ICC Medical Imaging Working Group

Boston, MA
1 Nov 2014 08:30 (EDT)

The meeting was called to order at 08:30 am (EDT) by Craig Revie, chair of MIWG, with the following attendees:

Steve Smiley, SmileyColor/FTA
Phil Green, Gjovik University College
Heijo Reinl, CGS
Markus Barbieri, Barbieri Electronics
James Chang, Sharp
Michael Flynn, HFHS, UofM
Mitchell Marks, Toshiba
Chaminda Weerasinghe, Toshiba
Bas Hulsken, Philips
J.P. Van de Capelle, X-Rite
Robert Horn, AGFA
Chris Bai, BenQ
Max Derhak, Onyx Graphics
Veronika Lovell, Sun Chemical
Marti Maria, Hewlett Packard
Marc Mahy, Agfa Graphics NV
Kaida Xiao, University of Liverpool
Hiroyuki Fukuda, Olympus
Michael Chang, Kyocera
Jeremie Pescatore, BioMereiux
James Vogh, X-Rite
William Li, Kodak
Tom Lianza, Photo Research
Craig Revie, FFEI, Ltd.
Po-Chieh Hung, Konica Minolta
Masahiro Yamaguchi, Tokyo Institute of Technology
Andy Masia, X-Rite
Debbie Orf, NPES
Pinky Bautista, MGH

On-line attendees:
Allen Olsen, Leica Biosystems
Glenn Davis
Brandon Gallus, FDA
Takashi Matsui, Eizo Corporation
John Dalrymple
Kathryn Epsig, Barco
Yusuke Bamba, Eizo Corporation
John Penczek, NIST
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

After self-introductions and a check of sound quality, Mr. Revie proposed the agenda for the meeting as follows:

Whole Slide Imaging

1. Round robin assessment status, objectives and next steps
2. Review of Leica's assessment
3. Review of Konica Minolta assessment and additional observations
4. Review of FFEI, Leeds and FDA assessment
5. Color Translator tool -possible use in calibration assessment
6. Sierra slide accelerated fading testing and extended slide

Multispectral Imaging

7. Status update
8. DICOM proposal for multispectral extensions
9. Demonstration of MCS connection with actual profiles and images

Skin Colour

10. Spectral measurement project status update

Medical displays

11. mRGB and dRGB update
12. Experiences in building an ICC Profile for an mRGB display
13. Characterisation of displays
14. Preparation of reference images for display testing

Medical Photography

15. Status update and next steps for digital photography workflow white paper

Petri plate imaging

16. A colour calibration method for Petri plate image acquisition
17. The need for standardisation of reading and viewing of Petri plates

FDA Working Group for Whole Slide Imaging
Medical Imaging Working Group activities for 2015

Whole Slide Imaging

1. Round robin assessment status, objectives and next steps

Mr Revie presented an update on the Sierra slide evaluation [see attached]. He described the Sierra calibration assessment slide, which uses a biopolymer to carry biomarker stains. The assessment focused on two areas: determining the transmittance of the patches, and scanning the slide on a calibrated scanner with an ICC profile. These two tasks will help understand how colour is being processed by digital microscopes. Several people have measured the slide, and there is good agreement between measurements. The most significant variation was probably due to fading of the Eosin stain. Five participants have completed the slide scanning, and a further five are in progress and are expected to complete by the end of the year. Participants are discussing how to publish the results, which will probably be anonymized.

Some other issues that need to be considered are:

- The gamut limit of sRGB (Eosin in particular is outside)
- The numerical aperture (NA) of the system (an issue being that measurements are made using collimated light, while scans are usually not)
- The encoding of over-range white (which is clipped in the ICC profile).

It was noted that NA differences were intentional, and the effect needed to be quantified in order to consider how to handle it.

Mr Revie summarised the main goal as a framework for conformance. One option was to agree a standard calibration method, but this could be difficult.

Dr Bas Hulsken noted that idea of 'true colour' was not applicable to whole-slide imaging. Staining is highly variable. More important is to have consistency in scanning – agreement between different scanners was more important than colour accuracy. Dr Allan Olsen agreed, adding that more uniformity between vendors was needed, and a standard viewing experience was the ideal. Mr Revie suggested that an option to show a calibrated image was provided in the scanner interface it would help users to understand what they were looking at, and this calibrated image could be a basis for consistency between scanners. Dr Hulsken also noted that regulatory approval is important, and if viewing options other than the calibrated image are provided, it might be necessary to flag to the user that the resulting image did not meet conformance requirements.

The issue of viewer displays was considered out of scope for this activity, although it was acknowledged that work on displays was needed to ensure consistency of presentation. A colour managed display might be sufficient, and GSDF may not be required for this application. The sRGB colour space is not suited to encoding stain colours as some stains are outside the sRGB gamut.

Mr Revie reported that it had been difficult to encode images in the DICOM format than expected, and in the short term a different way of assessing the results may be needed.

Dr Brendan Gallas stated that he would welcome a baseline calibration procedure.

Mr Revie concluded this discussion, stating that the next steps in the work would be reviewed after presentation of the results of the calibration slide evaluation.

2. Review of Leica's assessment

Dr Olsen reported results of Leica's assessment of the calibration slide [see attached]. He had computed results in Matlab and found there was good agreement between these and the results from the Sierra analysis tool. The visual comparison was also very good. He had built a profile (with help from FFEI) and was happy with the results from this. However, an average profile, using data from multiple scanners, might be desirable.

Dr Olsen identified sources of variability in the process, and summarised recommendations, the principle one being the scanner profiling procedure.

The light source in the Leica scanner is a blue pumped LED. No IR illumination is emitted by this source, so IR filtration is not needed. The scanner sensor is a trilinear array with R, G, B dye filters.

Dr Po-Chieh Hung observed that some white LEDs have low power at certain wavelengths, and can reduce quality depending on the spectral reflectance if the stain. Using the spectral power distribution of the source, and the spectral sensitivities of the sensors and optical system, it was possible to compute a Q factor, which essentially defined the device metamerism. He agreed to document the Q factor calculation for the group, using the manufacturers' published sensor sensitivities. It was noted that there was a standard procedure for measuring sensor sensitivity, and that if possible the sensitivity of the whole system should be measured, including the scanner optics.

3. Review of Konica Minolta assessment and additional observations

Dr Hung presented results from the assessment at Konica Minolta [see attached]. He had tested the slide with a fluorescence microscope. He reported that a diffuse:0 or a diffuse:large-aperture geometry is the best way to illuminate the slide, and noted that dust rings / bubbles were apparent on the scans. He showed an analysis of the illumination quality using the CQS spreadsheet from Dr Ohno.

Dr Hulsken observed that in his experience non-linear correction does not work, and a 3x3 scene analysis matrix gives best results since sensors are linear, and accuracy depends on the degree to which the sensor spectral sensitivities conform to the Luther condition (that sensitivities are a linear transform of colour matching functions). In his work he had tried to make a scanner for a broad range of samples rather than an individual stain. It was reported that approximately 80% of pathology stains at Leeds were eosin, followed by DAB at 15%. The remaining 5% comprised a wide range of stain types.

Mr Revie commented that multiple calibration slides might be needed to cover the different stain types, instead of the current one which is mainly H&E (haematoxylin and eosin), but using such calibration assessment slides might be difficult in practice due to the batch processing frequently performed in clinical practice. Mr Hulsken suggested another approach might be to build a stain detection system, which would have no need for colour management.

Mr Revie noted that a non-linear correction is used in the FFEI profile posted on the Sierra web site, but FFEI attempt to avoid distortion while minimising errors. Mr Revie agreed with Mr Hulsken that this is difficult to achieve but can be done using similar technology to that used in Graphic Arts scanners.

4. Review of FFEI, Leeds and FDA assessment

Mr Revie presented results of assessments carried out at FFEI, Leeds, Ventana and FDA [see attached]. Slide measurements (FFEI, Ventana, FDA) showed good agreement, the main difference being between the reflectance of eosin. This could be due to fading of eosin, or the use of different light sources.

He described the FFEI calibration method and demonstrated the use of the project Sierra web site. Sample CIELAB values had been obtained by applying profiles to RGB values averaged across each patch. FFEI results were consistent with the measurements, but Leeds and FDA differences were much higher. It was noted that the latter two had used the same model of Leica Aperio scanner. Mr Allen Olson of Leica stated that older scanners have no colour correction, being adjusted according to customer feedback.

It was found that different scanners imaged different portions of the slide, and a revised slide layout is being tested. While operators would normally focus on the comb element on the cover slip, it was noted that this would result in the colour patches being slightly out of focus.

Mr Revie also reported on some tests on the visual assessment method proposed by Yagi and Bautista, whereby the slide image on a display was compared to the original slide using the display backlight. This seemed to work well, and had received positive feedback from the pathologist at Leeds.

5. Color Translator tool -possible use in calibration assessment

Marti Maria demonstrated his Colour Translator tool (http://www.littlecms.com/professional/). This converts images using ICC profiles, and enables a default source profile to be defined for untagged images without having to embed the profile. It recognises abstract profiles and supports many image file formats and encoding precisions, including 8- and 16-bit integer and 16- and 32-bit floating point. The tool is extremely fast in operation, using parallel processing, and is suited to batch processing of images. Mr Maria stated that it was available at a low cost of possibly free for research and academic use.

6. Sierra slide accelerated fading testing and extended slide
Mr Revie reported results from a fading test of the calibration assessment slide [see attached]. Four different exposure protocols had been tested, using a halogen lamp at different intensities and durations. Results showed that in the full exposure phase there were significant changes in the reflectance of eosin, and that the change was larger for slides with a small amount of eosin stain. Mr Revie stated that it was possible to improve the slide manufacturing process by applying DABCO stabiliser as a separate step.

It is planned to employ the fading of eosin in future slides to infer the degree of light exposure undergone by the slide, and it was intended to estimate the number of scans that can be made before a slide changes unacceptably (possibly around 1-2 units of CIELAB 1976 colour difference).

FFEI are also developing a calibration slide, which currently has 55 patches covering the majority of stains used at Leeds. FFEI are evaluating the feasibility of this slide, but would look for another partner to manufacture. The format is currently too large for some scanners and may need adjustment. Dr Bautista suggested IHC as a further stain candidate, if different from DAB. It might also be useful to add tissue-based spectra such as haemoglobin.

Multispectral Imaging

7. Status update
Professor Yamaguchi provided an update of work on multi-spectral imaging [see attached]. Multi-spectral imaging is used in brightfield and fluorescence imaging, primarily in research rather than clinical practice. Yamaguchi-sensei showed a general model for spectral unmixing to infer biomarker quantities. It was desired by the DICOM committee that the original image is retained and a separate unmixing transform is provided. He showed two possible solutions: in the first and ICC v4 profile was used to define a virtual input device, where each channel represents a biomarker, and an ICC device link profile can be used to generate a biomarker image from a real multi-spectral image; while in the second solution an iccMAX Material Connection Space profile was used.

Yamaguchi-sensei described the current status of this work and a planned test implementation. He welcomed contributions.

8. DICOM proposal for multispectral extensions
Dr Bas Hulsken presented an update of his work to bring multispectral extensions to DICOM [see attached]. He had discussed this in WG26, so far with limited progress, and he hoped to get feedback from DICOM experts in this MIWG meeting.

He showed the extensions need to DICOM; some are simple, but adding modules defining needed functionality is more complex. Multispectral images could possibly be stored as multiple DICOM images. It was desirable to support sub-sampling, so it was not appropriate to impose a common resolution limit, although it was noted that variable resolution is typically only seen in WSI imaging. In the case of PET and CT, images have different resolutions but the presentation state has to combine them. For image alignment, fiducials are commonly used to map coordinates, with both linear and non-linear deformation fields defined (e.g. to compare pre- and post-excision images).

As a next step Dr Hulsken wished to work with DICOM experts to develop proposals. There was a need to consider use cases – initially this might just be WSI and possibly Petri dish images. It was suggested that Dr Hulsken contact DICOM WG6.

Professor Yamaguchi also suggested the need to consider hyperspectral imaging, and issues like interleaving, channels per plane etc. – some systems such as remote sensing are line-at-a-time.

9. Demonstration of MCS connection with actual profiles and images
Mr Max Derhak provided a demonstration of how iccMAX Material Connection Space (MCS) profiles can be used to provide quantitative representations of material amounts in an image [see attached]. He showed the workflows and connection rules, and an example of using MCS profiles to connect to material identification and visualization outputs.

The next step would be to develop an Interoperability Conformance Specification (ICS) for one or more medical imaging modalities, which Mr Derhak undertook to do in conjunction with Phil Green and anyone else interested in contributing.

Skin Colour

10. Spectral measurement project status update
Kaida Xiao presented a summary of work at University of Liverpool to evaluate methods of measuring human skin and to build a database of skin measurements [see attached]. By determining the reflectance properties independently of the illumination, it was possible to connect the results with skin chromophores such as melanin and haemoglobin.

Dr Xiao described the procedures used to measure skin. Calibration was considered very important, and this is performed with the aid of a test chart. A diffuse illumination is used, and a white card is imaged in order to recover the spectral power of the illumination. He had also explored the use of 3D photogrammetry, saving a 3D image.

Reflectances were reconstructed from RGB image data using the skin colour database.

Medical displays

11. mRGB and dRGB update
Dr Michael Flynn presented a progress report on dRGB (formerly mRGB) [see attached]. He showed the back ground to this work, including previous display standards, and introduced the report of AAPM Task Group 196 on requirements for medical displays. The neutral luminance scale had a variable Lmax (white point) and used the DICOM GSDF to define the relationship between RGB and luminance. The default colour gamut was sRGB, but others could be indicated by the profile description. Issues such as tolerances for the primaries, methods of display calibration and the use of source and destination ICC profiles, will be addressed in the dRGB standard.

12. Experiences in building an ICC Profile for an mRGB display
Mr Revie presented an analysis of display profiling requirements for dRGB [see attached]. The main issue is that LUT-based profiles are necessary, and few profiling applications support this (as opposed to Matrix/TRC profiles). Those commercial applications that do generate LUT-based profiles tend to modify the graphics card LUT at the calibration stage, which may be undesirable, especially with self-calibrating displays and with mixed-mode presentation. He proposed that ICC MIWG should specify requirements for display profiling software and work with vendors to test and deliver suitable profile creation software.

13. Characterisation of displays
It was noted that display calibration practices vary, and that users have little guidance on how to do this. Dr Green undertook to make information available on the ICC web site.

14. Preparation of reference images for display testing
Dr Hulsken presented an update on the call for reference images for use in testing displays and display calibration [see attached]. The aim was to validate a proposed display architecture that had been presented in previous MIWG meetings, and for this a limited set of representative images are required, together with a specification of the minimum performance required for the visualization. He proposed to continue collecting images and display measurement data, and to hold a conference call in December to select the display systems and reference images in order to proceed with bench testing and simulation in early 2015.

Medical Photography

15. Status update and next steps for digital photography workflow white paper
Dr John Penczek provided a draft "Recommended Image Capture Workflow for Medicine Photography" to the meeting [see attached]. This is a proposed best-practice guideline for medical capture workflow with a focus on colour accuracy. The draft lists the equipment needed, a basic outline of procedure and a summary of colour correction methods to use. The draft document will be posted on the ICC MIWG website.

Some of the areas discussed include:
1. The use of a test chart in the field of capture
2. Use of diffuse illumination would avoid some of the problems seen with directional lighting.
3. Camera RAW format is better for colour accuracy as it avoids the in-camera rendering applied in JPEG images.

Petri plate imaging

16. A colour calibration method for Petri plate image acquisition
Dr Jeremie Pescatore of Biomerieux presented a summary of colour calibration for Petri plate scanners and related issues [see attached]. He gave an overview of automated Petri plate scanning workflow and the use of ICC input profiles to transform from scanner RGB to CIE colorimetry. It is difficult to validate the results on Petri plate colonies since the colonies are too small to measure with the spectrophotometric equipment available in his lab, and he showed the InVivo hyperspectral imaging system which was built for this type of application. His goals were to build a standard setup to measure Petri plates with both specular included and excluded; and to develop an imaging system that could have similar accuracy in reflectance measurement to a spectrophotometer.

17. The need for standardisation of reading and viewing of Petri plates
Dr Pescatore reviewed the need for standardisation in reading and viewing Petri plate images [see attached]. He discussed the main requirements of reading and viewing environments, and identified open issues as:

- How should the effect ambient light be incorporated?
- How should the effect of the displayed background be taken into account?
- How should the display gamut be standardized?
- How should the display profile be attached or embedded with the Petri image?
- Could mRGB or dRGB colour spaces incorporate these considerations for Petri images?

It was agreed to establish an activity area on this topic on the ICC MIWG web site.

FDA Working Group for Whole Slide Imaging
Dr Brendan Gallas showed information about the FDA WSI group [see attached] and invited ICC MIWG members to participate.

Medical Imaging Working Group activities for 2015
Craig Revie agreed to prepare a schedule of ICC MIWG meetings for 2015, in conjunction with Debbie Orf and Phil Green.

Mr Revie closed the meeting at 12:00pm.

Action items

Sierra project
-Report results of round robin test to MIWG (Craig)
-Review next steps after presentation of results (Craig)
-Provide documentation on Q factor for assessing image quality (Po-Chieh)

Accelerated fading
- Modify manufacturing process to apply DABCO stabiliser as separate step (Craig)
- Estimate no of scans that can be made before slide fades unacceptably (Craig)

FFEI calibration slide
- Consider adding tissue-based spectra (e.g. haemoglobin) (Craig)
- Consider adding IHC stain (Craig)

Multi-spectral
-Provide contributions on proposed workflow and test implementations to Yamaguchi-san (all interested)

DICOM
-Contact DICOM WG6 to discuss extending DICOM format for colour support (Bas Hulsken)
-Develop ICS for medical imaging modalities (Derhak, Green)

Display calibration for WSI
-Define requirements for display profiling software and work with vendors to test and deliver suitable profiling software
-Add notes on display calibration to ICC web site (Green)

Petri dish imaging
-Establish activity page for Petri dish imaging on ICC MIWG web site (Green,

Next meetings
-Set up schedule of 2015 meetings (Revie, Green, Orf)

A full recording of the meeting is available at http://www.npes.org/Portals/0/standards/2014-11-01%2008.33%20ICC%20Regular%20Meetings.wmv

International Color Consortium

ICC Medical Imaging Working Group

Face-to-face meeting in Boston, USA

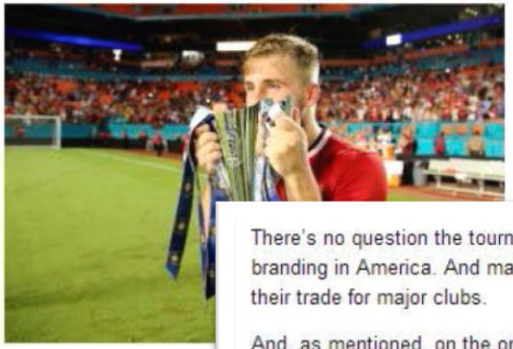
1st November 2014

First of all some breaking news from ‘The Beautiful Game’

Manchester United topped Liverpool in final; Did it raise ICC profile?

Nicholas Mendola | Aug 5, 2014, 10:38 AM EDT

3 Comments



A trophy was kissed after a championship match played between Liverpool and Manchester United on Sunday in Miami, a title tilt played as part of the two clubs' preseason tours of the United States. United claimed a 3-1 decision in the final game of the 2014 Guinness International Champions Cup (**Wayne Rooney**, Juan Mata and Jesse Lingard scored for Manchester, while **Steven Gerrard** scored for Liverpool).

And despite 51,000 fans in attendance at Sun Life Stadium, the question remains: how far away is the tournament from having relevance outside of big names and big crowds?

ICC: Wayne Rooney player of the tournament

There's no question the tournament itself was a success in terms of attendance and promotion of the clubs branding in America. And many of the matches were a good watch, as fans got to check out superstars plying their trade for major clubs.

And, as mentioned, on the one hand, there were the championship photos and celebrations...

Manchester United
@ManUtd
Follow

Manchester United: ICC champions! #mutour

3:27 AM - 5 Aug 2014

Clearly ICC Profiles are starting to be used in areas we had not anticipated – are there other sports that could benefit from our help?

ICC MIWG Agenda for Saturday 1st November 2014

- **Whole Slide Imaging**
  - 1. Round robin assessment status, objectives and next steps — Craig Revie
  - 2. Review of Leica's assessment — Allen Olson
  - 3. Review of Konica Minolta assessment and additional observations — Po-Chieh Hung
  - 4. Review of FFEI, Leeds and FDA assessment — Craig Revie
  - 5. Color Translator tool – possible use in calibration assessment — Marti Maria
  - 6. Sierra slide accelerated fading testing and extended slide — Craig Revie
- **Multispectral Imaging**
  - 7. Status update — Masahiro Yamaguchi
  - 8. DICOM proposal for multispectral extensions — Bas Hulsken
  - 9. Demonstration of MCS connection with actual profiles and images — Max Derhak
- **Skin Colour**
  - 10. Spectral measurement project status update — Kaida Xiao

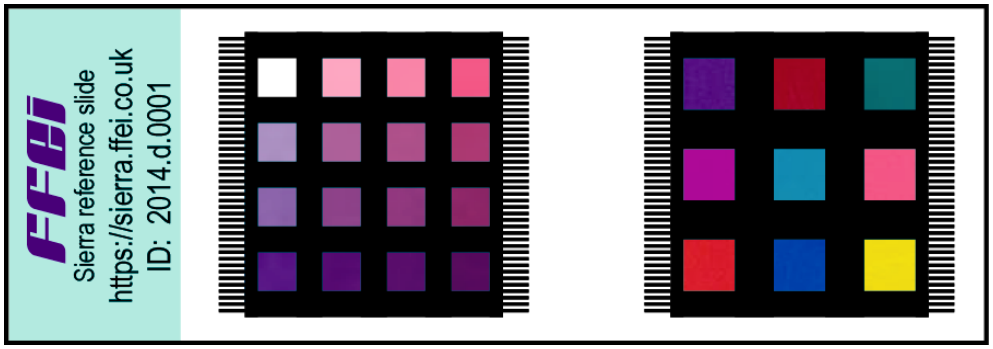
ICC MIWG Agenda for Saturday 1st November 2014

- **Medical Displays**
  - 11. mRGB and dRGB update — Mike Flynn
  - 12. Experiences in building an ICC Profile for an mRGB display — Craig Revie
  - 13. Characterisation of displays — Mike Flynn / Tom Kimpe
  - 13. Preparation of reference images for display testing — Mike Flynn / Tom Kimpe
- **Medical Photography**
  - 14. Status update and next steps for digital photography workflow white paper — Phil Green / John Penczek
- **Petri plate imaging**
  - 15. A color calibration method for Petri plate image acquisition — Jérémie Pescatore
  - 16. The need for standardisation of reading and viewing of Petri plates — Jérémie Pescatore
- **17. FDA Working Group for Whole Slide Imaging** — Brandon Gallas
- **Medical Imaging Working Group activities for 2015** — Craig Revie

Sierra calibration assessment slide

Round-robin status, objectives and next steps

1st November 2014



Round robin assessment status, objectives and next steps

- **Slide evaluation**
  - Completed: FFEI, Leeds, FDA, Leica, MGH
  - In progress: Omnyx, Datacolor, Ventana, Philips, Konica Minolta
  - Not yet started: Tokyo Institute of Technology, Ghent University
- **Some initial results have been presented**
  - Measurements of slide are in reasonably good agreement
  - Analysis of slide images has been difficult in some cases as it has been difficult for some vendors to create DICOM images
- **Publication of results**
  - Round-robin participants are discussing how to publish the comparative results and whether they should be anonymised
- **Other feedback**
  - sRGB gamut limitation; effect of system NA; encoding over-white

Round robin assessment status, objectives and next steps

- **Objectives**
  - make and compare measurements of slides
  - scan slides on a range of digital microscopes and provide feedback
  - provide feedback on framework for digital microscope evaluation
- **Framework for digital microscope evaluation options**
  - agree and document an assessment method
  - alternatively agree a standard calibration method
- **Publish results**
  - objective could be to show the current colour behaviour for digital microscopes in use today
  - an alternative approach could be for vendors to improve their calibration before measuring the colour result

Round robin assessment status, objectives and next steps

- **DICOM format has proved more difficult than expected**
  - Is this still a good long-term solution?
  - In the short term we need an alternative assessment method
- **Possible alternative assessment methods**
  - Export low-resolution image with embedded ICC Profile
  - Provide RGB image values for each patch along with an ICC Profile
  - MATLAB or Image J + R or some other tools
- **Possibly document a baseline calibration procedure**

- ***Review next steps following presentation of results***

Calibration Assessment Slide Results for ScanScope AT2

Allen H. Olson, PhD
Leica Biosystems

ICC Medical Imaging Working Group – 01 Nov 2014

Overview

- Experience with Sierra Website
- Scanning of the test slide
- Visual comparison – Leica/FFEI
- Processing with Matlab
- Results
- Sources of variability/error

Experience with Sierra Website

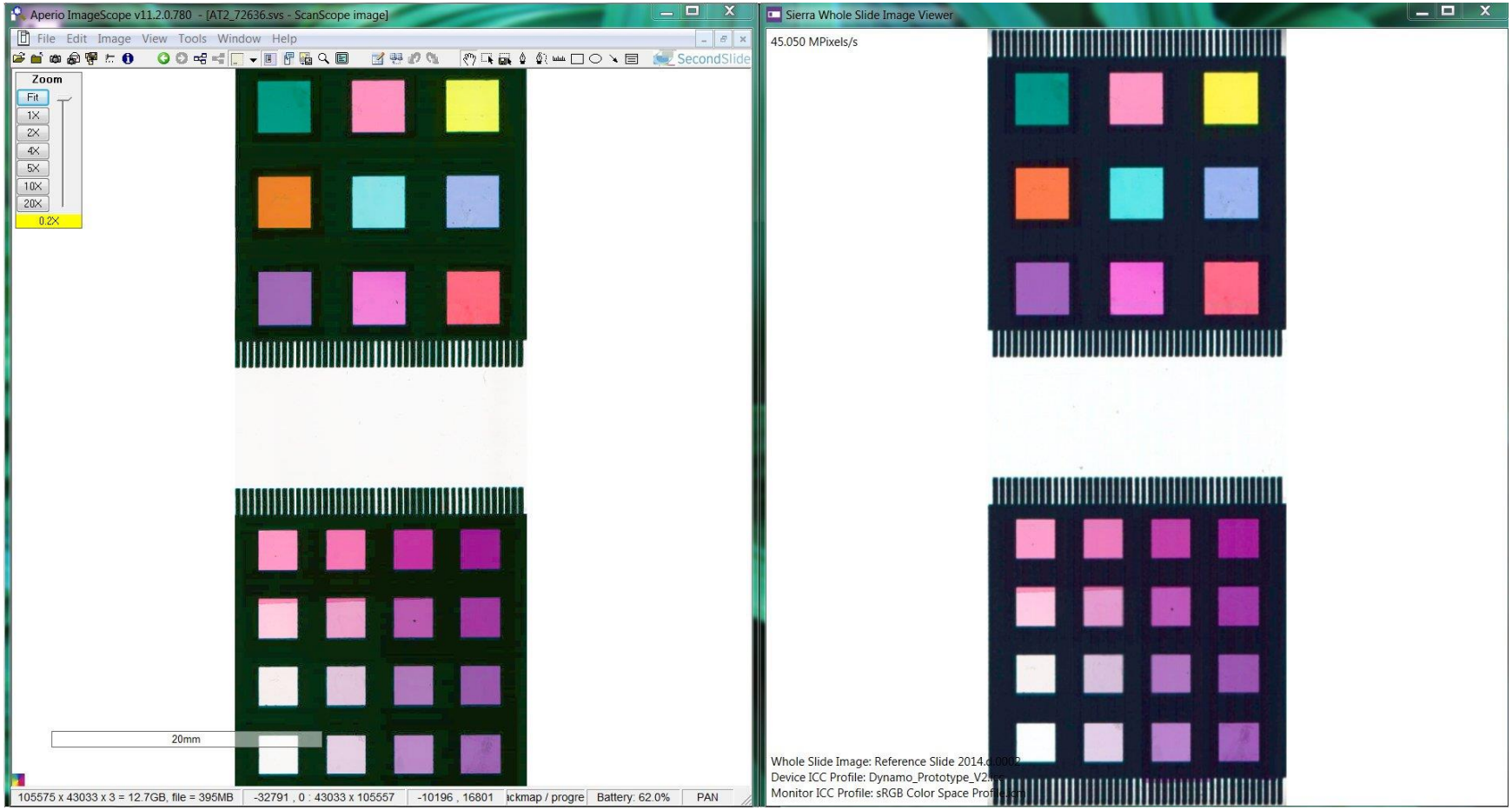
- Downloaded Sierra WSI Viewer
  - This was used to view FFEI WSI image for test slide
- Downloaded Sierra DICOM converter
  - This worked without issue on Leica ScanScope WSI image
- Downloaded spectral data file for my particular test slide
  - 2014.d.0002.csv, opened in Excel
  - The spectral data for each patch was extracted and utilized to calculate reference XYZ and Lab values for each patch
- Sierra Analysis Tool (web based)
  - Had some difficulty.
  - Profile was too large. Thanks to Simon Davidson (FFEI) for website software fix. Afterwards, it worked just fine.
  - Produced csv files with ReferenceLab and Sample Lab & RGB for WSI of target slide.
  - Sierra results agreed with independent Matlab calculations

Scanning of the test slide

- Target scanned on Leica AT2 scanner
- Manual scanning mode
  - Selected scan area to include target patches
  - Manual pre-focus on each target patch
  - Calibration taken on clear area between blocks
- Magnification - 20X
- Compression – JPEG, default setting
- File format – TIFF (svs)

Visual comparison – Leica/FFEI

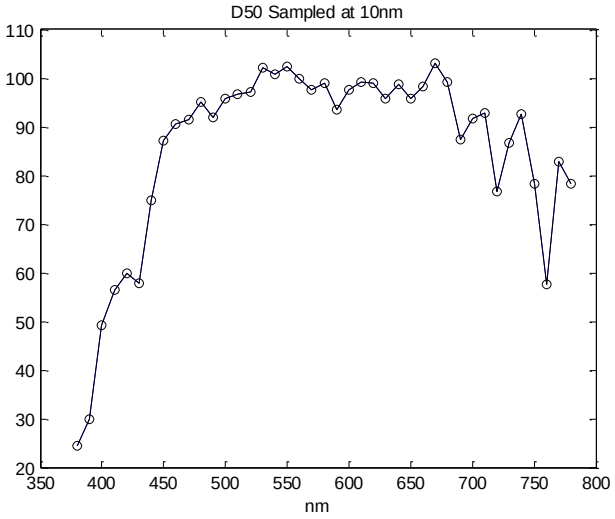
- Aperio Imagescope to view AT2 image
- Sierra WSI Viewer to view FFEI image
- Color management using vendor ICC and sRGB monitor profiles

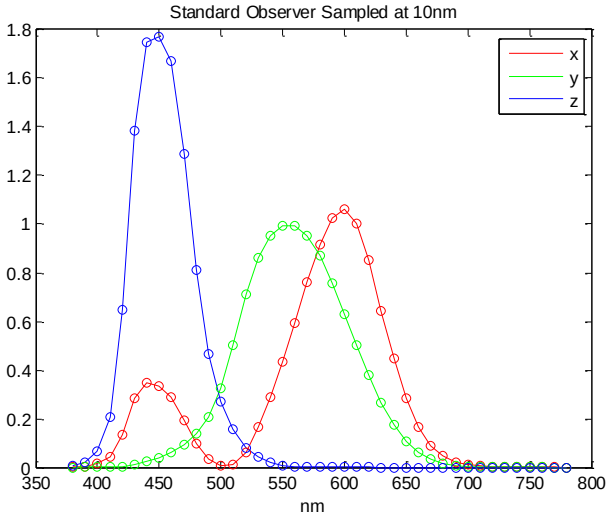


Processing with Matlab

- Calculate Reference XYZ, Lab values
  - Define Illuminant(D50)
  - Integrate target transmittances against standard observer curves
- Estimate WSI RGB values
  - Down-sample WSI to manageable size
  - Average central ¼ of each target patch
- Transform WSI/RGB to D50 PCS values
  - Use vendor calibrated ICC profile (eg, AT2.icc)
  - Matlab functions to convert RGB to XYZ, Lab, sRGB
- Compare Reference to WSI Color values

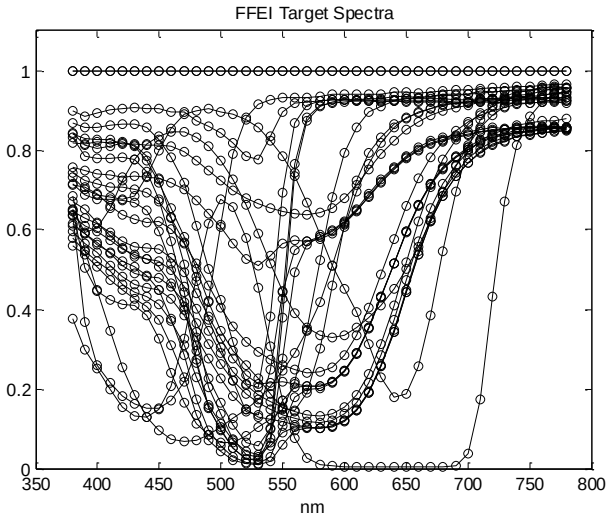
Calculate Reference XYZ Values





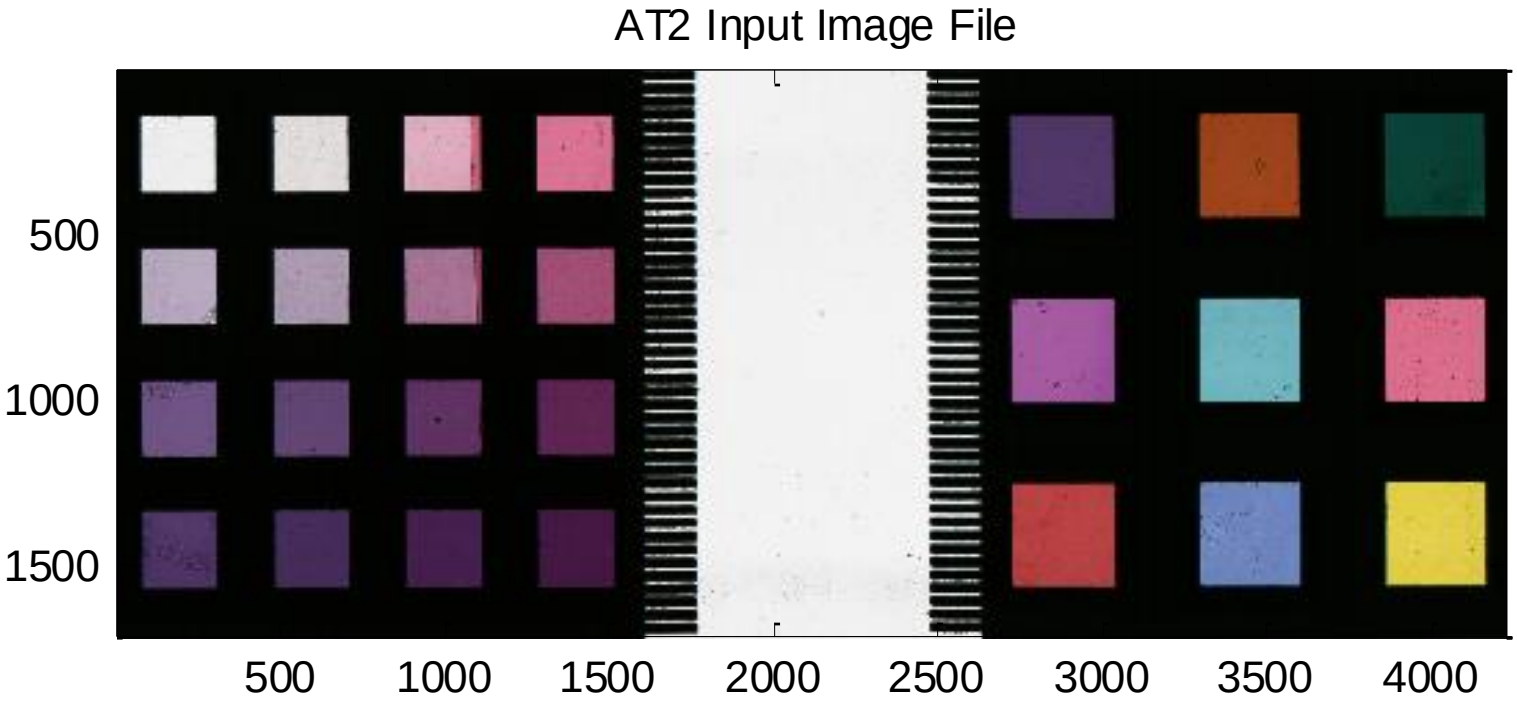
$$< X_j, Y_j, Z_j > = \frac{1}{W_y} \sum_{i=1}^{41} < x_i, y_i, z_i > D50_i \ T_{ij}$$

- Integral is approximated by summation
- W_y is normalization ($T=0$)
- XYZ to Lab transform using library



