Dicom multi-spectral presentation states

status update

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What are multi-spectral presentation states, and why do we need them?

Benefits of a DICOM multi-spectral presentation state

- **Improved true color (wide gamut) rendering** with 4 or more channels
- Standardized way to store and exchange multi-spectral image data
  - **Reproducible pseudo color images** (e.g. for fluorescent imaging)
  - **Standardize channel un-mixing** while preserving raw data

Current limitations in DICOM

- Only **3 input channel ICC v4 input profiles** are available in DICOM
  - 3 channels is too limited for most fluorescent & multi-spectral use cases
  - ICCv4 profiles describe transformations to 3 channel PCS, which will lead to information loss for all multi-spectral uses cases where true color rendering is not the sole objective.

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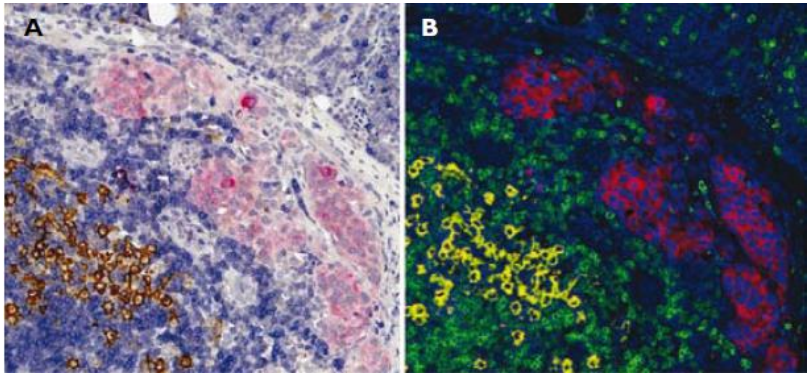
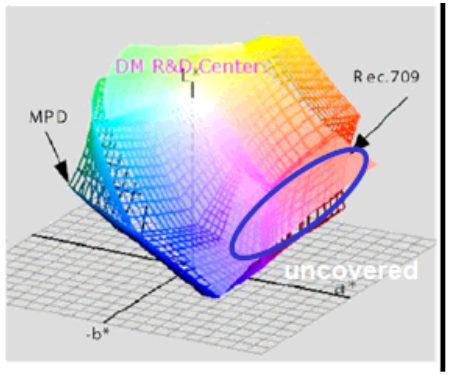
True color with more than 3 color channels

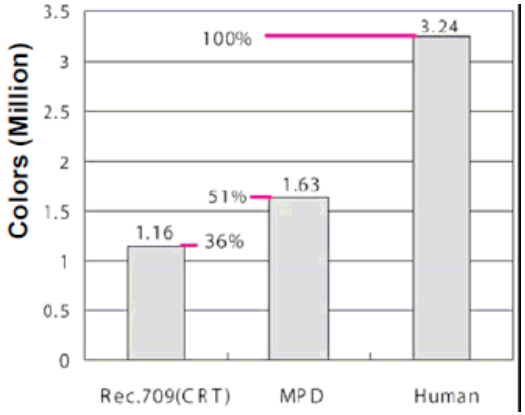
- Most Whole Slide Imaging devices are using LED illumination, this allows:
  - narrow band illumination with >3 channels for **wide gamut imaging**
  - narrow band illumination for **spectral analysis of images**, e.g., for "fluorescence-like" segmentation (for display& algorithms)



Multi-spectral bright field segmentation

Source:ttp://www.rms.org.uk/Resources/Royal%20Microscopical%20Society/infocus/infocus%20June%2009%20-%20Mansfield%20_%20Levenson%20Article.pdf





5 channel HDTV, **Source:** Journal of Imaging Science and Technology, Volume 49, Number 6, November/December 2005 , pp. 594-604(11)

