason for differences in whole slide imaging is the lack of a suitable calibration process which means that the same slide can look very different from system to system
- **Proposal**
  - Vendors that have worked in this area should pool their resources to develop a calibration system for digital microscopes
- **Participants**
  - Organisations: ICC, DICOM WG26, FDA
  - Individuals: <teleconference><others>
  - Project coordinator: Craig Revie

Why standard methodologies for the assessment of the color transfer properties in digital microscopy?

1. **Evidence of color performance of slide scanners will facilitate technology comparisons (not only with the optical microscope) and provide an approach to the bench test requisites for the regulatory review of such devices.**
2. **A methodology for measuring would allow for consistency within and among systems/vendors which is required to allow the development of robust computer-assisted detection and diagnosis approaches.**
3. **In addition, the methodology could be part of procedures for system and component QC/QA.**

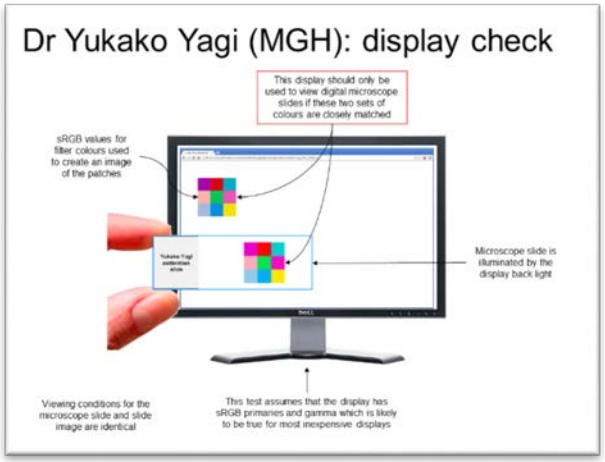
Aldo Badano, FDA Laboratory of Imaging Physics

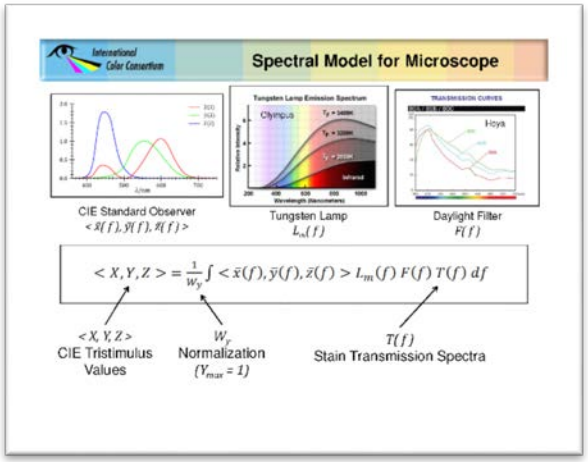
Why standard methodologies for the assessment of the color transfer properties in digital microscopy?

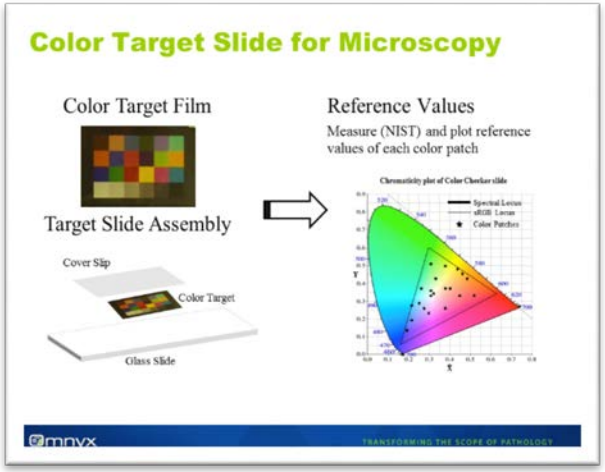
4. **Such a test might increase opportunities for innovation at all levels of the imaging chain by providing a standard methodology to identify components with improved performance.**
5. **The use of the methodology will contribute to the understanding of the limitations of digital systems in terms of color performance.**
6. **A standard methodology will be useful for other areas of digital microscopy including novel stains/techniques (eg, multispectral).**

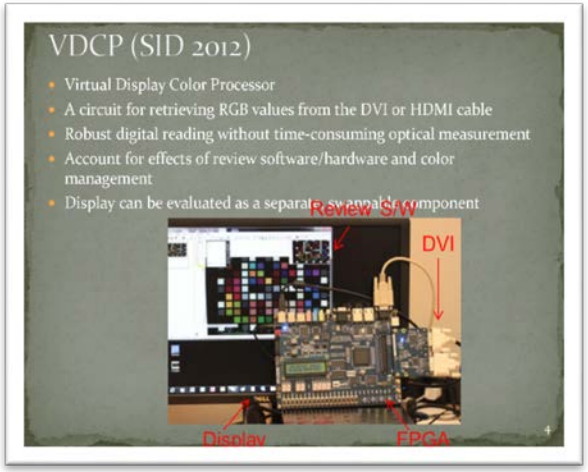
Aldo Badano, FDA Laboratory of Imaging Physics

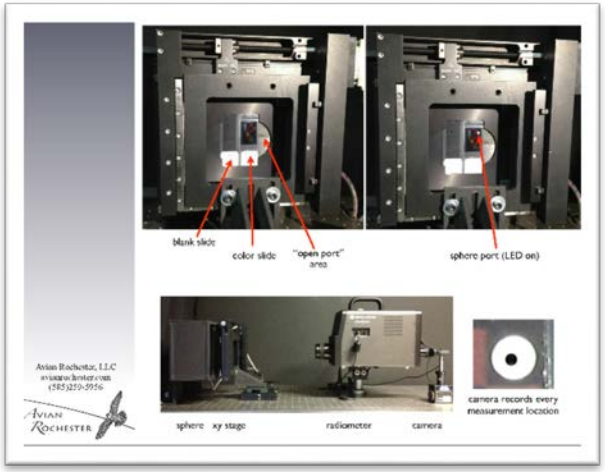
Calibration ideas shared by the group



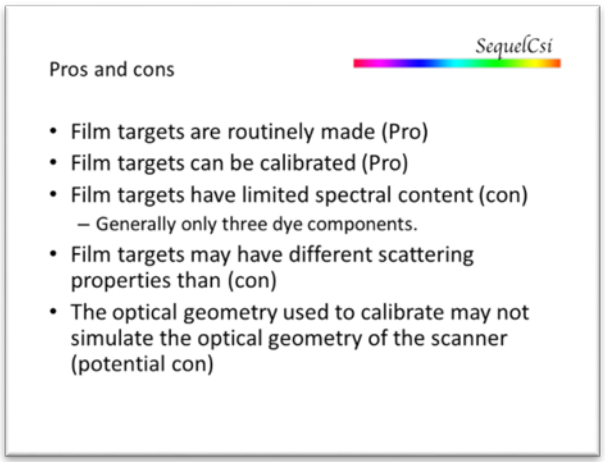


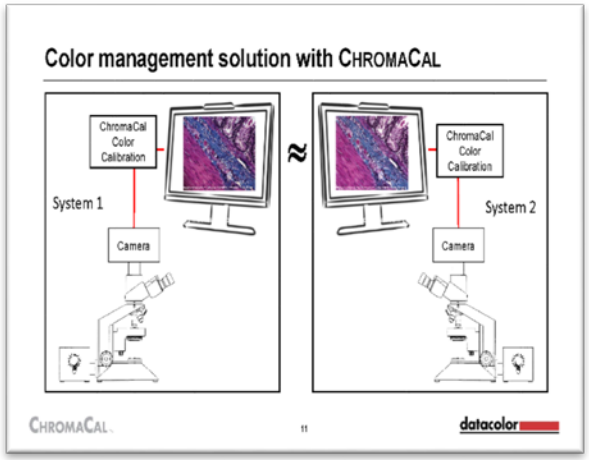


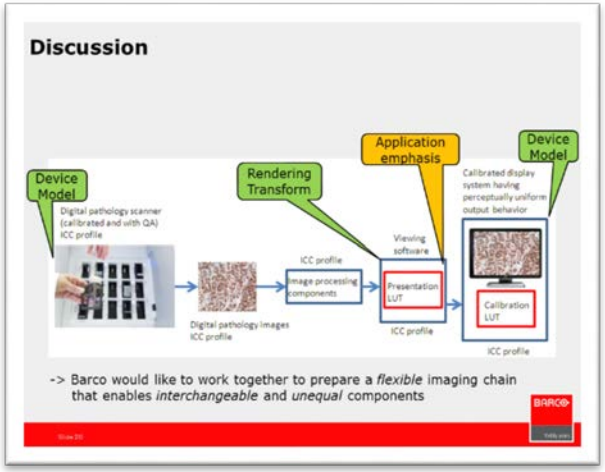


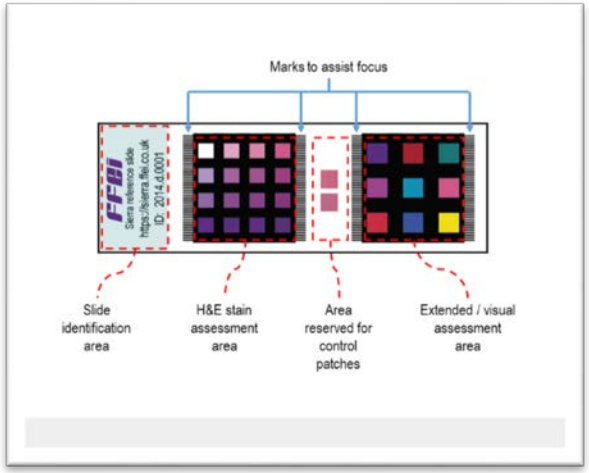


Calibration ideas shared by the group



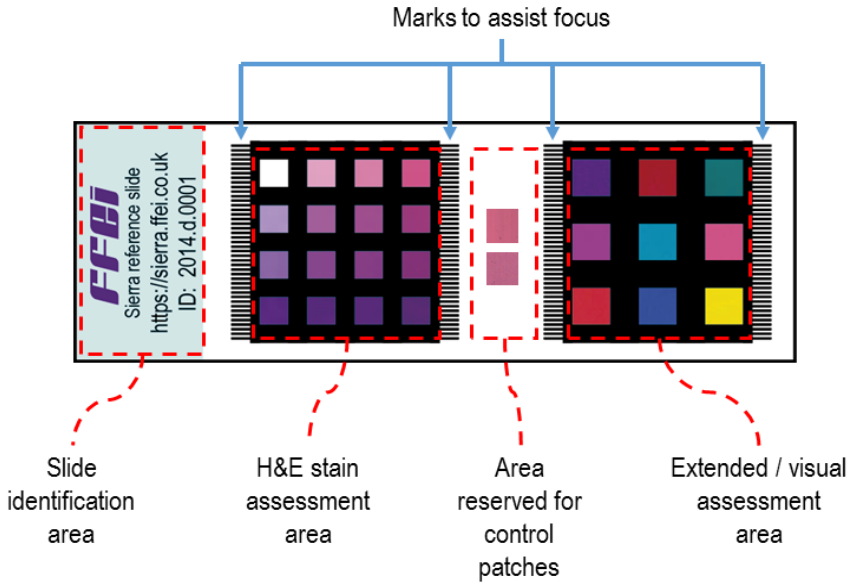






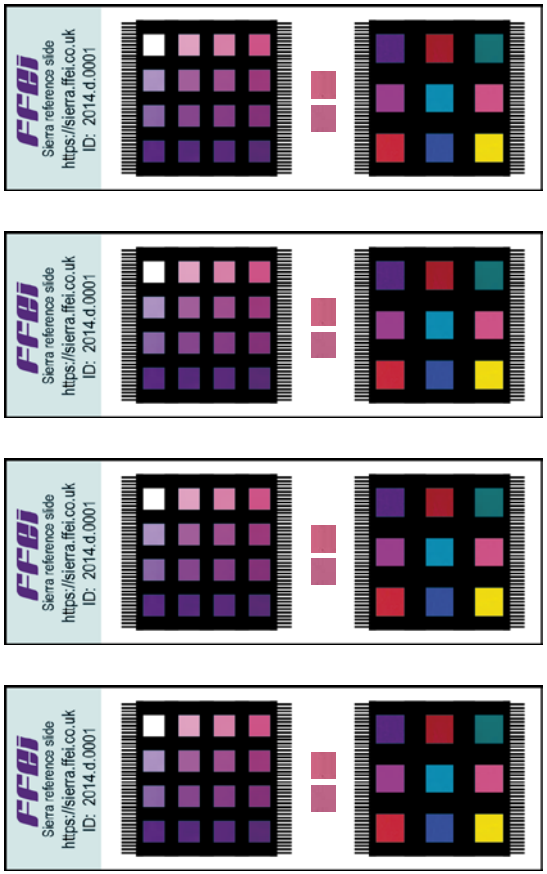
All presentations and audio recordings are available from www.color.org

Sierra calibration assessment slide



Slide comprises a number of patches of biopolymer stained using pathology stains to provide a good spectral match with colours typically viewed on digital microscope slides

Sierra: round-robin evaluation



Round-robin assessment planned to complete by end of 2014

Participants will:

- measure slide
- scan slide on calibrated scanner
- review stains and identify gaps
- provide feedback to the group

FFEI will measure the slide at start and end of the round-robin

Sierra: next steps

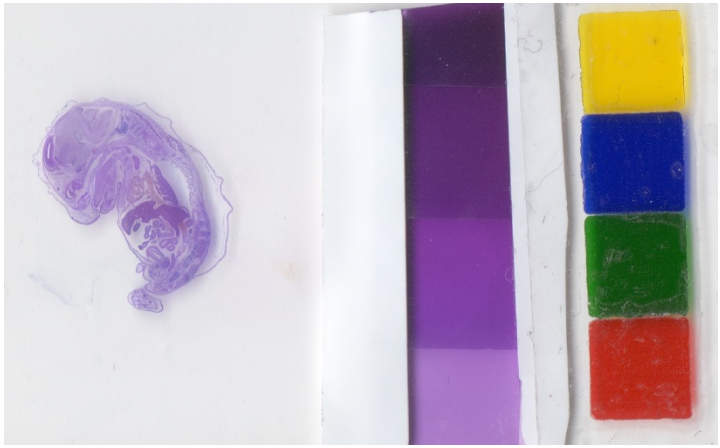
Project Sierra is a research project between FFEI Limited, Leeds Teaching Hospitals NHS Trust and University of Leeds funded primarily by FFEI Limited

We plan to build a second slide to be used to calibrate a digital microscope system using FFEI's biopolymer staining method

FFEI now invites participation in project Sierra to develop slide and supporting software and hardware and to develop a manufacturing process

Staining assessment: point of use QA

An embedded environment in the image that is responsive to all the processes applied to the image, from acquisition to display, and allows assessment of image quality at any time or point in the image life. For use on all mission critical images, x-ray, forensics etc.