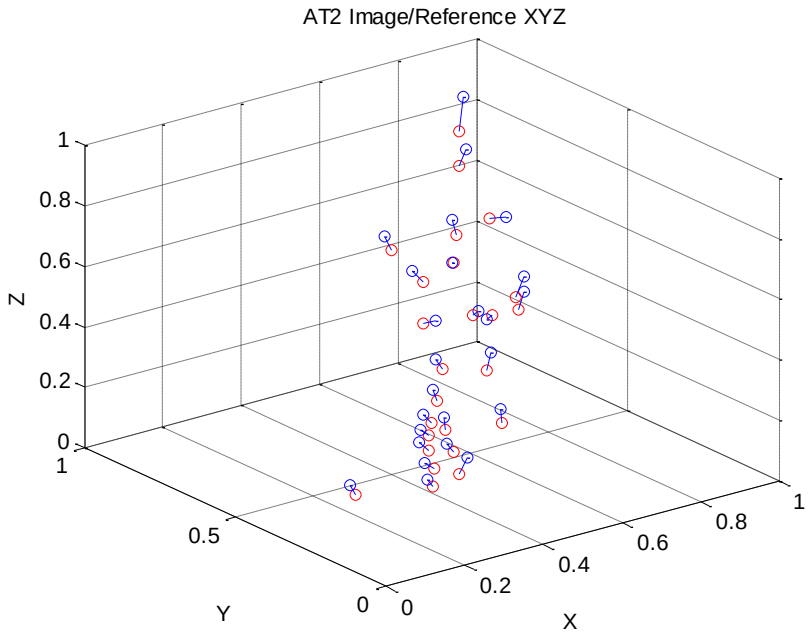
Estimate WSI RGB Values

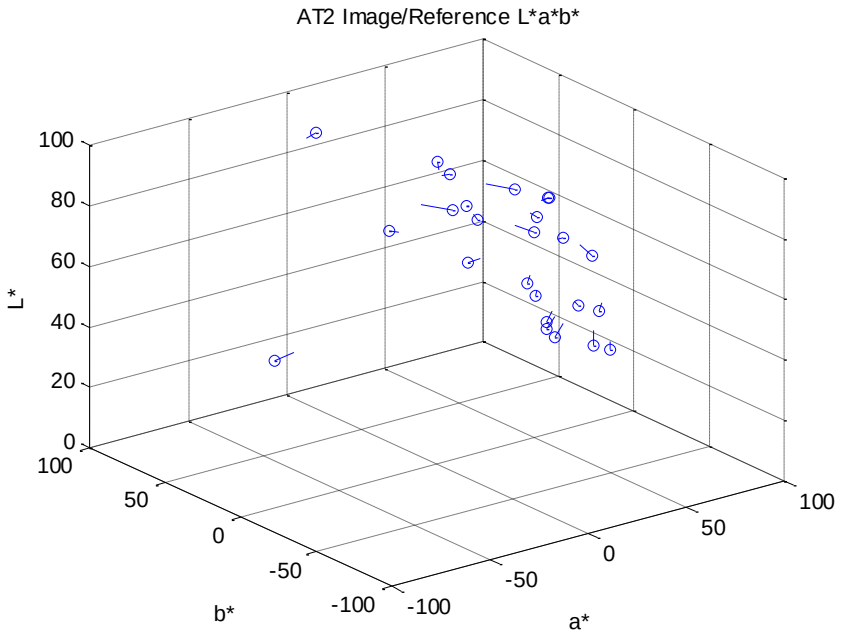
- Down-sample WSI to manageable size (1700x4000)
- Click on centers of corner patches for each block
- Average central ¼ of each target patch



Transform WSI/RGB to D50 PCS values

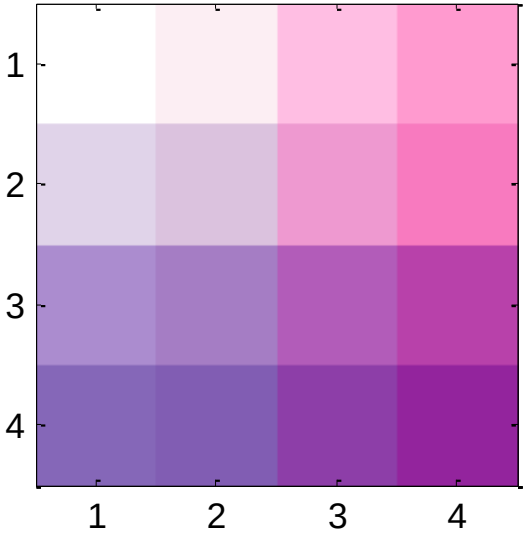
- Matlab used to perform transformations
- Average RGB values transformed to XYZ using ICC profile
- XYZ transformed to Lab using library function
- Values compared to Reference target values



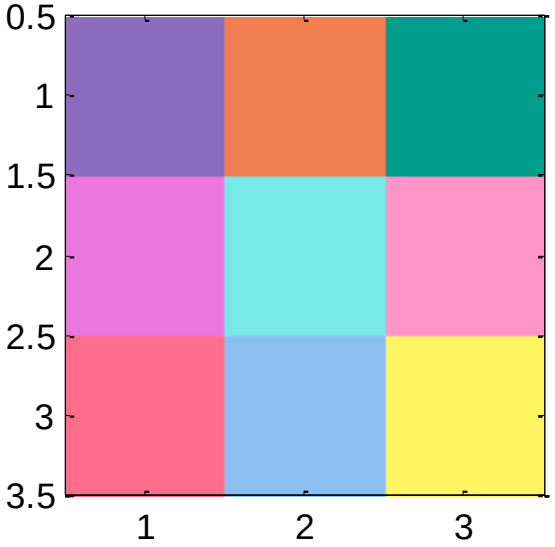


Transform to sRGB

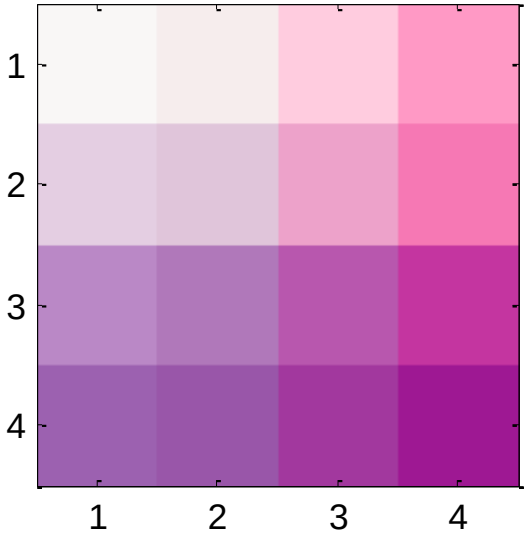
Reference Block 1 Spectral sRGB



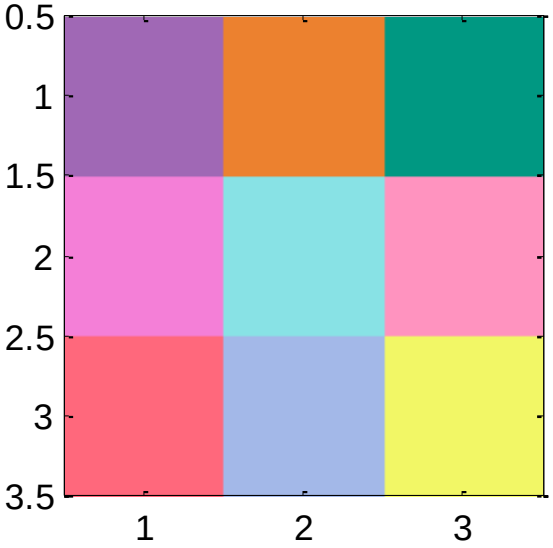
Reference Block 2 Spectral sRGB



AT2 Image Block 1 sRGB



AT2 Image Block 2 sRGB



Sources of variability/error

- Scanner profile
  - general model, based on component specs (light, camera)
  - scanner-specific profile could improve accuracy
  - method used and sample spectra (regression, LUT, spectral)
- Illuminant specified for profile:
  - halogen, D50, E, other?
  - chromatic adaptation to D50 PCS
- Rendering Intent
  - perceptual (default) or absolute
- Intensity of clear/white patch (255, 250, other)
- Noise in target image
  - actual target noise, system noise
- Spectral calibration of target slide
  - measurement errors
  - target fading

Recommendation

- Recommendation
  - Use the initial testing to identify approaches that work best for creating a standardized viewing experience.
  - Make recommendation for profile generation method and apply it to each system. Provide software and assistance to do this.
  - Publish recommended approach along with results from the various systems.
  - Importantly, this will allow us to establish acceptable variation.

- Recommend against publishing existing system results
  - This could unfairly make some systems look bad.
  - Not likely to get participation by all.

END

A Trial at Konica Minolta

Nov. 1, 2014

Shuji Ichiatani and Po-Chieh Hung

Summary

1) We tested as a user (we are not a manufacturer)
2) We scan the slide with Fluorescence Microscope "Keyence BZ-X710"
3) We measure the SPD of light source

We found:

- Slide image has a lot of dusts and bubbles
- The light source is not good in terms of color rendering

Keyence BZ-X710
Fluorescence Microscope

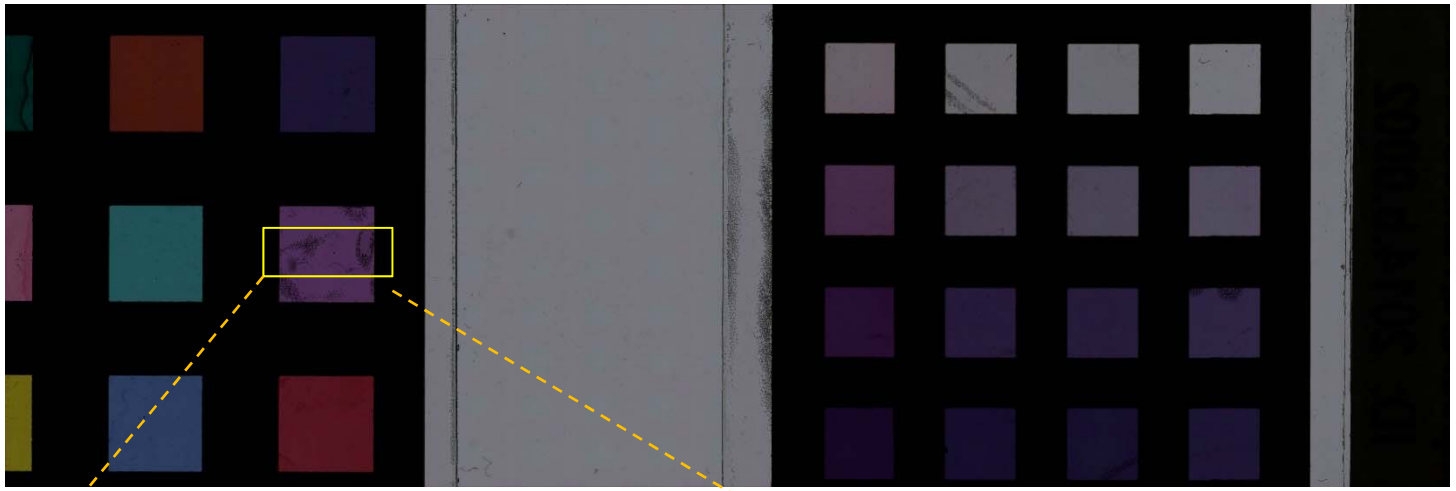
KONICA MINOLTA

- 3 CCDs for transparent color image
- Dichroic filter for color (?)

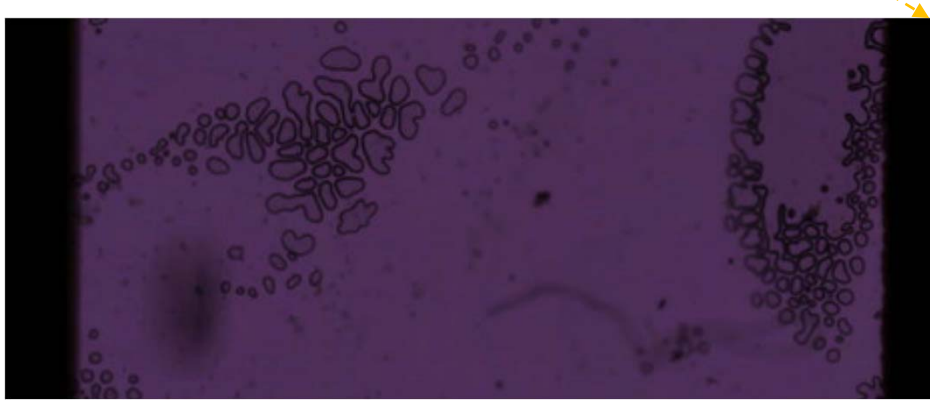
Copied from its catalogue
http://www.keyence.co.jp/frontend/documentdownload/documentdownload.do?fileKbn=3

Image Obtained

- Issue: the viewing (capturing) area is limited.



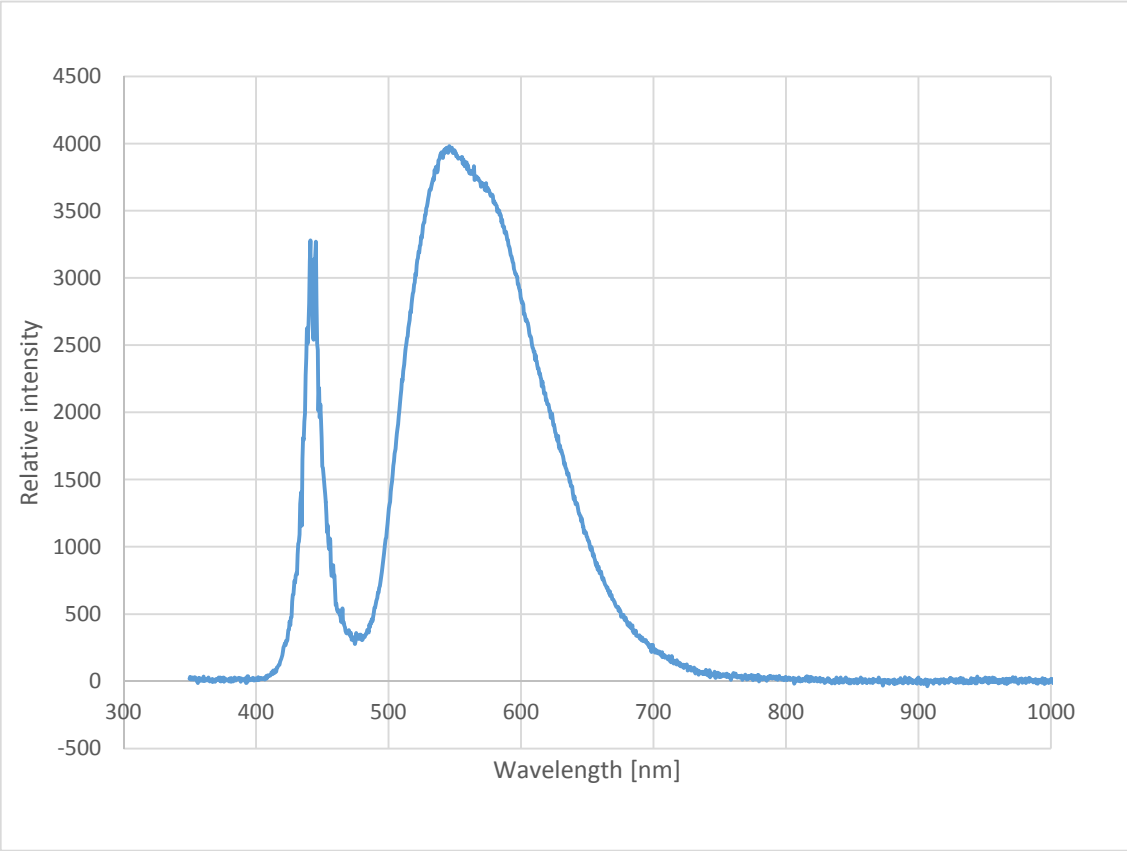
- Bubbles and dusts



Geometry issue?
Because it is designed for fluorescence?

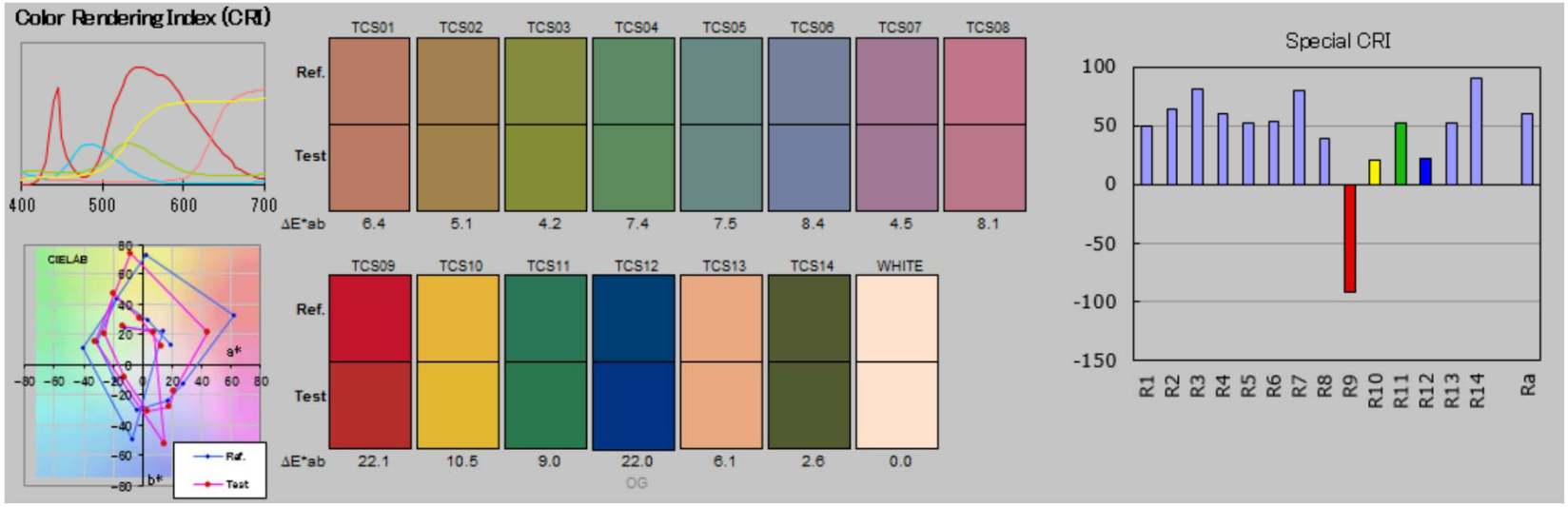
SPD of Illumination

- **White LED (blue-pumped phosphor)**



Color Characteristics of Illumination

- CCT: 4527K
- Duv: 0.032
- CRI Ra: 60
- R(9-12): 1
- R9: -92



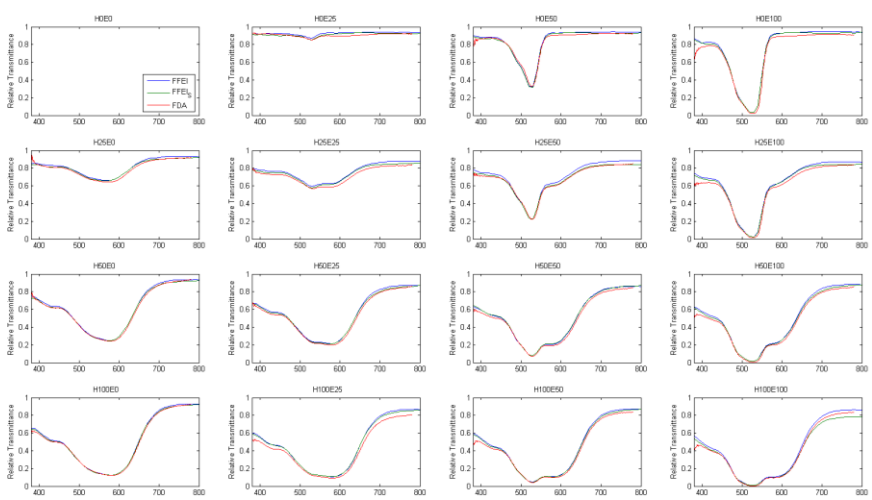
By “CQS 7.5a.xls” courtesy of Dr. Y. Ohno, NIST.

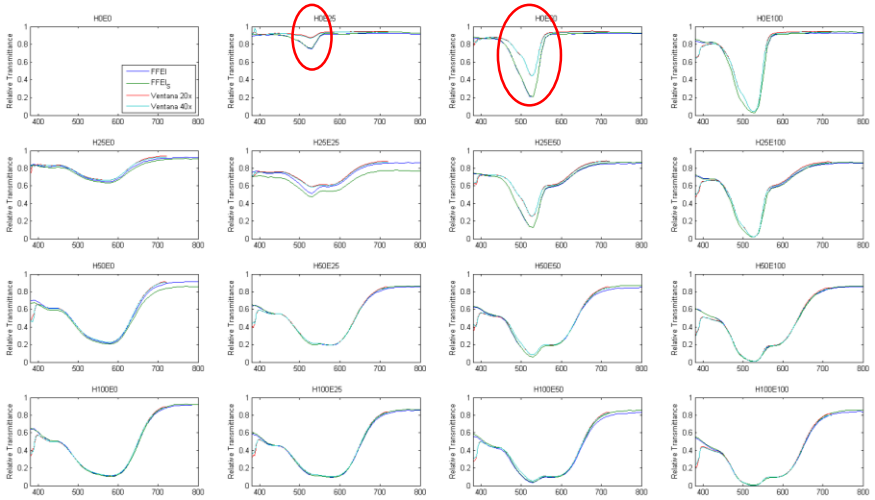
Not good for optical observations
-> It is likely to require non-linear color matrix

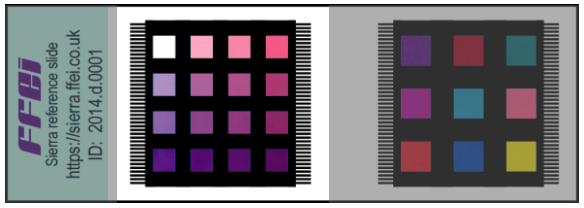
Measurements comparison and FFEI, Leeds and FDA image analysis results

1st November 2014

Slide measurements (FFEI / FDA / Ventana)

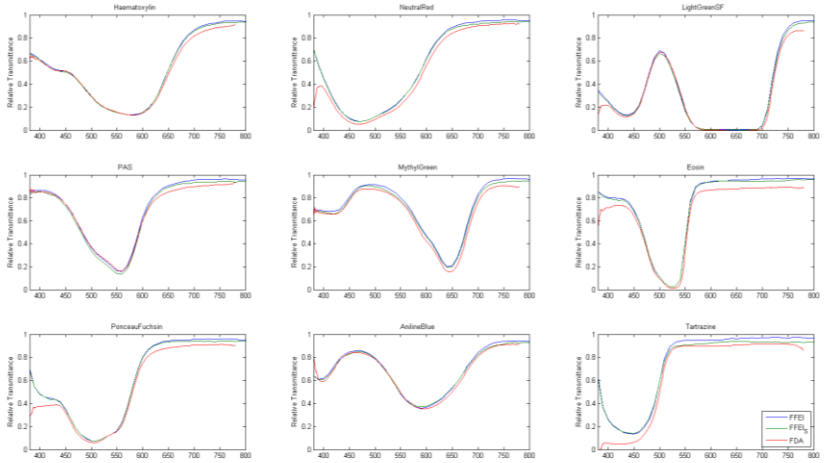


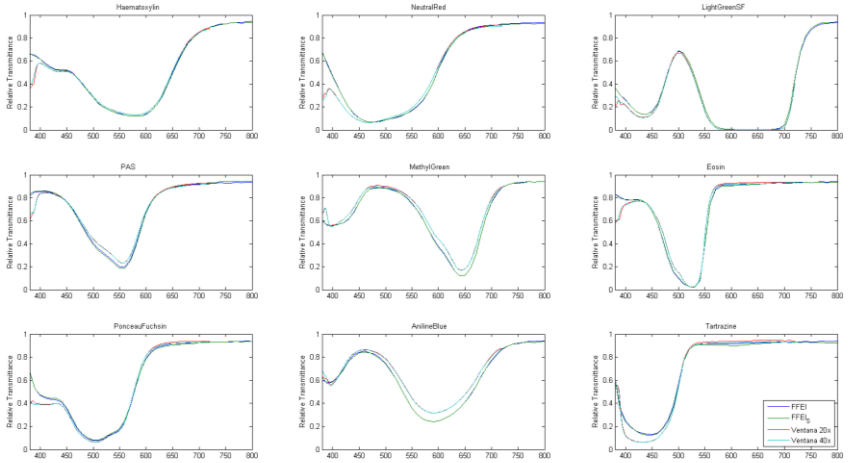


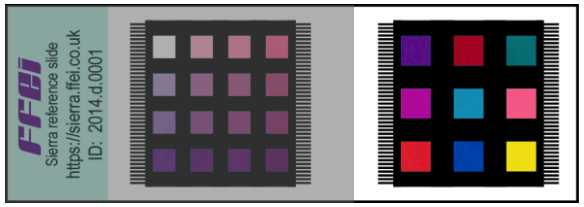


Possible problem with fading of light Eosin patches may indicate problem with application of anti-fading agent (DABCO)

Slide measurements (FFEI / FDA / Ventana)







FFEI calibration method

- Uses a model of the scanner based on ‘generic’ sensor sensitivities
- Training data was large set of measurements of stained pathology slides
- Measurements of Sierra calibration assessment slide were specifically not included in the training set
- Calibration process slightly biased in favour of H&E stains

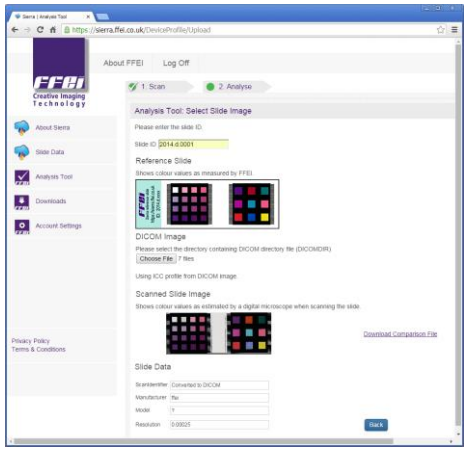
Note that these results were from FFEI’s development platform and should not be considered to be representative of any OEM product

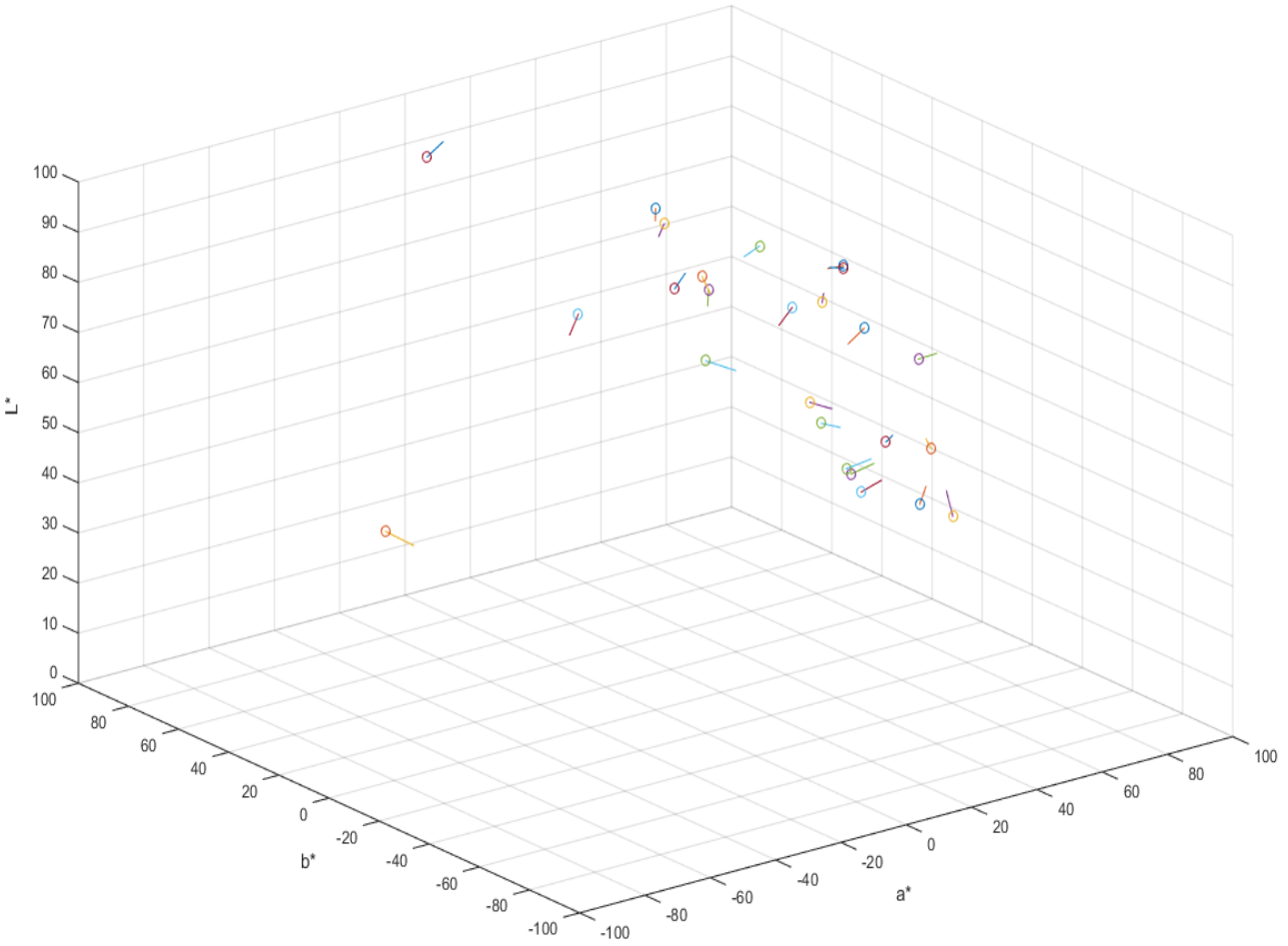
Calibration assessment method

- **Step 1: calibrate scanner and create ICC Profile**
- **Step 2: scan slide and create image of slide in DICOM format**
- **Step 3: use the Sierra calibration assessment tool**
  - https://sierra.ffei.co.uk
- **Step 4: save the analysis file created on the web site**

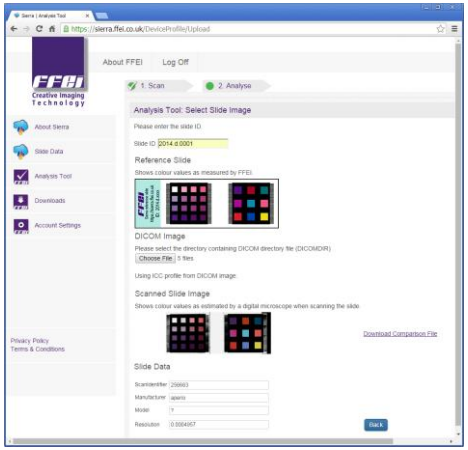
- **Demonstration**

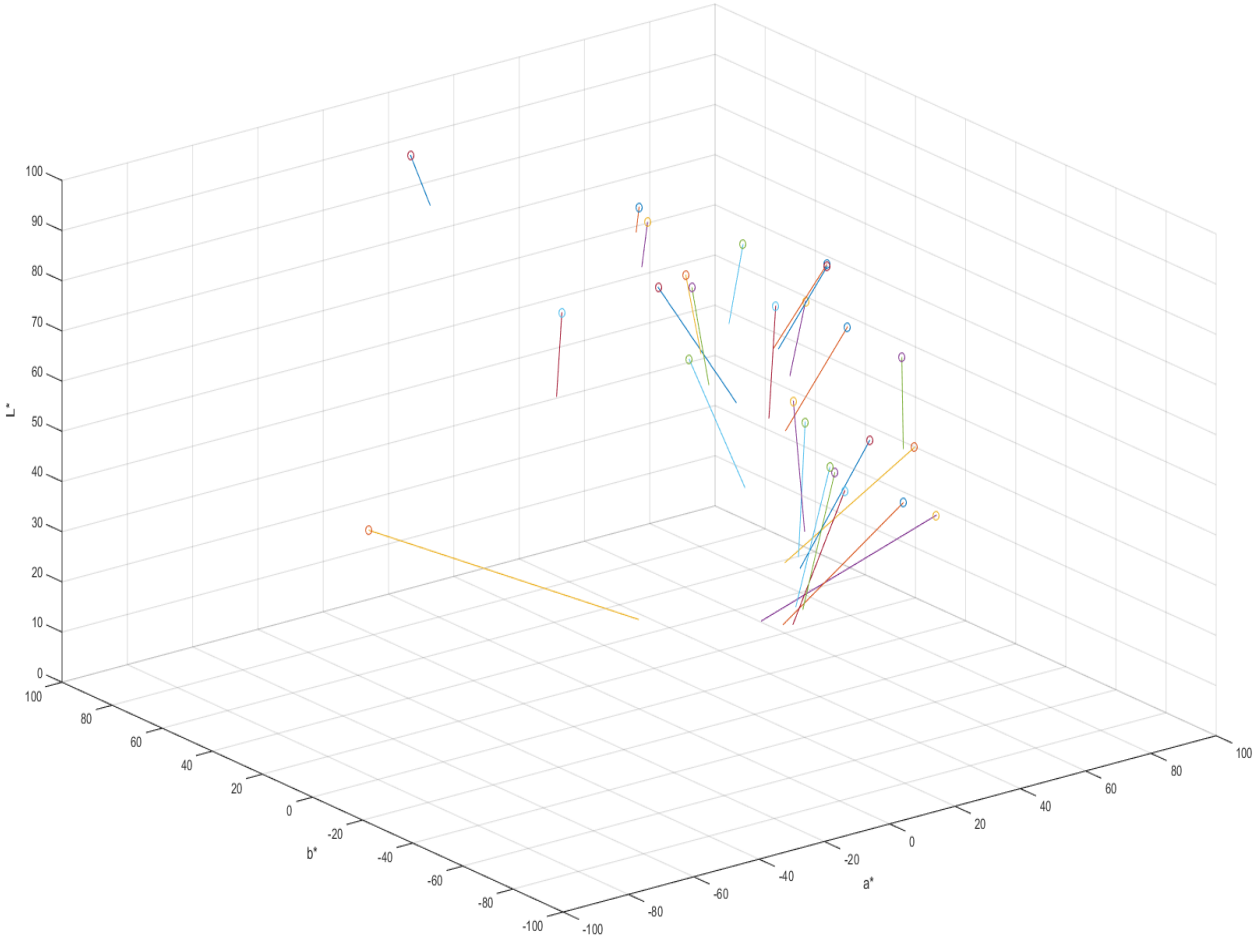
Slide image colour accuracy (FFEI)



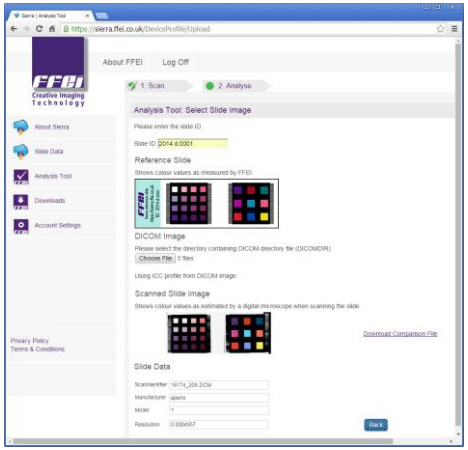


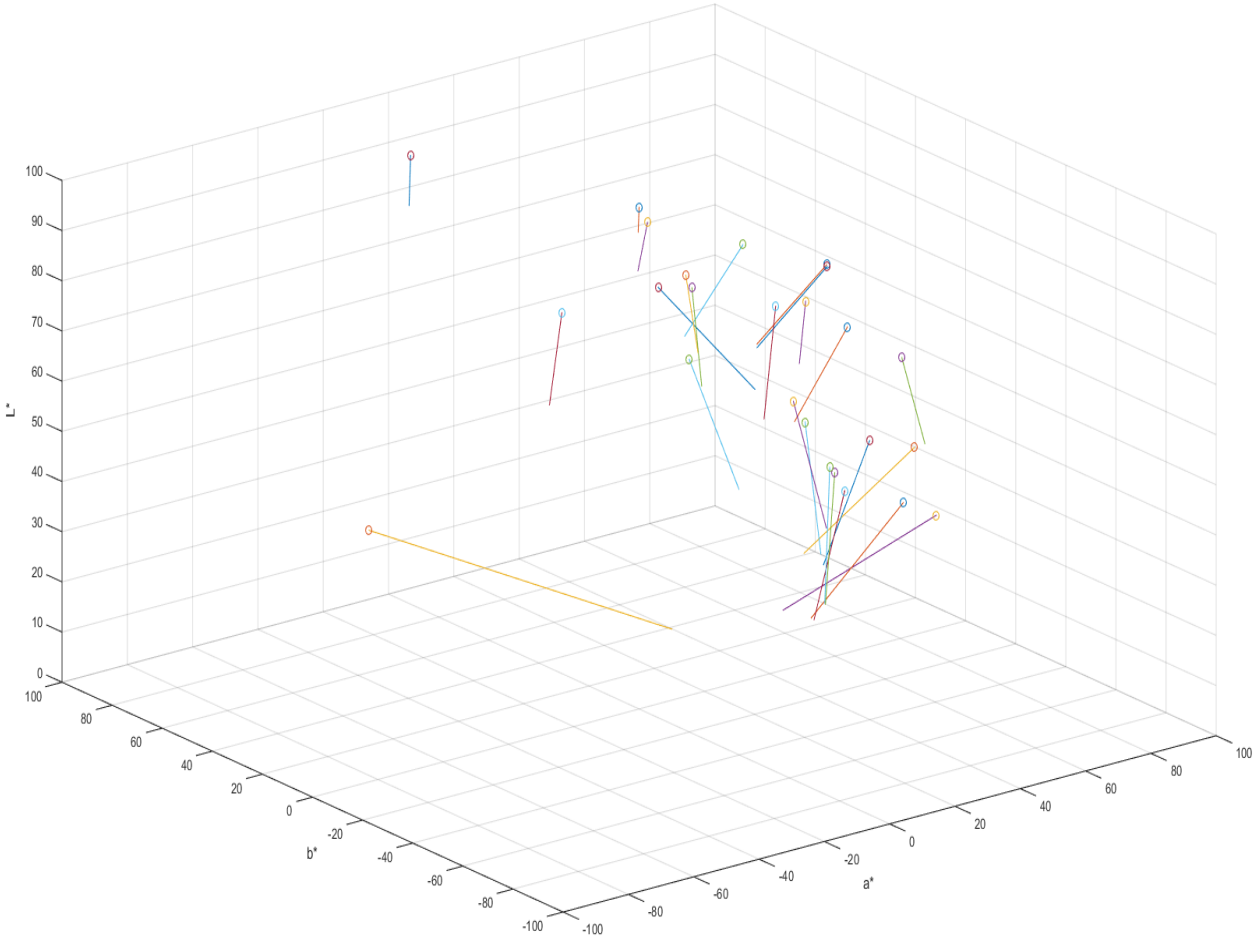
Slide image colour accuracy (Leeds)





Slide image colour accuracy (FDA)





Explanation of the Aperio result

Older ScanScope models were not corrected to a specific viewing condition. The profile was ***designed to adjust the color according to customer feedback*** and the effect is very small relative to no correction at all. The profile intentionally makes no correction for the tonal response of the instrument.

