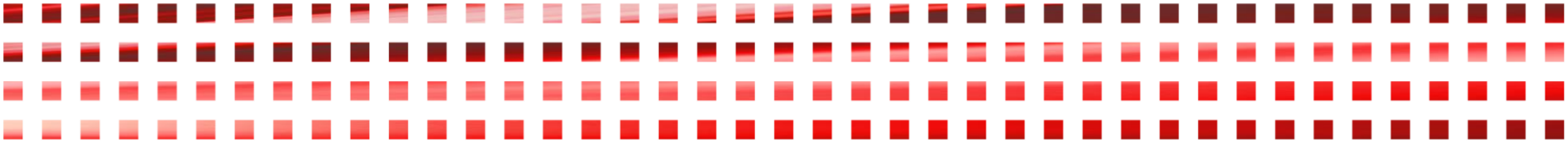
Display calibration with ICC profiles

ICC Medical Imaging Working Group



Kuurne, March 2015

Summary

- Protocol
- Simulation Platform
- Results
- What if ?
- Work in progress

Simulation Protocol

Simulation Protocol

Goal:

Achieve the best possible DICOM GSDF Calibration by using ICC framework only.

Workflow:

- Create input and display ICC profiles(LittleCMS 2.6).
- Connect them.
- Apply the correction on test pattern (Gray gradient).
- Simulate display's internal framework(internal LUT, bit-depth,...).
- Estimate the DICOM correctness from the pattern.

Simulation Protocol – Input ICC profile

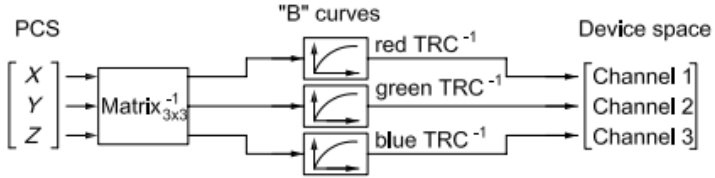
- Common to every test
- Created with LittleCMS 2.6
- V4.3
- Contains:
  - Chromatic adaptation to D65
  - Luminance (600 cd/m²)
  - Red, Green and Blue TRC (DICOM for range from 0.6cd:m² to 600.0 cd/m²)
  - Red XYZ, Green XYZ and Blue XYZ corresponding to sRGB.

Simulation Protocol – Output ICC profiles

- Created with LittleCMS2.6.
- V4.3
- Could be Monochrome:
  - Chromatic adaptation to D65
  - Luminance (600 cd/m²)
  - Gray TRC (DICOM, sRGB, Gamma,...)

Simulation Protocol – Output ICC profiles

- Created with LittleCMS2.6.
- V4.3
- Could be Three-component matrix-based Display profile:
  - Chromatic adaptation to D65
  - Luminance (600 cd/m²)
  - Red Green and Blue TRC (DICOM, sRGB, Gamma,...)
  - Red XYZ, Green XYZ and Blue XYZ corresponding to sRGB.



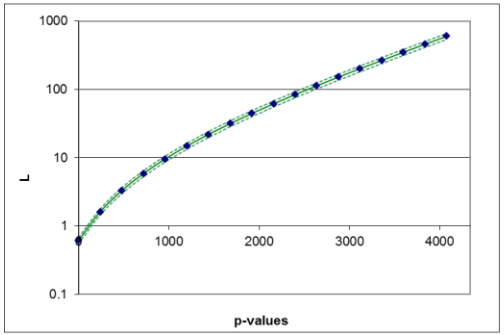
Simulation Protocol – Output ICC profiles

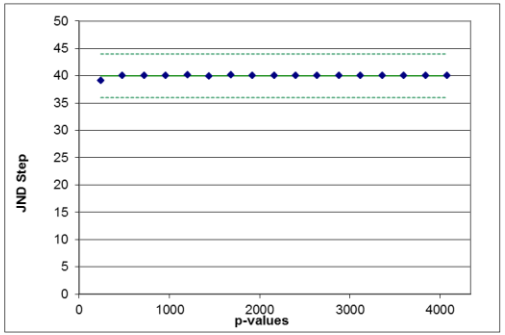
- Created with LittleCMS2.6.
- V4.3
- Could be Three-component LUT-based Display profile:
  - Chromatic adaptation to D65
  - Luminance (600 cd/m²)
  - LUT AToBx
  - LUT BToAx
  - Red XYZ, Green XYZ and Blue XYZ corresponding to sRGB.