Digital Pathology

X-ray

Discussion

Medical Imaging Working Group meeting
FDA interactive session

Medical RGB color space - mRGB (Michael Flynn / Albert Xthona)

June 20th 2014

US FDA - White Oak Conference Center

Goal of mRGB group

- Problem to be solved: “There is no suitable colour space and display calibration objective for medical imaging displays designed to display colour medical images”

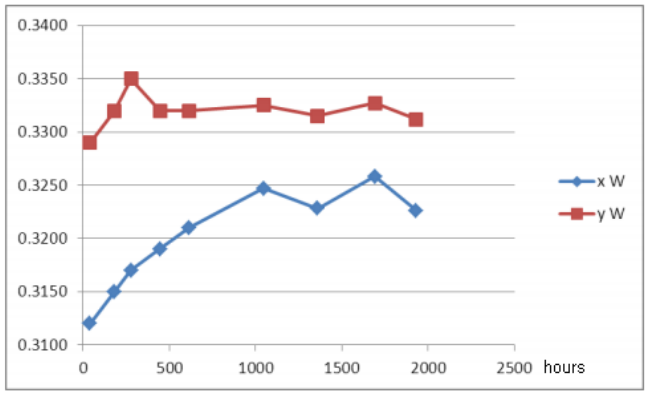
- Group activities
  - Educate
  - Standardize
  - Expose
  - Promote metrics

Educate

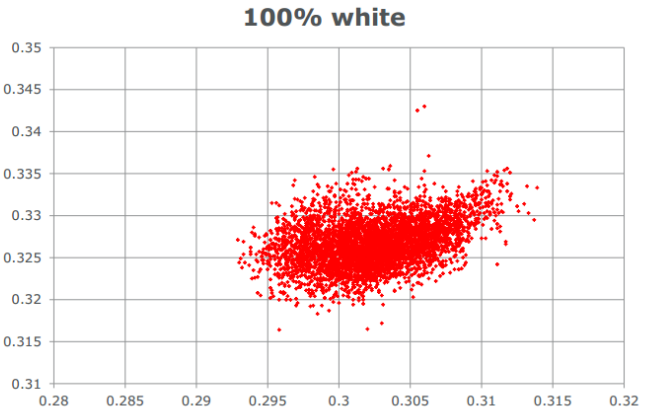
- Educate the community about inherent instability of color medical displays
  - Drift over time of displays (also colour behaviour)
  - Variability between types/brands and individual display units
  - Potential impact of variability/instabilities on clinical practice

- Eg. Results presented eg. at ICC/FDA summit on color in medical imaging and at other group meetings/conference calls

Color point stability of displays over time

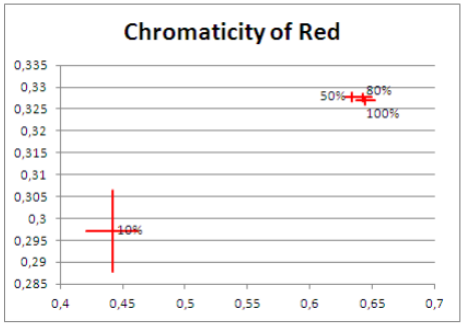


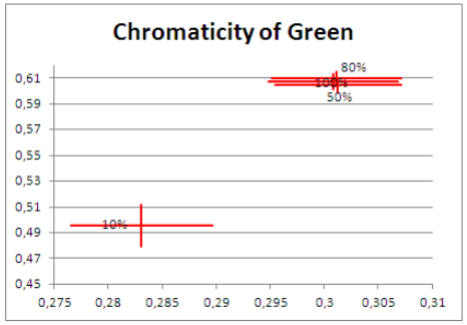
White point variation of color displays (1)

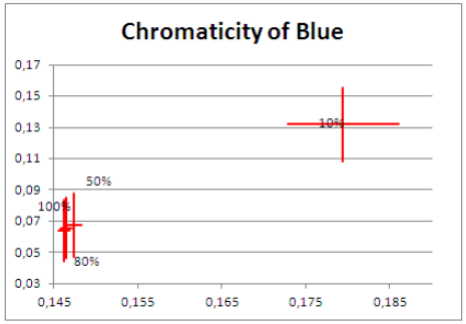


- (x,y)-coordinates of 4355 color displays during manufacturing measured with Minolta CA-210

Primary variation of color displays (1)







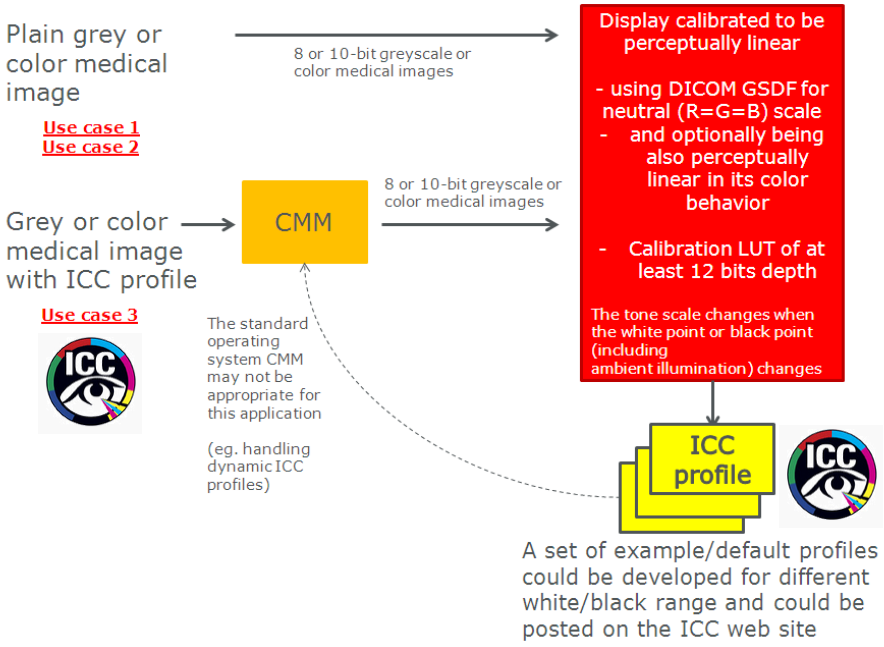
Standardize

- Standardize the visualization architecture and specifications for color medical visualization solutions

Color spaces compared — * IEC 62563 terminology

Specification*	sRGB	aRGB	ACR	mRGB
Luminance Response	~2.2 power function	2.199 power function	DICOM GSDF	DICOM GSDF
Color Gamut	HDTV based ITU-R BT.709-5	'Wide' (extended G)	-nd-	sRGB (aRGB option ?)
L_{max} , cd/m²	80	160 (125-200)	350/420/250	350/420/250
L_{min} , cd/m²	-nd-	0.56	L_{max} / LR	L_{max} / LR
Luminance Ratio (LR)	-nd-	287.9 (230-400)	350 (> 250)	350
White Point	D65	D65	D65	D65
Gray tracking	-nd-	-nd-	-nd-	IEC MT51
Surround	20% refl. Ix	Gray < 20% L_{max}	-nd-	20% L_{max}
Ambient Illumination, lx	64 (D50)	32	20-40	-nd-
Veiling Glare	1.0%	accounted	-nd-	-nd-
L_{amb} , cd/m²	-nd-	-nd-	$L_{amb} < L_{min}/4$	$L_{amb} < L_{min}/4$

AAPM TG196 http://www.color.org/groups/medical/Flynn.pdf



Expose

- Expose details of a suitable visualization architecture and corresponding specifications

- Provide a public reference implementation
  - Example ICC profiles
  - Sample application of how colour can be appropriately handled in medical imaging

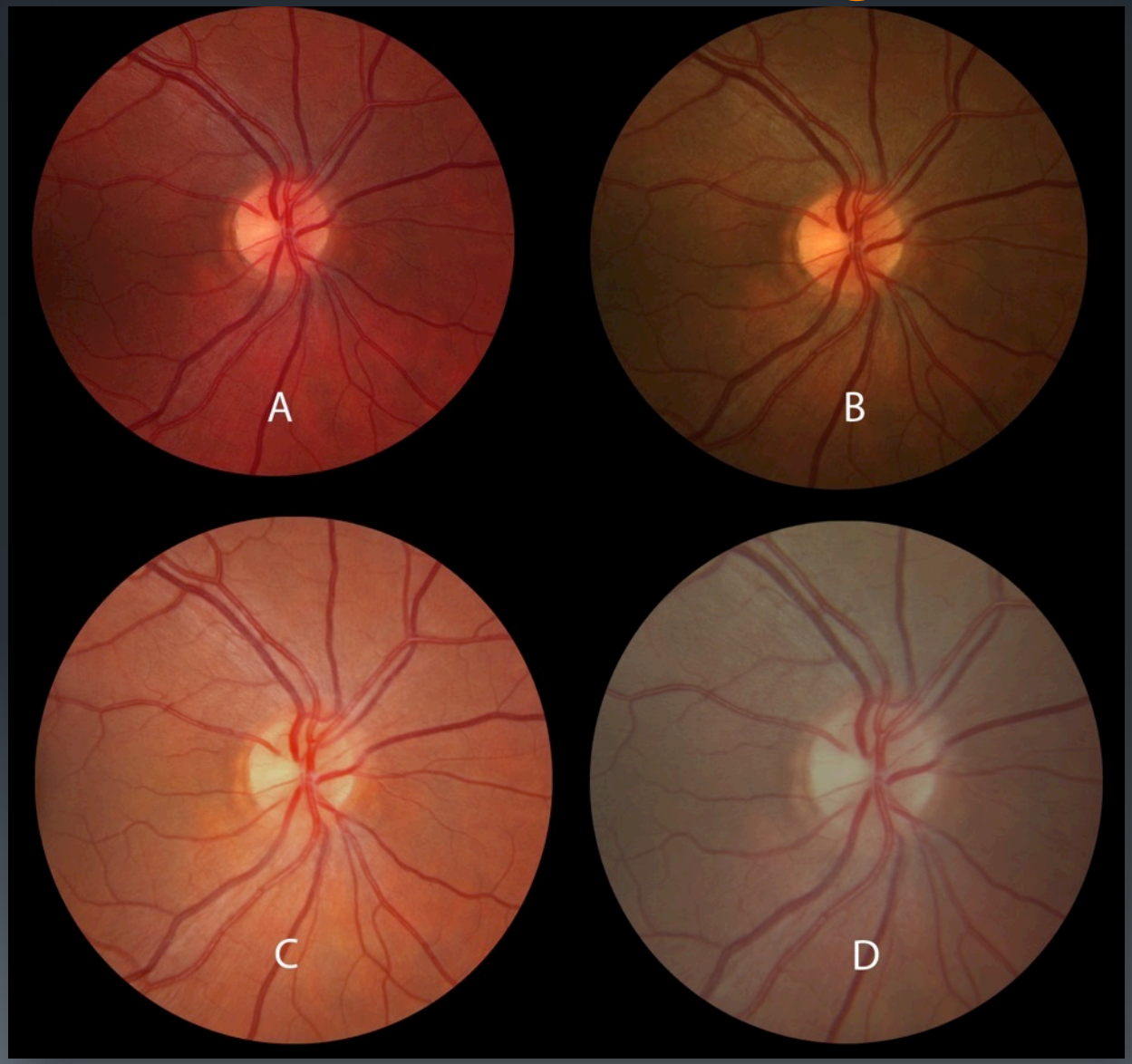
Promote

- Measurement methodologies & metrics
  - Primary stability
  - Perceptually Linear Color Behavior
  - Metrics for colour calibration accuracy
  - …

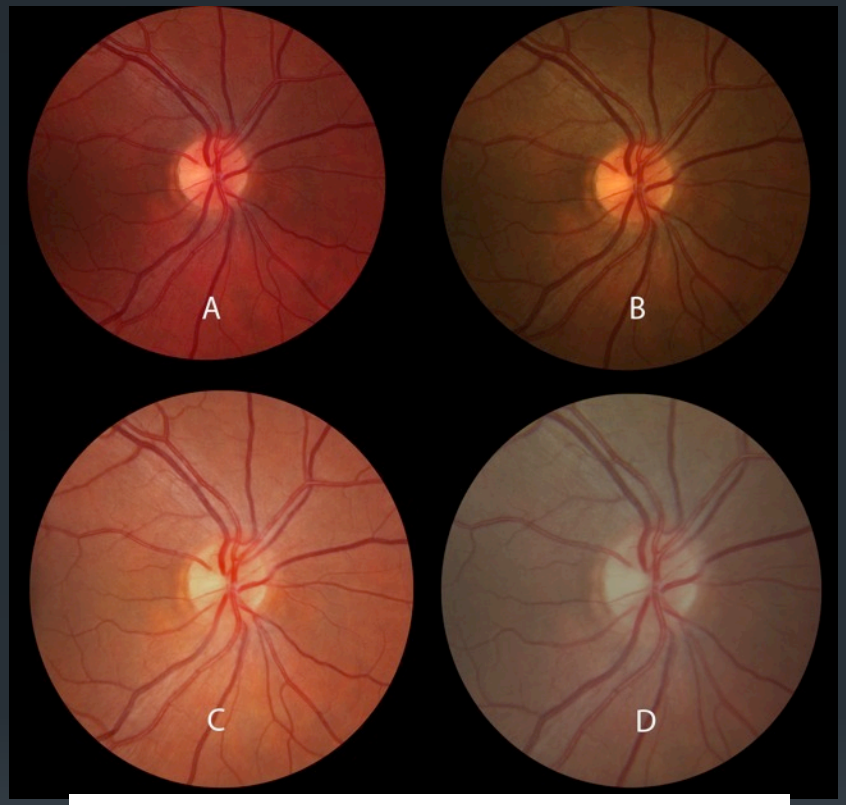
- Collaboration with other groups
  - AAPM TG 196
  - IEC MT51