The color profile for our most recent system (AT2) was developed with the goal of reproducing the viewing experience of a tungsten light microscope with daylight filter. The profile is then chromatically adapted to D50 connection space per ICC specifications.

- *Note that if you look at the Leeds/FDA results, you will see that the major part of the difference is in L, as the lines point primarily in the vertical direction of the 3D graph. As I said, we intentionally left the tonal response alone, since this was the what customers preferred. The two systems have nearly the same result and are very consistent.*

Allen Olson, Ph.D.

Senior Scientist, R&D Engineering and Analysis

Aperio ePathology

Problem with automatic scanning

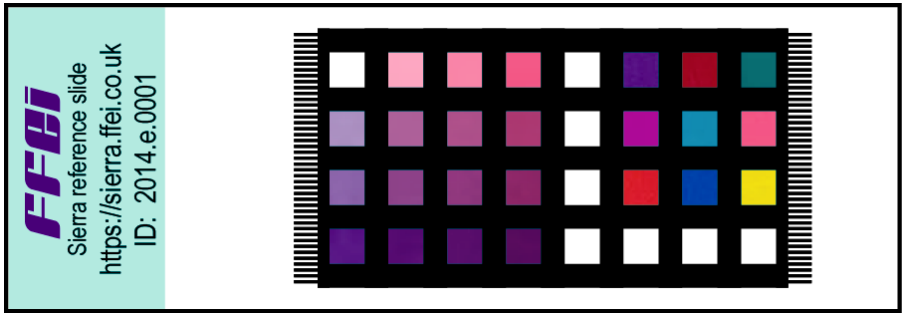
The current layout may limit the usefulness of the slide:

We have a bit of an issue when we scan the slide in automatic mode:
Some of the patches were not detected by the scanner. It could be because the luminance of the patch is low and we have a black background.
Not the whole area of the patches is detected by the scanner. We found that the label on the calibration slide is a bit slimmer than the usual slide labels we have in here.

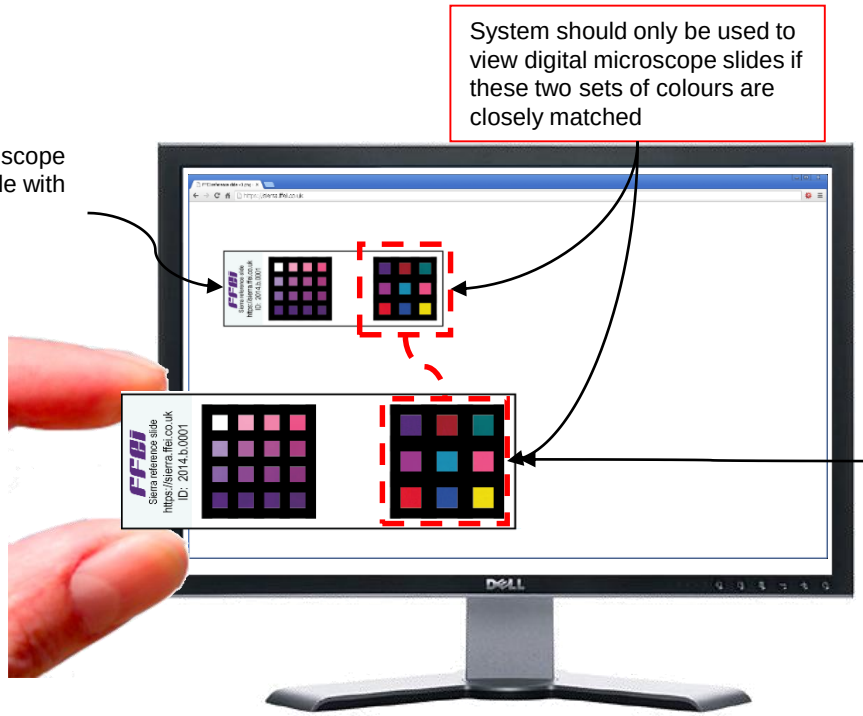
Kindly refer to the attached images.

Thanks.
-Pinky

Revised layout of slide currently being tested

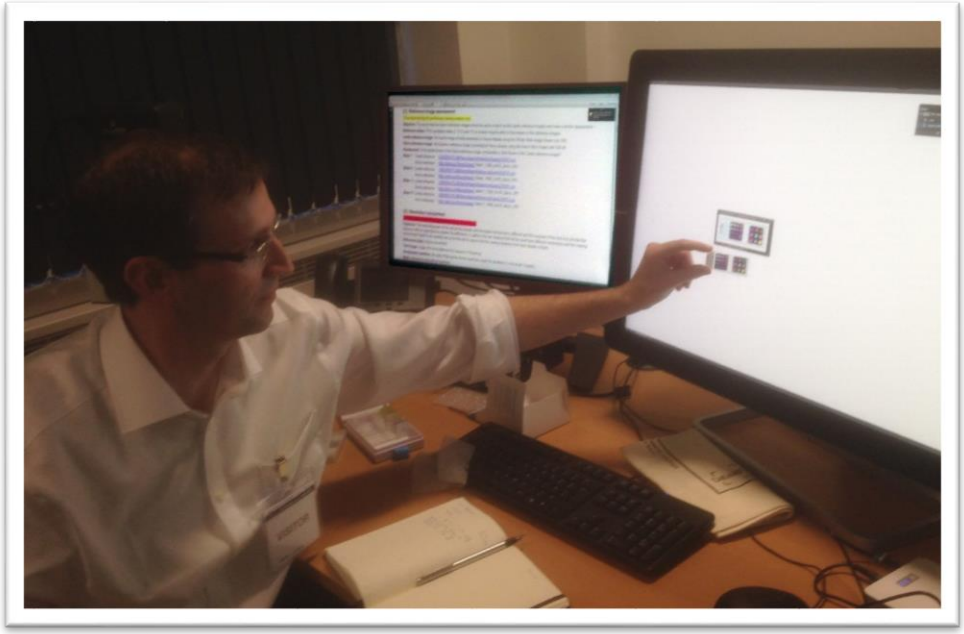


Visual assessment



Based on a method developed and promoted by Yukako Yagi and Pinky Bautista

Pathologist test as part of project Sierra



Initial feedback indicates that this method is easy to use and provides immediate feedback as to whether the system is calibrated to an acceptable level

Questions?

Color Translator tool – possible use in calibration assessment Marti Maria

- **No presentation as Marti described the Color Translator product that uses LittleCMS colour engine which could be useful for some kinds of colour assessment**
  - see http://www.littlecms.com/professional/

Sierra accelerated fading test and extended slide

1st November 2014

Accelerated fading test protocol

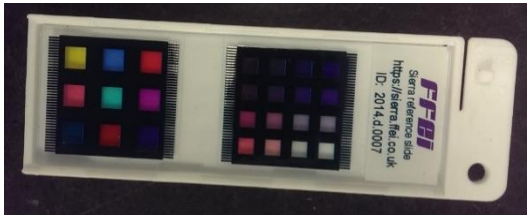
Sierra Calibration Assessment Slides exposed to light for different time periods over the course of six weeks in three phases:

- **Phase 1:** all slides scanned daily but otherwise kept out of any light sources in order to establish a baseline for one week
- **Phase 2:** individual slide protocol for low light light exposure observed for 2 weeks
- **Phase 3:** individual slide protocol for high level of light exposure observed for four weeks

Light source details

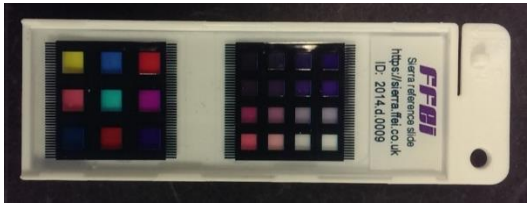
- Low light: Diall Halogen Eco bulb (24W, ~205 lumen)
- High light: Diall Halogen Eco Bulb (37W, ~370 lumen)
- Source deployed 250 mm above the slides

Accelerated fading test

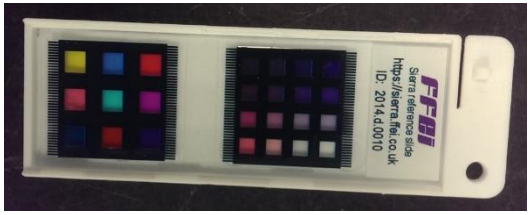


Slide 2014.d.0007 Negative Scan Control Slide
Not exposed to any light after the first week until the end of the experiment (total exposure of 8 measurement scans)

Slide 2014.d.0008 Positive Scan Control Slide
exposed to light only during the scan process (daily measurement scans)

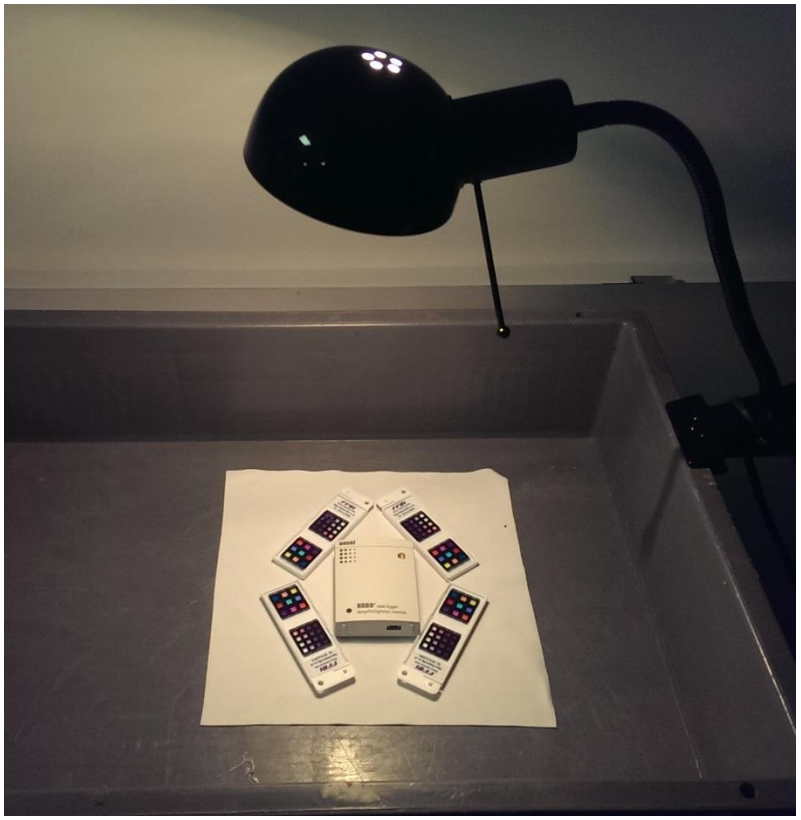


Slide 2014.d.0009 Half Exposure
exposed to an additional light source for four hours per day (daily measurement scans)



Slide 2014.d.0010 Full Exposure
exposed to an additional light source at all times (daily measurement scans)

Accelerated fading experimental setup

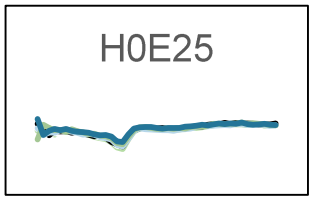


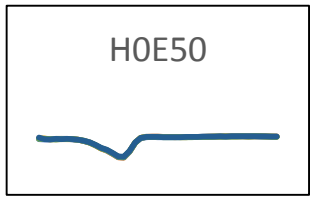
Distance from lamp to slide was approximately 250 mm

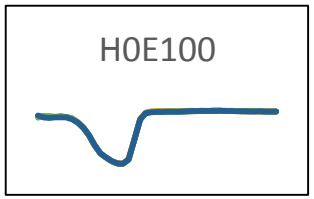
Data logger records light level, temperature and humidity

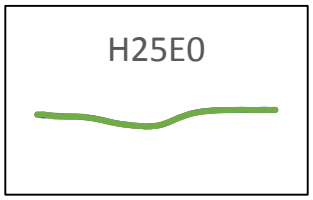
Slide 2014.d.0007 Negative Scan Control Slide

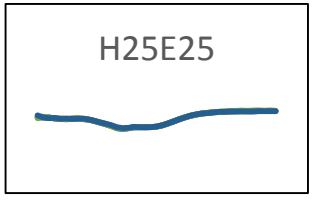
Initial analysis

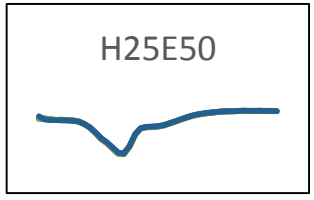


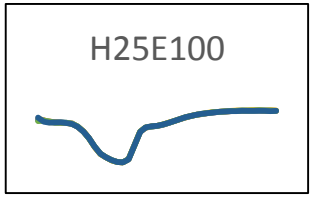


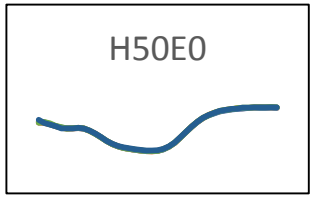


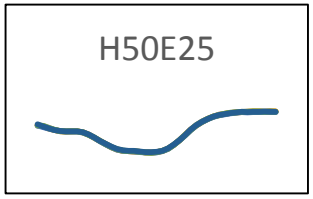


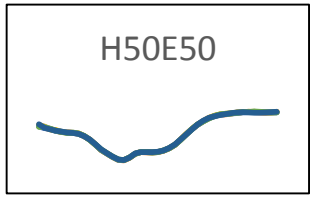


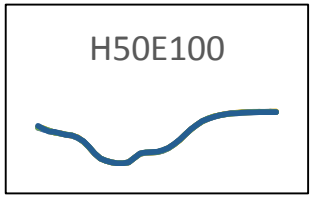


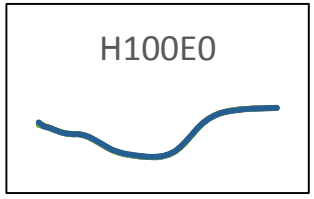


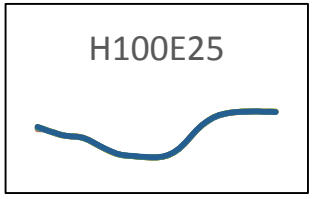


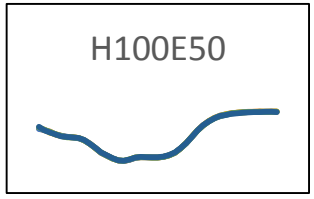


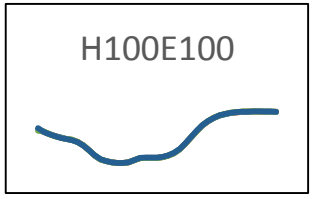




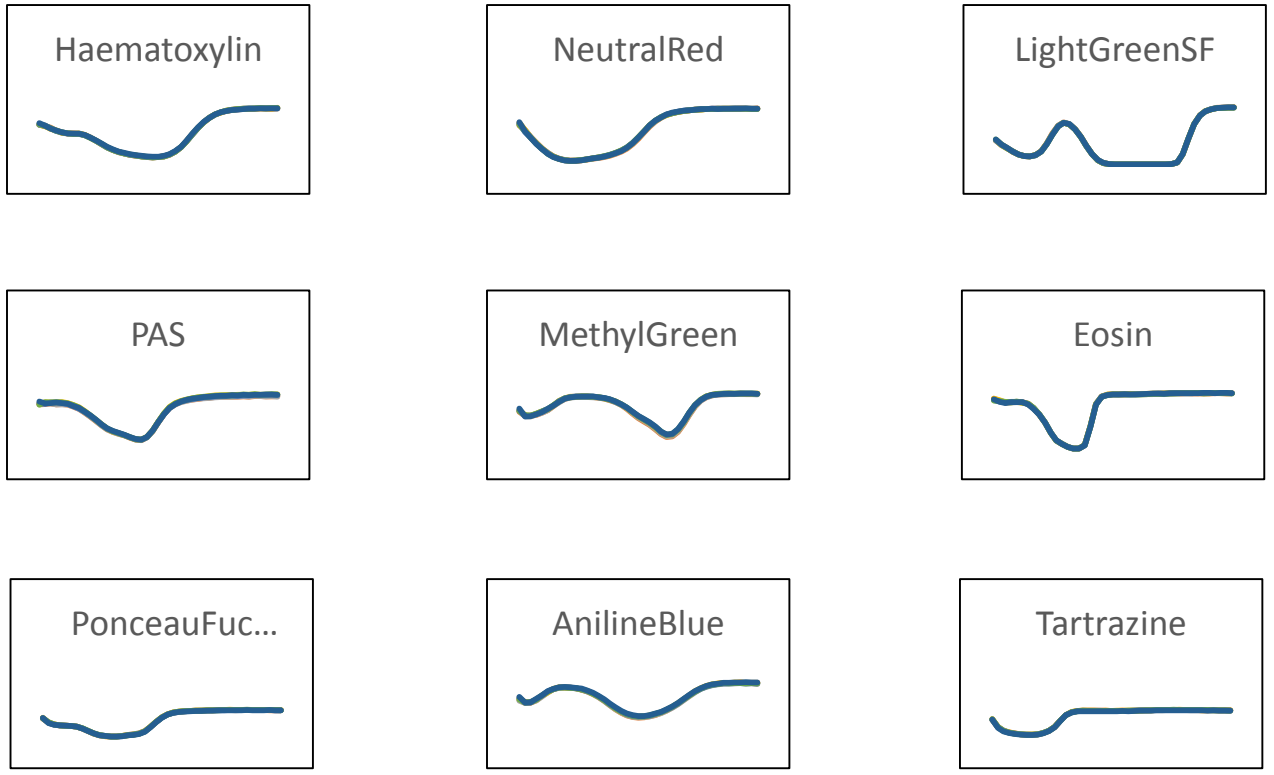






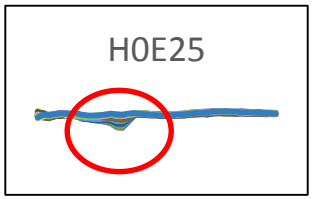


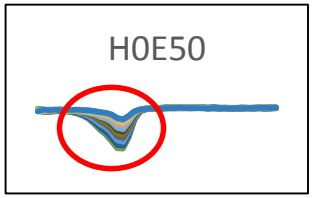
Slide 2014.d.0007 Negative Scan Control Slide

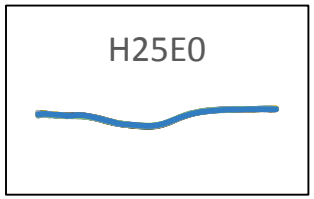


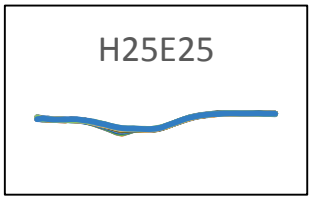
Slide 2014.d.0010 Full Exposure

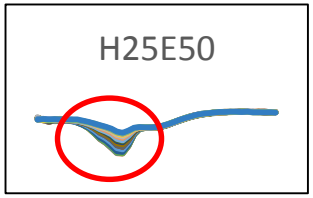
Eosin lightfastness canbe improved by slight modification to our manufacturing process

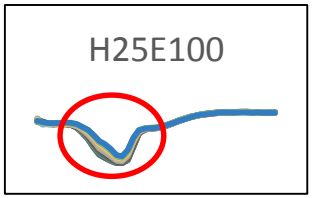


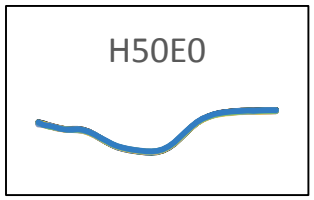


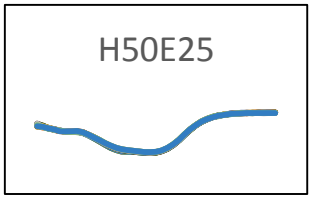


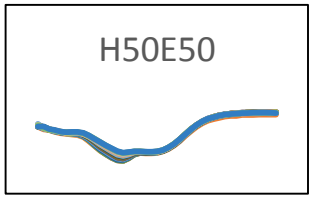


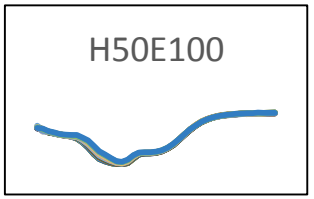


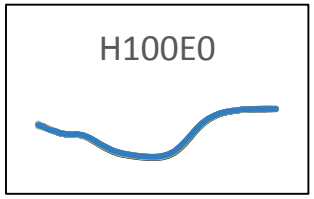


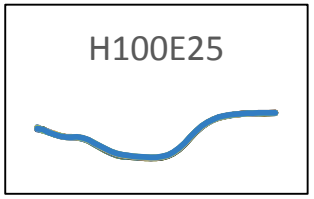


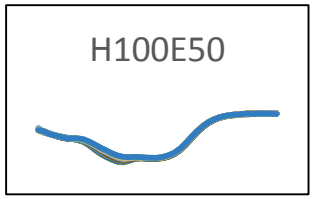


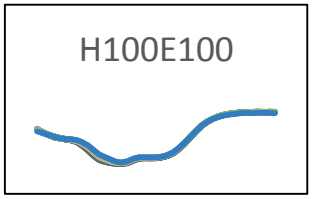




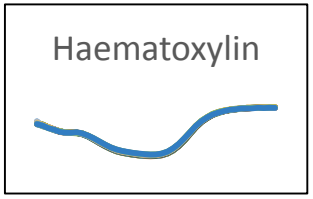


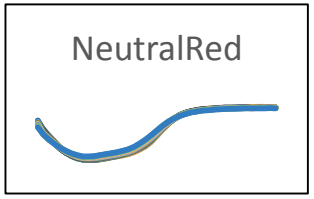


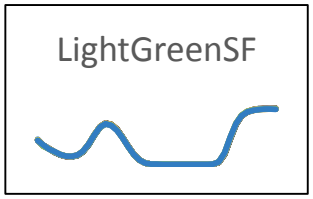


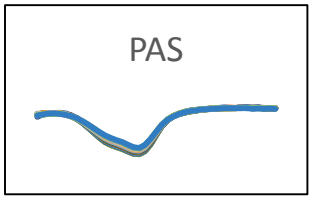


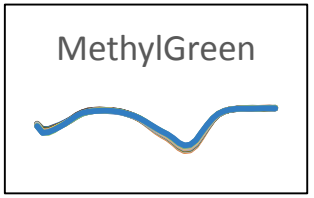
Slide 2014.d.0010 Full Exposure

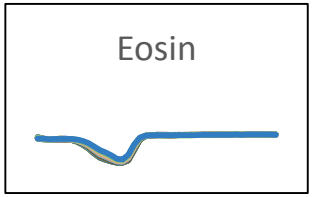


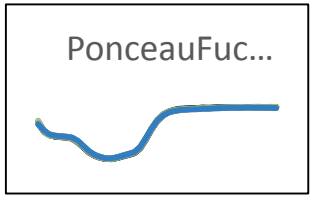


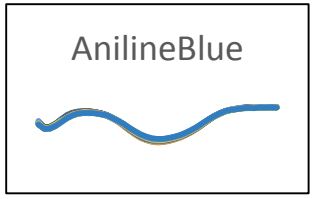


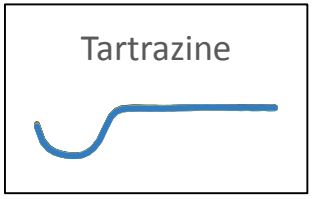




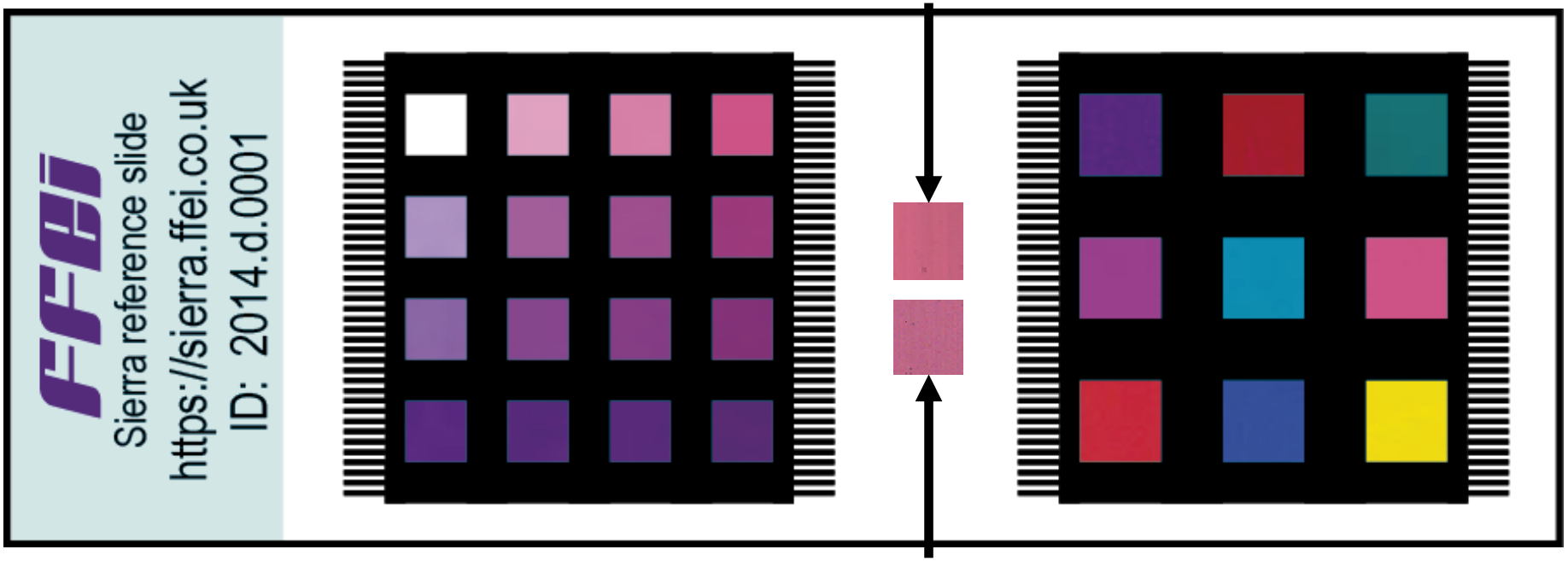




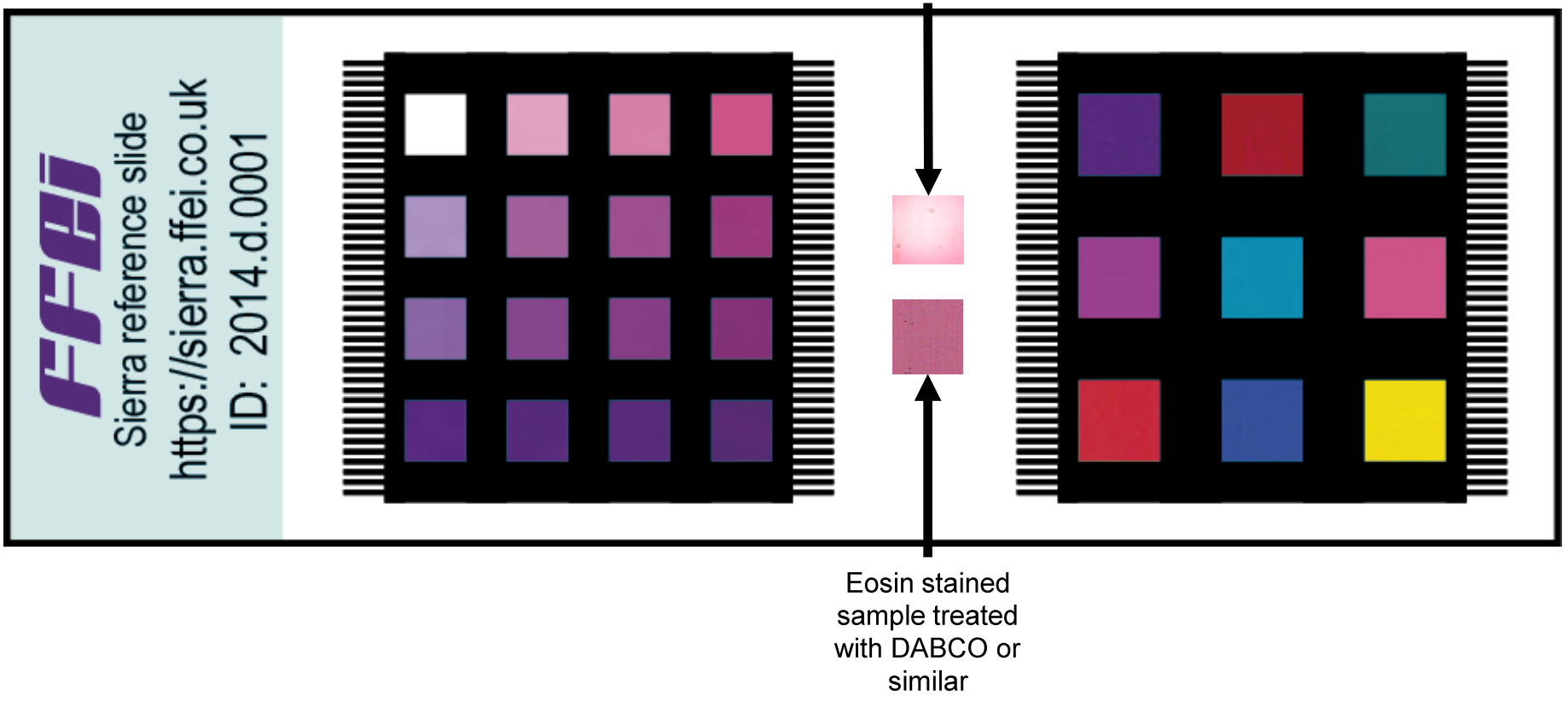




Light exposure control patches



Light exposure control patches

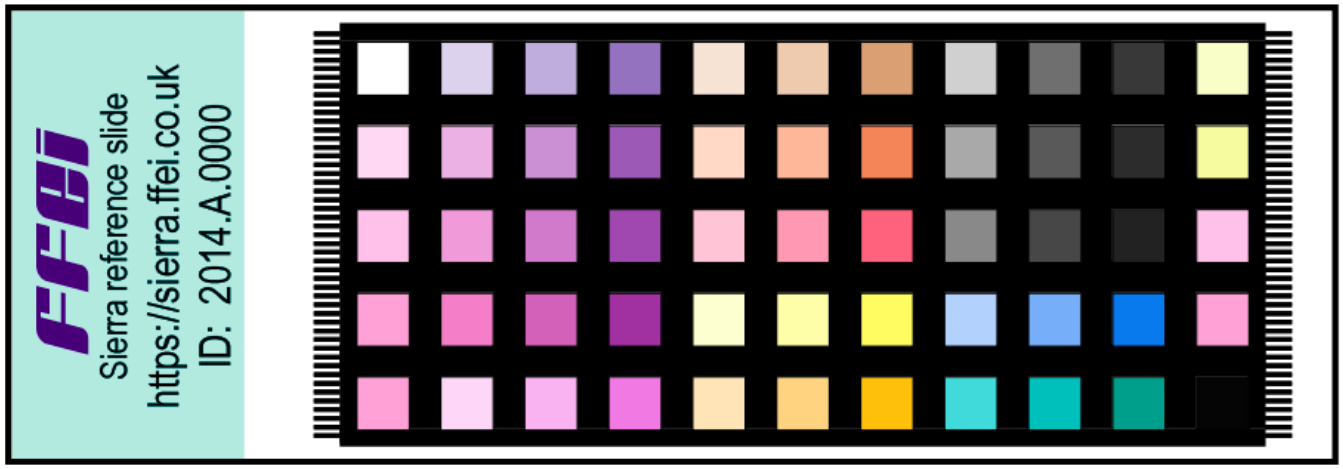


Sierra Calibration Slide

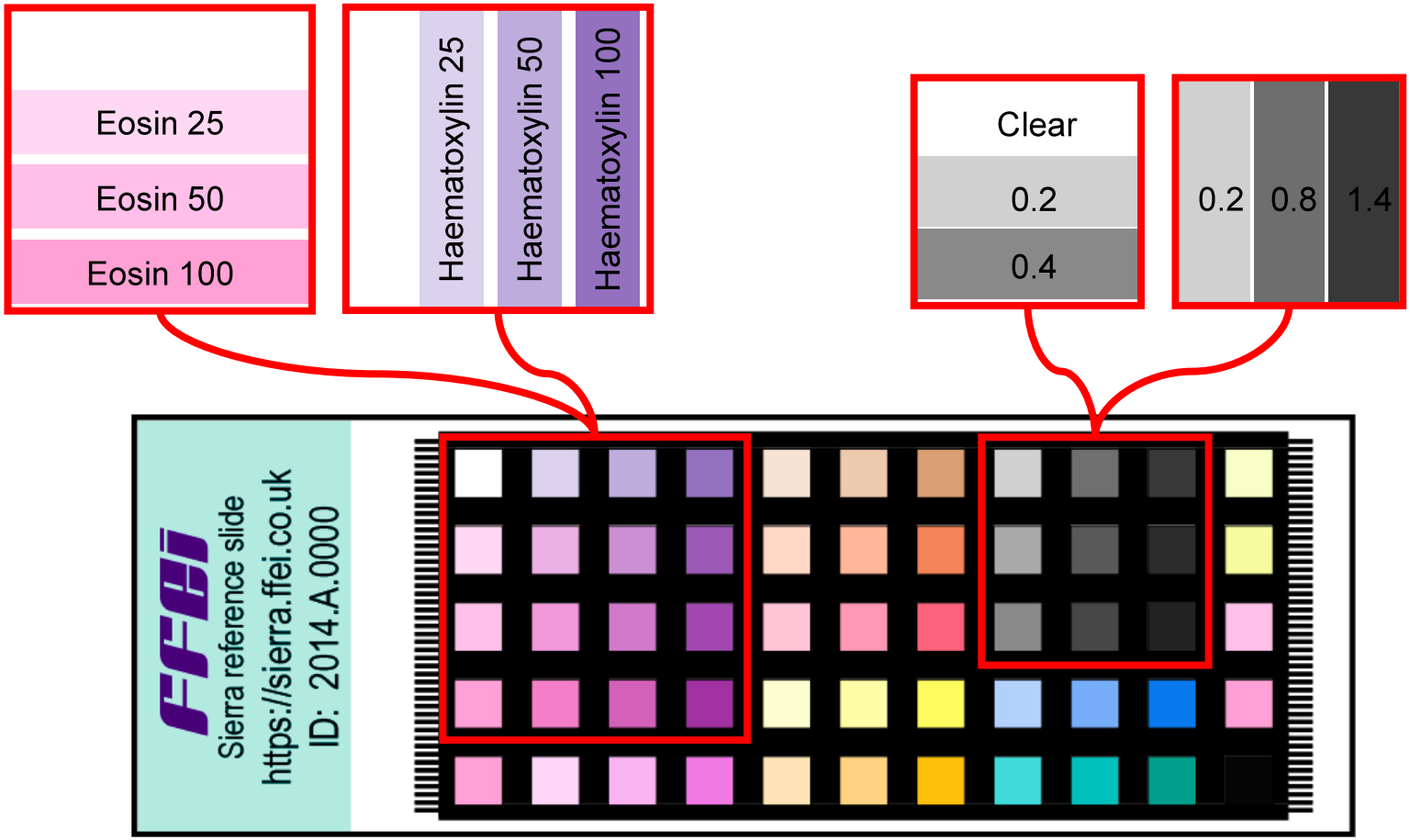
- As part of the Sierra project FFEI plans to create a small number of prototypes of a slide that could be used to calibrate digital microscopes
- Slide will have a set of 55 patches based on the set of spectra we use to build our ICC Profiles for our system
- The uniformity of biopolymer staining has been improved
- The slide will incorporate neutral patches and a fading assessment patch