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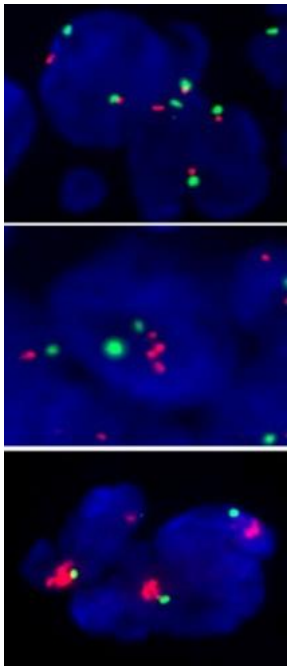
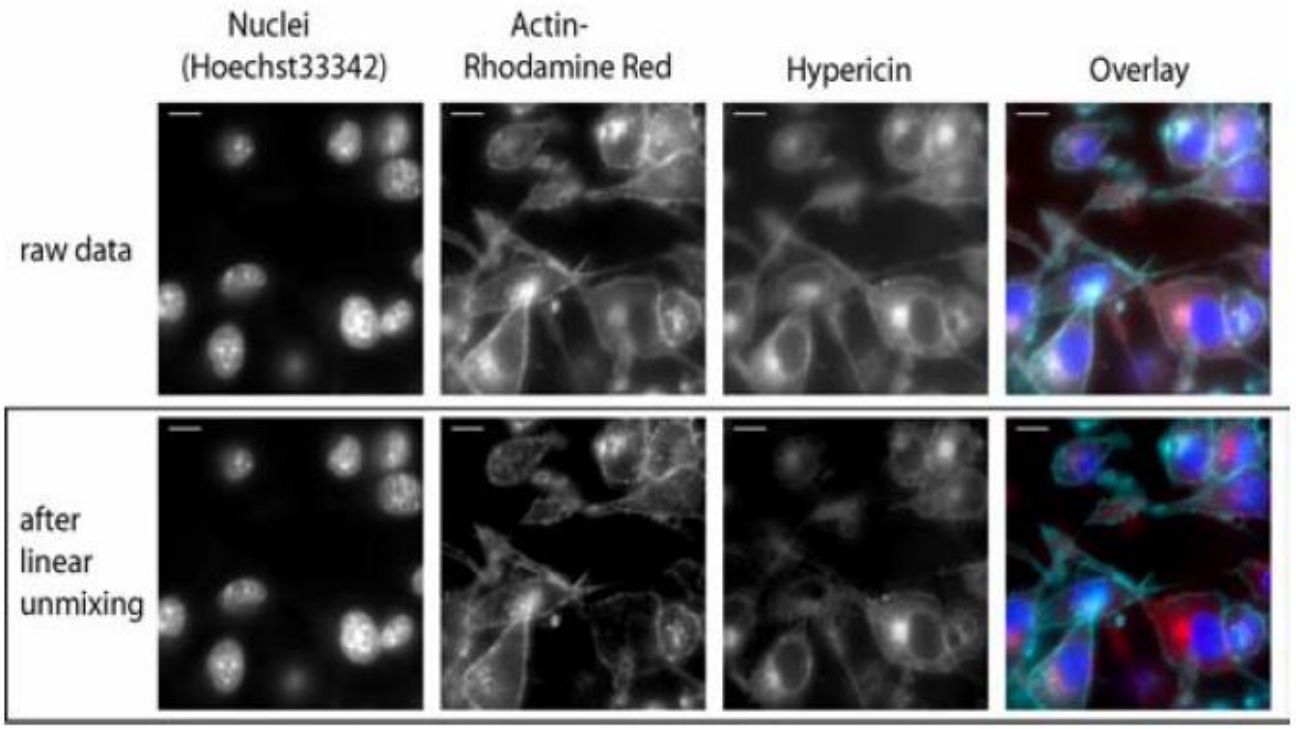
Multi spectral fluorescence

- **Remove raw capture channel crosstalk** to get one channel per biomarker and auto-fluorescence suppression, for display and algorithms.
- Define **standardized pseudo color display** for each bio-marker
- Allow capture device calibration to get **quantitative bio-marker concentrations**





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How to extend DICOM for these use cases

DICOM extensions required for the different use cases

1. Ability to define how to display multi-spectral images as true color visible light images.
2. Ability to define how to un-mix multispectral input channels for the purpose of deriving quantitative representations of individual biomarker intensities, said markers can be fluorescent or chromogenic.
3. Ability to define how to display (un-mixed) multi-spectral images (fluorescent, chromogenic) as pseudo color images. It should be possible to use the un-mixed output from **2)** as input for this mode.

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1. Ability to define how to display multi-spectral images as true color visible light images.