International Electrotechnical Commission

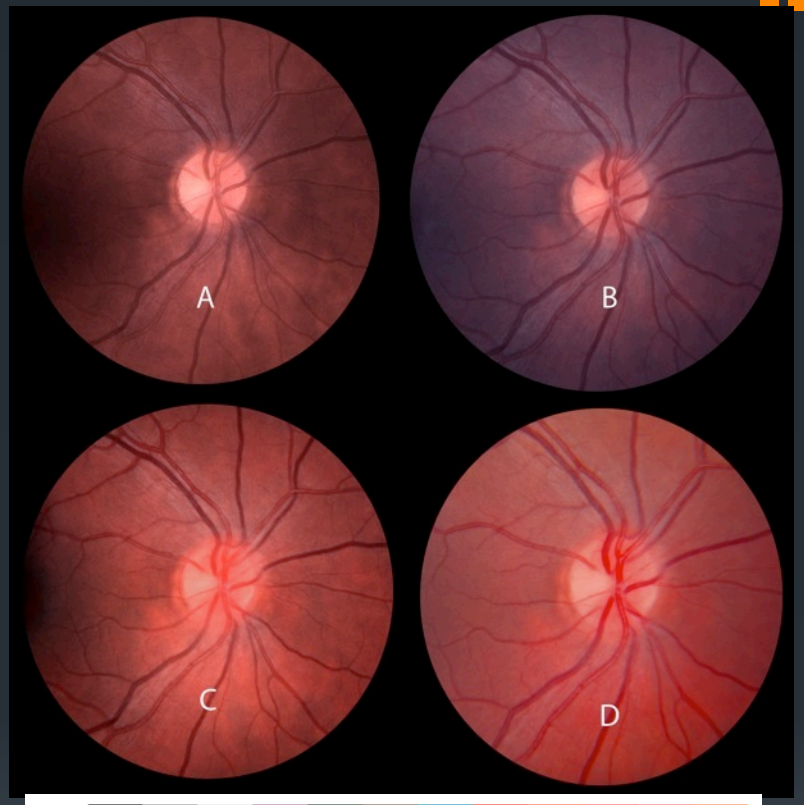
Camera Testing: Phase I

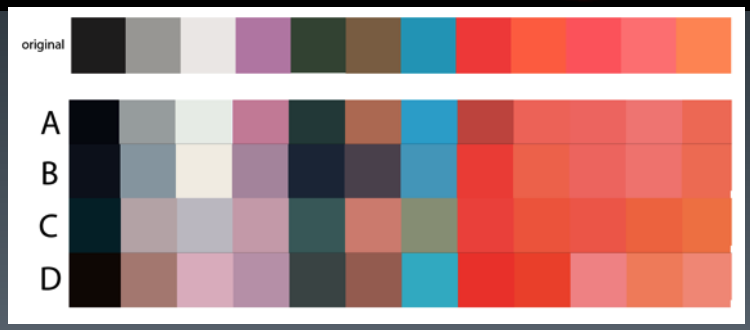


Captured vs. Processed



Before

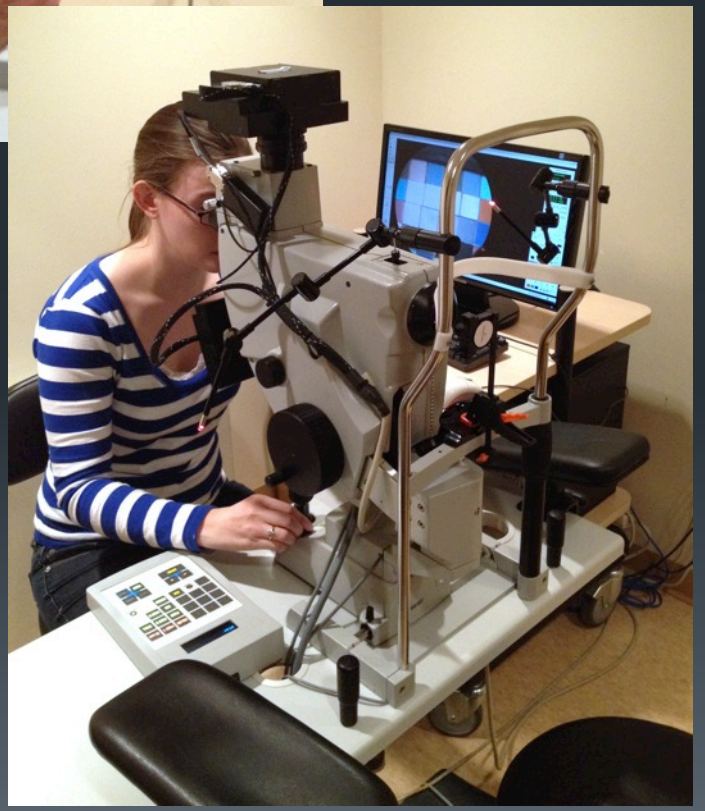


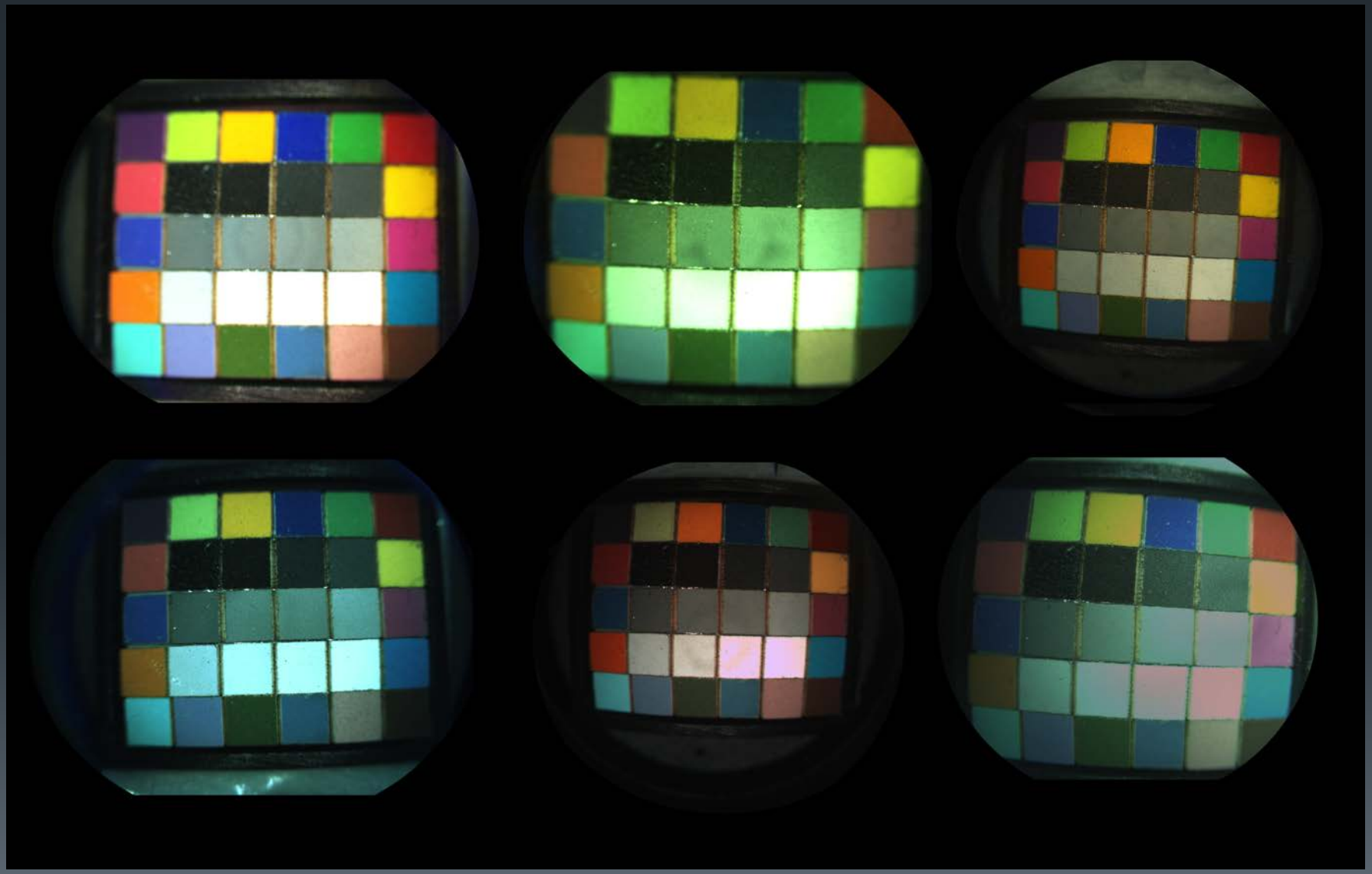


After

Protocol

- Inserted test target into model eye
- Chose “middle” angle of view
- Established proper alignment/working distance/focus
- Reduced/eliminate viewing illumination
- Captured at “normal” exposure, +/-





Color Model Eye: Phase III

- Modify model eye
  - Color patches to custom colors
  - Lower magnification aspheric lens
- Modify imaging protocol for angle of view and illumination considerations
- Extended camera testing at multiple sites
- Software implementation strategies
- Final feasibility report
  - Manufacturer vs. user implementation

Framework for Multispectral Imaging Application to digital pathology

Masahiro Yamaguchi, Tokyo Institute of Technology

Bas Hulsken, Phillips

Max Derhak, Onyx Graphics Inc.

Multispectral imaging in pathology

- Brightfield
  - Object detection, segmentation
  - Color unmixing – Stain amount image
  - Digital adjustment of staining strength
  - Digital staining

- Fluorescence

  # Molecular pathology
  - Simultaneous tests of multiple markers
  - Cross-talk, auto-fluorescence removal => Color unmixing
  - Combined brightfield and fluorescent images

Requirements from DICOM WG26

1. Display multi-spectral images as **true color** images.
2. **How to un-mix** multispectral input channels for deriving quantitative representations of individual biomarker intensities.
3. Display (un-mixed) multi-spectral images as **false color** images.

- Need to retain traceability

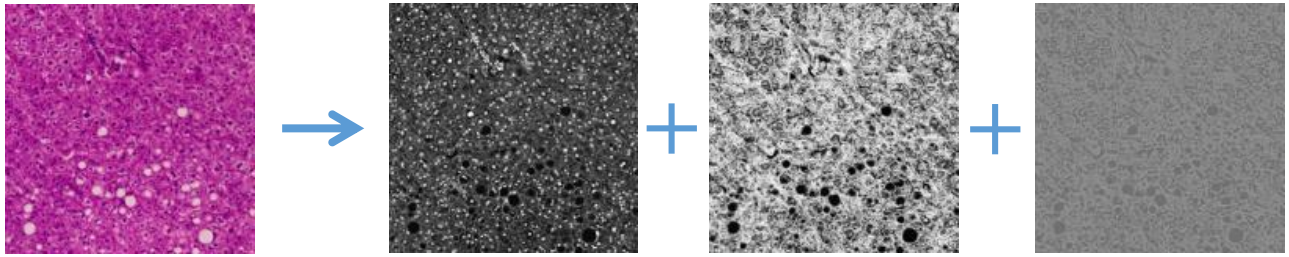
1&3: Color reproduction: ICC framework can make it!

2: Unmixing: Not the issue of color reproduction:

Can we adopt ICC framework?

Estimating dye amount image

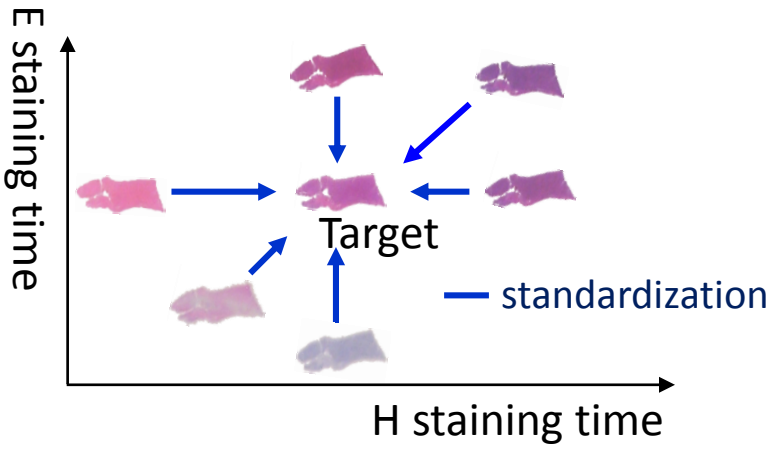
- Color unmixing
  - Estimation of dye amount image



HE stained image | H component -- nuclei | E component -- cytoplasm | Residual

Residual is not actual data

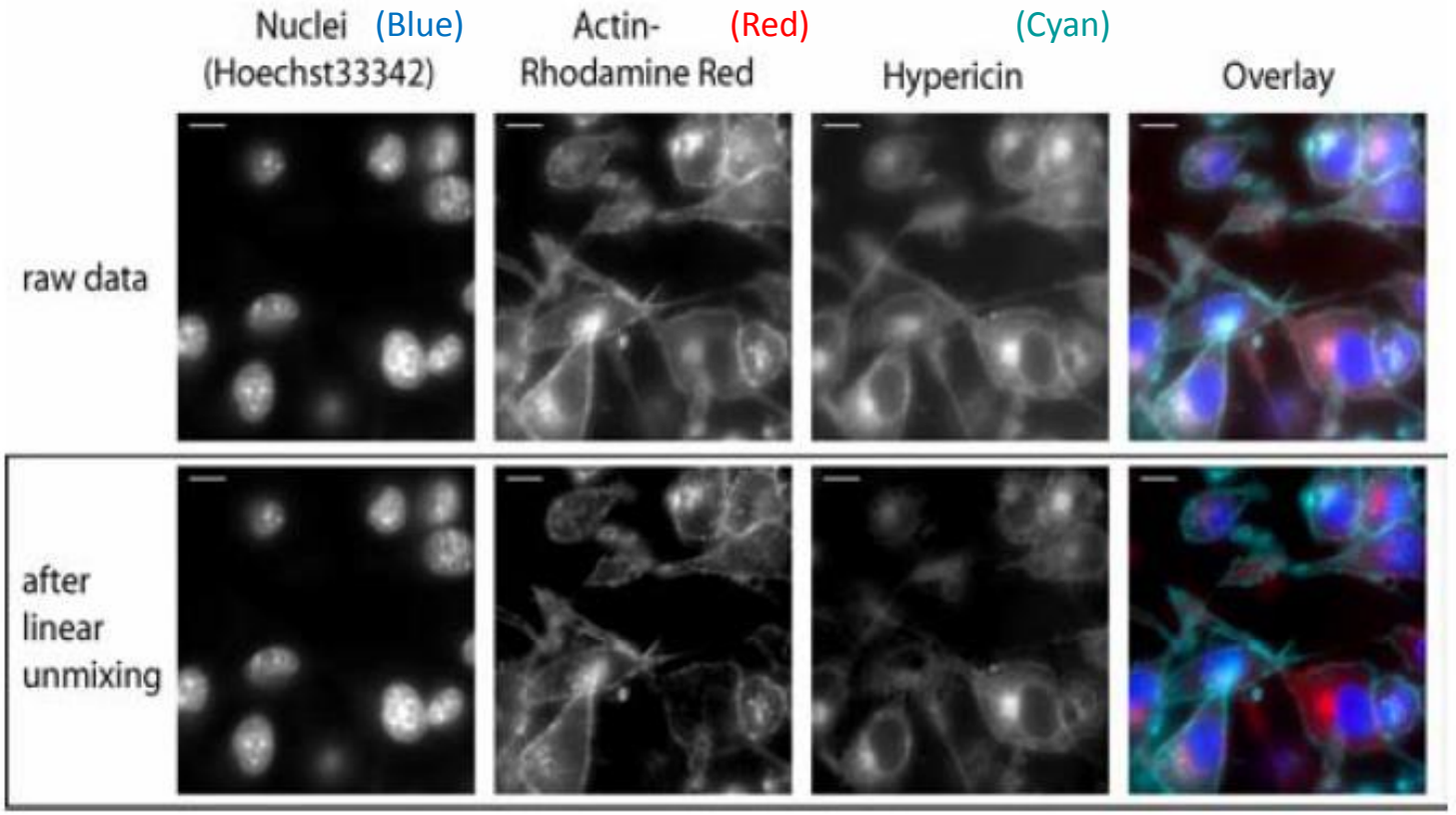
- Adjustment of staining strength
- Standardization of staining condition



K. Fujii, M. Yamaguchi, N. Ohyama, K. Mukai, "Development of support systems for pathology using spectral transmittance: the quantification method of stain conditions", Proc. SPIE 4684, 1516 (2002)

T. Abe, Y. Murakami, M. Yamaguchi, N. Ohyama, Y. Yagi “Color correction of pathological images based on dye amount quantification,” Opt. Rev., 12, (4), 293-300 (2005).

Color unmixing for unwanted fluorescence removal



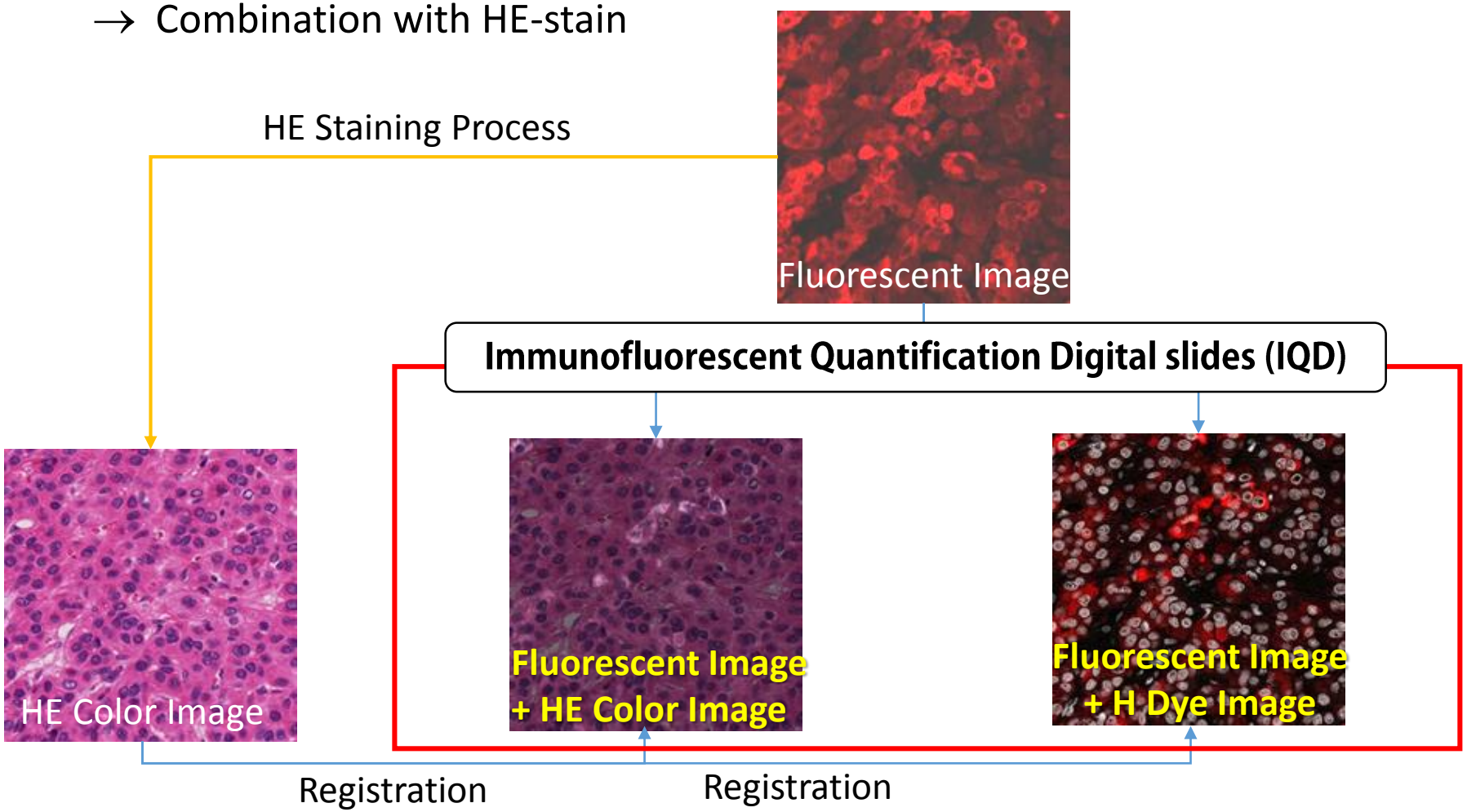
Modern Research and Educational Topics in Microscopy.
A. Méndez-Vilas and J. Díaz (Eds.)