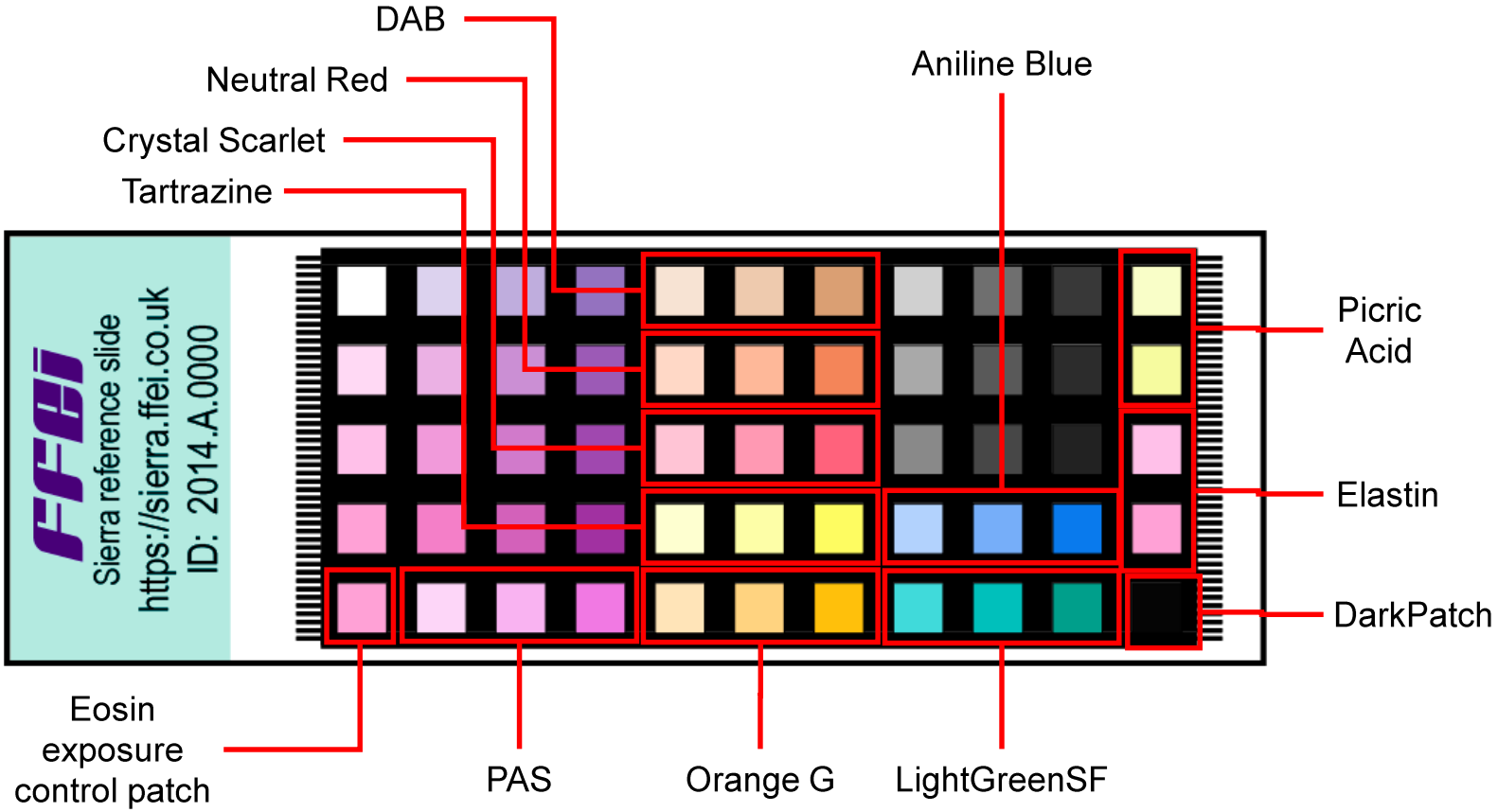
- ***We currently have no plans to manufacture this slide but are in the process of identifying possible partners***

Sierra Calibration Slide



H0E0	H25E0	H50E0	H100E0	DAB_25	DAB_50	DAB	N1	N4	N7	PicricAcid_50
H0E25	H25E25	H50E25	H100E25	NeutralRed_25	NeutralRed_50	NeutralRed	N2	N5	N8	PicricAcid
H0E50	H25E50	H50E50	H100E50	CrystalScarlet_25	CrystalScarlet_50	CrystalScarlet	N3	N6	N9	Elastin _50
H0E100	H25E100	H50E100	H100E100	Tartrazine_25	Tartrazine_50	Tartrazine	AnilineBlue_25	AnilineBlue_50	AnilineBlue	Elastin
EosinControl	PAS_25	PAS_50	PAS	OrangeG_25	OrangeG_50	OrangeG	LightGreenSF_25	LightGreenSF_50	LightGreenSF	DarkPatch


Eosin 25
Eosin 50
Eosin 100
Haematoxylin 25
Haematoxylin 50
Haematoxylin 100
Clear
0.2
0.4
0.2
0.8
1.4
FFEI
Sierra reference slide
https://sierra.ffei.co.uk
ID: 2014.A.0000

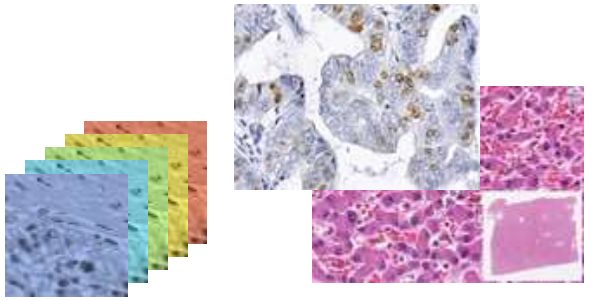

DAB
Neutral Red
Crystal Scarlet
Tartrazine
Aniline Blue
Picric Acid
Elastin
DarkPatch
Eosin exposure control patch
PAS
Orange G
LightGreenSF
FFEI
Sierra reference slide
https://sierra.ffei.co.uk
ID: 2014.A.0000

Framework for Multispectral Imaging Application to digital pathology

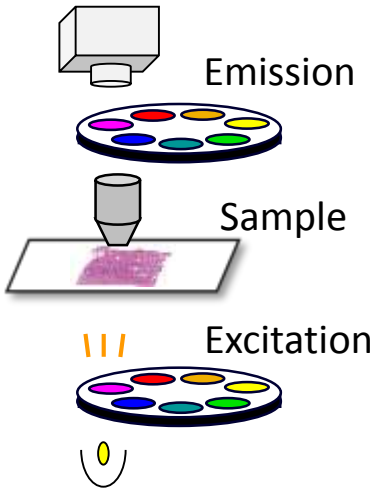
Masahiro Yamaguchi, Tokyo Institute of Technology
Bas Hulsken, Phillips
Max Derhak, Onyx Graphics Inc.

Multispectral imaging in pathology

- Brightfield
  - HE stain, Special stains, Immunohistochemistry(IHC) stains
  - Object detection, segmentation
  - Color unmixing – Stain amount image
  - Digital adjustment of staining strength
  - Digital staining



- Fluorescence
  - Simultaneous imaging of multiple markers
  - Cross-talk, auto-fluorescence removal
  - Combined brightfield and fluorescent images

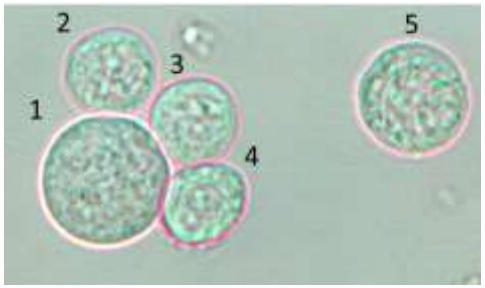


Classification of B lymphocytes without staining

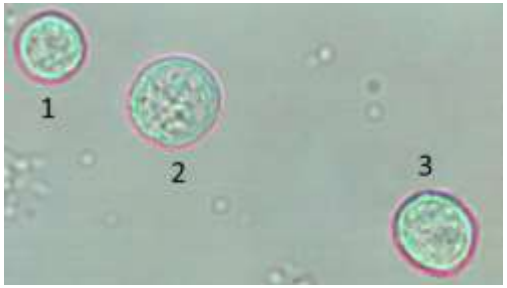
Spectral imaging:

Nonproducing cells (NP)

Ab producing cells A (PA)

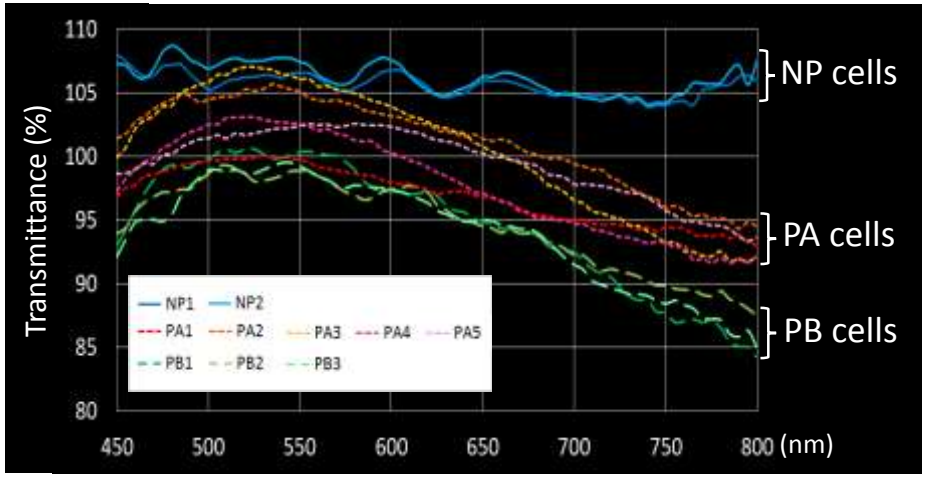


Ab producing cells B (PB)



*(Ab: antibody)

Spectral comparison

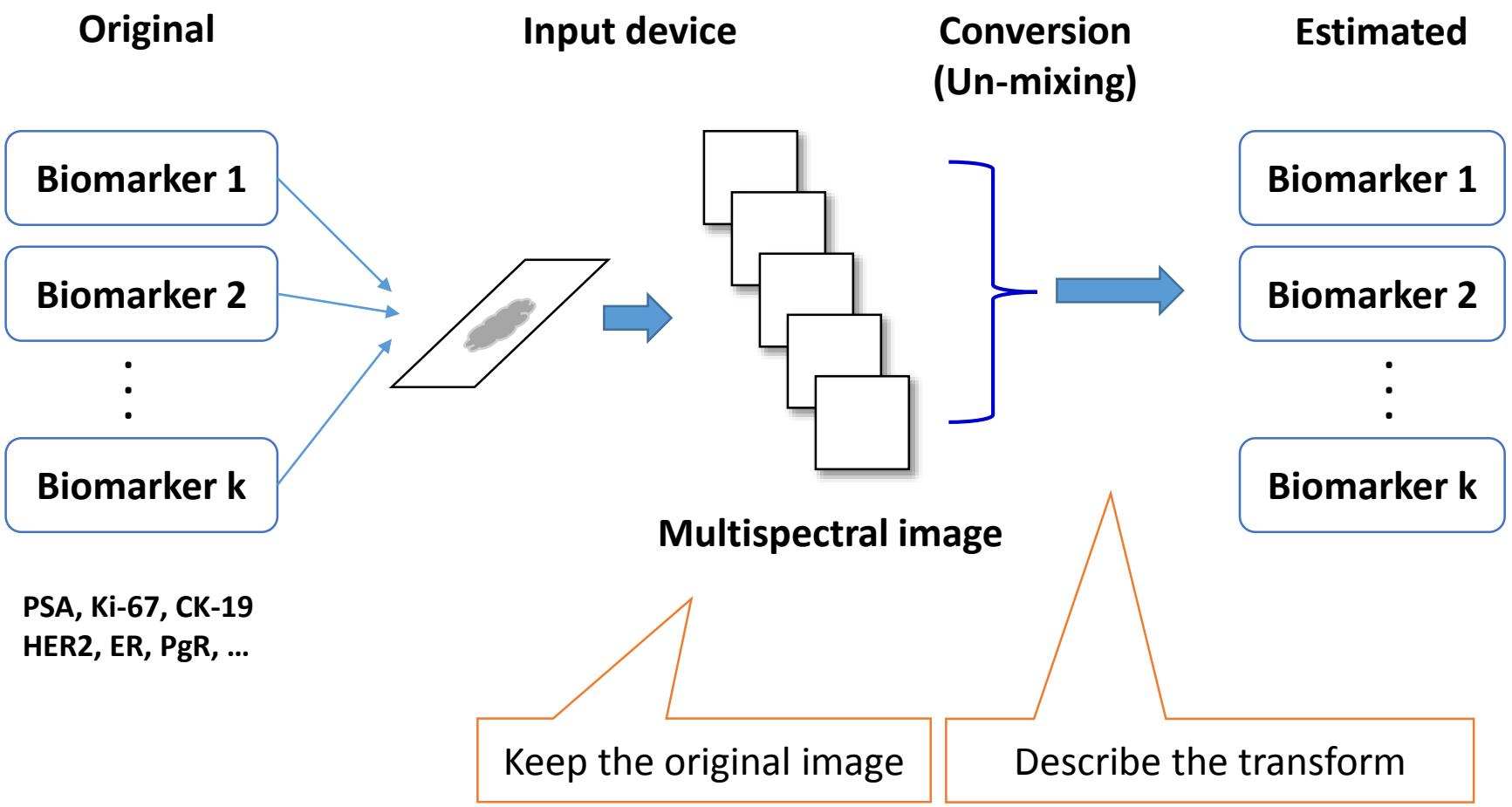


Live cell imaging and discrimination without any staining can be achieved using hyperspectral data.

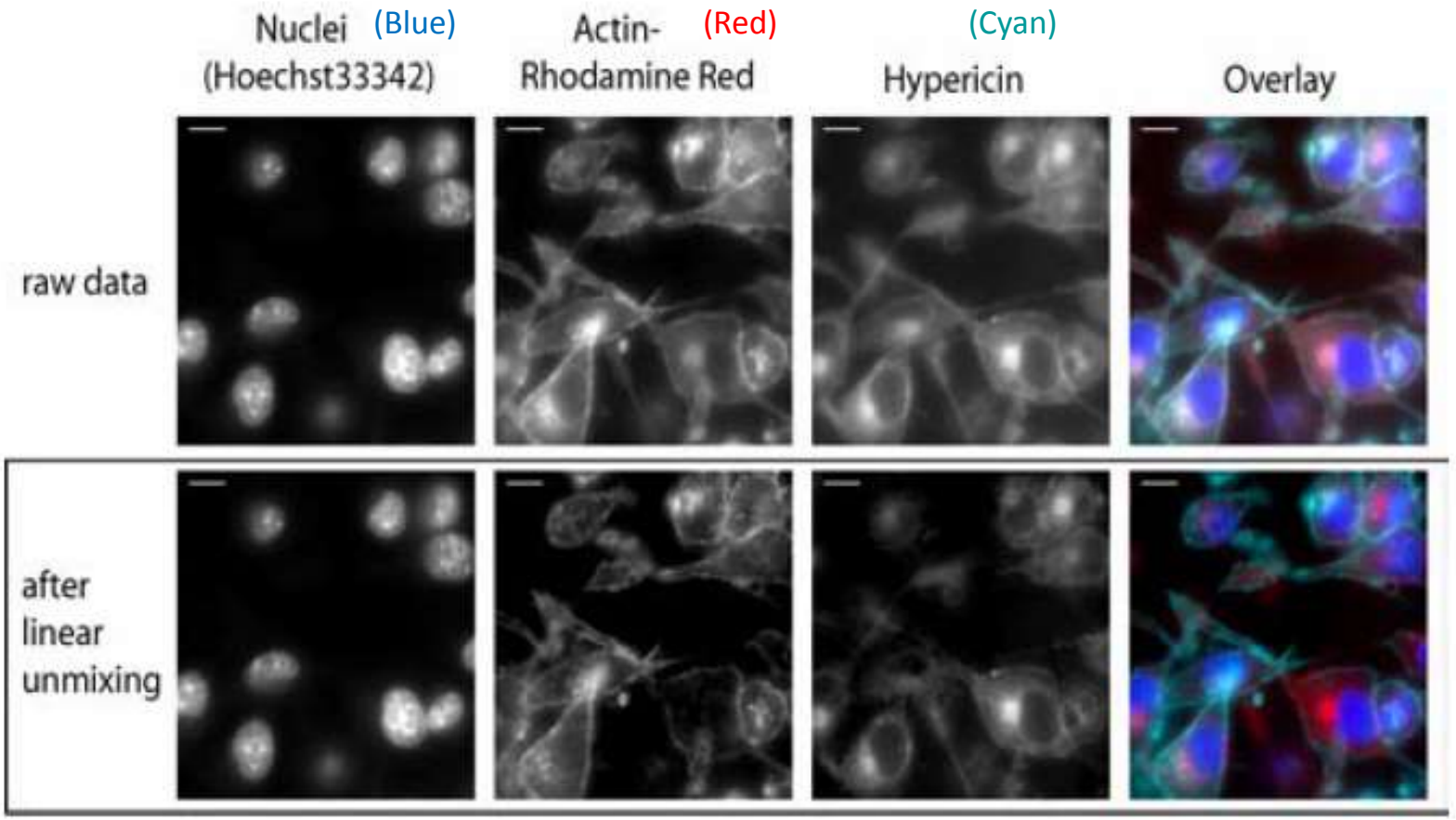
Qualitative evaluation of live cells (eg. activation state of cells) is also possible.

Courtesy of EBA Japan
http://www.ebajapan.jp/English/index.html

General model for multispectral un-mixing

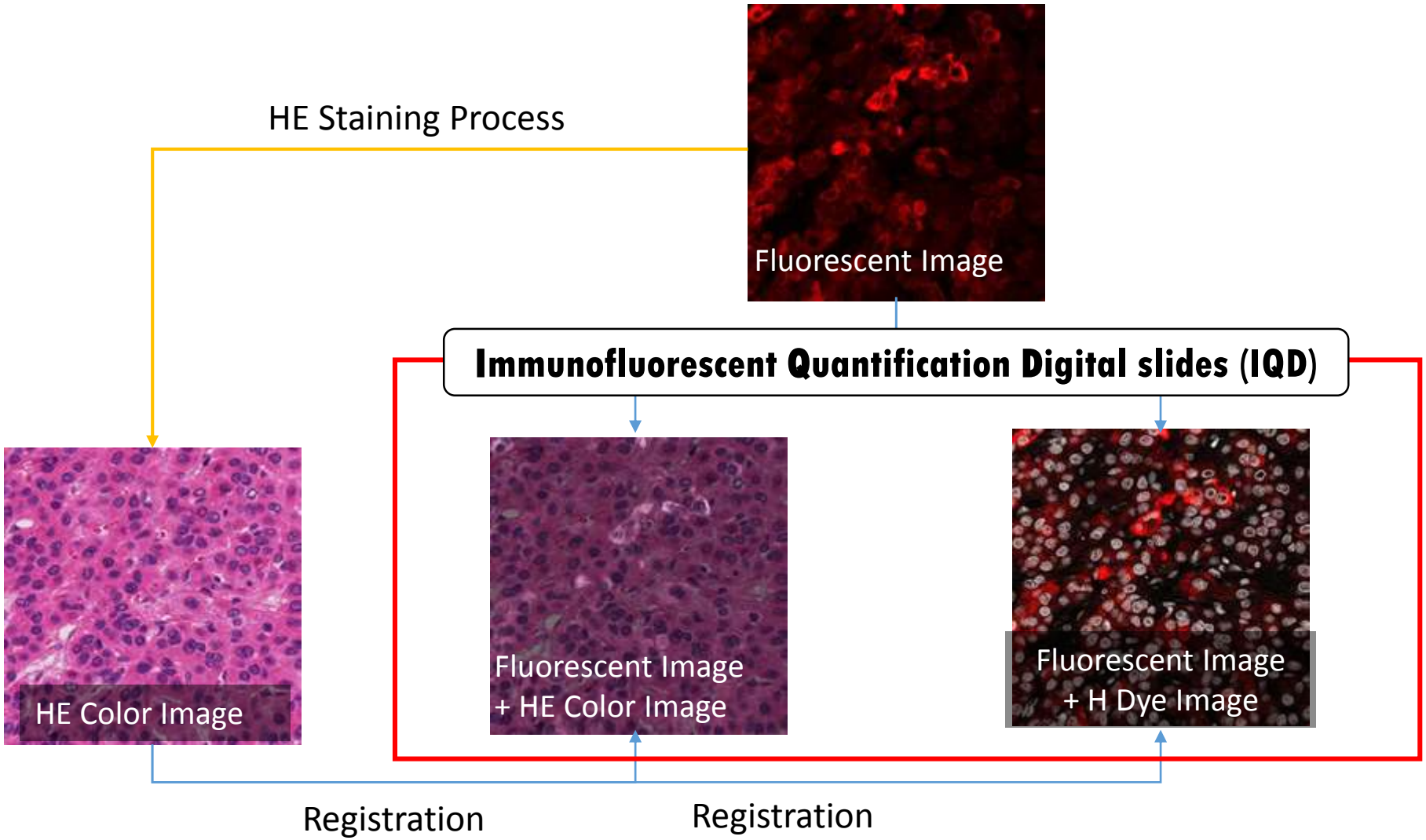


Color unmixing for unwanted fluorescence removal



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

Combination of Fluorescent and HE-stain

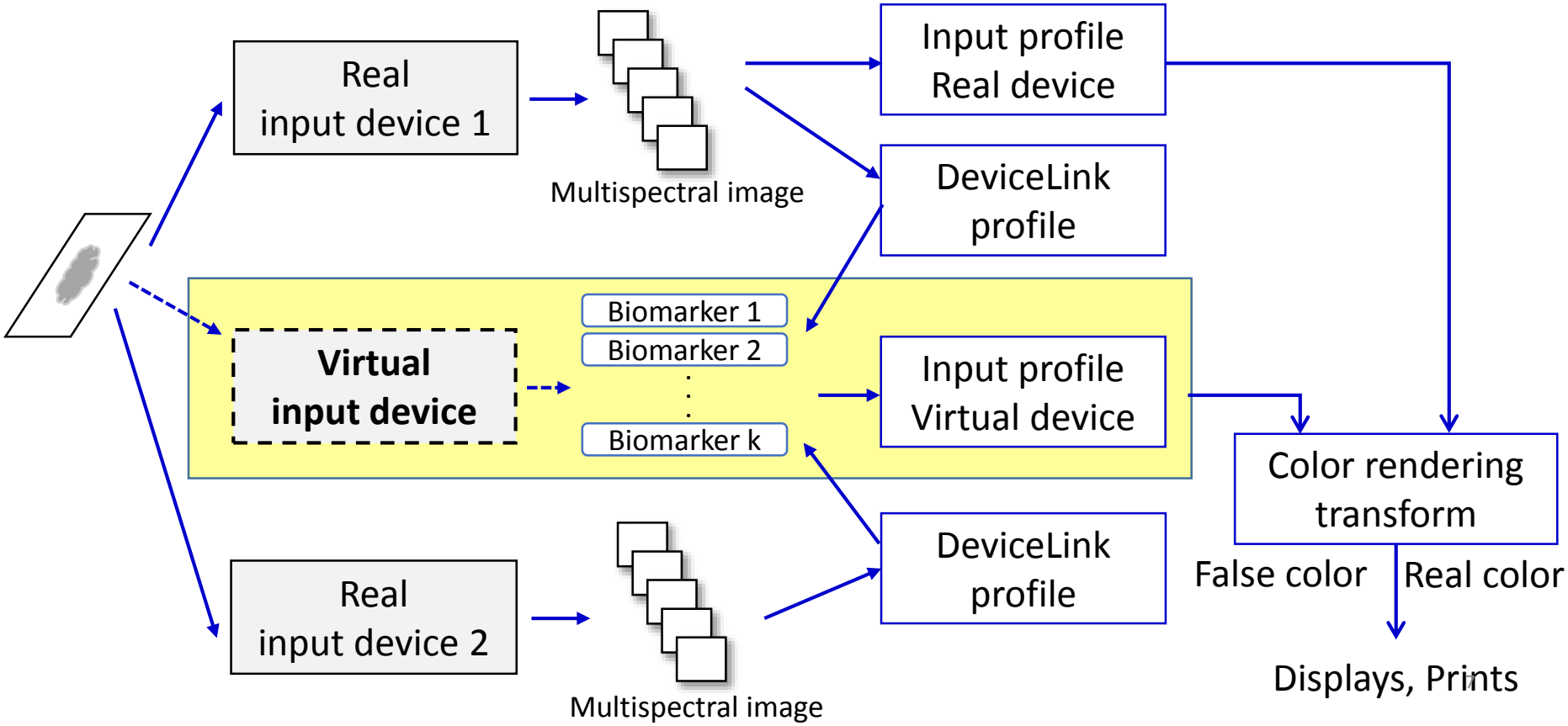


A. Hashiguchi et al 'Using immunofluorescent digital slide technology to quantify protein expression in archival paraffin-embedded tissue sections' *Pathol Int* 2010; 60: 720–5.

Courtesy of Department of Pathology, School of Medicine, Keio University

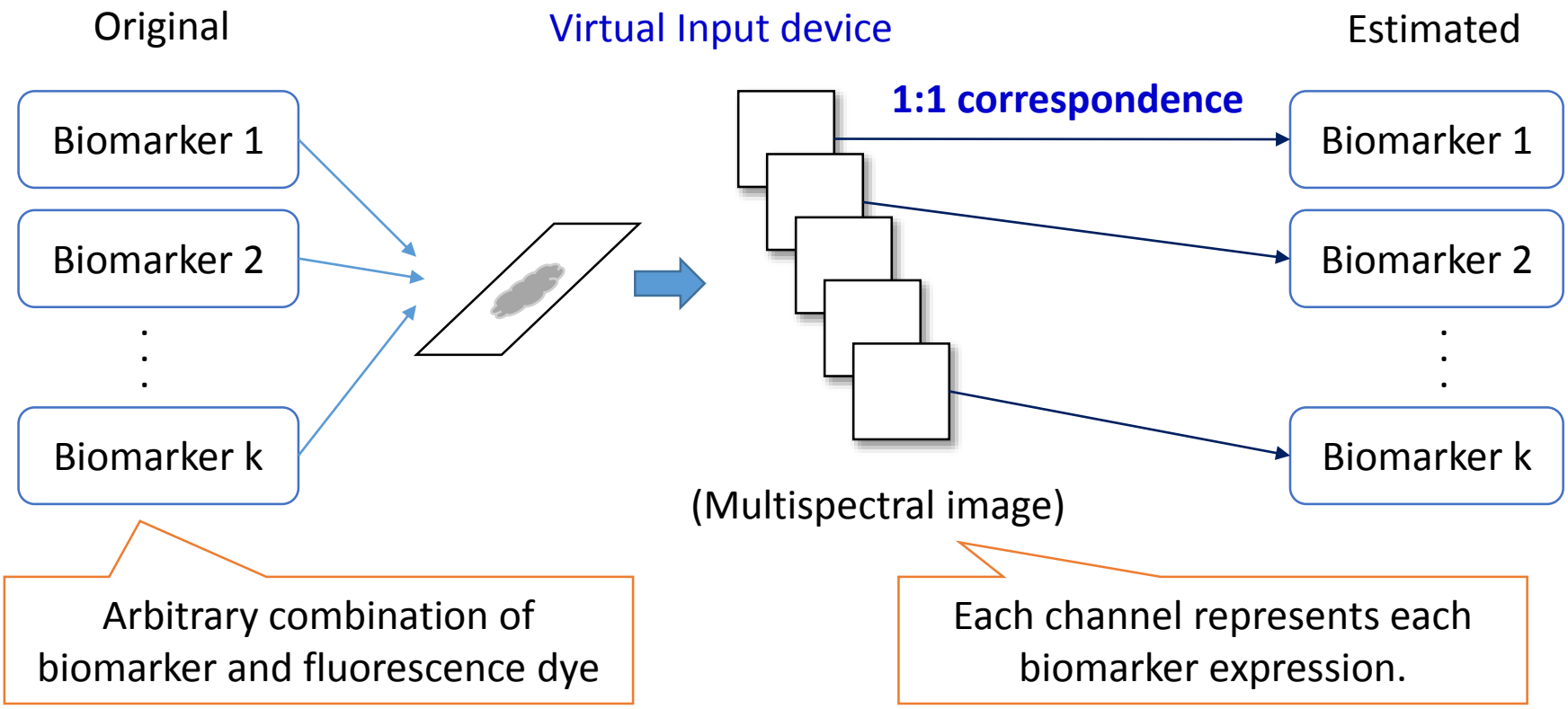
Solution to color unmixing by ICC v4

- Consider a virtual input device
  that can directly capture un-mixed biomarker images
- Use DeviceLink profile



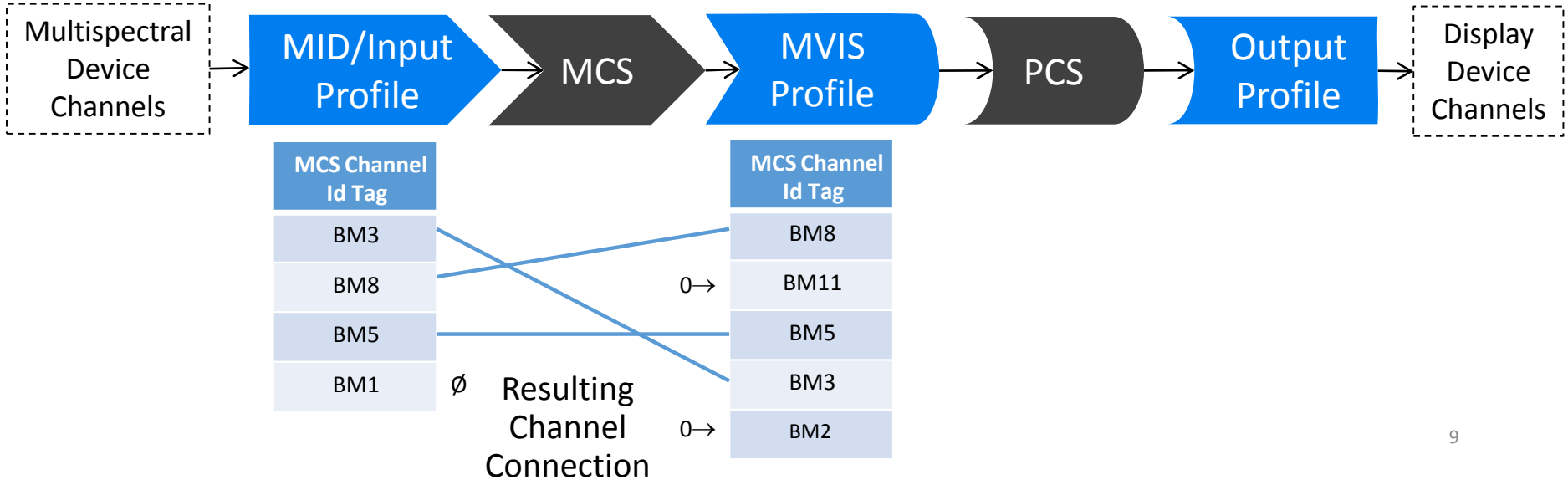
Virtual ‘ideal’ input device

that can directly capture un-mixed biomarker images



Solution to color unmixing by iccMAX

- Spectral profiles
- Multi-processing elements
- Application of “Material Connection Space” Profiles
  - MCS connection allowed between source biomarker Material Identification (MID) and destination biomarker Material Visualization (MVIS) profiles



Current status

- Investigating the adoption of ICC v4 considering the upper compatibility in iccMax.
- Documentation for implementation to DICOM.
- Planning the test implementation of iccMax MCS approach for investigating its advantage and feasibility.

* We welcome contribution from anyone who can provide sample multispectral fluorescent images

Dicomizing multi-spectral presentation states

Bas Hulsken
Digital Pathology Solutions
October 31, 2014

innovation + you

PHILIPS

Steps to take to get multi-spectral presentation states in DICOM

1) Discuss high-level DICOM implementation in WG26
2) WG26 to agree on high-level implementation
3) Send to WG6 for discussion
4) Write the full DICOM implementation

Required DICOM extensions

Simple removal of limitations:

1) Allow multiple ICC profiles in one DICOM object (**1 now**)
2) Allow devicelink ICC profiles (**only input profile now**)
3) Allow ICC profiles for *n* channels (**3 channels now**)

More complex additional functionality

4) Add module describing multi ICC profile render pipeline
5) Define way to store multi-channel image data
6) Add module describing characteristics of channels (spectral, biomarker, etc.)

4) module describing multi ICC profile render pipeline

- Add module to describe chaining of ICC profiles in render pipeline
  - Can use softcopy presentation state either for inspiration, or by extending
  - Need to combine multiple images and/or channels
    - Option A: enhance presentation states to blend more than 2 images
      - Currently the advanced blending and display pipeline is both too complex and too limited. Too complex because ICC profiles contain all required functionality, too limited because maximum 3 data frames are supported(C7.6.23-1 of Part3).
    - Option B: add new module describing chaining, use (chained) ICC profiles for rendering pipeline

5) Define way to store multi-channel image data

- Option **A**, pack all channels in existing DICOM image IOD elements& modules
  - For *n* channel data: specify samples per pixel (0028,2000) to *n* (**currently allowed, but meaning undefined**)
  - Define Photometric Interpretation(0028,0004) to *multi-spectral* (**currently allowed, but meaning undefined**)

  Advantages: easy, no DICOM enhancements required

  Disadvantages: legacy DICOM tools can not do anything with these images, no easy way to define subsampling, different bit depths (only via Photometric Interp.)
- Option **B**, channels in separate DICOM IOD's and combine with presentation states
  - For *n* channel data: use *n* monochrome images, or RGB + monochrome images (**currently allowed**)
  - Enhance or make new softcopy presentation state
    - Allow *n* referenced images

  Advantages: legacy DICOM tools can handle the separate images (channels)

  Disadvantages: requires new/enhanced presentation states. Cannot define correct rendering in Image IOD itself.
- Option **C**, channels in raw data, not image data, define all from scratch

  Advantages: full flexibility

  Disadvantages: lose all existing image handling tools/functionality

6) Add module describing characteristics of channels (spectral, biomarker, etc.)