Can be done within an ICCv4 input profile

2. Ability to define how to un-mix multispectral input channels for the purpose of deriving quantitative representations of individual biomarker intensities, said markers can be fluorescent or chromogenic.

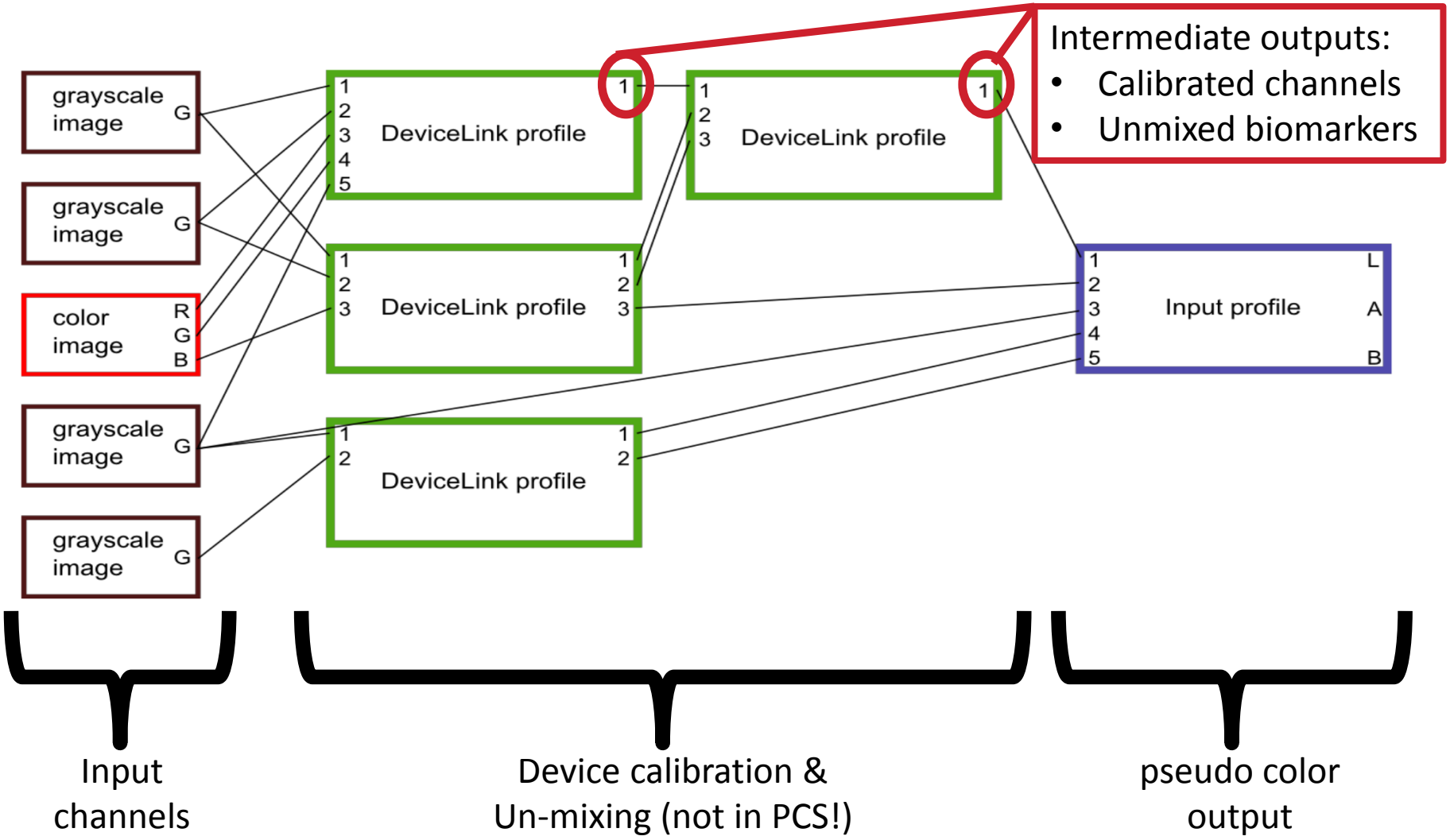
Can NOT be done within an ICCv4 input profile

- option 1: use chained ICCv4 device link profiles
- option 2: use ICCv5 biomarker connection space

3. Ability to define how to display (un-mixed) multi-spectral images (fluorescent, chromogenic) as pseudo color images. It should be possible to use the un-mixed output from **2)** as input for this mode.