Combination of Fluorescent and HE-stain

In quantification / semi-quantification of marker expression

Identification of tumor, tissue, nuclei, or membrane is needed

→ Combination with HE-stain



A. Hashiguchi et al 'Using immunofluorescent digital slide technology to quantify protein expression in archival paraffin-embedded tissue sections' *Pathol Int* 2010; 60: 720–5.

Solutions to color unmixing

- **Solution based on ICC v4**
  - Consider a virtual input device
    that can directly capture un-mixed biomarker images
  - Use DeviceLink profile:
    Connect Real device => Virtual device
  - Virtual Device Input Profile => Color rendering based on ICC

- **Solution based on ICC Labs**
  - RefICCLabs - - - ICC v5:
    Features suitable for multispectral
  - Proposal of "Material Connection Space" Profiles

Next step

- Consider adoption of ICC v4 keeping in mind the upper compatibility in v5.
- Documentation for implementation to DICOM.
- Investigate the advantage and feasibility of ICC v5 application.

Best Practices for Digital Color Photography in Medicine

John Penczek
NIST & Univ. Colorado, Boulder

Medical Photography

ICC Medical Imaging Working Group

June 20, 2014

Mission & Scope

Mission:

Collect industry best practices in the field of digital photography and write a guidance document which can be used by the medical industry to minimize the color errors created during the digital color camera image capture process.

Scope:

This guidance document will apply for a range of digital cameras (from cellphone cameras to scientific grade cameras) and lighting conditions. Recommendations will also be made for camera setup and color correction in post processing.

Contributors

John Penczek, NIST/Univ. of Colorado (project coordinator)

Yves Vander Haeghen, University of Ghent Hospital

Stein Olav Skrovseth, Norwegian Centre for Telemedicine

Elizabeth Krupinski, Arizona State University

Aldo Badano, FDA

Phil Green, ICC

Hong Wei, Datacolor

Draft Outline

Introduction and background
Penczek, Krupinski, Skrovseth

Factors that can contribute to color errors
Penczek, Krupinski

Recommended light conditions
Penczek, Krupinski

Recommended camera setup
Penczek, Krupinski, Skrovseth, Vander Haeghen

Use of reference color charts
Penczek, Vander Haeghen

Color correction in post-processing
Skrovseth, Vander Haeghen

Recommendations on color management
Green, Vander Haeghen

Note: Content should expand on or introduce new information to what is already available (e.g. ATA Practice Guidelines for Teledermatology 2007)

Color Accuracy in Image Workflow

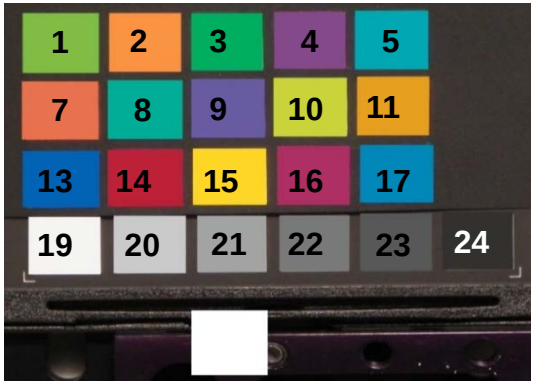
Color error can come from several sources in the color image workflow.

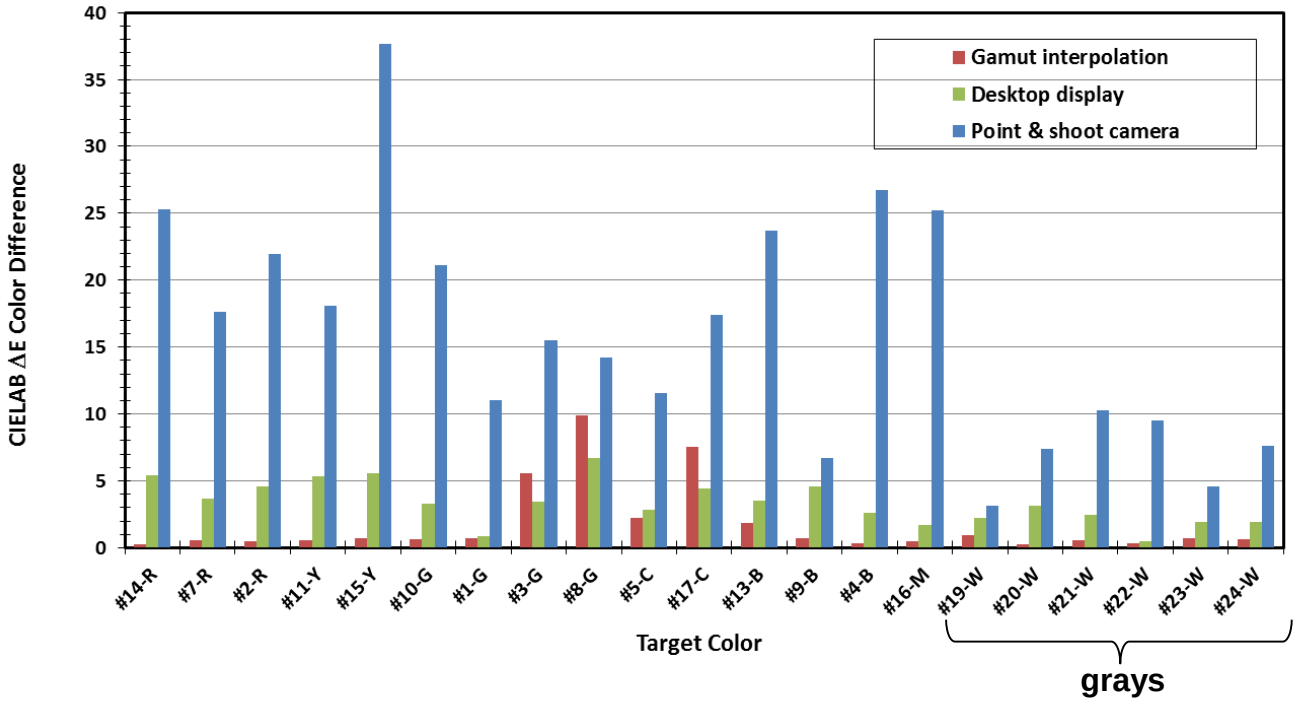
Object

Camera

Viewing Software

Display





Camera color error was determined to be dominant.

Data published at the Society of Information Display Symposium, June 2014

Draft Outline

Introduction and background
Penczek, Krupinski, Skrovseth

Factors that can contribute to color errors
Penczek, Krupinski, Vander Haeghen

Recommended light conditions
Penczek, Krupinski

Recommended camera setup
Penczek, Krupinski, Skrovseth, Vander Haeghen

Use of reference color charts
Penczek, Vander Haeghen

Color correction in post-processing
Skrovseth, Vander Haeghen

Recommendations on color management
Green, Vander Haeghen

Camera Color Accuracy Studies

Some studies were conducted to identify the critical parameters that contribute to camera color error.

Camera

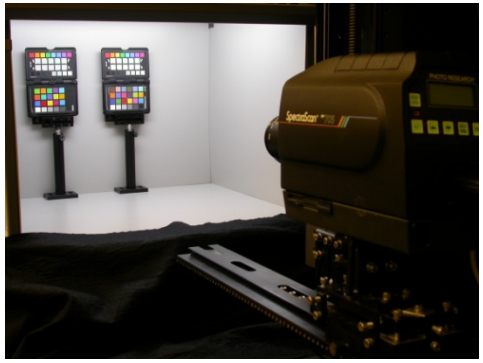
Camera image data

RGB → CIE XYZ @ sRGB → External correction → **Perceived color** CIE LAB → ΔE Color Difference

Dependencies

- Lighting color
- Lighting uniformity
- Camera quality
- Camera cal
- White balance
- Camera exposure
- Calibration target
- Correction software
- Reference sample
- Reference geometry
- Reference cal data

Spectroradiometer



- Lighting color
- Instrument cal
- Stray light

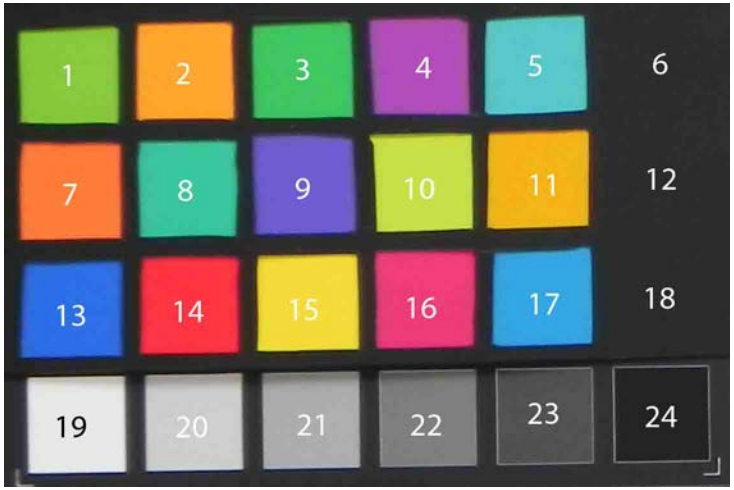
Spectra → CIE XYZ @ sRGB → CIE LAB

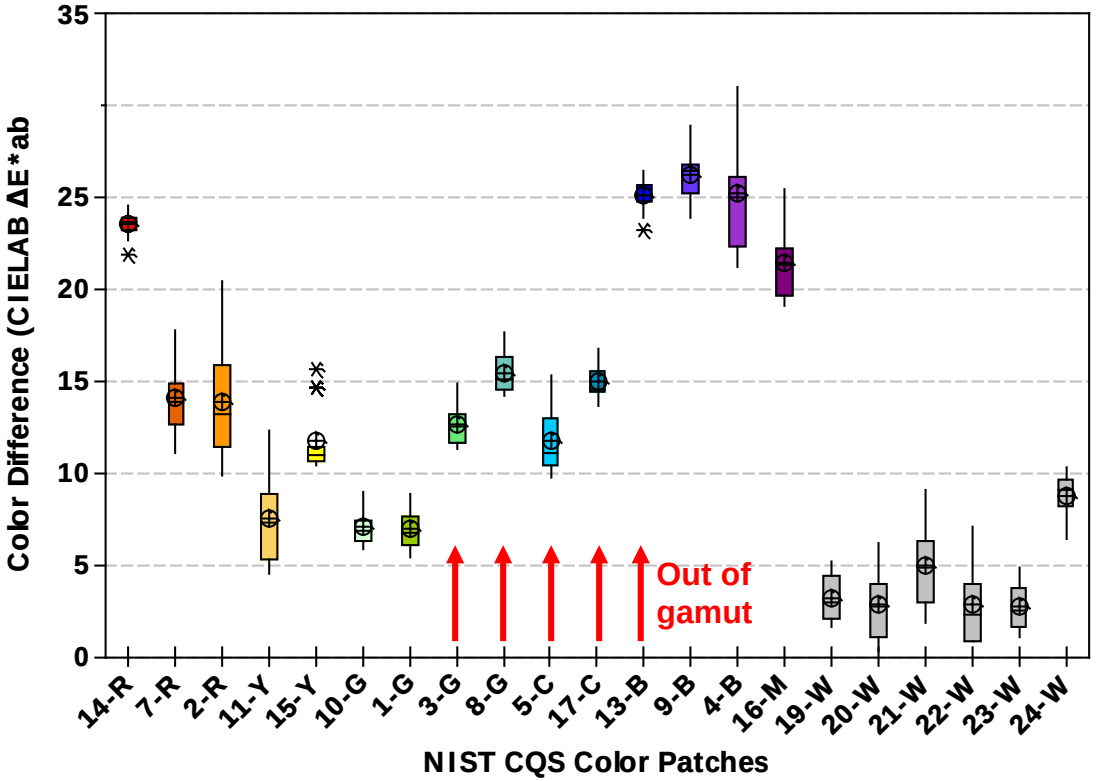
Spectroradiometer data

Camera Color Error Dependence on Color

Image color error of the NIST CQS color target using a mid-priced point & shoot camera under daylight fluorescent lighting conditions.

NIST CQS Color Chart



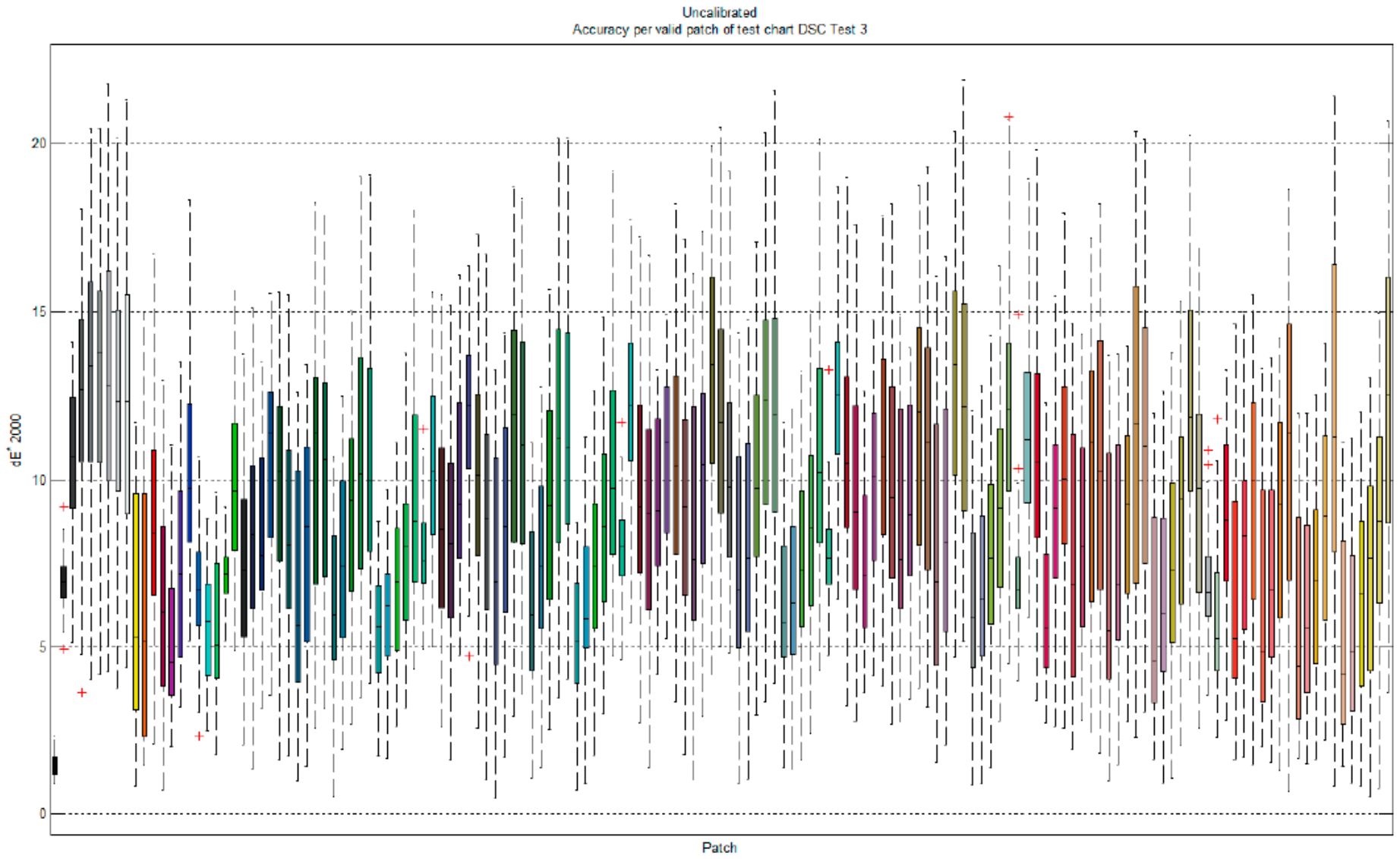


A color difference of CIELAB ΔE^*_{ab}= 1 is considered a just noticeable difference (JND). Color difference is calculated relative to spectroradiometer data.