- Add module that describes for the image the channel characteristics
  - Can use multi-spectral MR for inspiration
  - Multiple modes:
    - 1) Spectral characterization per channel (Illumination spectrum, detection spectrum, excitation spectrum)
    - 2) Biomarker concentration representation

- Module should describe derived channels?
  - ICC profile pipeline has intermediate results, which can have meaning (biomarker concentration)


PHILIPS

Material Connection Space Profiles in iccMAX

Problem Statements

- **Provide ability to define how to process input channels for the purpose of deriving quantitative representations of individual material values**
- **Provide means of visualizing these quantitative representations**

- **Need to answer the question “What is it?” rather than “What does it look like?”**

Possible Solution with Problems

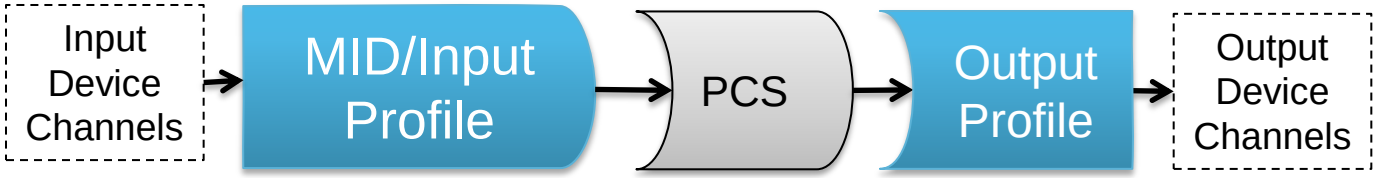
- **One proposed approach to solving these problems would be to successively apply device link profiles**

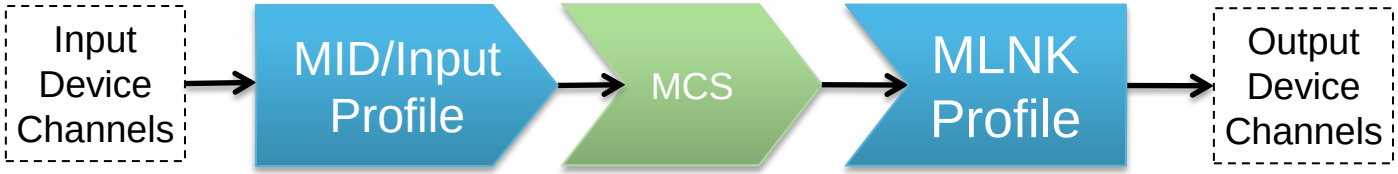
- **Intermediate device channels must exactly match**
- **This can quickly become unwieldy!**
  - Requires standardization of intermediate device channels for linking purposes
  - Explicit channel order is required
  - Cannot easily compensate for cases when only a subset of channels is needed/provided by one of the profiles

Material Connection Spaces

- **An entirely new method of connecting profiles based on the concept of a Material Connection Space (MCS)**
  - Can conceptually be thought of as a material “device like” space with flexibility in channel routing
- **An MCS is completely separate from a PCS and therefore has no computational relationship to a PCS**
  - Relationships are completely provided by transforms in profile
    - AtoM0Tag, MToA0Tag, MToB0Tag, MToS0Tag - All based on multiProcessElementType
  - CMM performs no direct conversions between an MCS and a PCS
- **Like device channels, encoding of MCS channel data values is not explicitly defined**
  - Encoding of MCS channel values allowed to be defined by domain specific use cases
- **Rules for connecting profiles and routing channel data are well defined to be clearly implemented by a CMM**
- **MCS usage defined by new profile classes or extension to Input Class**

MCS Connection Workflows





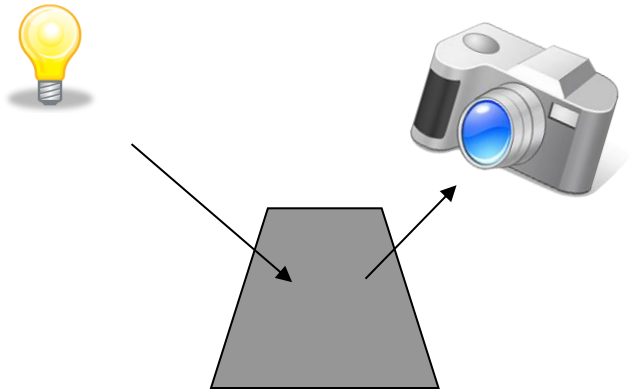
Material Channel Connection Rules

- **MCS connection allowed between source profiles with AToM0Tag [Input profiles / Material Identification profiles] and destination Material Visualization (MVIS) or Material Link (MLNK) profiles**
- **Apply MCS subset requirements**
  - If profile has MCS subset flag set then it's MCS channels need to be a proper subset of MCS channels in the connected profile
  - This ensures interoperability where channel requirements are needed
- **CMM simply passes channel data directly between source profile to destination profile for channels with same material channel identifications**
- **Ignore AToM0Tag MCS channels not present in MVIS/MLNK profile**
- **Use materialDefaultValuesTag values as input for MVIS/MLNK MCS channels not present in source MID profile**
  - This assumes independence of material channels
  - Use zero if materialDefaultValuesTag not present

Example

Hypothetical Scanner

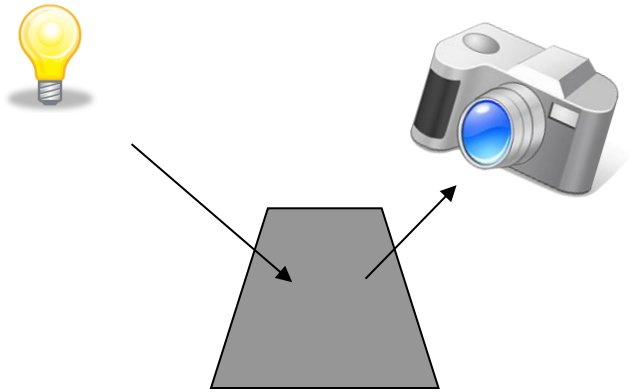
Measurement #1



Results in Channels
c0, c1, c2

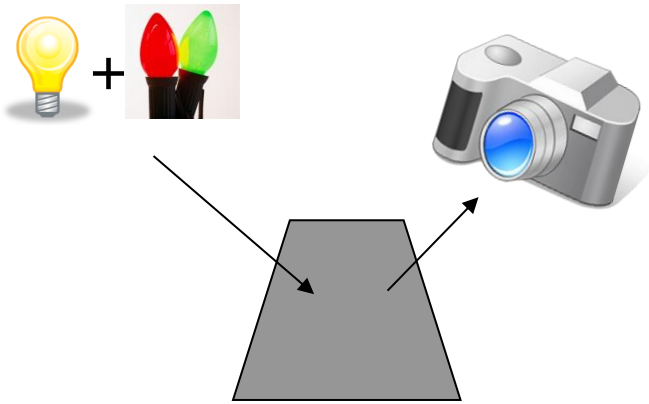
Hypothetical Scanner

Measurement #1



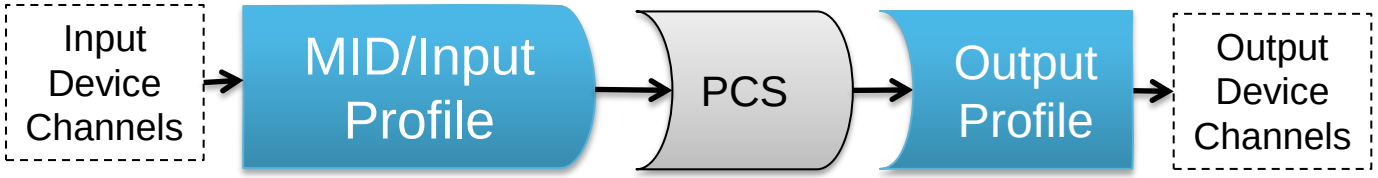
Results in Channels
c0, c1, c2

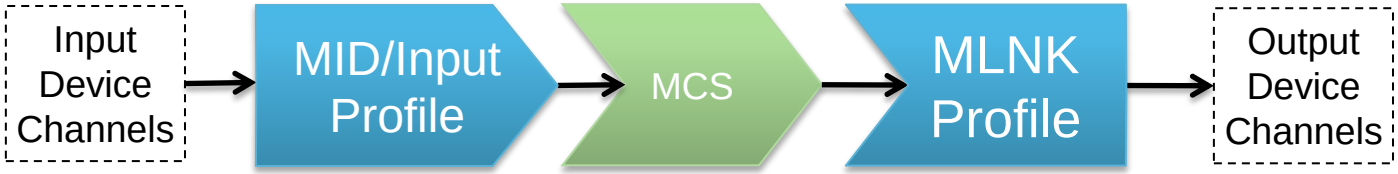
Measurement #2



Results in Channels
c3, c4, c5

MCS Connection Workflows



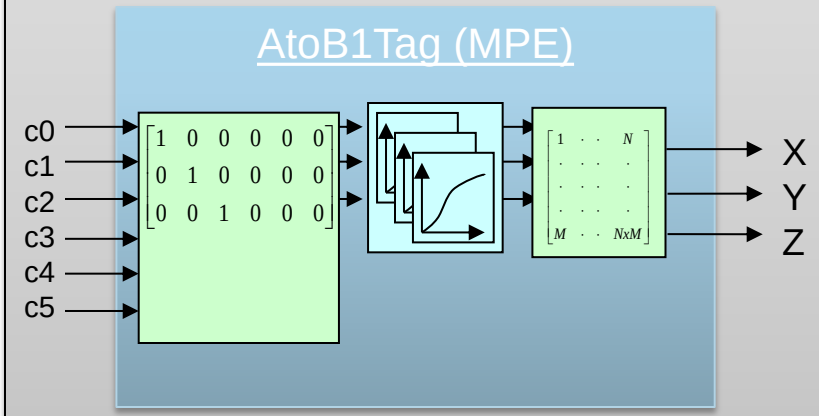


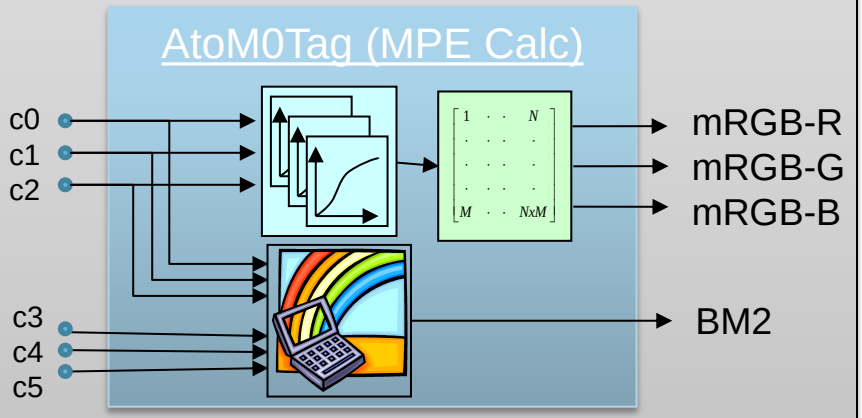
Example MCS Input Profile

Profile Header
Profile Class: ‘scnr’
Flags : MCS Sub-Set Requirements=false
Device: “nc0006”
PCS: XYZ
MCS: “mc0004”
Profile SubClass: TBD

Material Type Array Tag
Channel 0: “mRGB-R”
Channel 1: “mRGB-G”
Channel 2: “mRGB-B”
Channel 3: “BM2”

Other Metadata Tags)



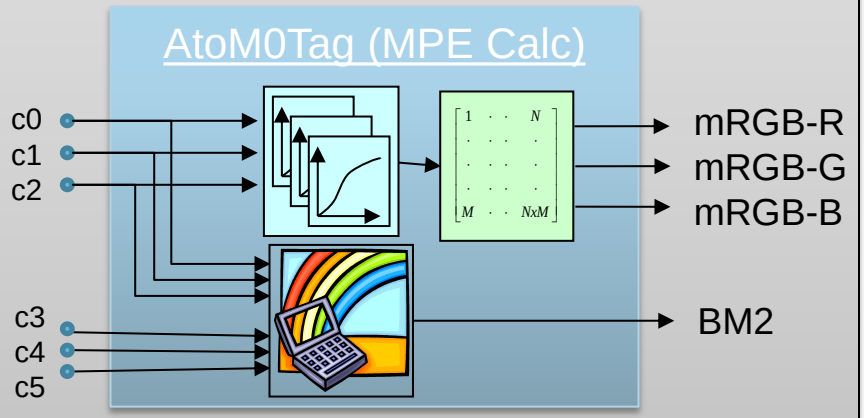


Example MCS Identification Profile

Profile Header
Profile Class: ‘mid ’
Flags : MCS Sub-Set Requirements=false
Device: “nc0006”
MCS: “mc0004”
Profile SubClass: TBD

Material Type Array Tag
Channel 0: “mRGB-R”
Channel 1: “mRGB-G”
Channel 2: “mRGB-B”
Channel 3: “BM2”

Other Metadata Tags)

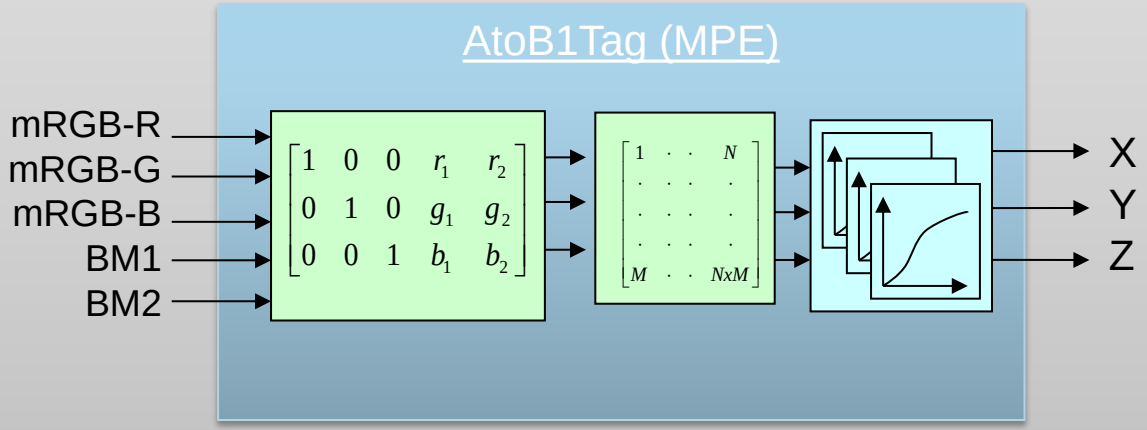


Example MCS Visualization Profile

Profile Header
Profile Class: ‘mvis’
Flags : MCS Sub-Set Requirements=false
MCS: “mc0005”
PCS: XYZ
Profile SubClass: TBD

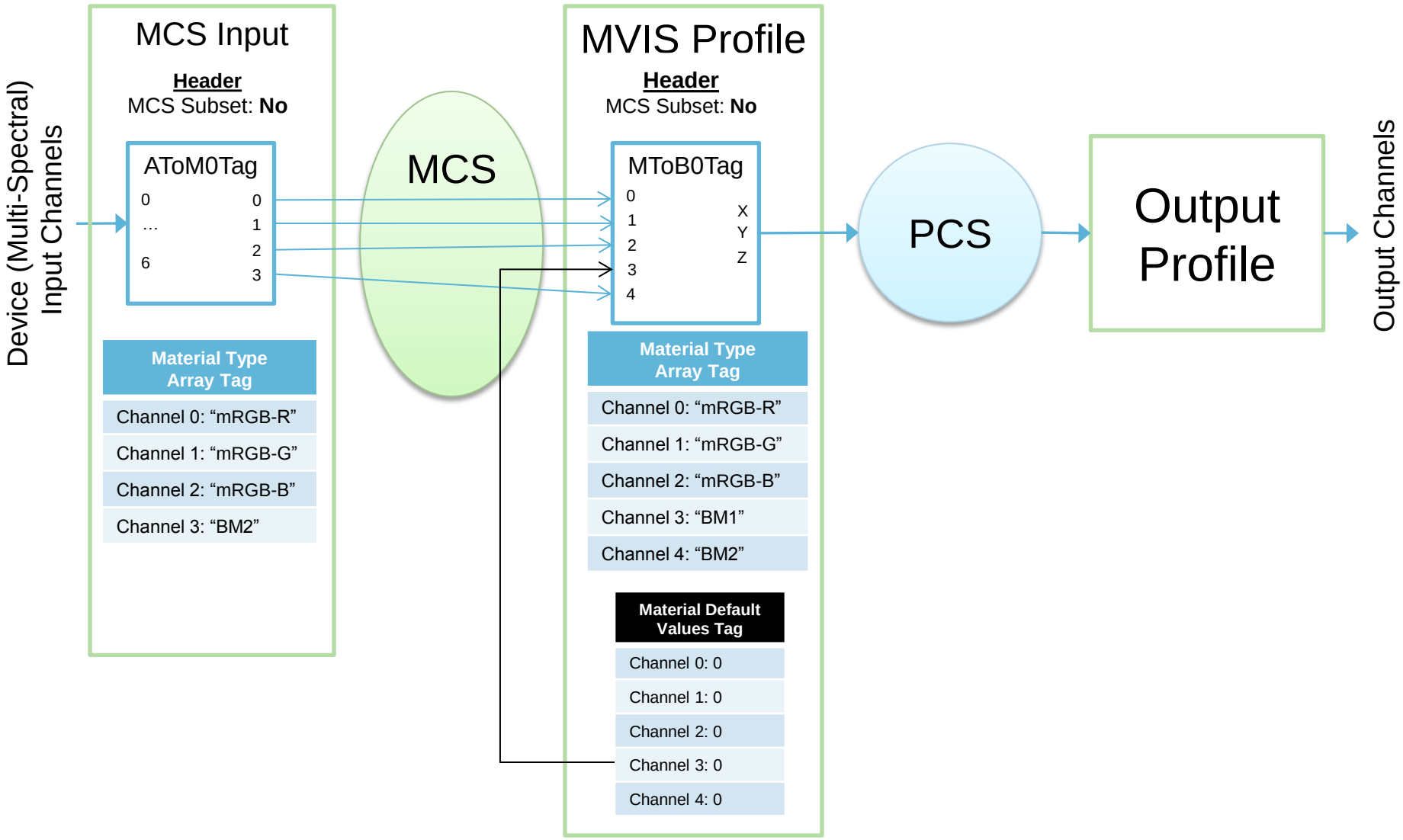
Other Metadata Tags)

Material Type Array Tag
Channel 0: “mRGB-R”
Channel 1: “mRGB-G”
Channel 2: “mRGB-B”
Channel 3: “BM1”
Channel 4: “BM2”



Material Default Values Tag
Channel 0: 0
Channel 1: 0
Channel 2: 0
Channel 3: 0
Channel 4: 0

MCS Connection Example

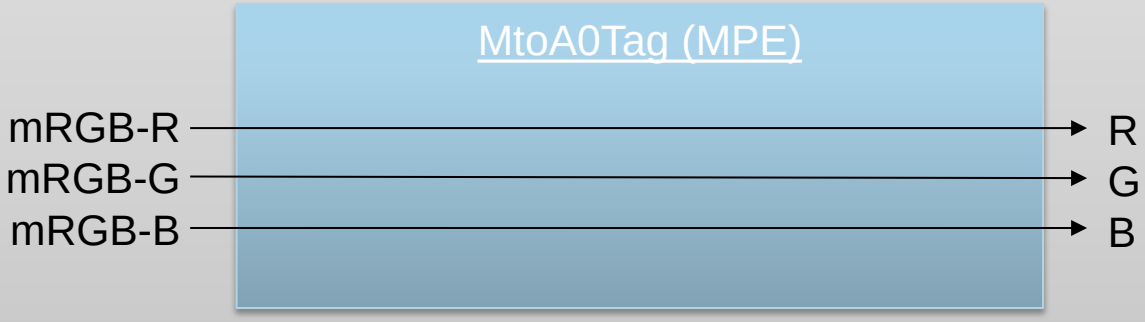


Example MCS Link Profile

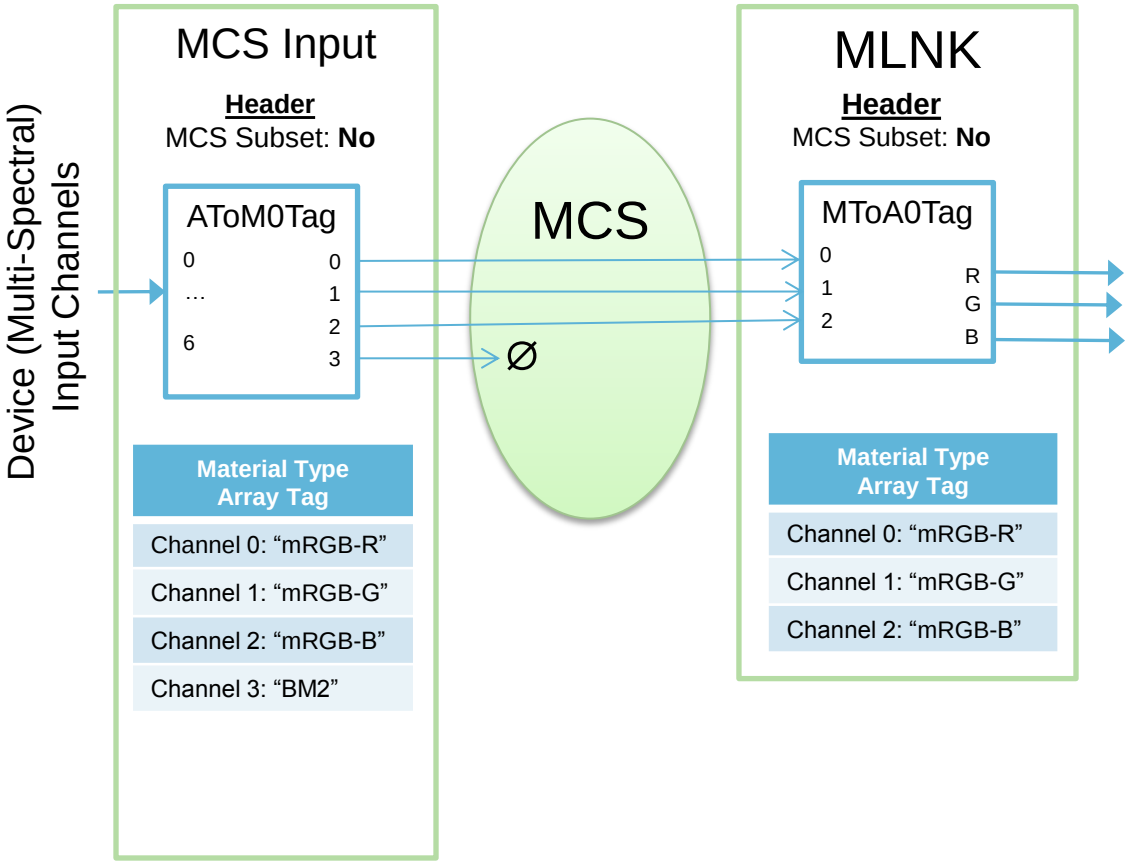
Profile Header
Profile Class: ‘mlnk’
Flags : MCS Sub-Set Requirements=true
Device: RGB
MCS: “mc0003”

Other Metadata Tags)

Material Type Array Tag
Channel 0: “mRGB-R”
Channel 1: “mRGB-G”
Channel 2: “mRGB-B”



MCS Connection Example



Thank You!

Questions

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Spectral Measurement of Human Skin Colour

Kaida Xiao

University of Liverpool

ICC MIWG Meeting, Boston

UNIVERSITY OF LIVERPOOL

Objectives

- To establish a skin spectral database for different ethnic groups, aging and body areas;
- To develop a method to predict skin spectral using a digital camera;
- To develop a skin image database covering true information of colour, spectral, texture, gloss, and shape.

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Why Spectral Reflectance?

- **More informative**
- **Independent of illumination**
- **True colour reproduction**
- **Direct connects with skin chromophores**
  - melanin, haemoglobin

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Procedures

- ❑ Lighting measurement
- ❑ Image capture for colour chart
- ❑ Consent and information
- ❑ Spectrophotometer Measurement
- ❑ Spectroradiometer Measurement
- ❑ Skin image capture by a 2D camera
- ❑ Facial image capture by a 3D camera

Skin Measurement

Lighting in the booth

- Diffuse light
- D65 simulator

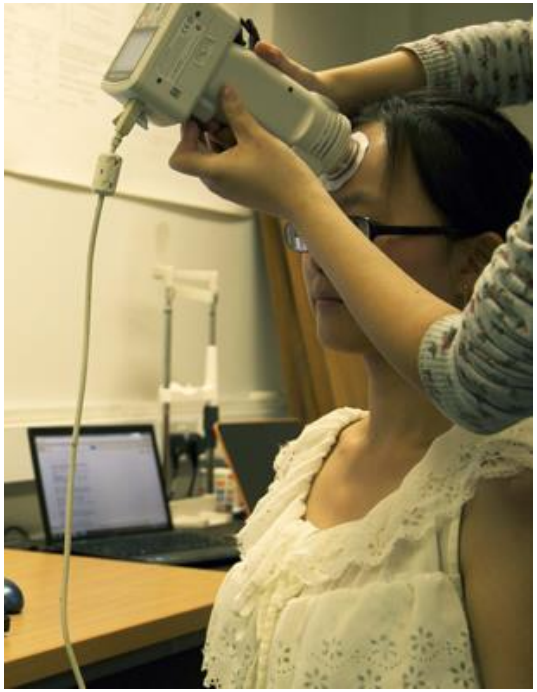
Lighting Measurement

- TSR (White Diffuser)
- Digital Camera (white board)

Skin Measurement

Spectrophotometer

- 10 body positions
- 2 measurement sizes
- Low measurement pressure
- 3 repetitions



Spectroradiotometer

- 5 body positions
- Fixed distance
- Fixed measurement angle
- 3 repetitions

Skin Image Capture

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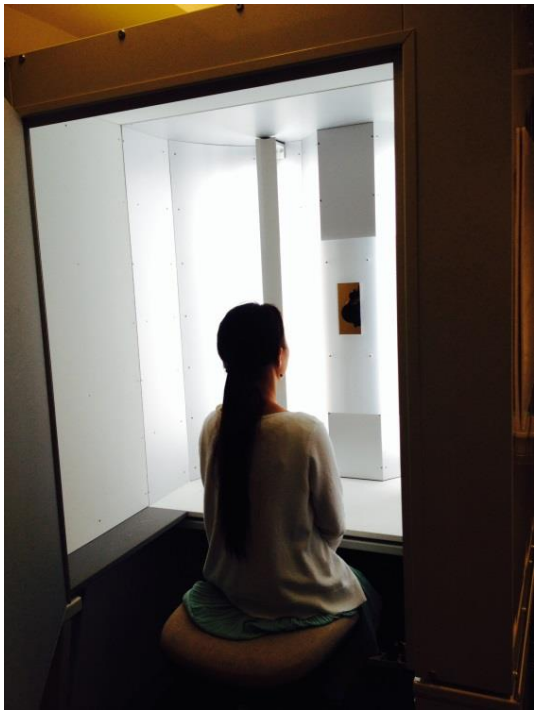
Digital SLR Camera



- ❑ Fixed capture distance
- ❑ Fixed capture angle

- ❑ Fixed lens focus
- ❑ Fixed exposure setting
- ❑ Fixed ISO setting
- ❑ Fixed white balance

- ❑ Save in raw image
- ❑ 3 repetitions

Skin Image Capture

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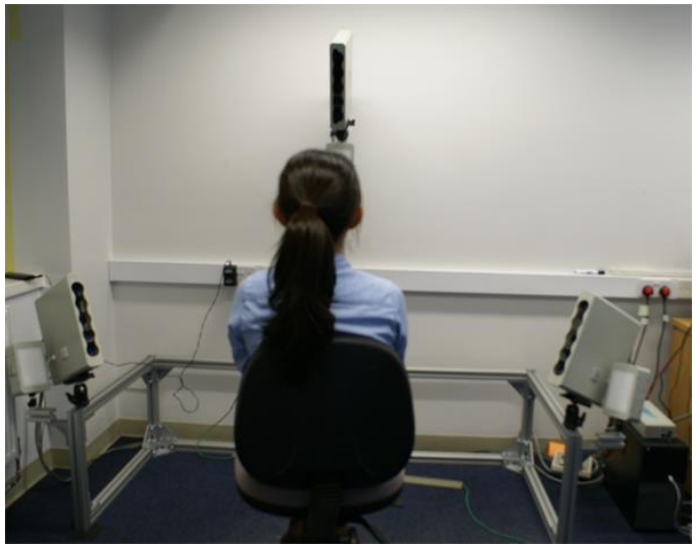
3D photogrammetry system

- ❑ Built-in flash lighting
- ❑ Room Lighting

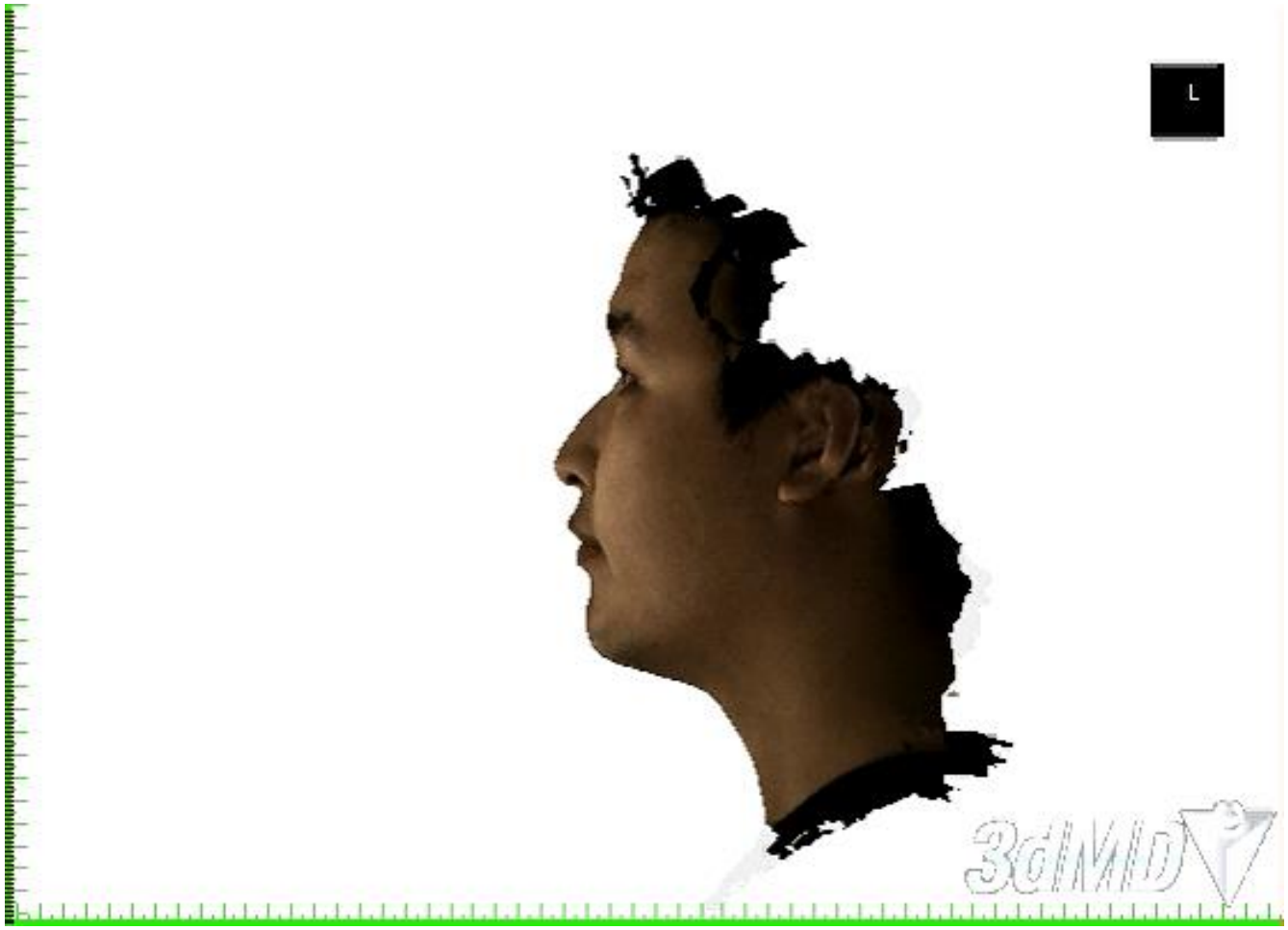
- ❑ Fixed capture distance
- ❑ Fixed capture angle

- ❑ Fixed lens focus
- ❑ Fixed exposure setting

- ❑ Save in 3D image

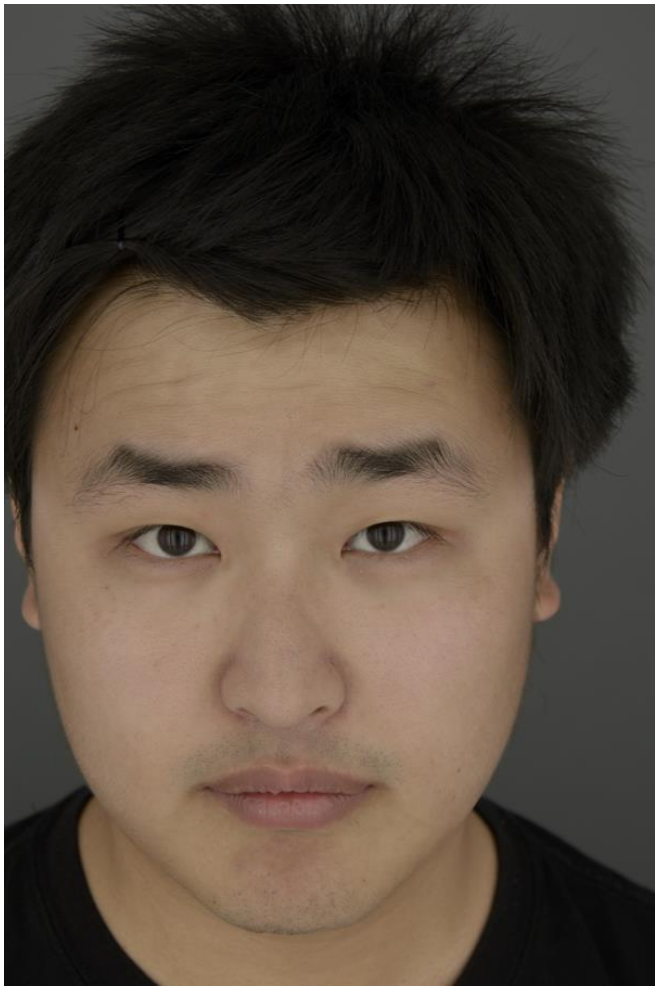


Skin Image Capture

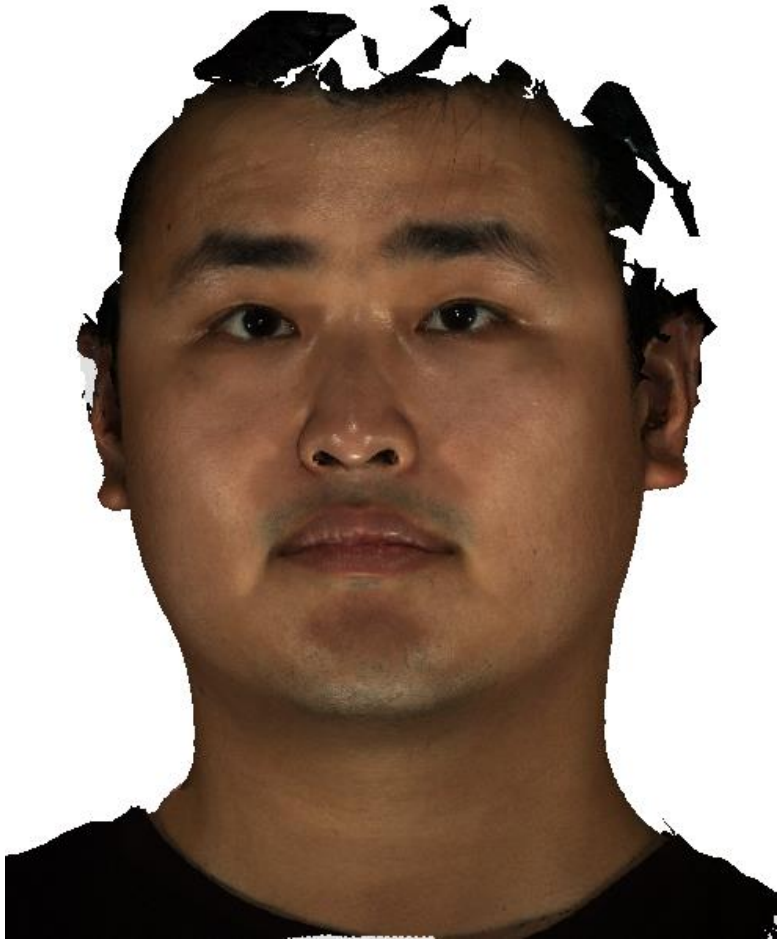


3D facial image

Skin Image Capture



2D camera image



3D camera image

Skin Reflectance Prediction

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Model Development

- Selection of colour chart
- Selection of skin colour database
- Applied Mathematical models
  - camera colour characterisation
  - camera sensitivity function prediction
  - skin reflectance re-construction

Model Evaluation

Proposed skin spectral data

Current progress

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Skin spectral data

Caucasian	Oriental	Sub Asian	African
32	61	4	5

Skin colour chart

Silicone skin colour chart

Skin colour reflectance prediction model

New reflectance reconstruction model

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Thanks

k.xiao@liverpool.ac.uk

dRGB

AAPM TG196 Progress

Michael Flynn
Radiology Research
Henry Ford Health System
Detroit, MI

Reference Document: sRGB: IEC 61966-2-1

- sRGB is a standard RGB color space created cooperatively by HP and Microsoft in 1996 for use on monitors, printers and the Internet.
- the sRGB gamma cannot be expressed as a single numerical value. The overall gamma is approximately 2.2, consisting of a linear (gamma 1.0) section near black, and a non-linear section elsewhere
- IEC 61966-2-1:1999 is the official specification of sRGB. It provides viewing environment, encoding, and colorimetric details.

http://en.wikipedia.org/wiki/SRGB

IEC 61966-2-1
Colour Measurement and Management
in Multimedia Systems and Equipment
Part 2-1: Default RGB Colour Space – sRGB

Reference Document: aRGB: Adobe RGB (1998)

- The Adobe RGB color space is an RGB color space developed by Adobe Systems in 1998.
- It was designed to encompass most of the colors achievable on CMYK color printers, but by using RGB primary colors on a computer display.
- A gamma of 2.2 is assumed.
- The color space encompasses roughly 50% of the visible colors specified by the Lab color space, improving upon the gamut of the sRGB color space primarily in cyan-greens.

Adobe RGB (1998)

Color Image Encoding

Version 2005-05, May 2005

Introduction

1. Scope
2. References
3. Terms
4. Requirements
    1. General
    2. Reference Viewing Environment
    3. Adobe RGB (1998) Color Image Encoding
5. Indicating the use of Adobe RGB (1998) ..

Annex A: The Adobe RGB (1998) ICC profile

Annex B: Practical tolerances for display devices

Annex C: Implementation notes

http://http://en.wikipedia.org/wiki/Adobe_RGB_color_space
http://www.adobe.com/digitalimag/pdfs/AdobeRGB1998.pdf

Reference Document:
ACR-AAPM-SIIM standard

- The ACR-AAPM-SIIM technical guideline for electronic imaging was recently revised with participation by three professional Radiology organizations:
  - American College of Radiology
  - American Assoc. of Physicists in Medicine
  - Society for Imaging Informatics in Medicine
- The recently published guidelines contain specific recommendations for viewing conditions and display characteristics.
  - DICOM Grayscale with defined L_{max} and L_{min}
  - D65 white point.
  - Undefined color gamut.