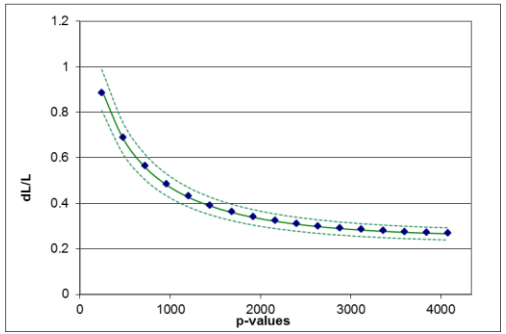
Results of the simulations

Results
DICOM Compliance for different display Profiles

10 bits Precision	sRGB	Gamma 3.5	Gamma 2.2	Gamma 1.0
Monochrome	0.102 %	0.138 %	0.145 %	1.622 %
Matrix based	2.711 %	0.214 %	0.437 %	2.320 %



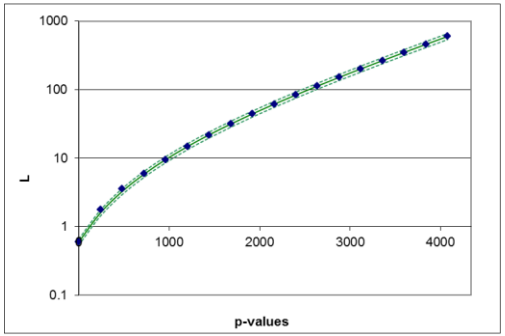


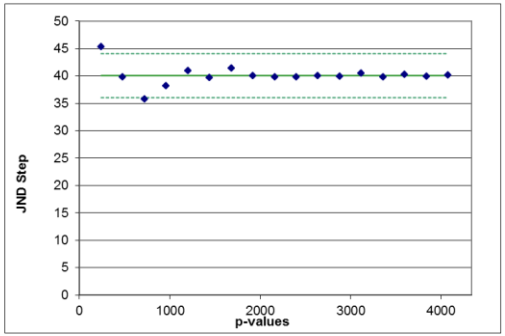


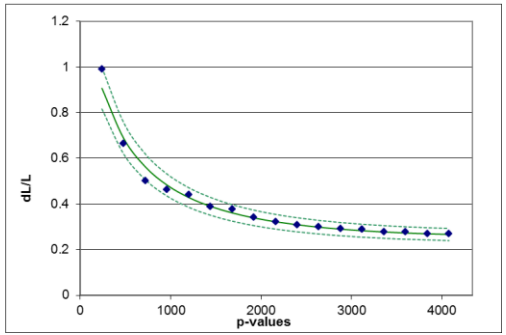
Results
DICOM Compliance for different display Profiles

- Display input limited to 10 bits.

10 bits Precision	sRGB	Gamma 3.5	Gamma 2.2	Gamma 1.0
Monochrome	1.522 %	1.191 %	1.661 %	13.037 %
Matrix based	1.521 %	1.187 %	1.649 %	13.037 %



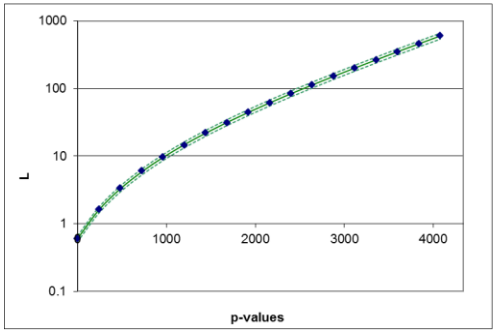


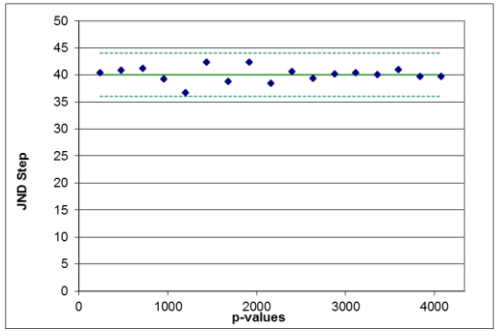


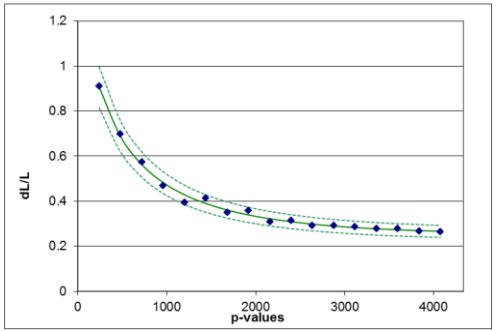
Results
DICOM Compliance for different display Profiles

- Display input limited to 8 bits.

8 bits Precision	sRGB	Gamma 3.5	Gamma 2.2	Gamma 1.0
Monochrome	8.352 %	6.823 %	8.375 %	100 %
Matrix based	8.328 %	6.827 %	8.352 %	100 %







What if ?

What if ?

The results presented in previous section represent the optimal situation where both the input and display profiles perfectly correspond to the characteristics of the display.

Even then, the quality of the calibration is quite low, especially for 8 bits configuration.

What if ?

- What would be the Calibration quality in more realistic conditions ?