Color code: R=red, Y=yellow, G=green, C=cyan, B=blue, M=magenta, W=white and gray

J. Penczek, P.A. Boynton, J.D. Splett, "Color error in the digital camera image capture process," J. Digital Imaging, 27, p182-191 (2013).

Color Accuracy Data from Univ. of Ghent



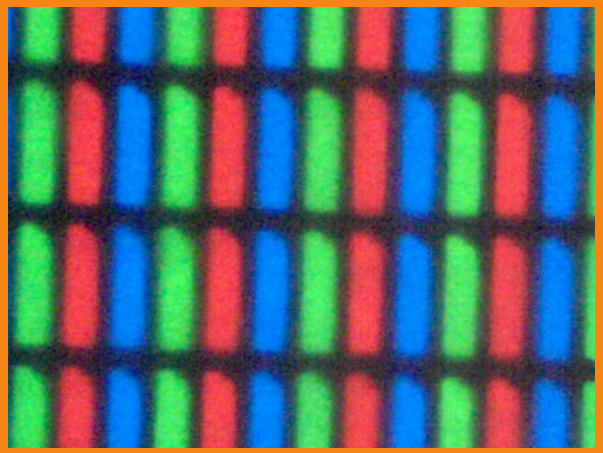
Unpublished data from Yves Vander Haeghen entitled "Pragmatic color calibration", June, 2014.

Status

- Compiling camera color accuracy data to estimate magnitude of problem
- Identifying dominant factors that can contribute to camera color errors
- Initial recommendations developed for camera setup
- Measured relative improvements in various calibration color charts
- Evaluating various color correction methods
- Datacolor is developing a general camera calibration procedure
- Further discussions needed on color management

MOBILE FOR MEDICAL

DISPLAY CALIBRATION STATUS



x-rite
PANTONE®

INTRODUCTION

- **Practitioners use mobile devices (tablets, phones) for a wide range of functions including**
  - Access to patient records
  - Ordering procedures
  - Viewing medical images from numerous imaging modalities for a variety of purposes
  - Making graphical record with tablet and phone camera features
- **Mobile devices are ubiquitous and their use will continue to grow due to**
  - Cost
  - Portability
  - Convenience
  - UI
  - Use paradigm carry-over from other applications
- **Better to be ready to embrace this technology**

STATUS

- **Two WG sessions were held since the May 2013 FDA/ICC Colour Summit – slides from both sessions available at *color.org***
  1. *Display calibration challenges* – Vancouver November 2013
     - Problems statement from perspective of display engineers, not users or practitioners
     - Discussions of architectures with comparison to work-station and server based solutions
     - Suggestions for next steps including solicitation of needs from user community
     - Little response
  2. *MIWG Web Meeting* – April, 2014
     - Presented X-Rite *ColorTrue* solution and offered platform for solution prototyping and evaluation
     - Solicited additional solutions from other suppliers
     - Repeated solicitation for user need analysis
     - Little response

PROBLEMS STATEMENTS

- **Mobile display devices vary significantly with regard to**
  - Image quality
  - Color rendering characteristics
  - Dynamic behaviors (ambient adjustments, DCC, power savings)
- **No standard color image data processing pipeline across mobile devices**
- **Display and platform technology changes rapidly**
  - Engineering trade offs do not always favor image and color quality and consistency
  - Especially true for mass production – non specialty displays
- **No standard target color rendering condition defined for display modalities used in medical applications**
- **The result:**
  - The same digital data displays differently on different devices
  - Image and color quality is poorly defined and controlled

ISSUES AND NEXT STEPS

- **Determine requirements**
  - Taxonomy of uses cases
  - Reproduction Aims
  - Calibration enough?
    - Calibration and characterization both needed?
  - Ambient/stray light compensation required?
  - Dynamic controls to be defeated?
- **Quantify “out of box” mobile display variability**
- **Determine architecture**
  - Server based
  - Client based
  - In-app
  - In-OS
- **Interested parties**
  - Contact amasia@xrite.com

DISCUSSION

UNIVERSITY OF LIVERPOOL

Skin colour measurement and reproduction

Kaida Xiao

University of Liverpool

ICC MIWG Meeting, FDA

Outline

UNIVERSITY OF LIVERPOOL

- Introduction
- Skin colour measurement
- Skin colour database
- Skin colour reproduction

UNIVERSITY OF LIVERPOOL

Automated rapid manufacture of facial soft tissue prostheses

The University Of Sheffield.

2010-2013

fripp design ltd

Measuring and reproducing the 3D appearance of human facial skin under varying illumination condition:

A 3D Imaging System for Human Facial Skin

2013.10 - 2016.9

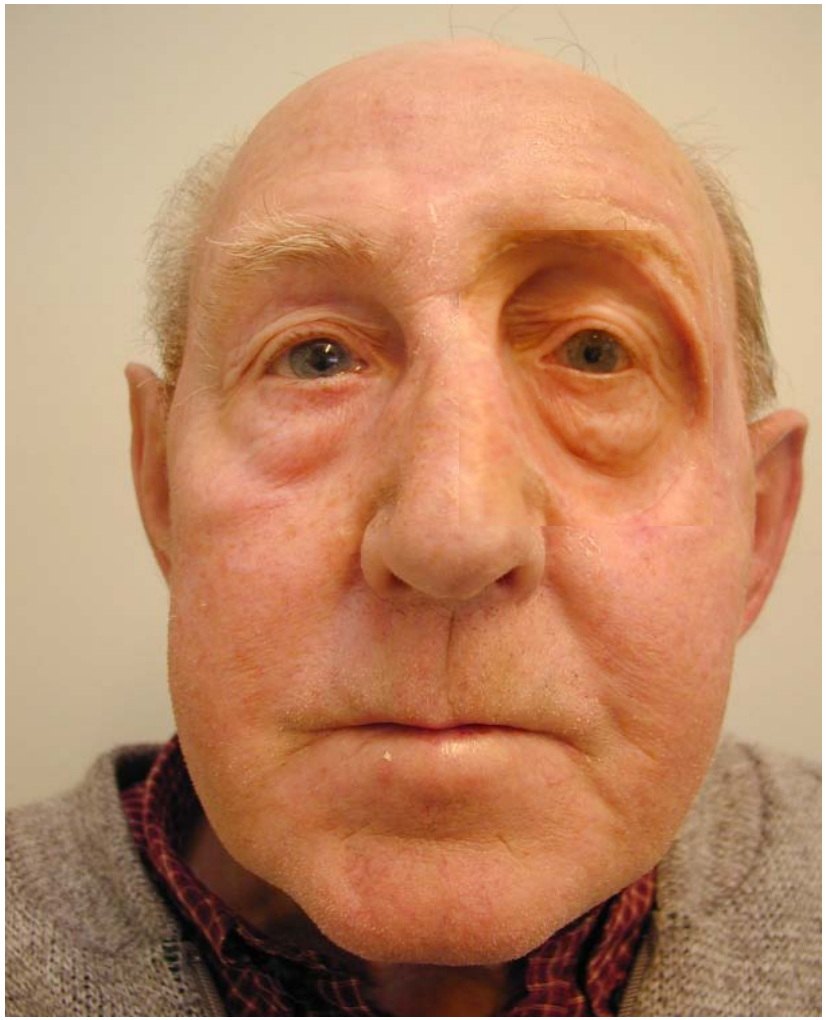
EPSRC
Engineering and Physical Sciences Research Council

UNIVERSITY OF LIVERPOOL

MANCHESTER 1824
The University of Manchester

ROYAL ACADEMY OF ENGINEERING

Introduction



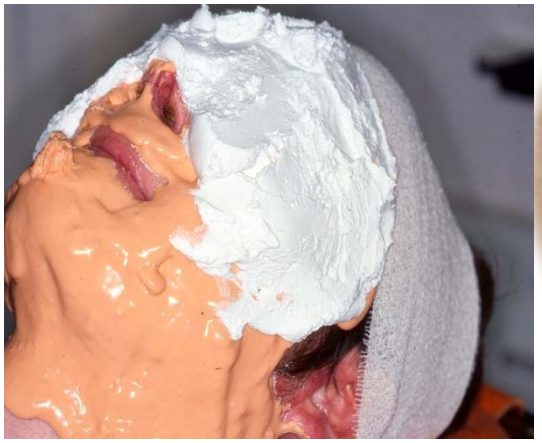
Soft Tissue Prostheses

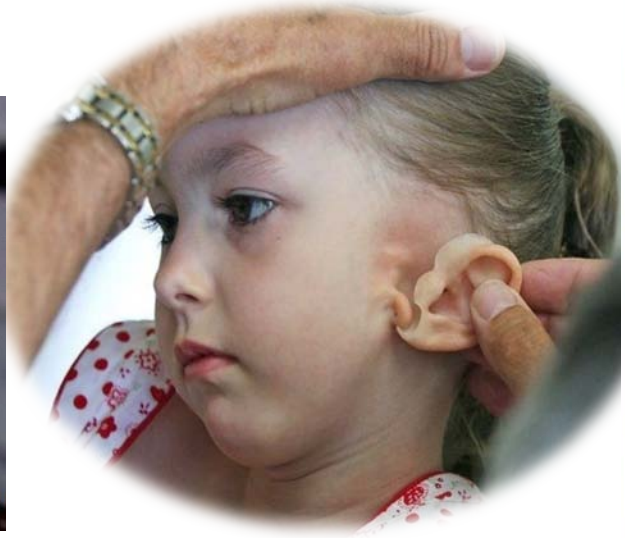
Automated additive manufacture of facial soft tissue prostheses

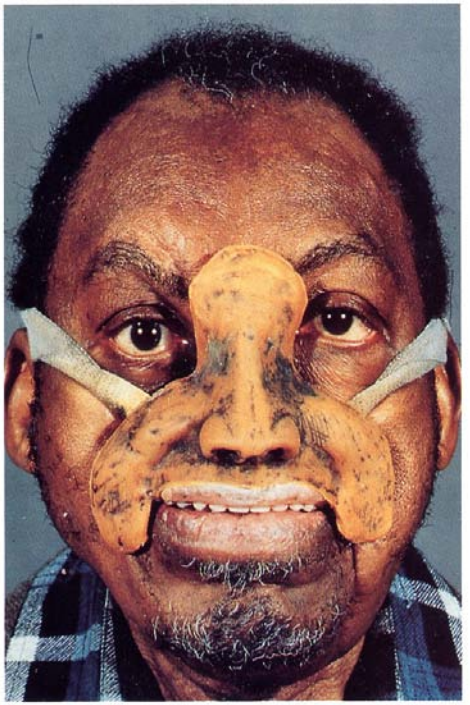
UNIVERSITY OF LIVERPOOL

Conventional methods of facial prostheses

- Impression technique and Impression materials
- High technical skill
- High cost and long processing time
- No assess in world wide



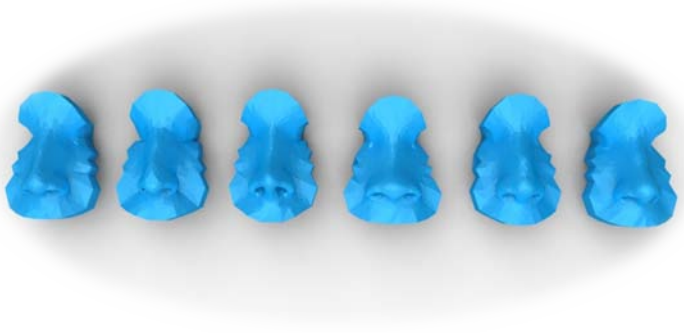




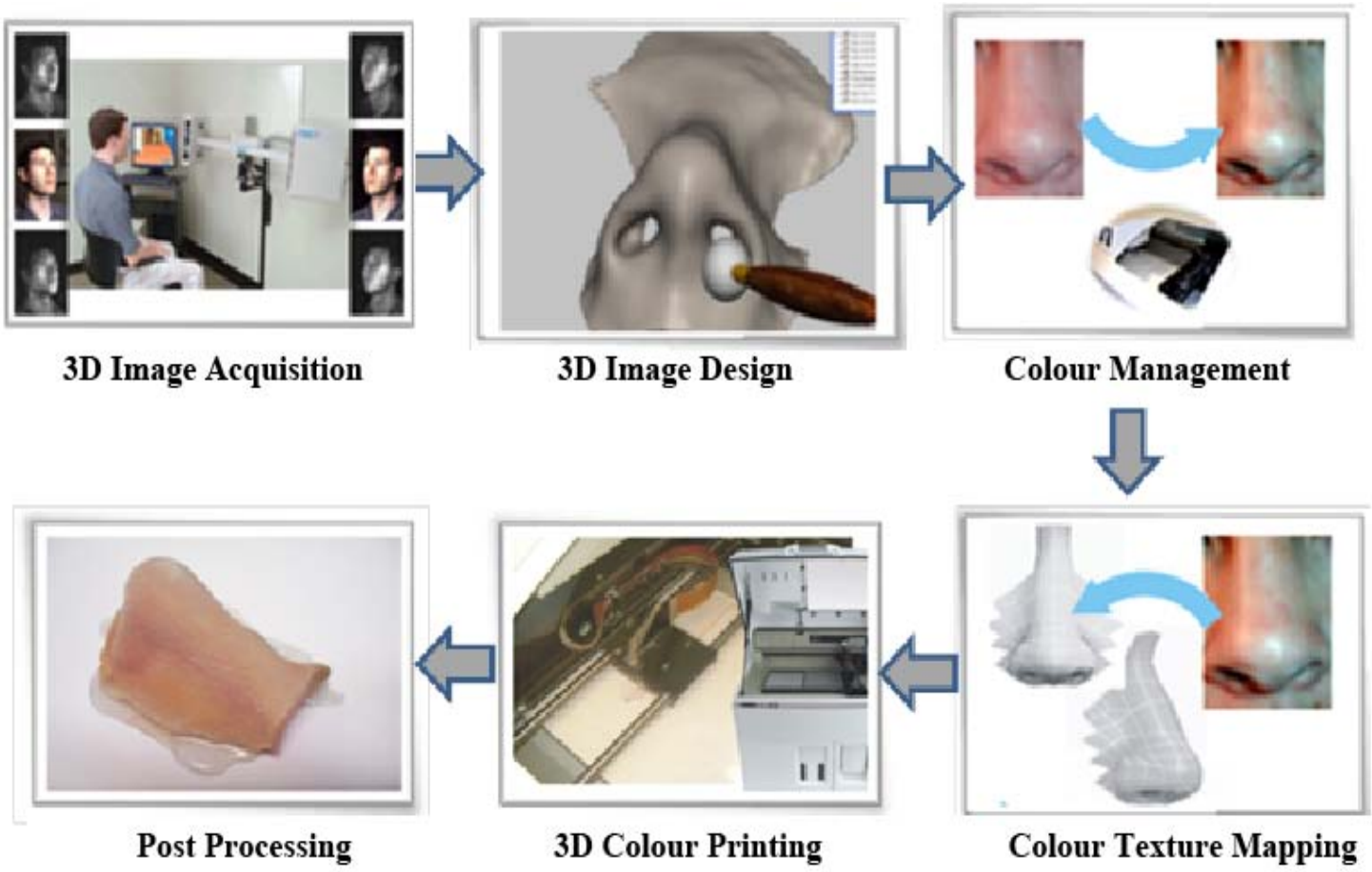
UNIVERSITY OF LIVERPOOL

Advanced Methods of Facial Prostheses

- Non-contact measurement
- Additive manufacturing (3D Printing)
- Automatic processing
- Accurate skin colour reproduction
- Saving time and cost



Frame work



Advanced Method of Facial Prostheses

Application of Skin Colour Database

UNIVERSITY OF LIVERPOOL

Research Fields	Applications	Data Format
Computer Graphic	colour reproduction	LAB, Reflectance
Cosmetic	Colour Foundation	LAB, Reflectance
Medical	Facial Prosthesis	LAB, Reflectance
Medical	Plastic Surgery	LAB, Reflectance
Medical	Skin Disease Diagnose	Melanin and Erythema index
Computer Vision	Face Detection	Ycbcr
Lighting	Colour rendering	LAB, Reflectance

Skin colour database

UNIVERSITY OF LIVERPOOL

- Skin colour database are required for multi-disciplinary research.
- Skin colour variation for individuals is know to be significant.
- None of the presently available skin colour databases is comprehensive.
- Existing skin colour databases are not comparable.