ACR–AAPM–SIIM Technical Standard for Electronic Practice of Medical Imaging

JT Norweck, JA Seibert, KP Andriole,
DA Clunie, BH Curran, MJ Flynn,
E Krupinski, RP Lieto, DJ Peck, TAMian

…

Display

1. Workstation Characteristics
   - f. Ergonomic factors
     2. Viewing Conditions
2. Display characteristics
   - a. Luminance response
     1. Ambient Luminance, L_{amb}
     2. Minimum Luminance, L_{min}
     3. Maximum Luminance, L_{max}
     4. Luminance Ratio, LR
     5. L_{max} for Diagnostic & other
     6. Luminance vs Gray Level
     7. Calibration
     8. Quality Control
     9. White Point.
   - b. Pixel Pitch and Display Size

…

J Digit Imaging (2013) 26:38–52

http://link.springer.com/article/10.1007%2Fs10278-012-9522-2

Additional Reference Documents & Efforts

AAPM on-line report No. 03 (2003)

- *Assessment of Display Performance for Medical Imaging Systems*
- "The intent of this report is to provide standard guidelines to practicing medical physicists, engineers, researchers, and radiologists for the performance evaluation of electronic display devices intended for medical use."

IEC 62563-1 (2009)

- *Medical Electrical Equipment – Medical Image Display Systems*

  Part 1: Evaluation Methods.
- "This International Standard provides evaluation methods for testing image display systems used in medical electrical equipment and medical electrical systems for diagnostic imaging."

CIE TC 1-93 (formed 2013)

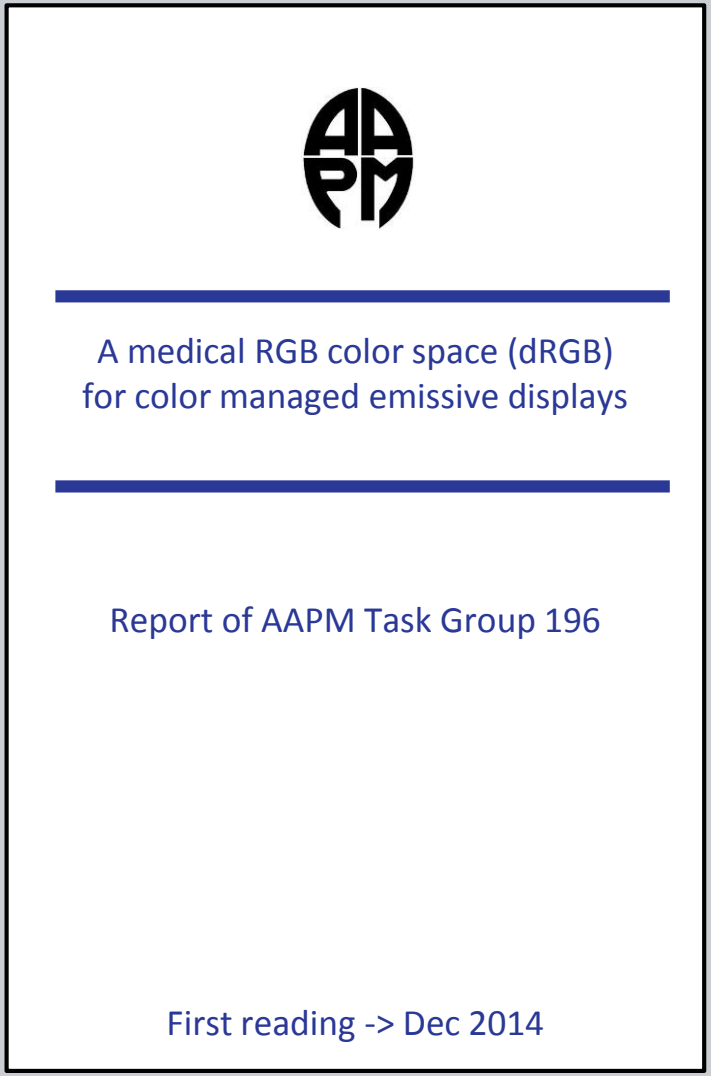
- *Calculation of self-luminous neutral scale*
- Charge: To recommend a formula or computational method for an achromatic, neutral or gray scale for self-luminous (i.e. non-reflective) surfaces. (This computation complements CIE Lightness, L*, which serves a similar purpose for reflective surfaces.)

AAPM TG196: dRGB

AAPM Task Group No. 196
Requirements and methods for color displays in medicine.

Aldo Badano, PhD *
Paul Boynton
Wei-Chung Cheng
Danny Deroo
Michael Flynn
Mikio Hasegawa
Patrick Le Callet
Takashi Matsui
Balazs Nagy
John Penczek
Craig Revie
Ehsan Samei *
Peter Steven
Stan Swiderski
Gert Van Hoey

* co-chair



http://www.aapm.org/pubs/reports/

http://www.aapm.org/org/structure/default.asp?committee_code=TG196

Color spaces compared

(1) IEC 62563 terminology

Specification (1)	sRGB	aRGB	ACR	dRGB
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-	[*] (referenced)
L_{max} , cd/m^2	80	160 (125-200)	350/420/250	350 (250-450)
L_{min} , cd/m^2	-nd-	0.56	L_{max} / LR	L_{max} / LR
Luminance Ratio (LR)	-nd-	287.9 (230-400)	350 (> 250)	350 (300-400)
White Point	D65	D65	D65	D65
Gray tracking	-nd-	-nd-	-nd-	IEC MT51
Surround	20% refl. lx	Gray (D65, 2^o) 20% L_{max}	-nd-	Gray (D65, >2^o) 20% L_{max}
Ambient Illumination, lx	64 (D50)	32 (D65) (16-64)	20-40	-nd-
Veiling Glare	1.0%	accounted	-nd-	-nd-
L_{amb} , cd/m^2	-nd-	-nd-	$L_{amb} < {}^1/_4\ L_{min}$	$L_{amb} < [{}^1/_4 , {}^2/_3]\ L_{min}$

dRGB - as a color space framework.

- Variable neutral luminance response:
  - DICOM GSDF (Lmax & Lmin in profile description)
  - Lmax = 250-450.
  - LR = 300-400 (LR = Lmax/Lmin)
  - May have Lamb dependence.
- Variable color gamut:
  - sRGB default
  - Other spaces indicated by profile description
- Surround is specified as the near field effecting adaption.
- Lamb uses the 1/4th or 2/3rd criteria from AAPM TG-18.

AAPM dRGM objectives

- Monitor Calibration: The dRGB color space will provide a full specification for the calibration of a medical monitor including white point, color space, luminance response, luminance ratio, and viewing conditions.
- Monitor Specifications: The dRGB color space will provide specifications for the performance of a monitor for which a manufacturer can provide firmware correction through OSD selection for the target performance.
- Display Profile: For monitors conforming with the dRGB color space, an ICC profile can be used by a color management system to transform image values from profile connection space to display values.
- Source Profile: For images in the dRGB color space, an ICC profile can be used by a color management system to transform these image values to profile connection space.

AAPM approved charge, 'AAPM-IPC-IISC_TG-mRGB_Charge-v3'

AAPM TG-18 Display Device Classification

Primary (a.k.a. diagnostic)

- Primary display systems are those used for the interpretation of medical images.
- They are typically used in radiology and in certain medical specialties such as orthopedics.

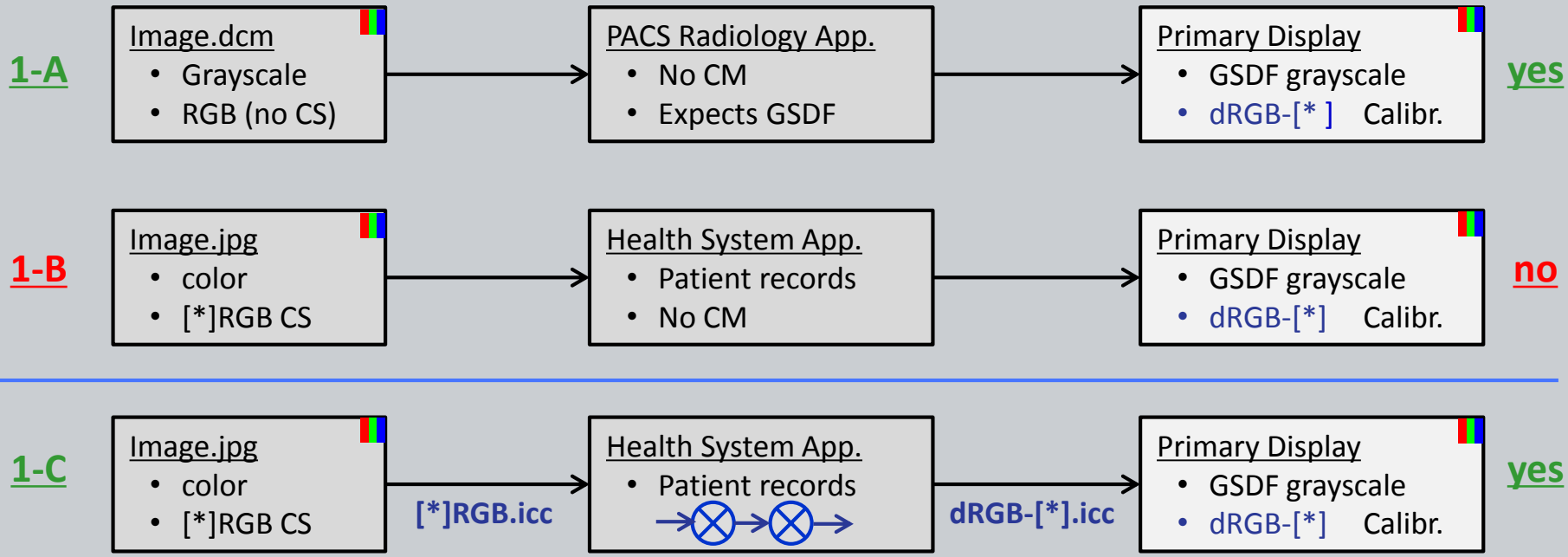
Secondary (a.k.a. review, enterprise, other)

- Secondary systems are those used for viewing medical images for purposes other than for providing a medical interpretation.
- They are usually used for viewing images by general medical staff and medical specialists other than radiologists and utilized after an interpretive report is provided for the images.

From Section 2.5 of AAPM On-Line Report No. 3

Case 1 – Primary display, radiologist workstation

1. Medical image presentation on a workstation with DICOM calibrated primary monitors used for medical interpretations



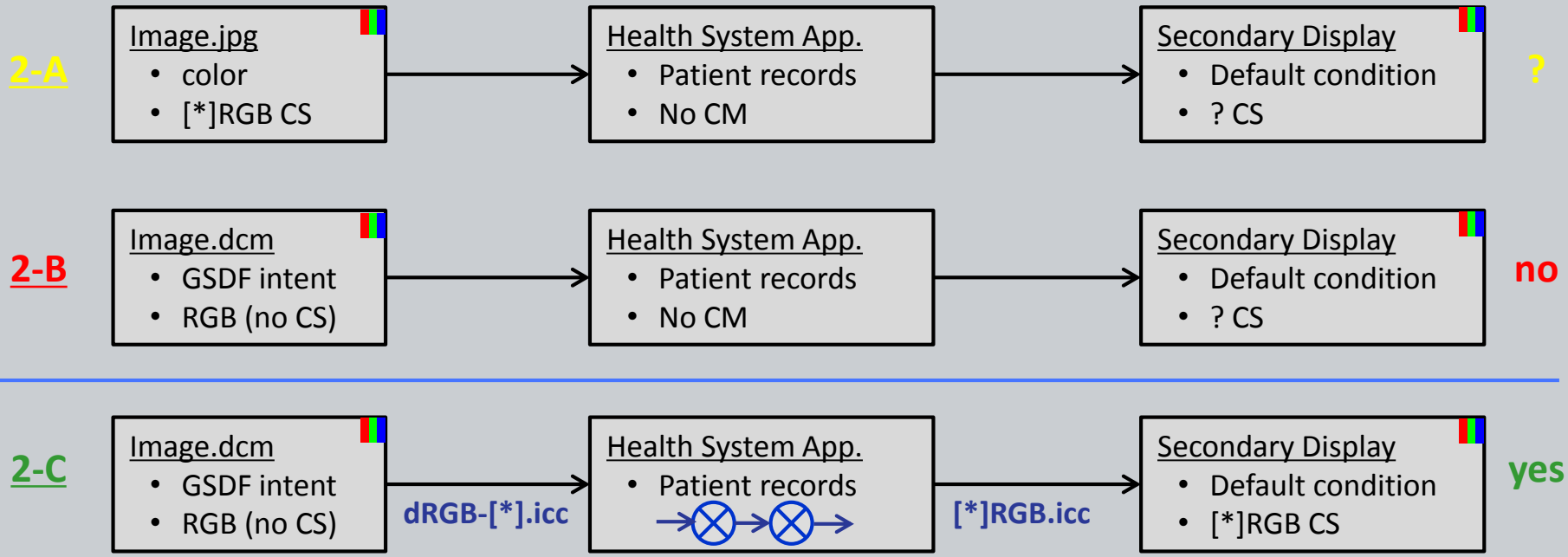
Case A:	Correct	Grayscale & pseudo-color DICOM images with GSDF neutral tones.
Case B:	Incorrect	Color photograph is presented with GSDF neutral tones.
Case C:	Correct	Color photograph is presented with the intended color space.

Denotes a color managed module
Using source and display profiles

CS – Color Space
CMS – ICC Color Management (full)

Case 2 – Secondary display, physician workstation

2. Medical image presentation on a workstation with secondary monitors used for reviewing patient information.



Case A:	Uncertain	Color photograph is presented with the default configuration .
Case B:	Incorrect	Grayscale & pseudo-color DICOM images not presented with GSDF.
Case C:	Correct	Grayscale & pseudo-color DICOM images are mapped to GSDF

Denotes a color managed module
Using source and display profiles

CS – Color Space
CMS – ICC Color Management (full)

Dependence of GSDF on Lmax, Lmin, and Lamb

- Display Profiles

  The approach is to have a profile for each luminance states (Lmin & Lmax) and state these conditions in the profile description. This is usually shown when profile lists are displayed, thus supporting both manual and automated selection (*see MIWG 6-Aug-2014 minutes*) .

- Source Profiles

  The approach is to require that the color management engine register the Lmax, Lmin and Lamb conditions of the color space associated with image creation. (*Note: DICOM does not currently define these values but simply denotes the GSDF space as p values. Thus default values for the luminance state are appropriate.)*

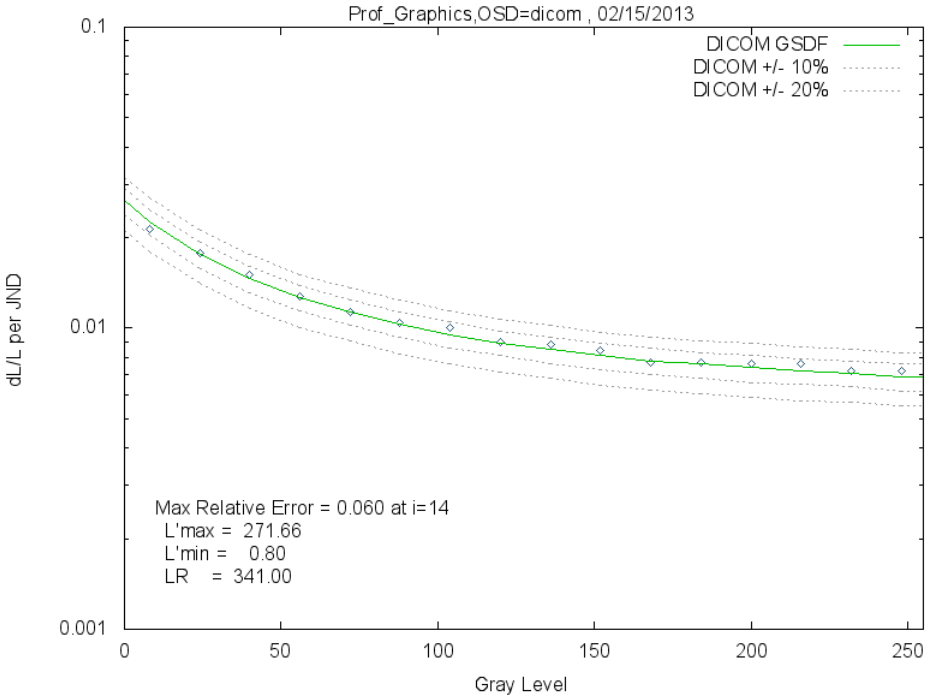
- dRGB by reference

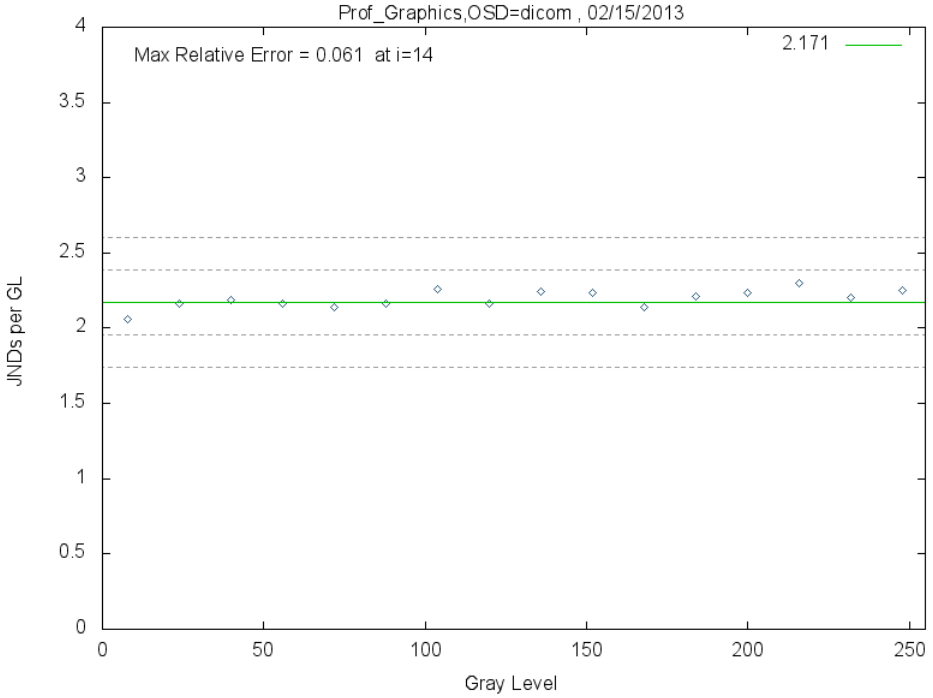
  A color management engine may identify the color space as dRGB by reference and register the luminance state in the CMS application. This permits use of the DICOM GSDF polynomial expressions.

Neutral scale allowed error

The dRGB neutral scale, DICOM GSDF, is to be evaluated in terms of the slope (i.e. contrast) in relation to display value.

- dL/L vs DDL (AAPM TG18)
- JNDs vs DDL (DICOM)

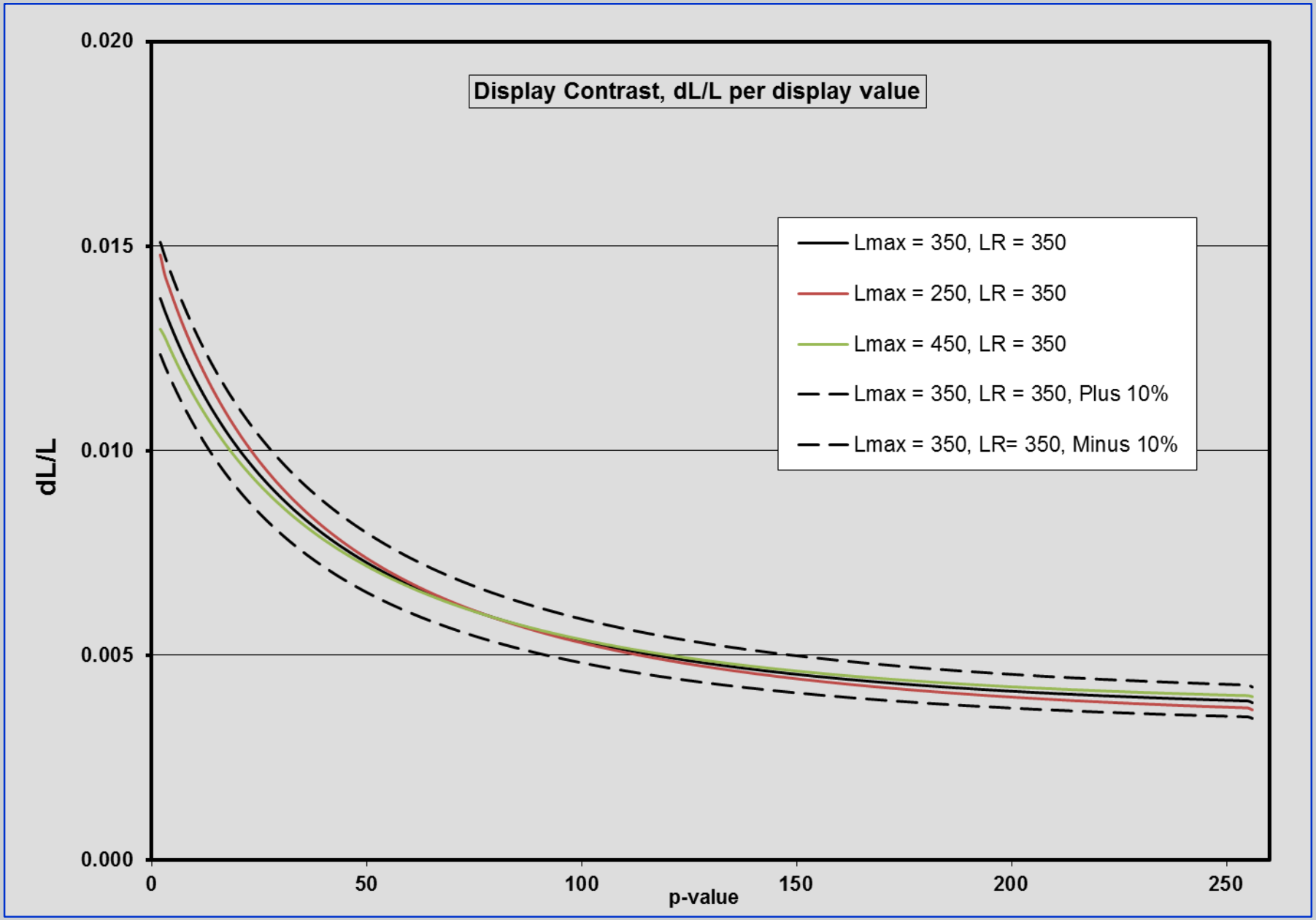




For coarse measurements made at 17 gray levels (AAPM TG18), conformance is well established (ACR Guidelines).

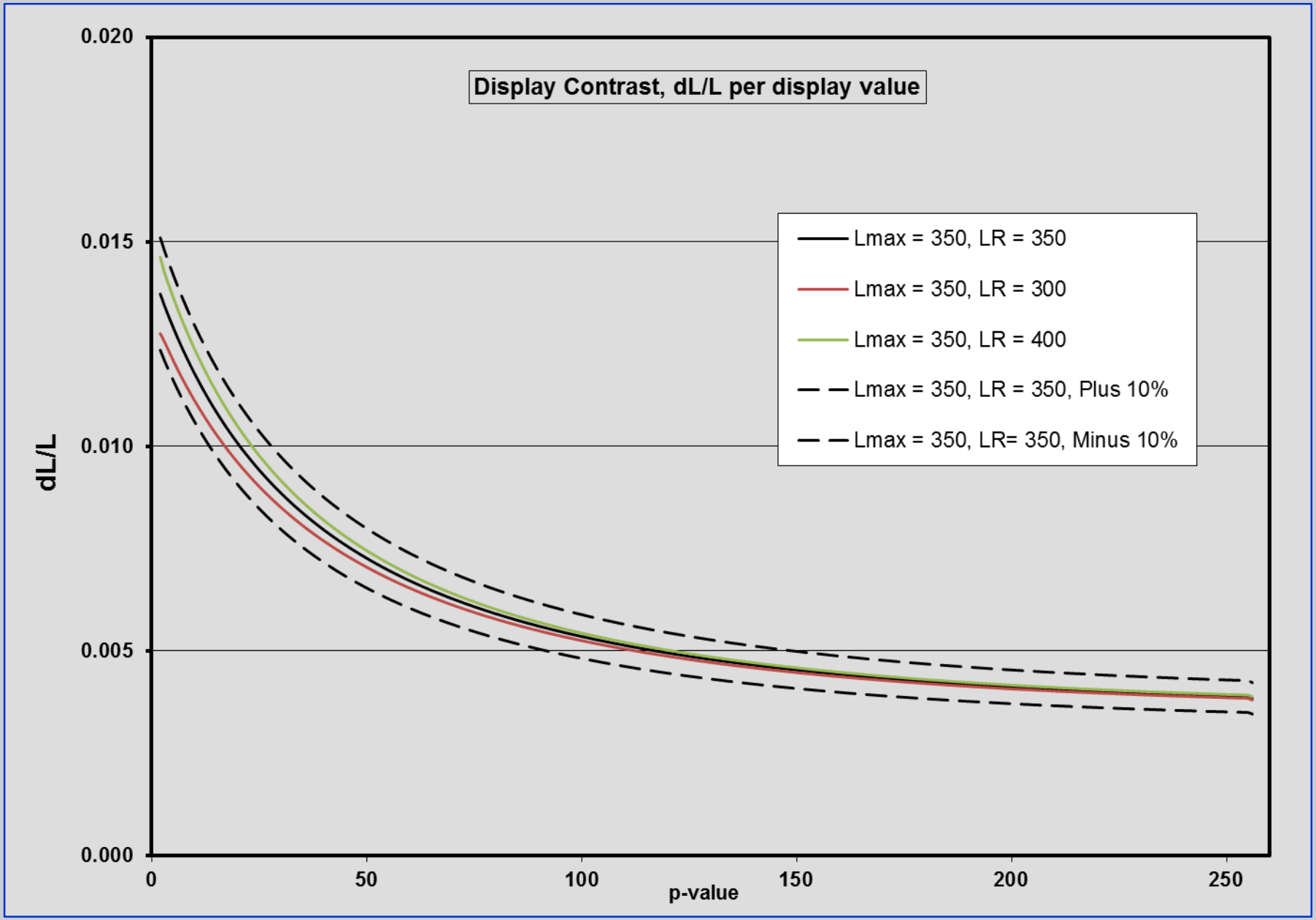
- 10% for primary displays
- 20% for secondary displays

Lmax variation of 350 +/- 100 (LR=350)



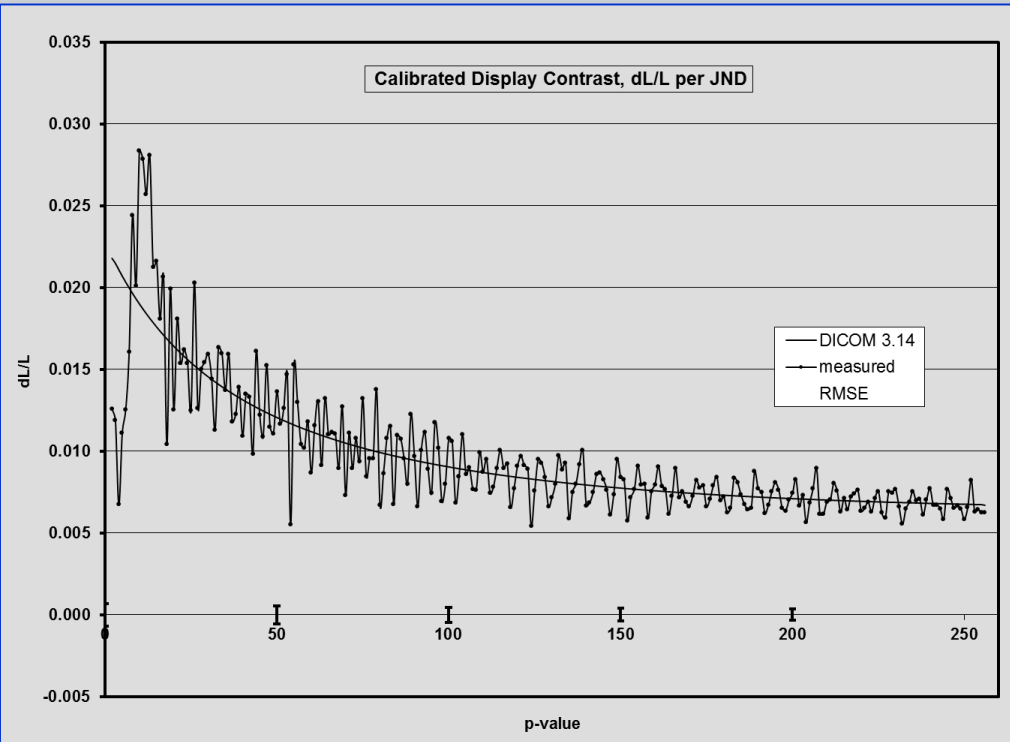
Effect of Lmax & LR on the GSDF

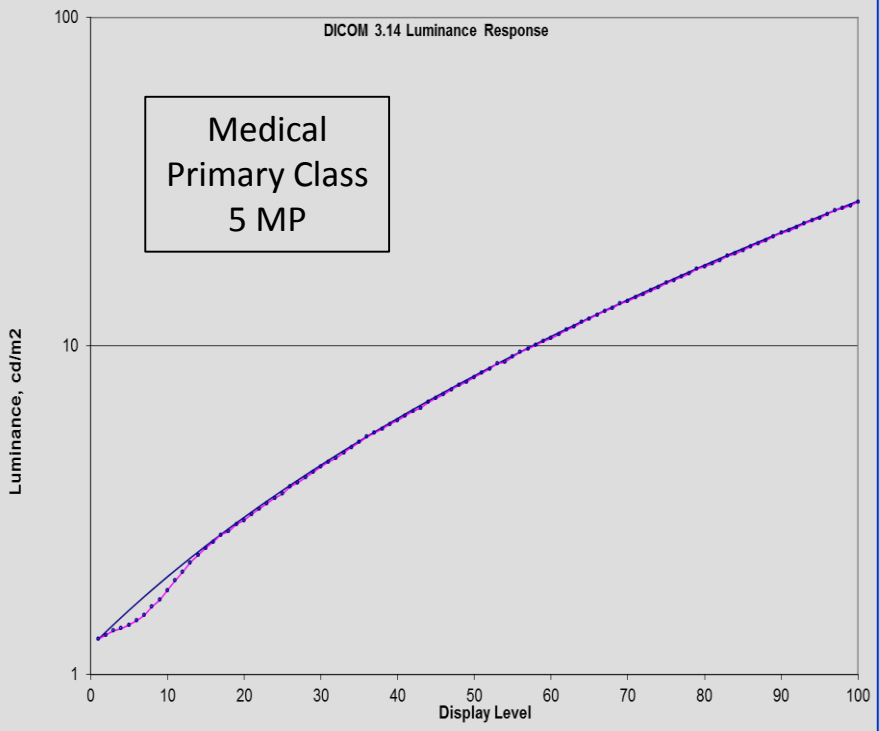
LR variation of 350 +/- 50 (Lmax=350)



Neutral scale allowed error

- GSDF contrast performance for incremental display values is also required for dRGB conformance.
- This result shows low luminance contrast deviations that were not identified on the coarse measurement (17 levels)

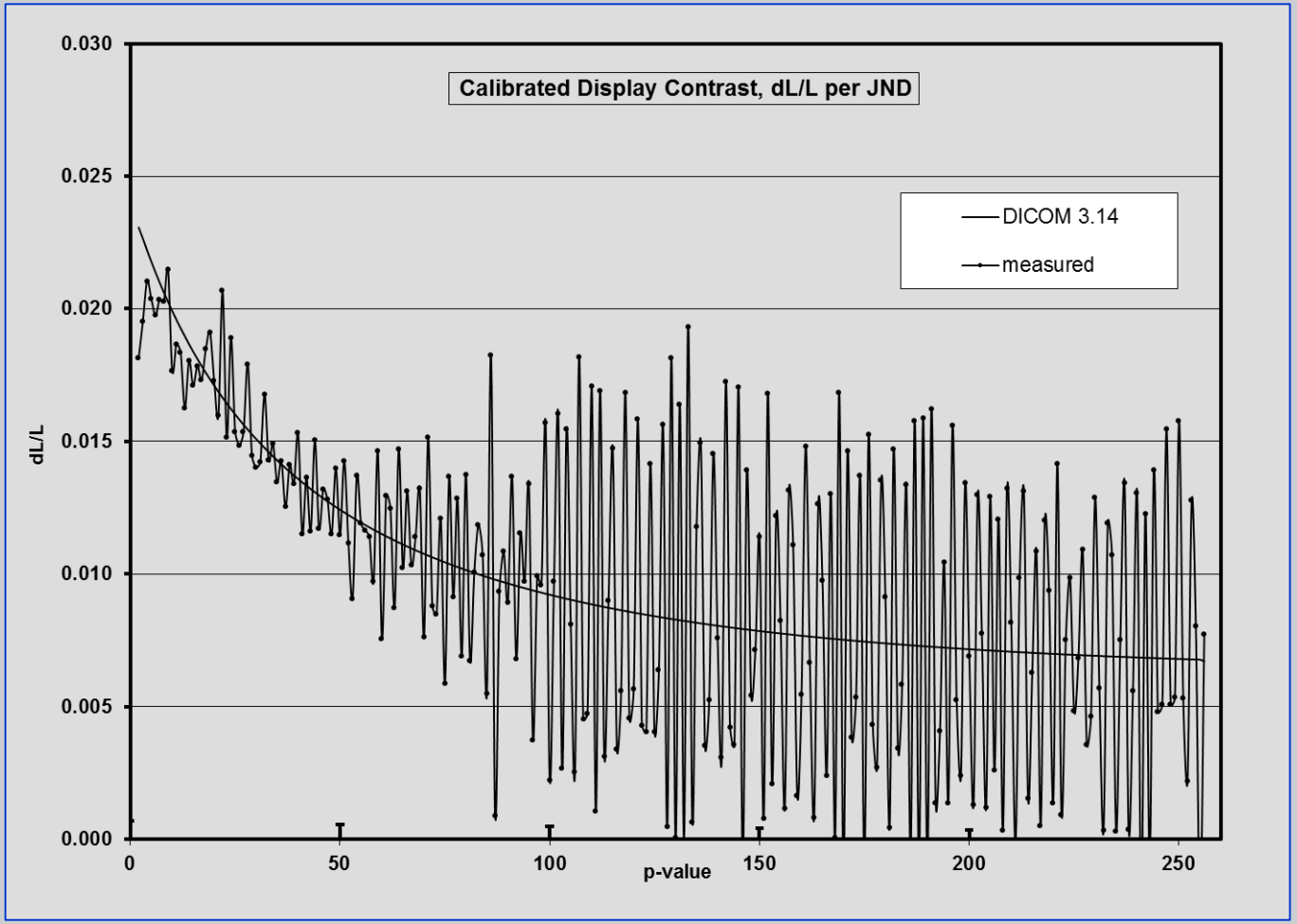




Appropriate conformance requirements for 256 level measures are currently under discussion. It is generally recognized that these measurements will require precise photometers and may have more deviation that coarse measures.

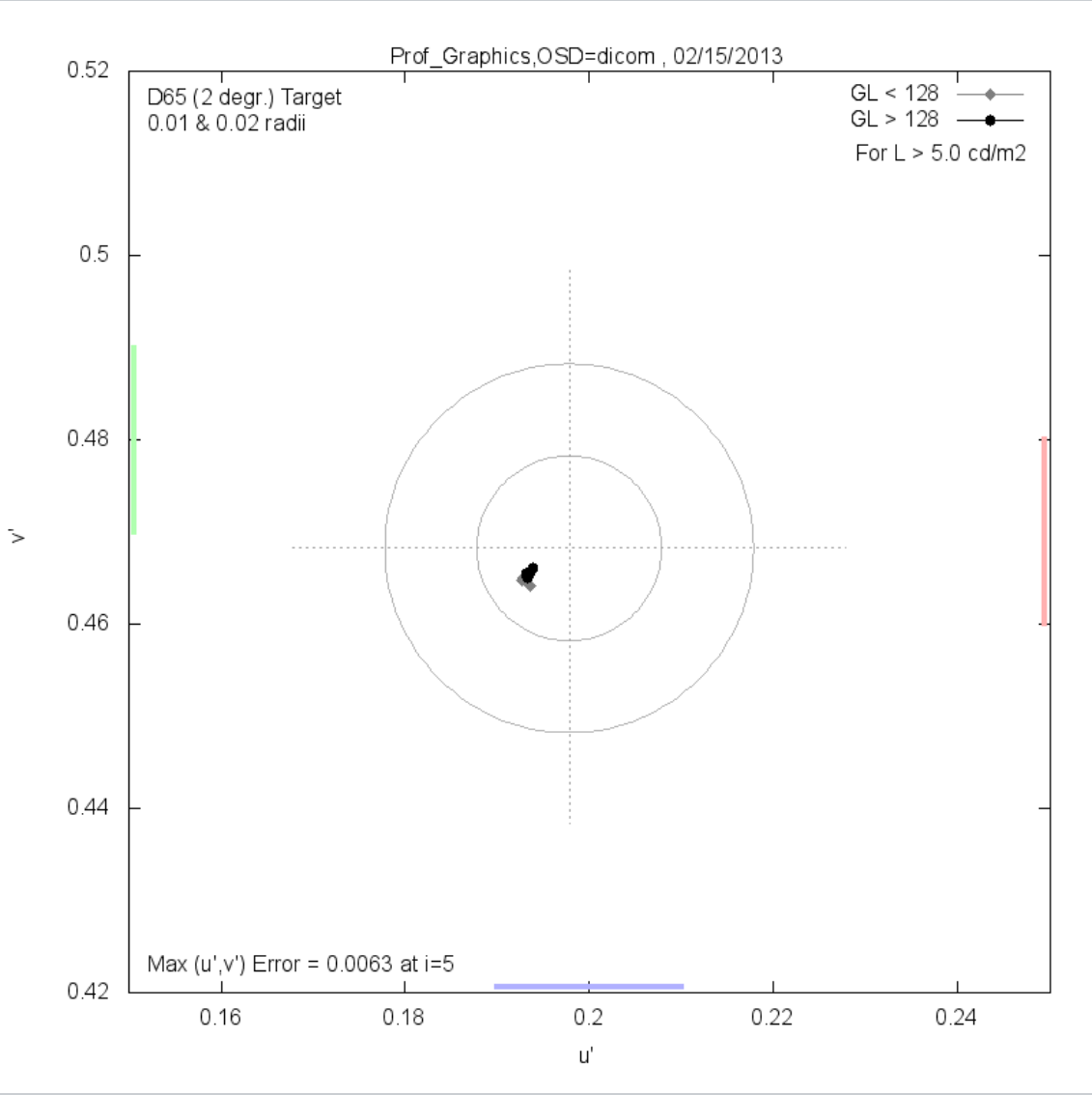
Neutral scale allowed error

This result shows cyclic contrast deviations at high luminance indicative of a luminance response with staircase characteristics.