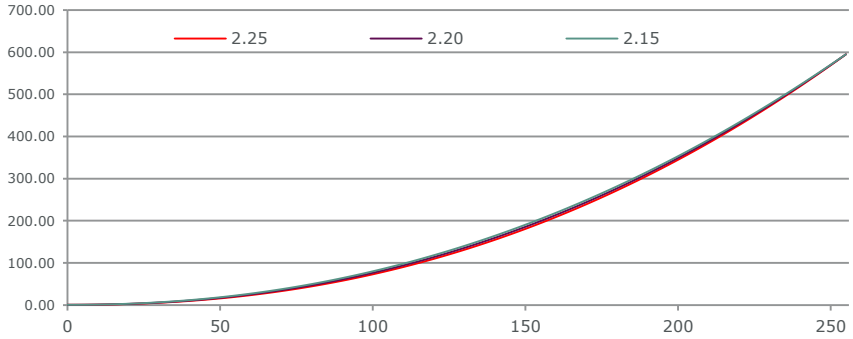
- All the scenarios tested hereafter are derived from a display gamma 2.2 display with a luminance of 600 cd/m² and a contrast of 1000:1.

What if the Tone Response Curve is wrong ?

The Transfer Function of the display is different from the assumed one:

Let’s assume Gamma 2.2 while the display actually behaves as Gamma 2.25 or 2.15 with a Matrix based display profile.

Real Gamma	2.15	2.20	2.25
10 bits	12.026 %	1.649 %	10.023 %
8 bits	13.343 %	8.352 %	9.85 %



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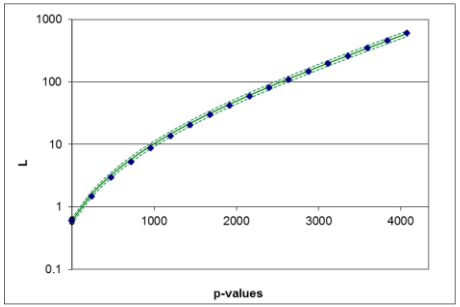

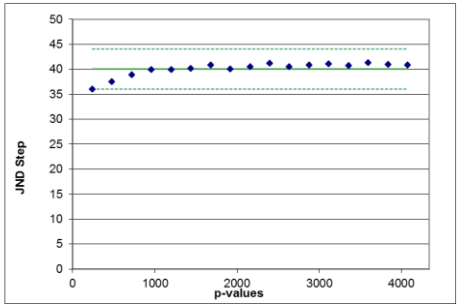

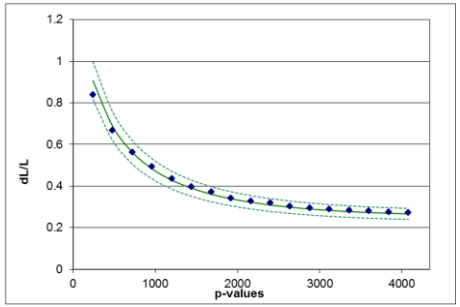

What if the Contrast is wrong ?

- The display contrast is different from the assumed one.
- Different contrast means same White luminance, different black luminance: $Y_{black} = \frac{Y_{white}}{Contrast}$
- Let's assume a contrast of 1000:1 while the real display contrast is 1200:1 or 800:1.
  - This represents a variation of luminance of the Black of ~0.12cd/m²

Real Contrast	800:1	1000:1	1200:1
10 bits	6.926 %	1.649 %	6.479 %
8 bits	8.168 %	8.352 %	9.138 %

What if the Luminance is wrong ?

- The display luminance is different from the assumed one.
- Different luminance means different White and Black luminance, but constan contrast.
- Let’s assume a contrast of 600 cd/m² while the real display luminance is 500cd/m² or 700 cd/m².

Real Luminance	500 cd/m²	600 cd/m²	700 cd/m²
10 bits	5.909 %	1.649 %	4.628 %
8 bits	9.695 %	8.352 %	8.006 %

What if the Ambient light varies ?

- By reflecting on the front glass, the ambient light adds an offsett to the perceived luminance of the display.
- The ambient light must be taken into account dring the calibration process.

$$Y_{perceived} = Y_{display} + Ambient\ Light$$

What if the Ambient light varies ?

- Let’s assume an abient light of 5 Lux (typical diagnostic room) for the calibration while the real ambient light varies from 0 to 15 Lux.

Real Ambient light	0 Lux	2 Lux	5 Lux	8 Lux	10 Lux	15 Lux
10 bits	122.123 %	37.269 %	1.397 %	18.024 %	26.003 %	39.153 %
8 bits	123.187 %	40.624 %	5.490 %	17.086 %	23.905 %	37.385 %

Work in Progress

Work in Progress

- Integration of display aging to the simulations.
- Use of LUT based Profiles (Perceptual and Saturation Intent mappings must be defined).
- Study the quality of color calibration (absolute color matching and perceptually linear calibration).

Conclusion

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- An accurate DICOM GSDF calibration is possible with the current ICC Framework for 10 bits configurations, but it requires that the image (input profile) is perfectly aware of the monitor it will be displayed on, which is hardly feasible.

- Using generic profiles describing the average behavior of a display model is not acceptable.

- Because of the ambient light, the DICOM TRC must be frequently updated, and then the input profile must be updated too.

- Absolute and CSDF Calibrations still have to be evaluated.

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