UNIVERSITY OF LIVERPOOL

CIE TC1.92 Skin colour database

- **Year Established:** 2013

- **Terms of Reference:**

1. To investigate the uncertainty in skin color measurement and to recommend protocols for good measurement practice.

2. To tabulate skin color measurements that accord with these protocols covering different ethnicity, gender, age and body location.

UNIVERSITY OF LIVERPOOL

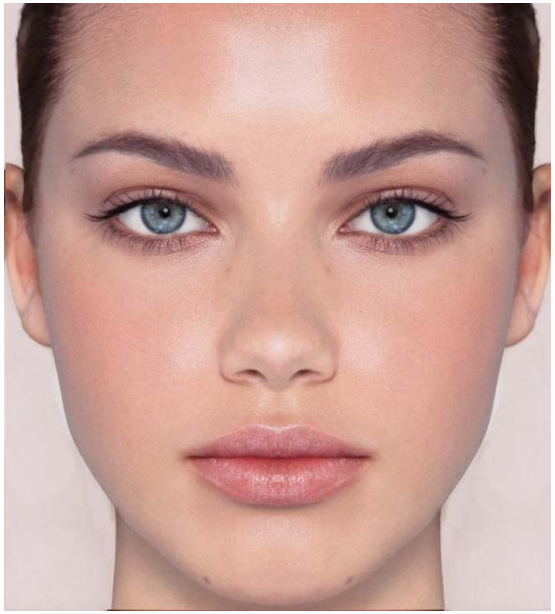
Skin colour data

Spectral reflectance

Skin measurement methods

- Spectrophotometer measurement
- Spectroradiometer measurement
- Digital camera measurement

Human Skin Colour



Non-uniform

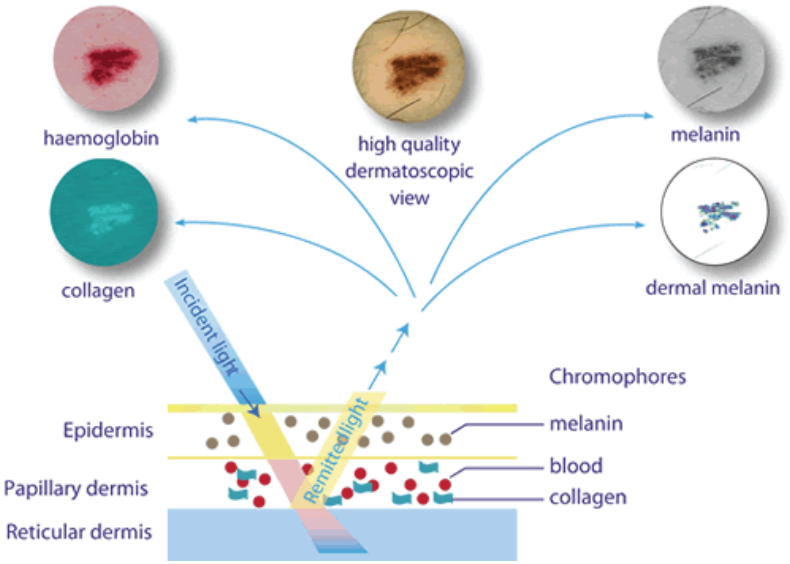
Non-flat

Un-stable

Small Colour Gamut

Similar shape of colour spectrum

Complicated structure



Spectrophotometer Measurement

The spectral reflectance can be measured directly using an instrument with a built in light source.

Konia Minolta CM-700d

- Easy to handle
- Built in illumination
- Easy to control measurement angle

Uncertainty:

Effect of measurement pressure
Effect of measurement size

Applications:

Medicine, Dentistry, Cosmetic

UNIVERSITY OF LIVERPOOL

Spectroradiometer Measurement

The spectral power distribution (SPD) of skin under a defined lighting system is measured. The spectral reflectance of skin is calculated based on the SPD of the light source and that of the skin sample.

Photoresearch PR 650

ChromaSphere by L'Oreal

Non-contact measurement
Measurement under light source applied

Uncertainty:

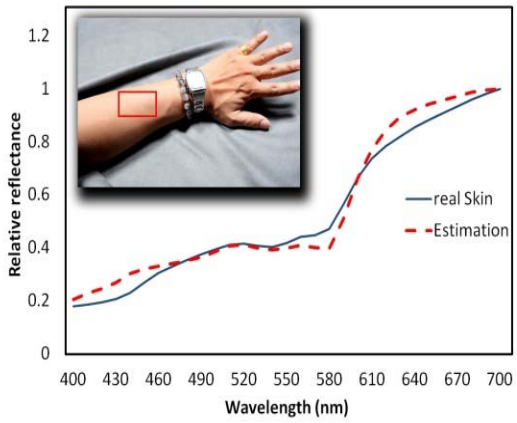
- Smoothness of lighting system
- Effect of measurement size
- Effect of measurement angle (Shadow effect)

Application:

Computer Graphic, Lighting, Cosmetic

Camera Measurement

Camera RGB of skin under a defined lighting system is obtained and transformed to skin reflectance using reflectance re-construction algorithm.



Non-contact measurement
Measurement under light source applied
Fine detail of skin image

Uncertainty:

- Smoothness of lighting system
- Accuracy of colour transform algorithm

Application:

Computer Graphic

UNIVERSITY OF LIVERPOOL

Advantages of camera measurement

- Small measurement size
- Calibration for lighting and measurement angle
- Easy to evaluate system accuracy
- Low cost

Skin Colour Database

UNIVERSITY OF LIVERPOOL

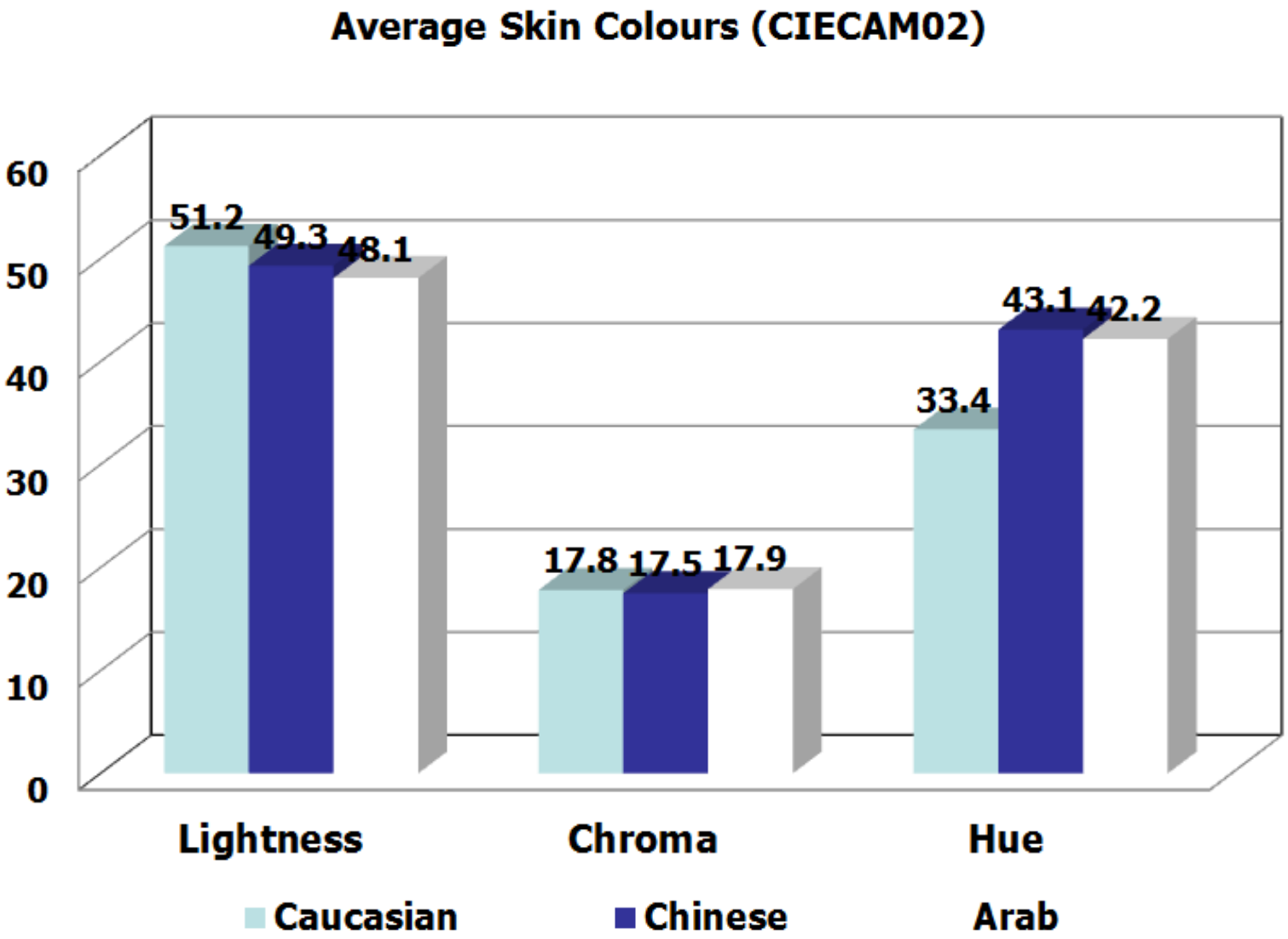
634 Subjects in 9 body areas

Caucasians	Chinese	Arabs	Asians	Africans
173	234	161	34	32

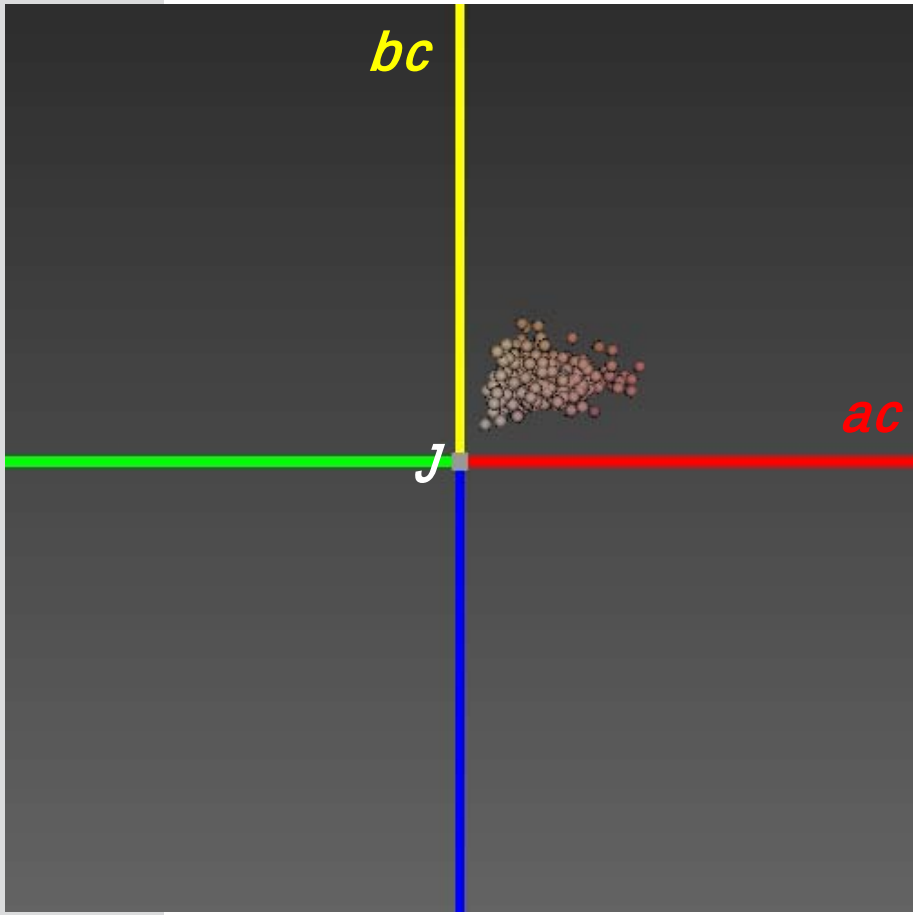
Data: CIELAB values and Spectral Reflectance