Neutral Chromaticity Shift

The default white point for dRGB is d65 (2 degr).



- AAPM TG196 has recently reported on medical gray tracking measures.
- dRGB presently requires conformnace to within an 0.01 radius for coarse measurements.
- Values below 5 cd/m2 are not considered.

The default color space for dRGB is sRGB.

- Other color spaces are permitted with documentation in the profile description.
- Appropriate conformance error for the color primaries are presently being discussed.

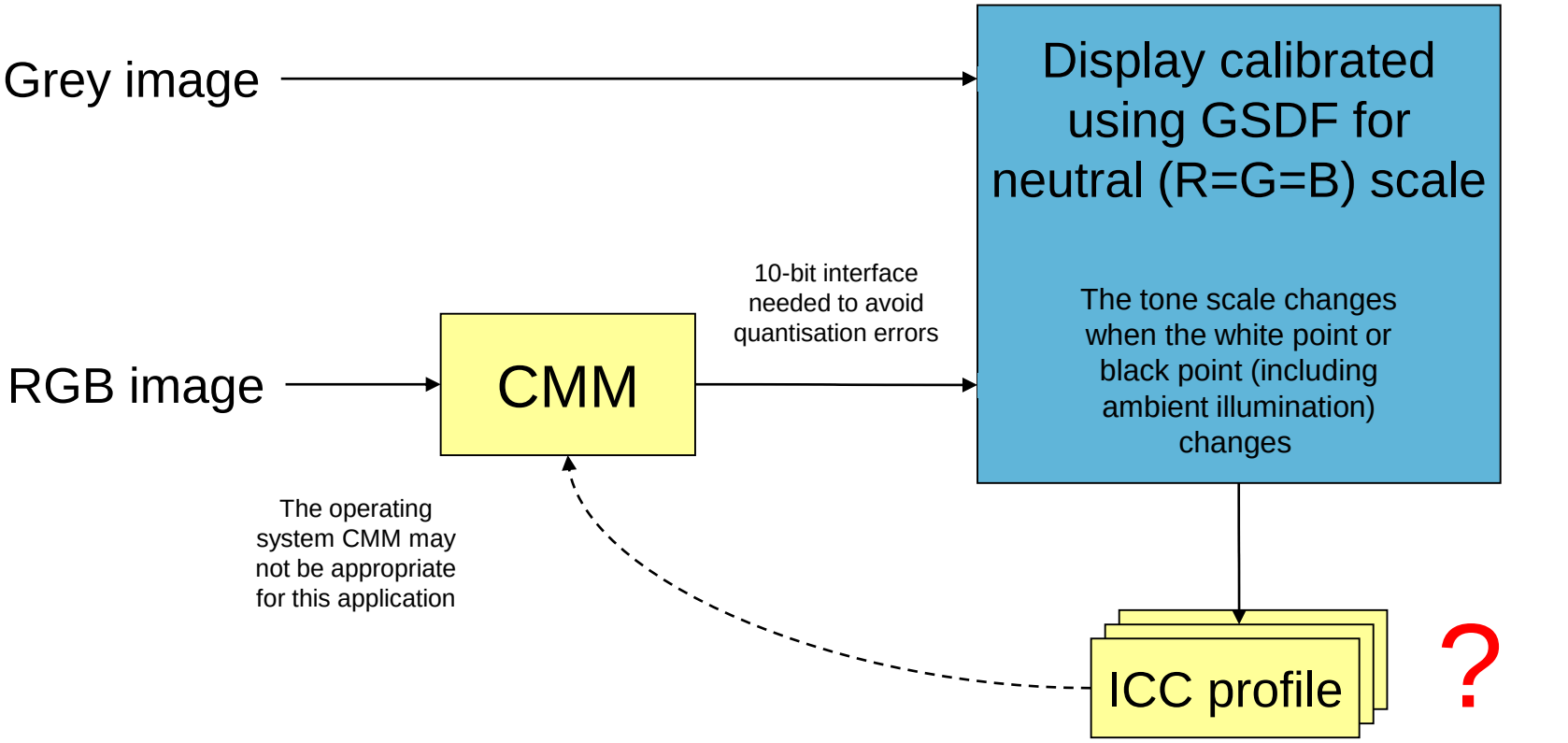
Note: dRGB is a color space framework primarily directed at the incorporation of the DICOM GSDF neutral scale. As such wide latitude is provided for the color gamut and white point.

Display profiling requirements for mRGB / dRGB

Craig Revie, FFEI Limited

1st November 2014

Proposed DICOM RGB colour space



A set of example/default profiles could be developed for different white/black range and could be posted on the ICC web site

Requirements

- **Matrix / TRC profiles are not suitable for this application**
- **Few ICC Profiling applications support LUT-based tables**
- **Commercially-available profiling software that can build LUT-based profiles modifies the graphics card LUT**
  - This produces poor results for self-calibrating displays

Proposal: *the ICC MIWG should specify requirements for display profiling software and work with manufacturers to test and deliver suitable profile creation software*

International Color Consortium

MIWG – Displays

Update reference images for display testing

November 1st 2014

Call for participation

- On Oct 3rd 2014 a call for participation was sent out to the MIWG – Displays.

- We are looking for medical color images that can be used as reference/test images by the MIWG.
- We are also looking for people that are willing to characterize their (relevant) color display and share the measurement data with the group

- See: ftp://tok_icc_miwg_displays:xbochi0@ftp.barco.com

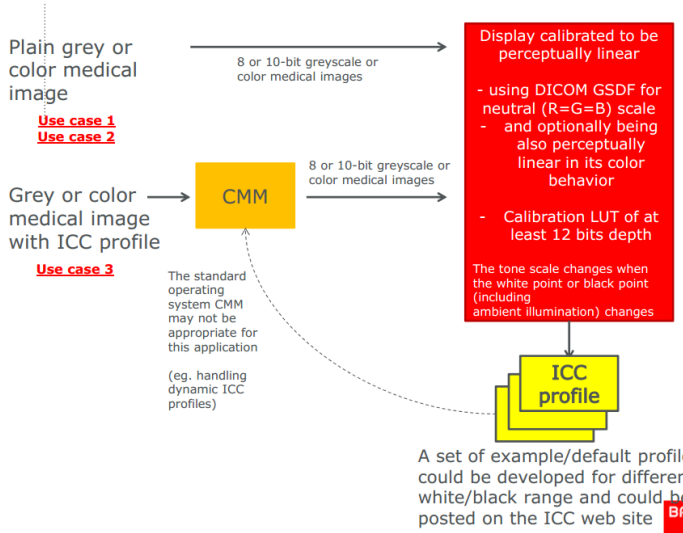
Status

- Several people reacted to the request and indicated they are willing to contribute.
- Some radiology and pathology images already have been contributed to the FTP server
- David provided a list of publicly available images

- Other people expressed interest but raised specific questions about the goals and the method.
- The next few slides will try to answer these questions

Background of this exercise

- Background
  - The MIWG Displays defined an architecture of which we believe it is suitable for color medical imaging. (see eg. http://www.color.org/groups/medical/Minutes_Aug2014_SpecialTopics.pdf)
  - This architecure however has not been validated yet, so we don't know whether it is possible to meet the requirements and tolerances that are needed for accuate visualization of medical (color) images



Goals of this exercise

- Goal: validating by means of bench testing and software simulations whether the proposed architecture is fit for purpose

  - Assembling a representative set of medical color images, together with corresponding requirements /performance needs for visualization
  - Selecting a number of display systems that will be used for the bench testing & simulations
  - Measuring/characterizing these display systems such that we can run software simulations of different configurations instead of having to "build" all configurations (eg. display bit depth, size of LUTs, ...)
  - Performing the bench testing and simulation work

Relevance of gathering “unrelated measurement data”

- It is true that performing accurate, consistent measurements to characterize color behavior of color displays is a challenge (variability of measurement equipment, measurement environment, stability of displays, ...)
- This was discussed in the MIWG group and it was decided that nevertheless we feel it is useful to gather measurement data (details of what to measure have been provided) as long as the data is accompagnied with a clear description of display ID & setting, measurement conditions and measurement equipment description.

Relevance of gathering “medical color images”

- We are not aiming to collect any “color medical image”
- The goal really is to look for a limited set of representative/relevant color medical images, with corresponding specification of what minimum performance the visualization needs to conform to.
  - Eg. a greyscale PACS image, requirement (guidance): deviate no more than 10% from GSDF
  - Eg. a dermatology image, requirement: absolute colorimetric correct visualization with no more than 2 deltaE2000 maximum error
  - Eg. a quantitative imaging doppler ultrasound image, requirement: perceptually linear color behavior with no more than 15% variability in deltaE2000 contrast/step along the color scale

Suggested planning

- Until Nov 28th
  - Continue collection of representative images and display measurement data
- December (email & conference call)
  - Selection of the exact display systems to be used
  - Selection of the exact images to be used
- Early Q1 2015: bench testing & simulation
- March 2015: in depth discussion of the results during ICC MIWG face-to-face meeting

Questions?

Recommended Image Capture Workflow for Medicine Photography

John Penczek

Oct. 13, 2014

Introduction:
This general procedure outlines a recommended digital camera image capture workflow that can be used to improve image color accuracy.

Required equipment:

- Digital color camera capable of exporting raw format image files. An ability to perform an in-camera white balance is also desirable.
- Reference color test chart (e.g. ColorChecker or Spyderchecker)
- Light source that can provide uniform illumination on the image plane at a 45 degree inclination angle. The light source should produce spectrally smooth broadband white light, approximating daylight.
- Software that is able to import RAW image files from camera, perform a white balance, and export the image in a 16-bit TIF format.
- Color correction software that can recognize each color in the reference color chart, create an HSL Preset file or ICC profile, and use this file to color correct the images of interest.

Procedure:
Image capture

1. Setup up the illumination and background for photographing the object of interest. The background should be a neutral gray color, ideally a 20% gray. The light source should produce light that is nominally at a 45 degree inclination angle to the image plane, and uniformity illuminating the entire region for the relevant image area.
2. Place a uniform gray target in the image plane. It should ideally be 20% gray. Skip this step if the camera does not have in-camera white balance capability.
3. Position the camera in front of the gray target and align the camera so that its optical axis is centered on the chart and perpendicular to it. It is best to use a tripod, or similar mechanism, to hold the camera stationary for the remainder of the photographs. Adjust the camera field of view so that it does not extend beyond the gray background. This field of view should be fixed for all photographs.
4. Use the in-camera white balance function to determine the proper white balance for this lighting condition. Use this white balance setting for all subsequent photographs. Skip this step if the camera does not have in-camera white balance capability.

5. Place the reference color test chart in the image plane. The camera field of view should capture all of the colors in the chart. The optical axis of the camera should be centered on the chart and perpendicular to it.
6. Set the exposure time to such that the brightest objects in the image are approximately 90% of the maximum brightness. The brightest object should be the whitest color patch. Use the intensity histogram (if available) to ensure that the image is not overexposed.
7. Capture the image of the reference color test chart and export the image in RAW file format. In some cameras, it is possible to use a "neutral" mode RAW format which minimizes perceptual enhancements.
8. Replace the reference color test chart with the objects to be photographed. Determine the proper exposure times for each object, and export the images in the same RAW file format.

Color correction

1. Import the RAW file of the reference color test chart into a program that is capable of performing a white balance on the image. Use the program to set the whitest color patch to an exposure of 90%, or RGB= 230, 230, 230. Then set the darkest patch to an exposure of 4%, or RGB= 10, 10, 10. If the black patch is below this level, then use the current setting or reshoot the photograph with brighter illumination. Export the white-balanced image as a 16-bit color TIF file.
2. Repeat this process for all of the other images taken under these image capture conditions.
3. Import the 16-bit TIF file of the reference color test chart image into a program that can recognize the reference color chart and create a HSL Preset or ICC profile based on that image. The color correction software should automatically find the centers of each color patch. Use colorimetric mode to create the HSL Preset or ICC profile.
4. Import the TIF files of the other photographed objects into the image editing program that is capable of using HSL Presets or ICC profiles. Apply the HSL Preset or ICC profile to each image and save the new color-corrected image in the desired format.

PETRI PLATES IMAGE ACQUISITION :

A COLOR CALIBRATION METHOD

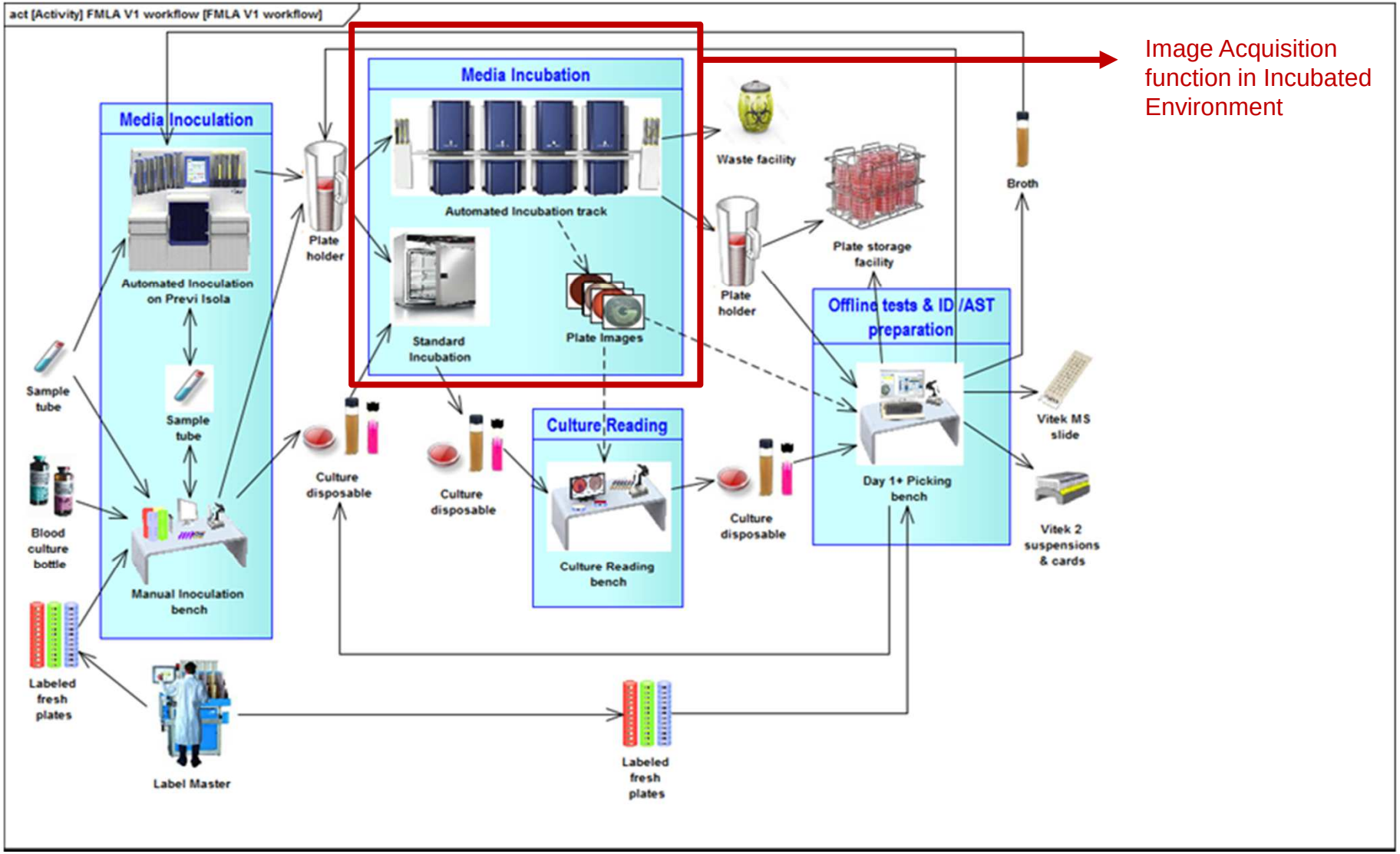
PIONEERING DIAGNOSTICS

Jeremie Pescatore, System Architect, bioMérieux

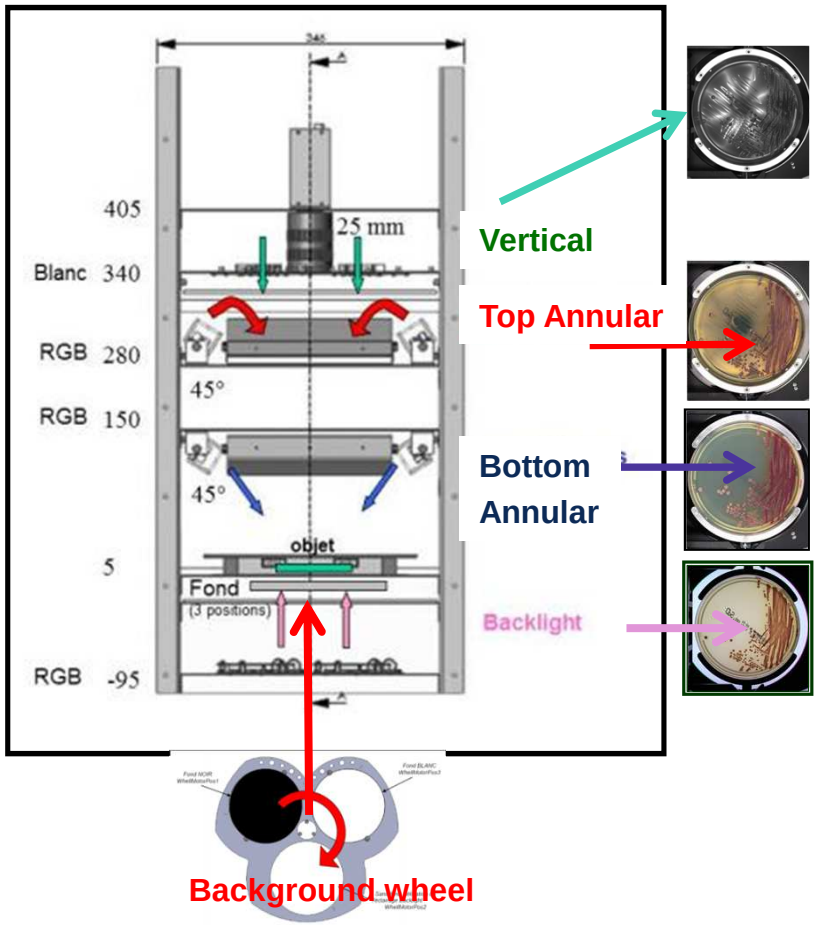
BIOMÉRIEUX

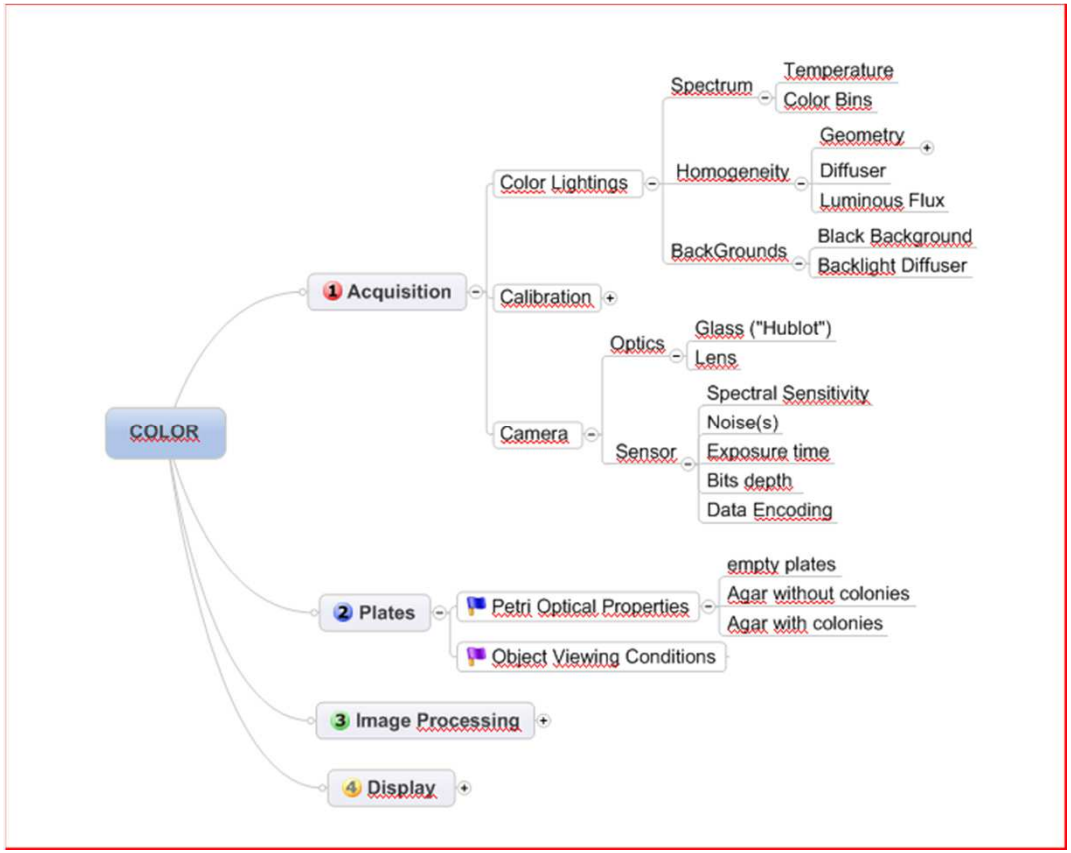
Revision 0

Lab Automation Workflow : Where is Petri dish image acquisition ?



Imager : Physical description



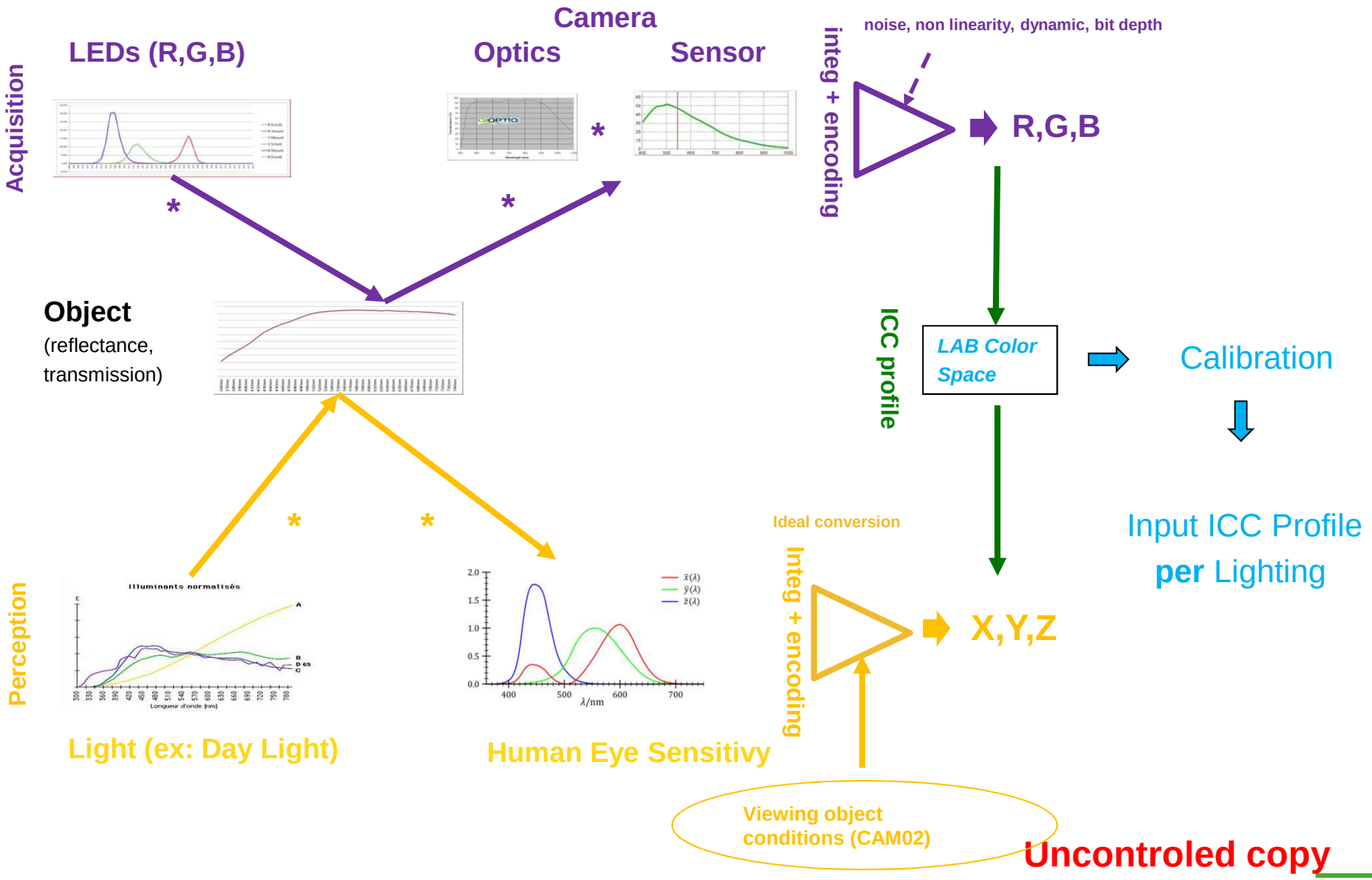


Imager Resolution = 1800 x 1800

Pixel resolution = 47-52 µm w.r.t. focal length calibration

Field of view = 85,71 - 94,73 mm

Perceived Colorimetric Model : Input ICC Profile



Petri Imager : current color calibration & goal

While Balancing

w. White Background for reflexion

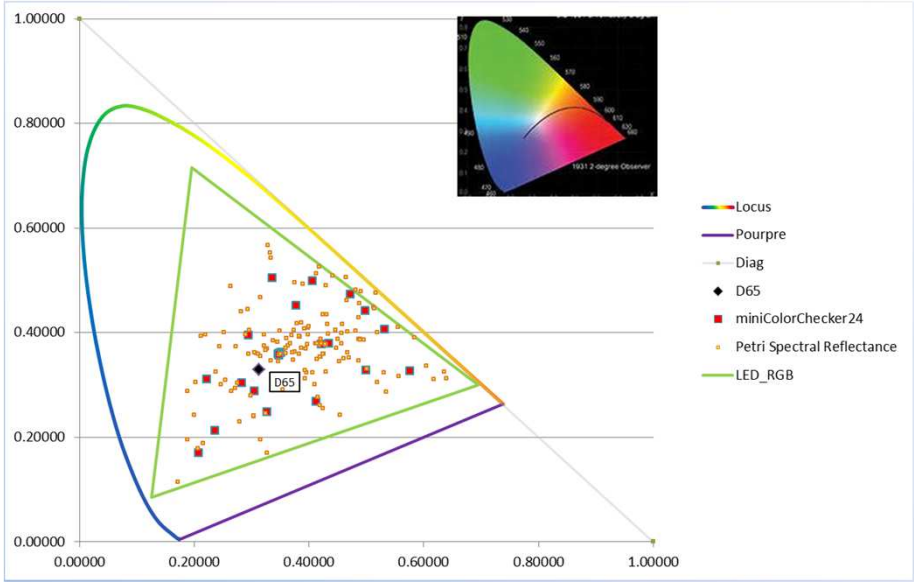
w. White diffuser for transmission

Acquisition

- w Mini 24 ColorChecker 

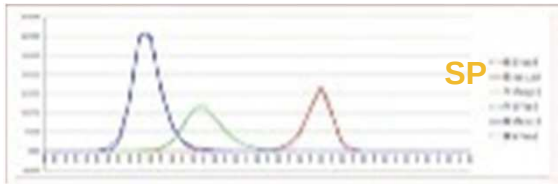
- w IT8 targets 

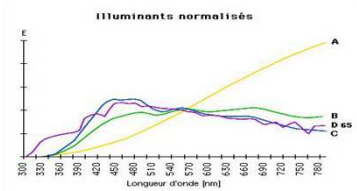
ICC Profiler v2



Goal : minimize the perceived variability (metamerism errors)

Proposal : ICC Model Base Color Calibration





WR

« Acquired » PPM & colonies

Acquisition Model

OOP

ICC Profiler v4

Perception Model

OVC

« Perceived » PPM & colonies

Legend :

SP : Spectral Light Properties

OVC : object viewing conditions (CAM02 model)

OOP = Object Optical Properties (Spectral Reflectance, Spectral Transmittance)

WR : white reference

How to **standardise** measure for defining spectral reflectance & transmittance ?

PPM Plates Imaging : Spectral reflectance measurement

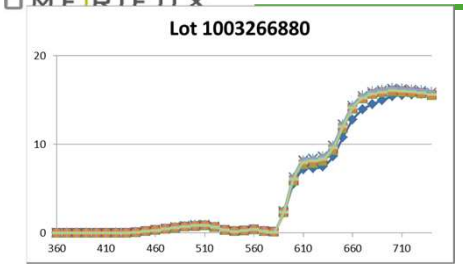
Spectrophotomer

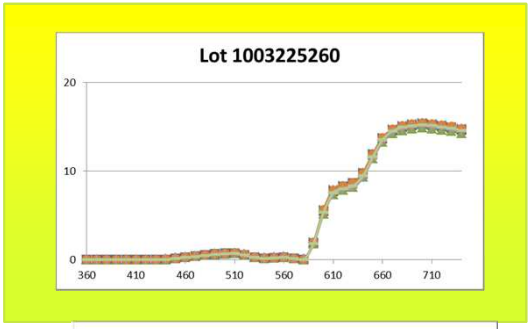
Measurement Setup

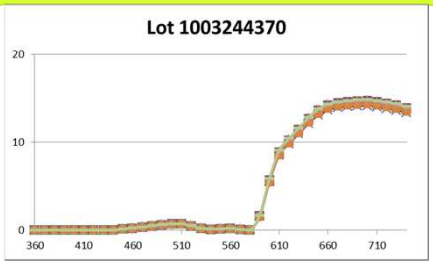
Konica Minolta 2600d

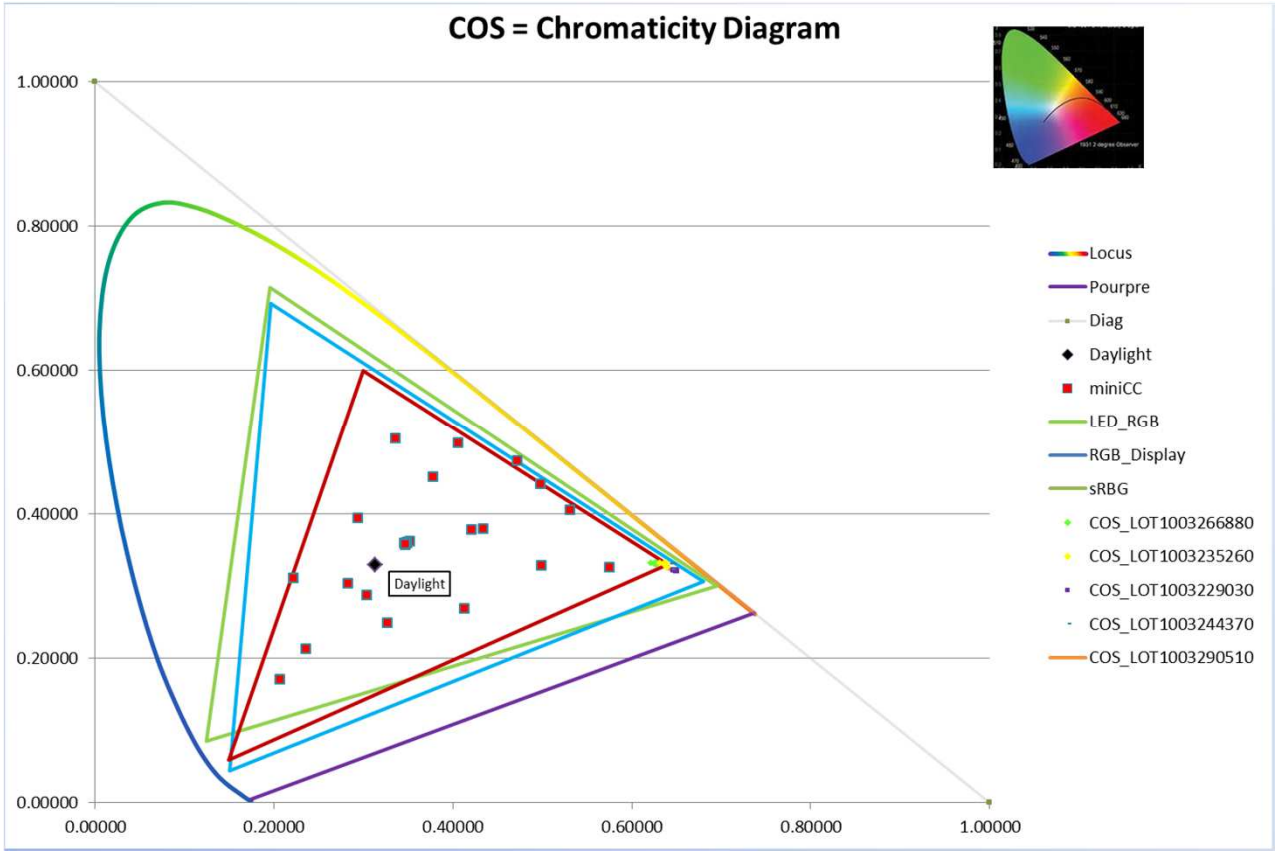
Measurement apertures (∅): 8 or 3 mm
Size of integrating sphere (∅) : 52 mm
Wavelength range : 360 nm to 740 nm
Wavelength pitch : 10 nm
Light : 3 pulsed xenon lamps
Specular included (SCI) & excluded (SCE) measures

An example : COS Spectral reflectance to XYZ (D50)





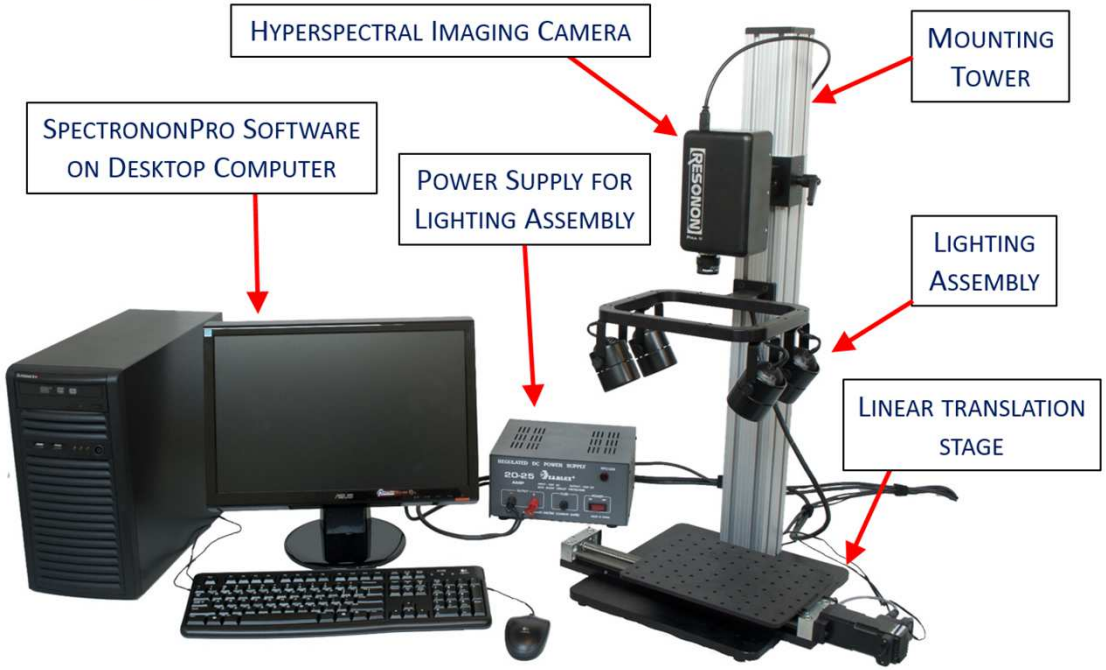




Current Limitations

- ➔ The minimal size is too small (3 mm) : difficult to measure isolated colonies (1 to 2 mm) optical properties
- ➔ No spectral transmittance measure possible with this device
- ➔ Variability of the distance of the device to the petri plates may have an impact (ie : specular component)

HSI : InVivo Spectral Measurement System



Resonon Spectronon

Spectral range : 400 nm to 900 nm

Spectral Resolution : 2.1 nm

Spectral channels : 240

Can make sense in a biological characterisation context:

- **Fast** analysis (<5 seconds) ➔ large spectral signatures database
- **High** resolution measurements (< 1 mm) ➔ single colony signature
- Reflectance & Transmittance **simultaneous** measures ➔ no time effect
- **Contact less** system ➔ no cleaning & contamination issue

Next Steps

ICC model based calibration

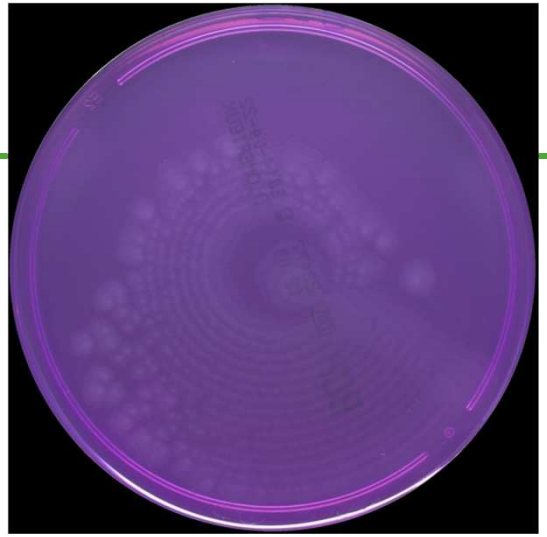
- Can we build a **normalised s**etup to measure spectral signature of petri images (w and wo) specular component) ?