Can be done within an ICCv4 input profile

Extending DICOM for multi-spectral with ICCv4



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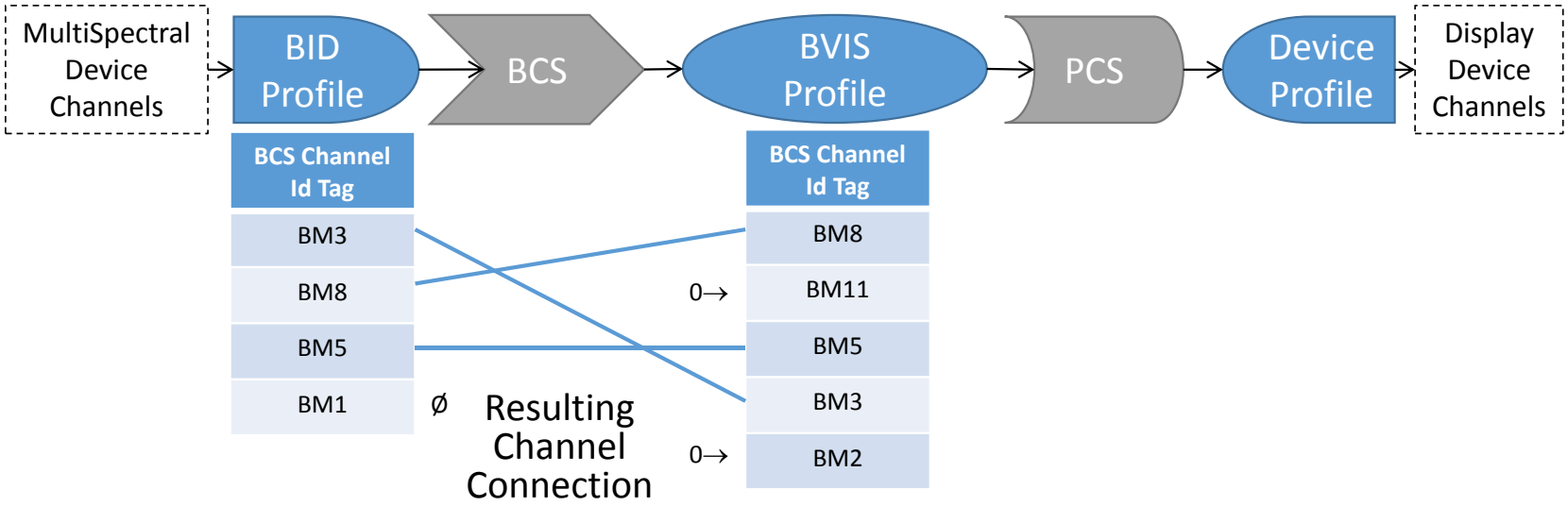
Extending DICOM for multi-spectral with ICCv5

(slide from Max Derhak)

- RefICCLabs - - - ICC v5
  - Spectral profile
  - Calc element
  - …
- Proposal of “Biomarker Connection Space” Profiles
  - BCS connection allowed between source Biomarker Identification (BID) and destination Biomarker Visualization (BVIS) profiles



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Benefits of a DICOM multi-spectral presentation state
(recap)

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Current limitations in DICOM

- Only **3 input channel ICC v4 input profiles** are available in DICOM
  - 3 channels is too limited for most fluorescent & multi-spectral use cases **Ok!**
  - ICCv4 profiles describe transformations to 3 channel PCS, which will lead to information loss for all multi-spectral uses cases where true color rendering is not the sole objective. **Ok!**

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Getting it in DICOM

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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 (scheduled for March 22nd 2015)
3) Send to WG6 for discussion
4) Write the full DICOM implementation

Required DICOM extensions

(only for ICCv4, only for ICCv5)

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**)
4) Allow ICCv5 profiles

More complex additional functionality

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

5) 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

6) 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

Option **D,** channels in multi-frame image, additional fields to define the colors of the frames

Advantages: easy, no DICOM enhancements required

Disadvantages: legacy DICOM wont know how to display these images

7) 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)