Location: UK, China, Iraq, Thailand

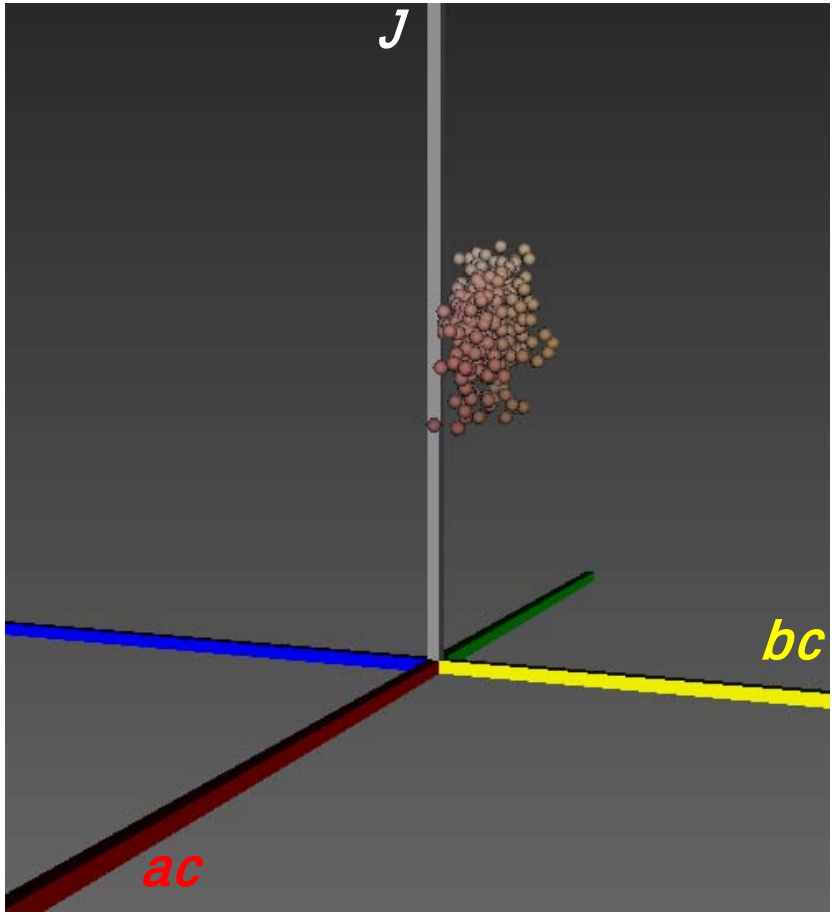
Difference in Ethnic Groups



Caucasian skin gamut



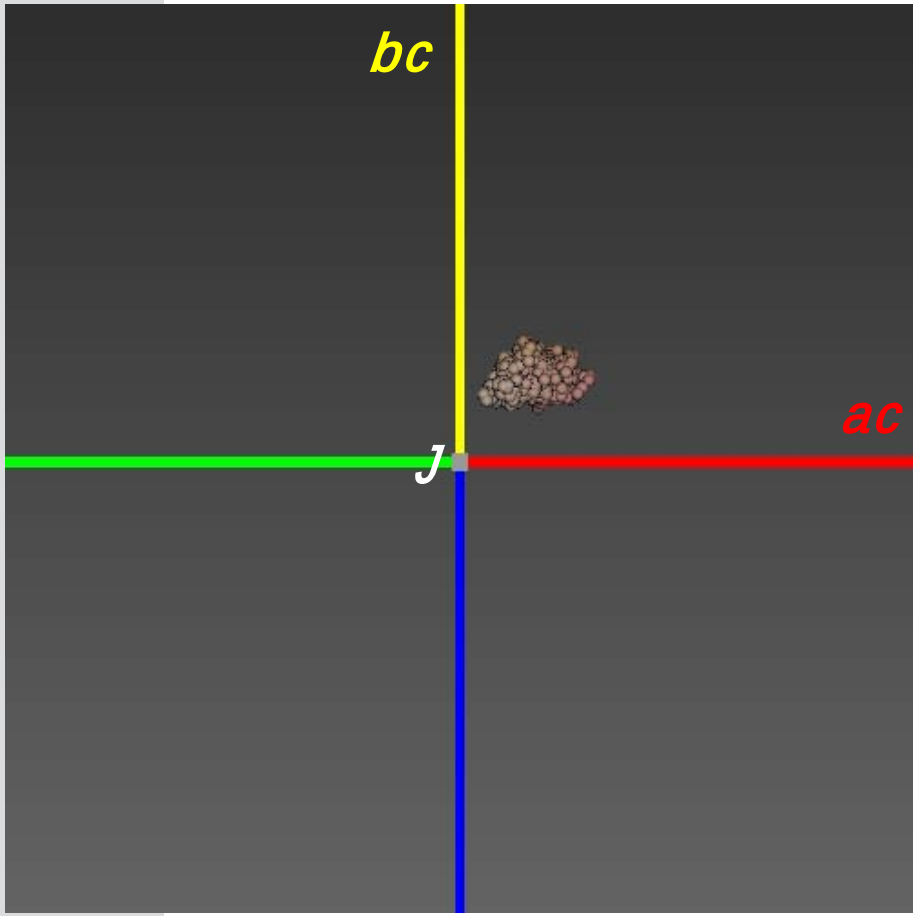
CIECAM02 -Top View



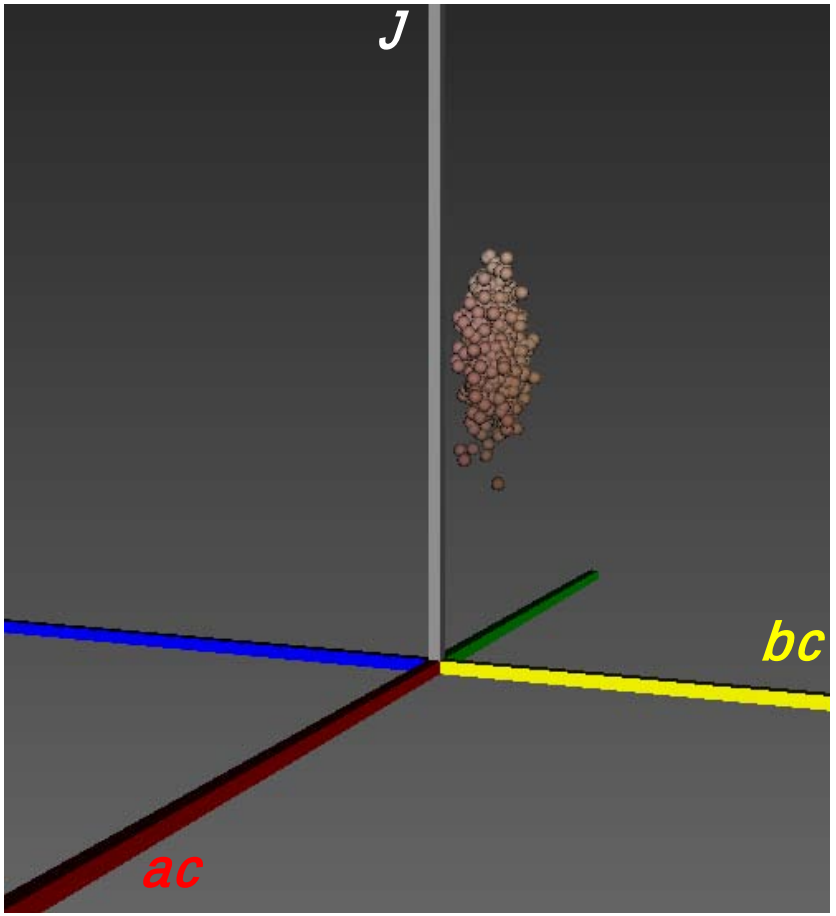
CIECAM02- Side View

Chinese skin gamut

UNIVERSITY OF LIVERPOOL

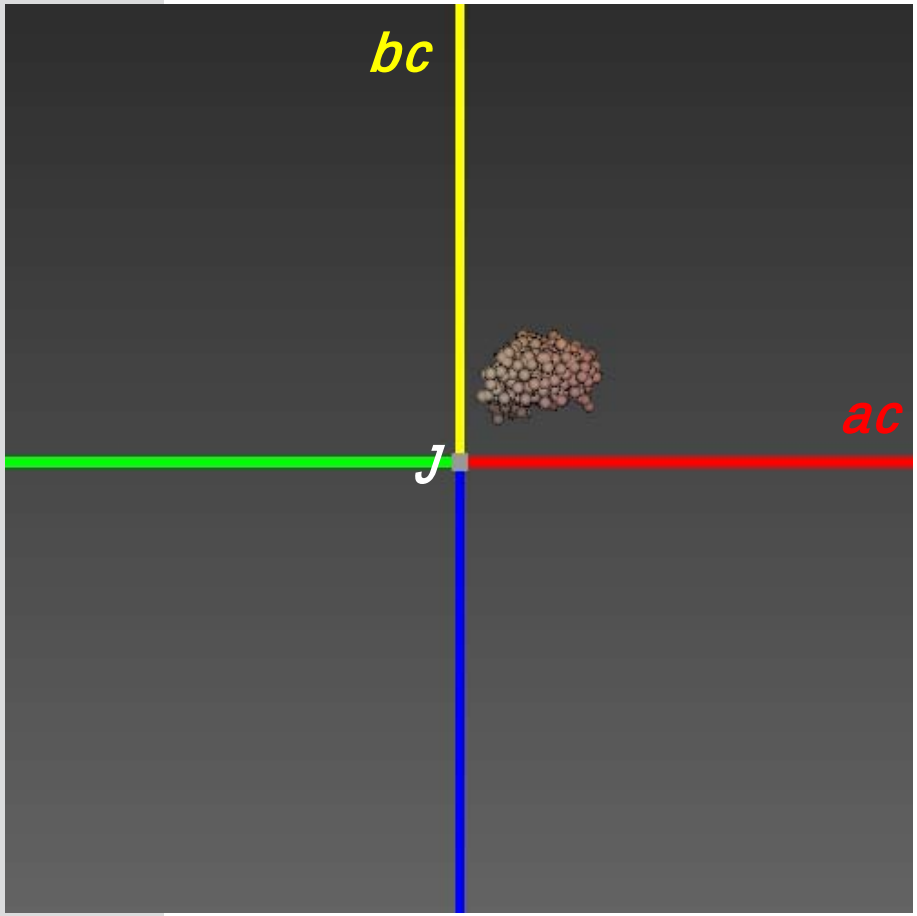


CIECAM02 -Top View

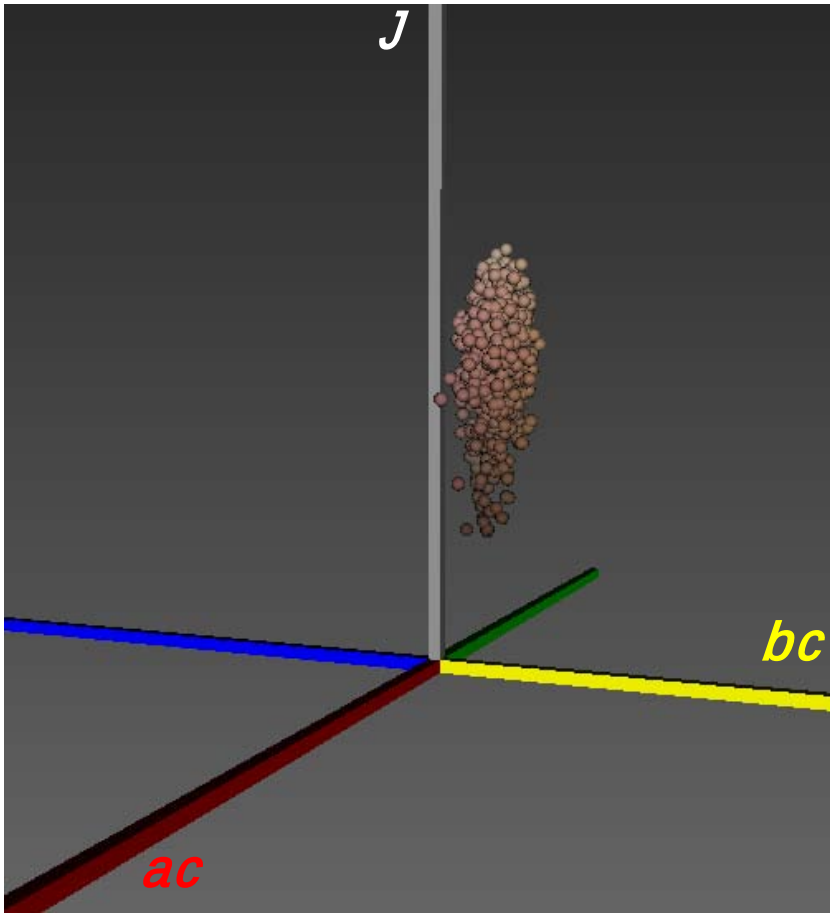


CIECAM02- Side View

Arabs (Iraqi) skin gamut

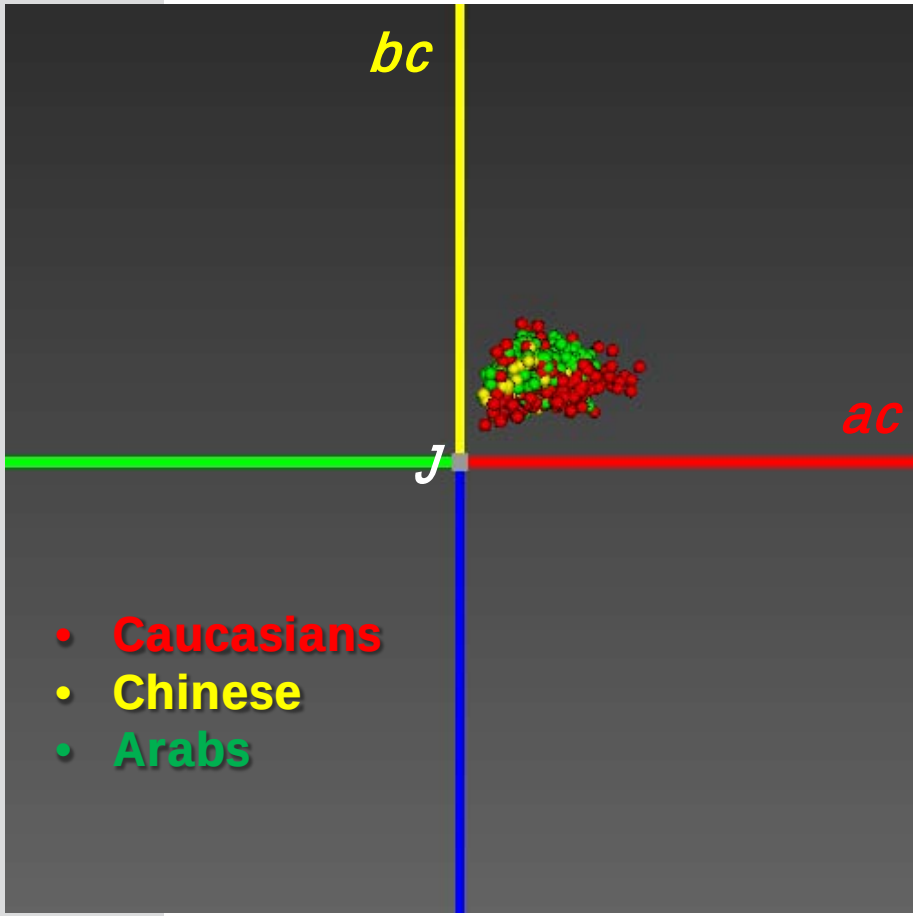


CIECAM02 -Top View

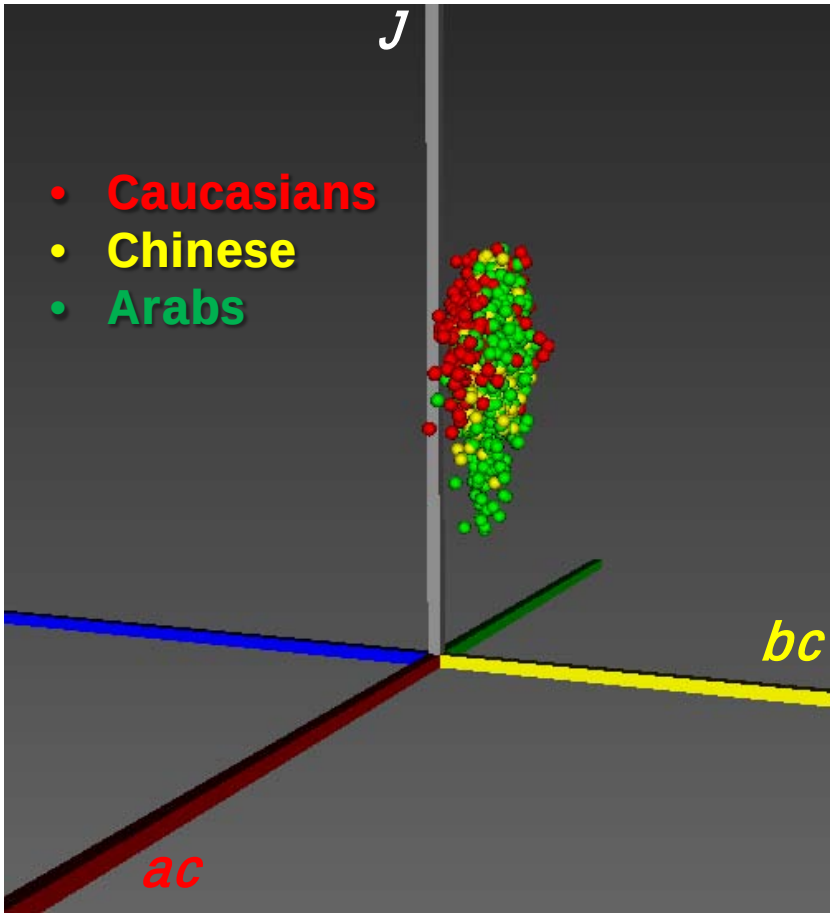


CIECAM02- Side View

All skin colour gamut

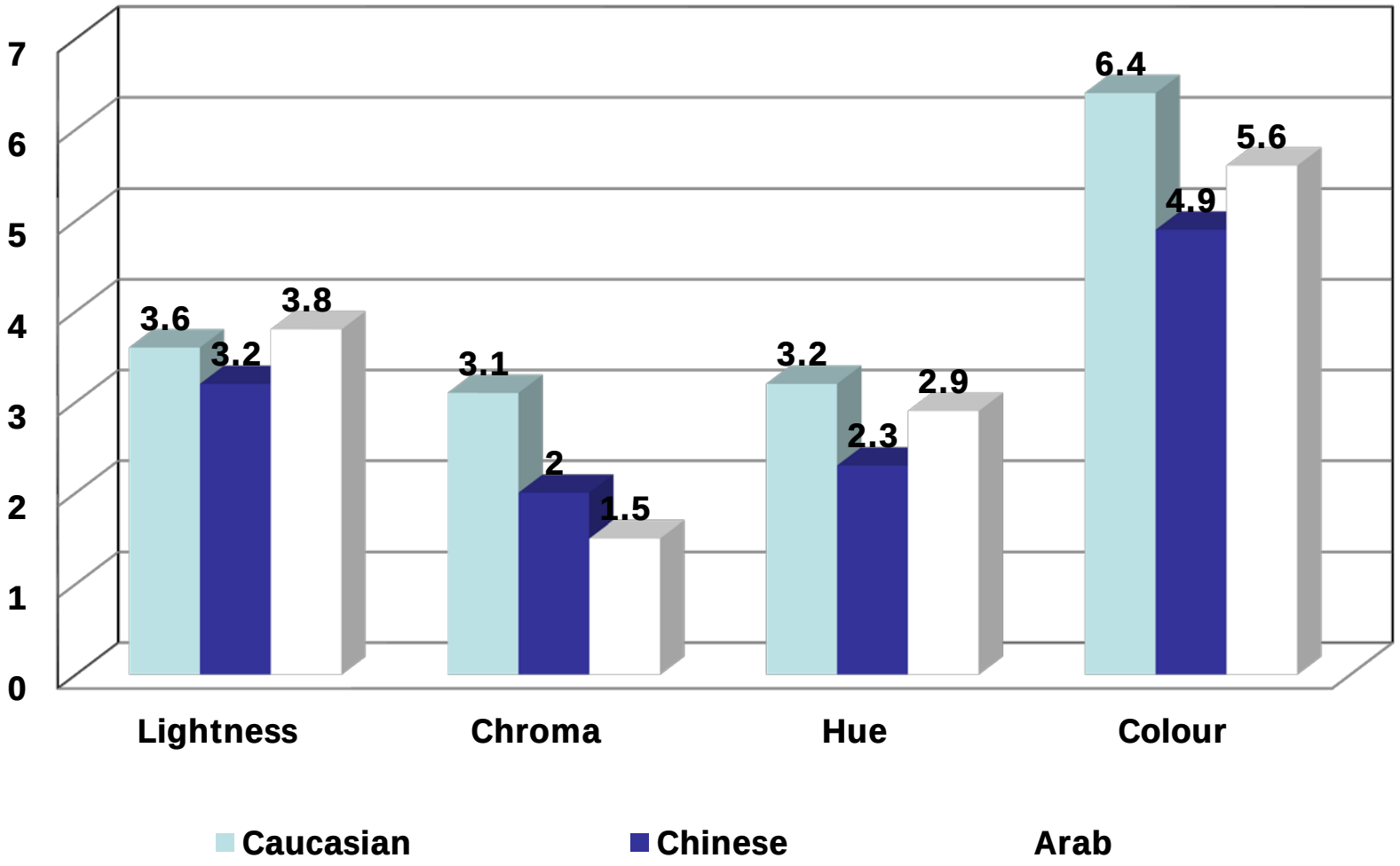


CIECAM02 -Top View



CIECAM02- Side View

Skin colour variation



Application of Skin Colour Database

UNIVERSITY OF LIVERPOOL

❑ Colour Reproduction

Skin colour chart

❑ Spectral Reproduction

To develop skin reflectance reconstruction algorithm for camera

❑ Skin image analysis

To predict Melanin, Haemoglobin, Shade etc. based on both CIELAB and skin reflectance

UNIVERSITY OF LIVERPOOL

Subjective method

- Visual assessment and match
- Skin colour chart

Objective method

- Spectrophotometer
- Spectroradiometer
- Camera

Skin colour chart

- Based on skin measurement
- Either Printed or painted colour
- Paper material
- Valid with reference illumination

Skin colour reproduction