- Can we build a **equivalence** measurement system a the golden standard being the spectrophotomer (at least for reflectance) ?

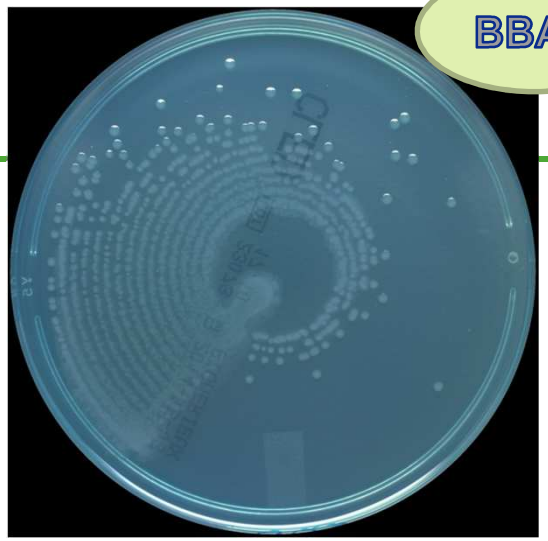
A few images of Petri Plates ….

BBAB

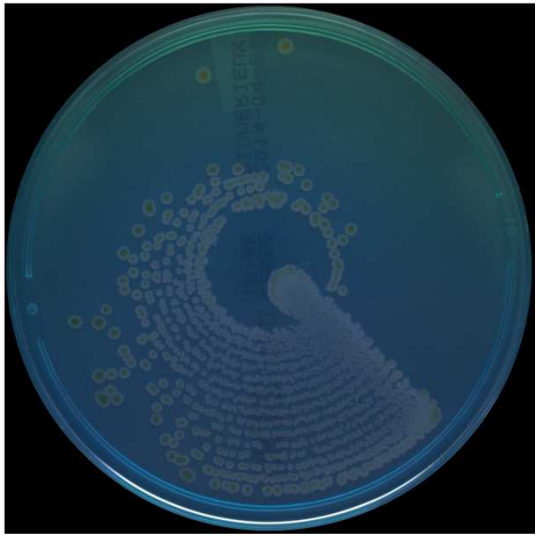
CAN2 / UCA



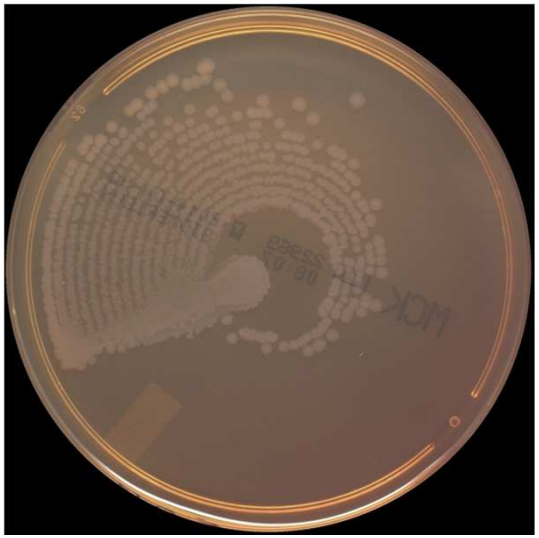
BCP / EQB



CLED / EQB



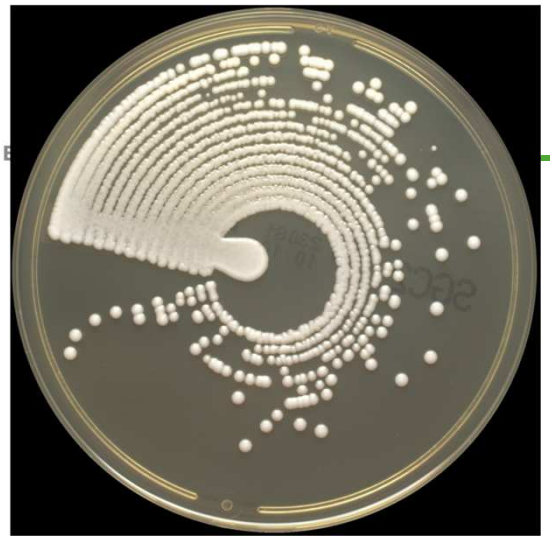
DRIG / EQB



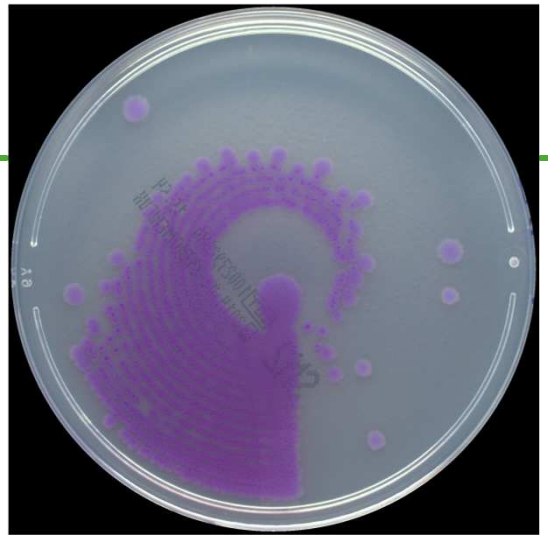
MCK / EQB

PAID / PPA

BBAB



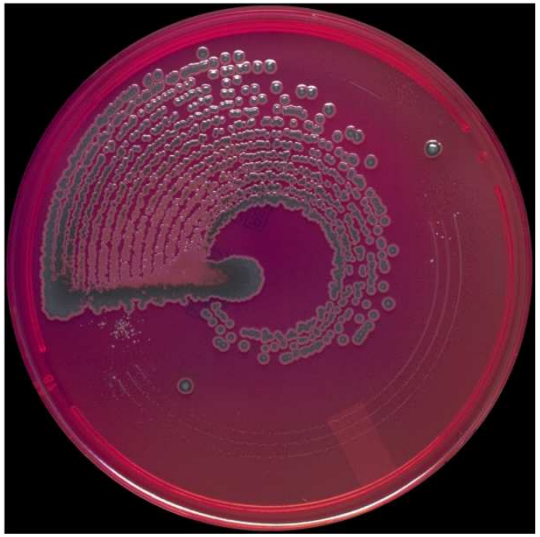
SGC2 / UCA



SM2 / EOM

STRPB / SAG

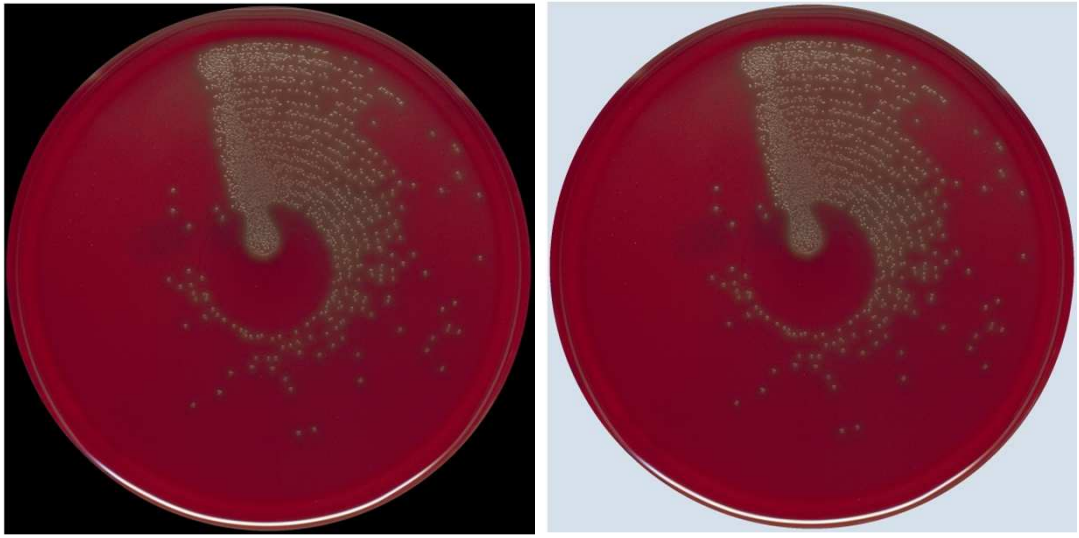
URI4 / KPN



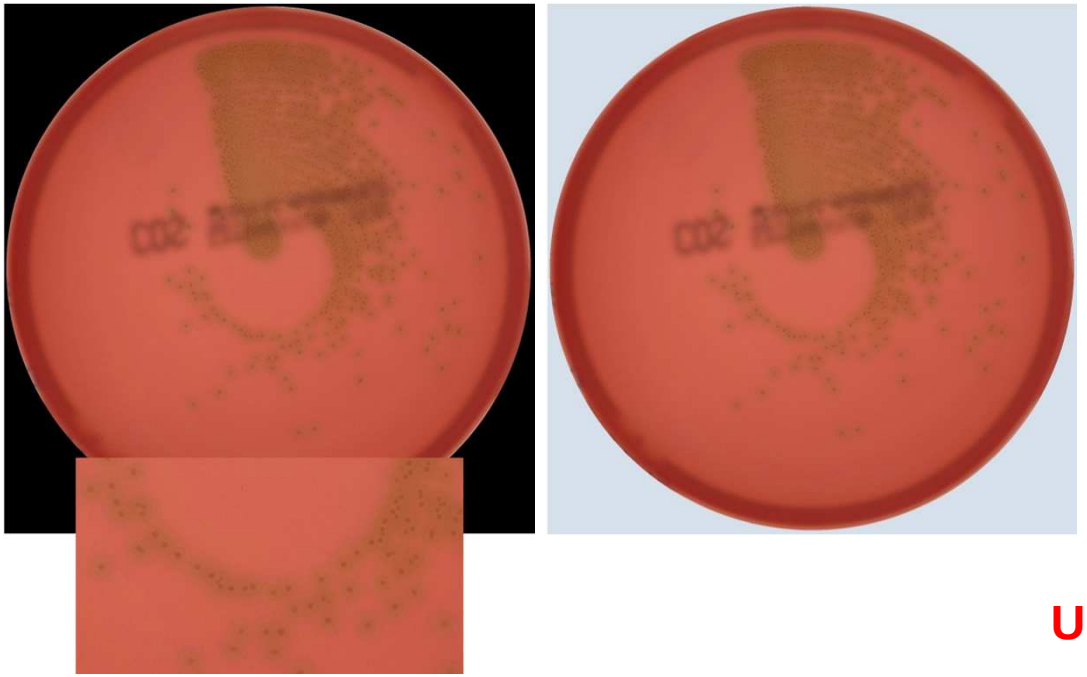
XLD / EOM

XLD / ESF

COS / SPN 0510039



BBAB



BL

THANK YOU FOR YOUR ATTENTION

jeremie.pescatore@biomerieux.com

PETRI PLATES READING & VIEWING :

➔ A NEED FOR STANDARDISATION

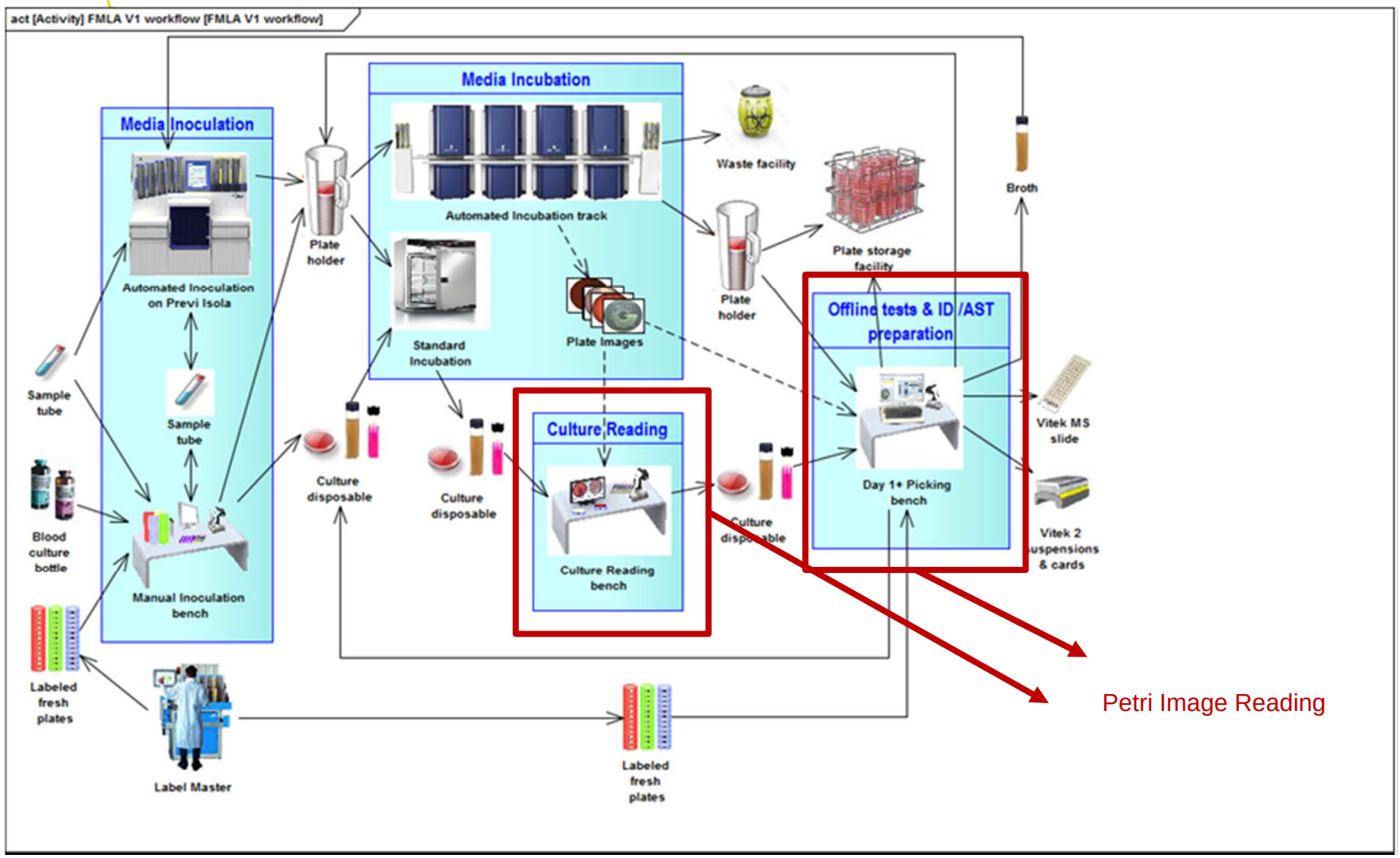
PIONEERING DIAGNOSTICS

Jeremie Pescatore, System Architect, bioMérieux

BIOMÉRIEUX

Revision 0

Clinical Imaging & Aided Diagnosis (CIAD)



PPM Plates : Reading Environements

Culture Reading = Reading of petri plates to define « isolates »

Clean Environement where **clinical diagnostic** is performed.

➔ ambient room conditions may (to some extent) be controlled

ID / AST Reading = Reading of petri plates to pick « isolates »

Dirty Environement : where **clinical diagnostic** is not necesseraly performed

➔ ambient room conditions is difficult to control

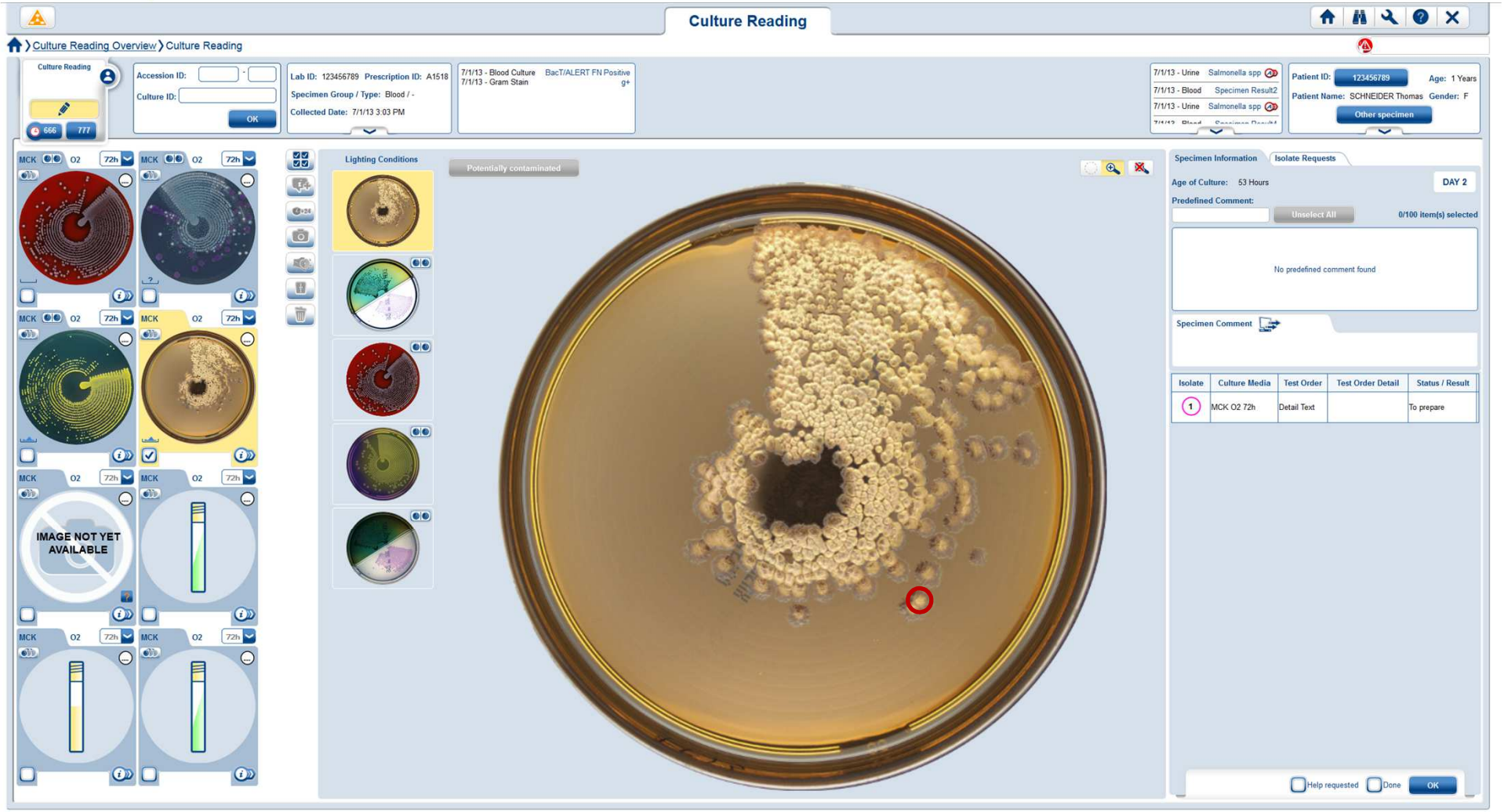
Mobile Culture Reading = Reading of petri plates out of the Laboratory

Environement : where **clinical diagnostic may be** performed

➔ ambient room conditions is difficult to control

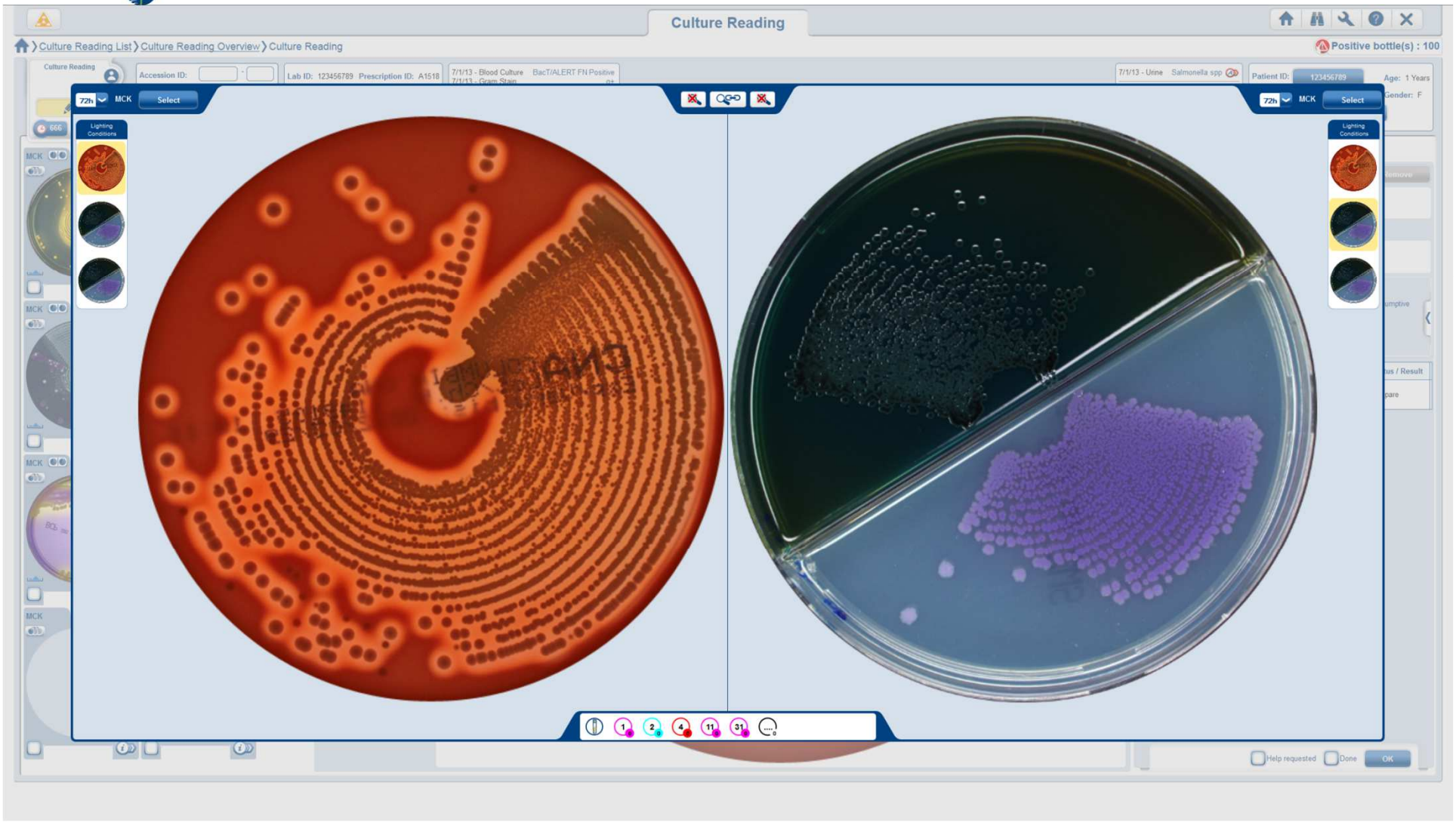
Can be build standardized common viewing conditions = Display ICC Output profile ?

Culture Reading : Clinical Diagnostics Screen (I)



- **EIZO CG 276** : **16/9 , 27”** (2540 x 1440) **w. sRGB gamut**
- Default display 1000 x 1000 up to full resolution (in zoom mode) **with a « bluyish background »**

Culture Reading : Clinical Diagnostics Screen (II)

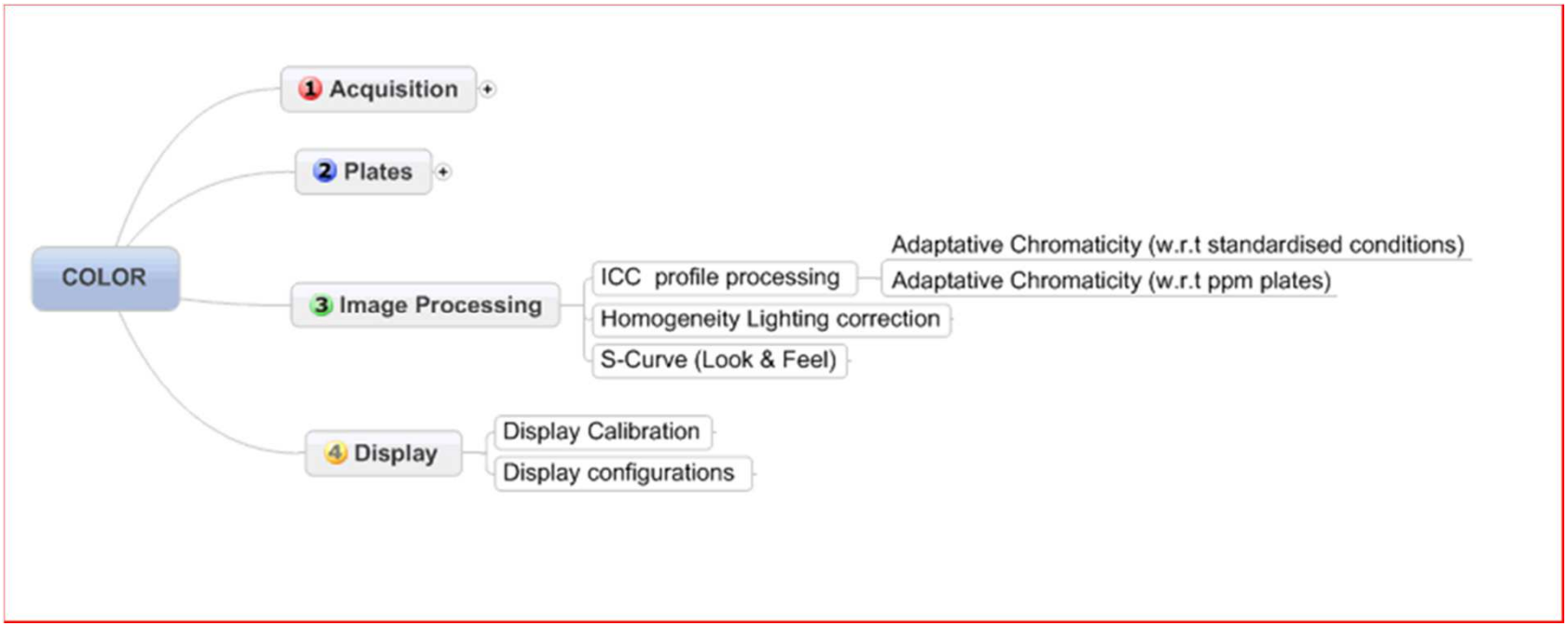


- EIZO CG 276 : **16/9 , 27”** (2540 x 1440**)** **w. sRGB gamut**
- Default display **1000 x 1000** up to full resolution (in zoom mode) with a **« bluyish background »**

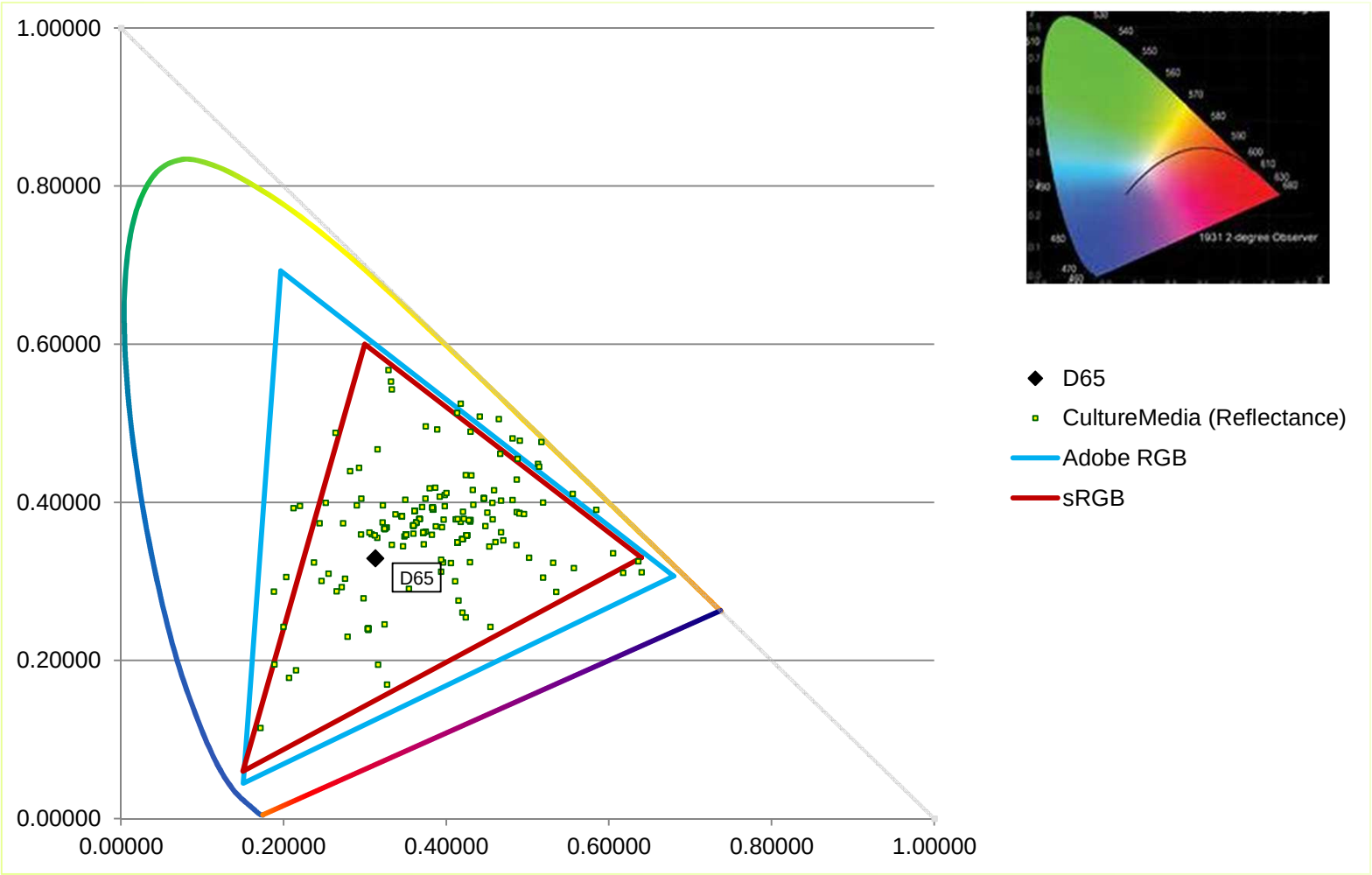
ID / AST : Clinical Diagnostics Screen (II)

- ELO Medical 1519 Resolution : **16/9** ➔ 1366 x 768
- Default display **350 x 350** (no zoom mode) with a **« bluyish background »**

Petri Plates Reading & Viewing



Media Plates Reflectance & Existing Gamut



Can we define a **standardized** gamut w.r.t. to monitor characteristics ?

A need for standardisation

Open Points :

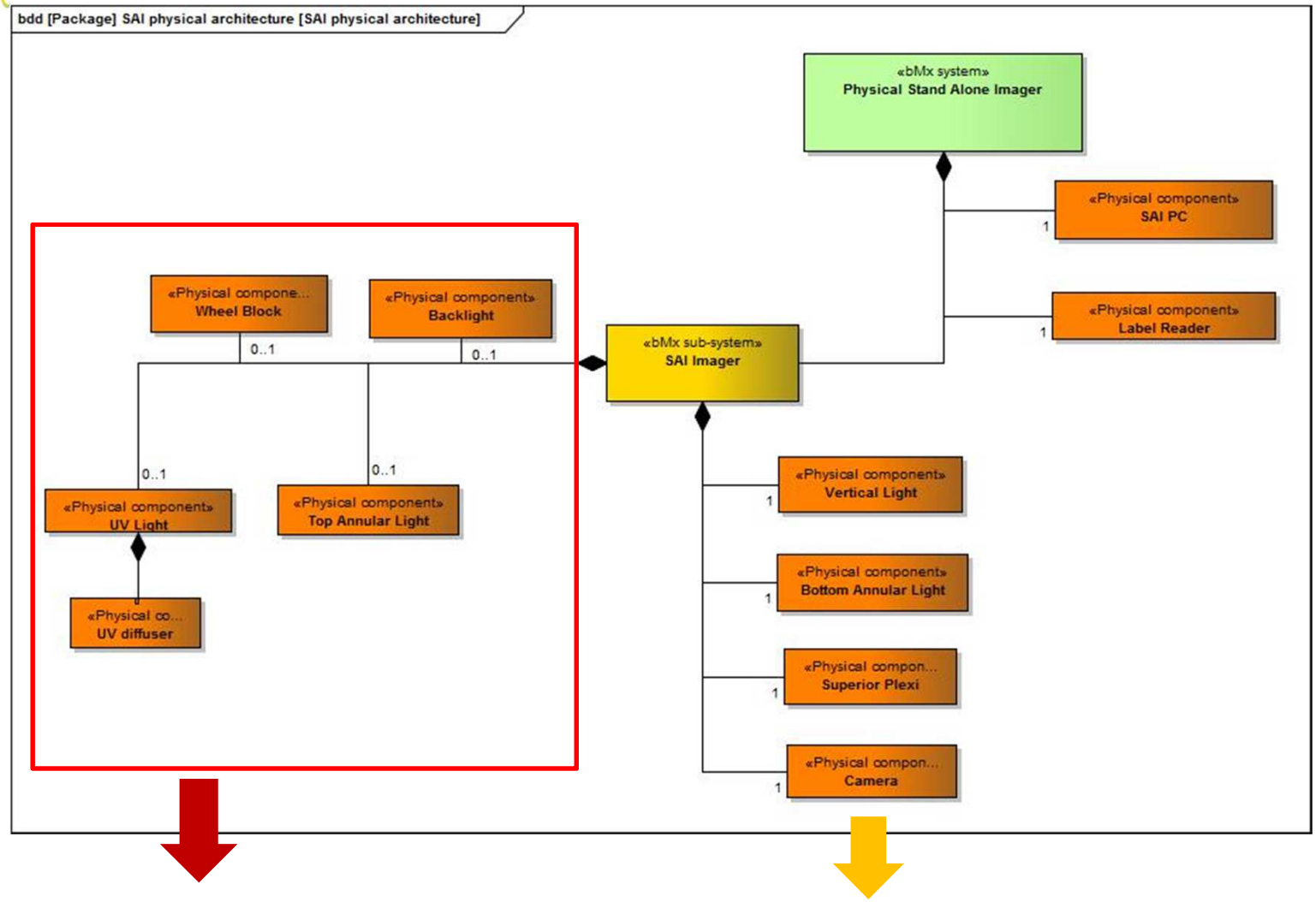
1. How should the effect ambiant light incorporated and standardized ?
2. How should the effect of the displayed background (chromatic adaptation) standardized with respect to viewing conditions
3. How should the **in/out gamut** of the display w.r.t. to petri optical properties (transmittance & reflectance) shall be standardized ?
4. How should (ie : image format, DICOM ?) output display profile shall be attached to the petri image data in order to display with the same manner on different displays ?

➔ **Could mRGB or dRGB color spaces could include these considerations for petri images ?**

THANK YOU FOR YOUR ATTENTION

jeremie.pescatore@biomerieux.com

Imager : Physical Architecture



TBC : No need for AST Imaging

Optics Change for AST imaging : square 120 - 140 mm

WSI Working Group

- Collaboration portal
  - Register an account at https://nciphub.org
  - Join the group https://nciphub.org/groups/wsi_working_group

- Resources have been added https://nciphub.org/groups/wsi_working_group/resources
  - Editorial from WG organizers
    - "Evaluating Whole Slide Imaging: A Working Group Opportunity"
    - Motivation and Goals from organizers' perspectives
  - Slides from Sept. meeting of ICC MIWG

- Survey being developed to collect input
  - WG organizational structure
  - Topics to be pursued

- Ideas for how to proceed