Applications:

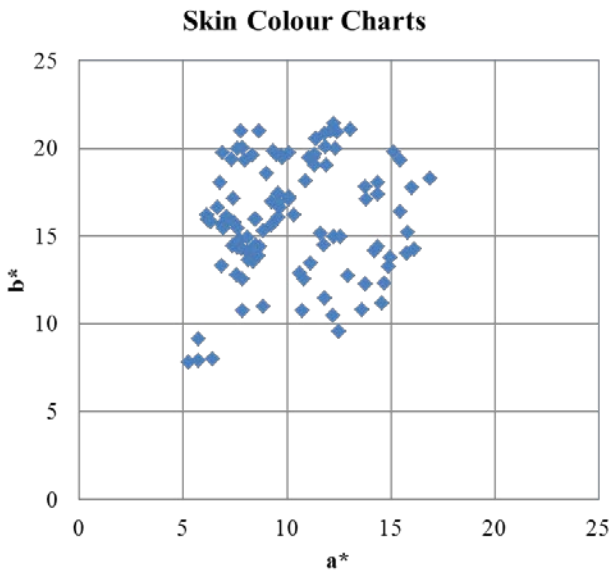
- Skin colour reproduction
- Skin image capture (reference chart)

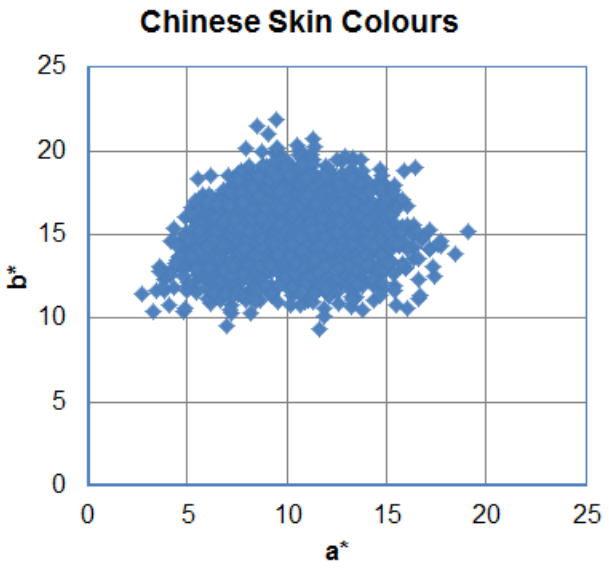
Evaluation of skin colour charts

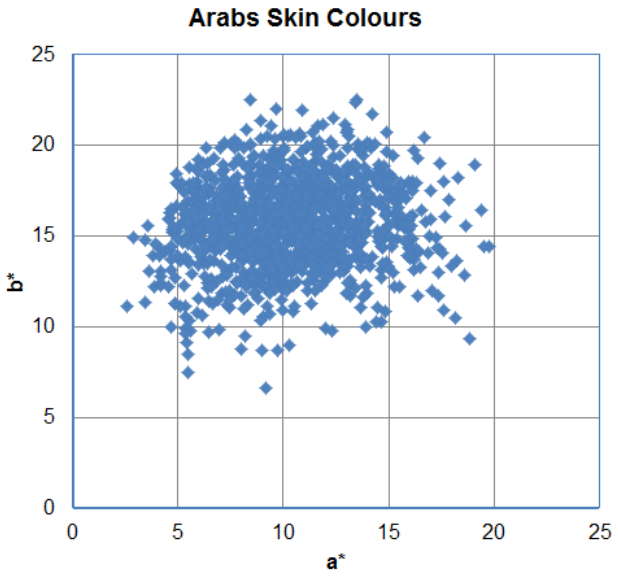
- Spectrophotometer Measurement
- CIELAB values
- D65 reference white

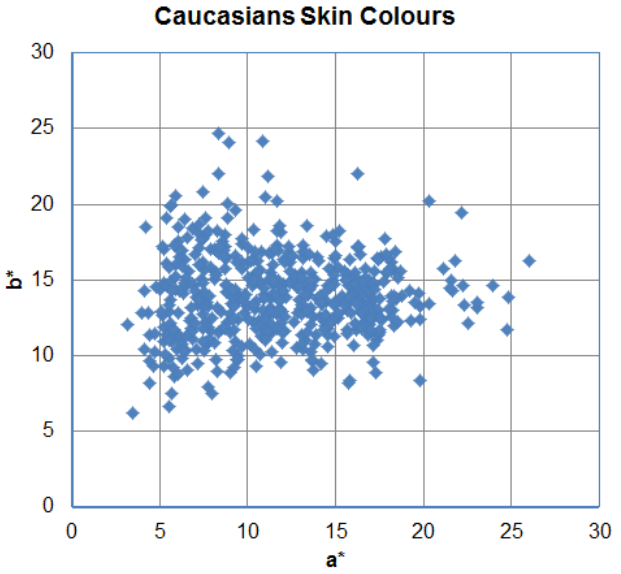
Skin colour charts

UNIVERSITY OF LIVERPOOL



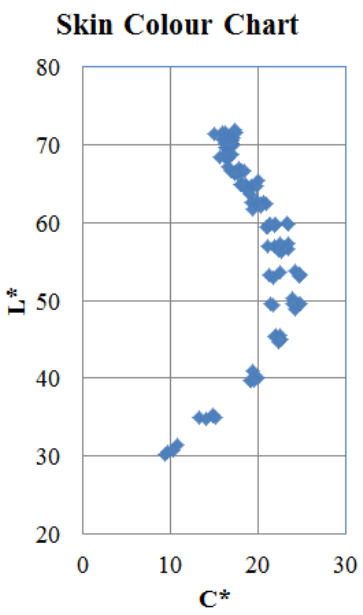


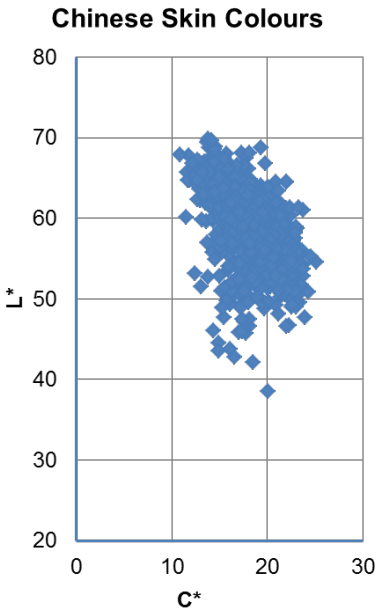


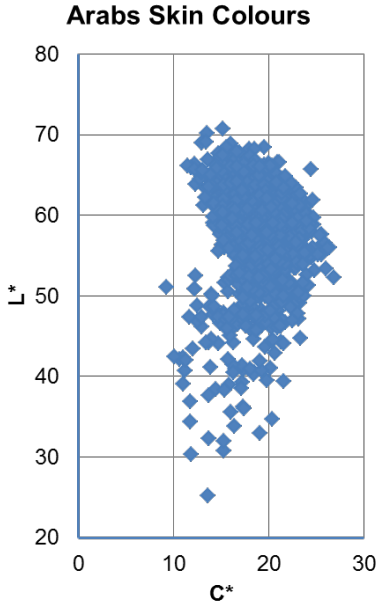


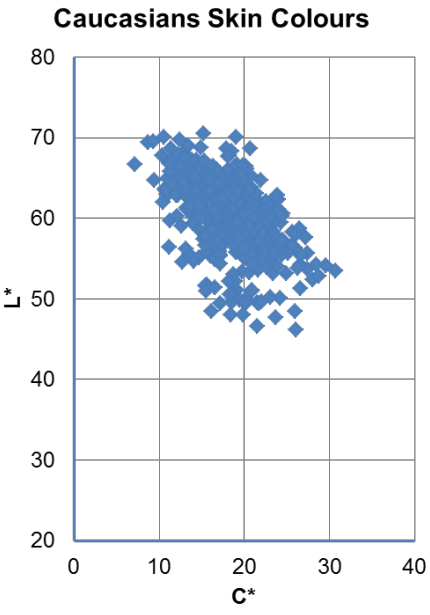
Skin colour chart

UNIVERSITY OF LIVERPOOL

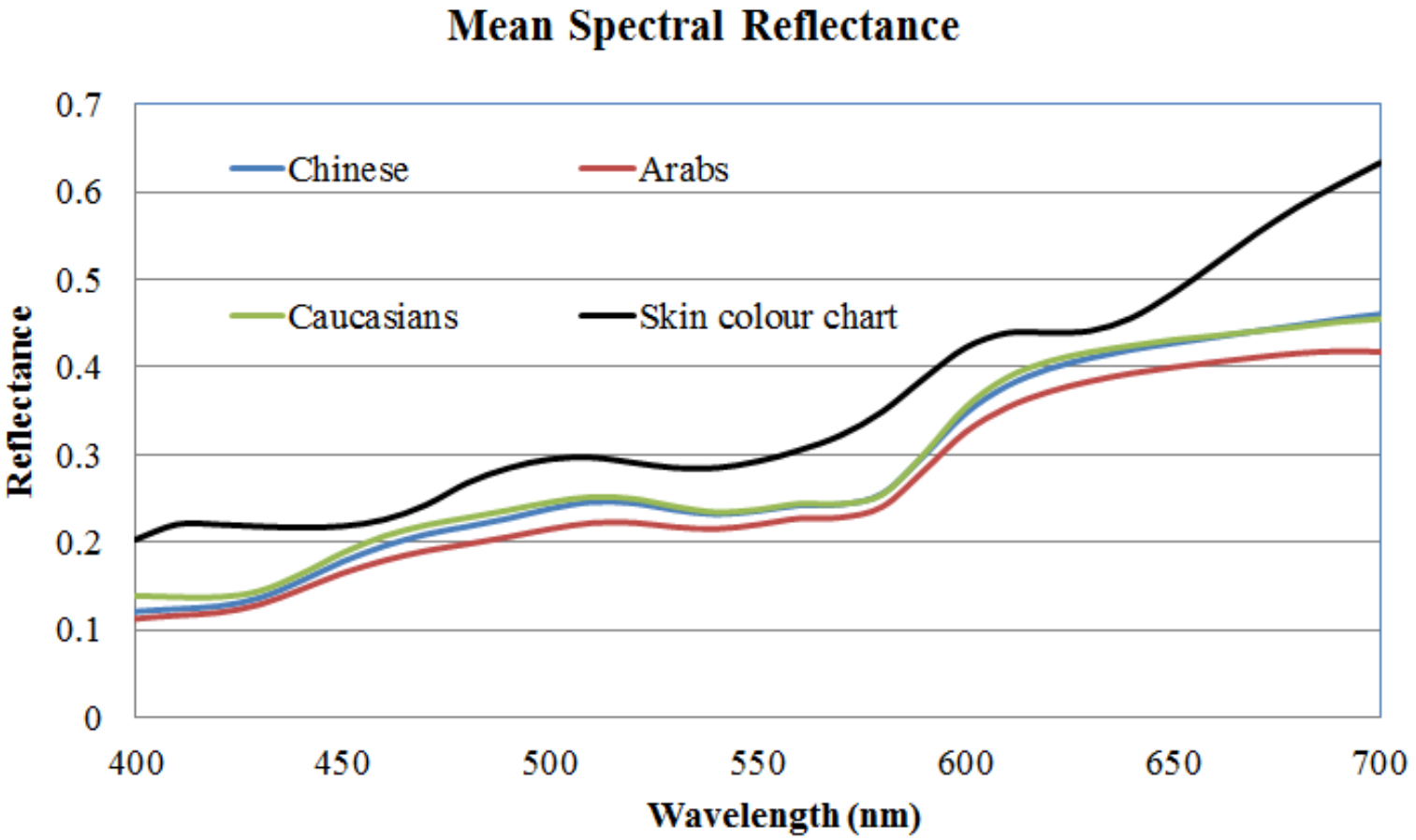








Skin colour chart



UNIVERSITY OF LIVERPOOL

Skin colour chart for skin image capture

- A large skin colour gamut
- Different skin ethnic groups
- Accurate skin reflectance
- Trade off between colour number and accuracy

UNIVERSITY OF LIVERPOOL

Skin image capture

- Lighting design
- Protocol of measurement

Skin image colour management

- Skin colour chart
- Calibration procedure
- Colour transform and spectral reflectance reconstruction

UNIVERSITY OF LIVERPOOL

Skin colour measurement and reproduction in university of Liverpool

- Spectrophotometer
- Spectroradiometer
- Camera
- 3D camera
- Multi-angle camera
- 400 subjects

UNIVERSITY OF LIVERPOOL

Thanks

k.xiao@liverpool.ac.uk