ICC DEVCON 2020

Spectral Reproduction

by

Tanzima Habib

NTNU, Gjøvik, Norway

syedath@studntnu.no

THE FUTURE OF COLOR MANAGEMENT

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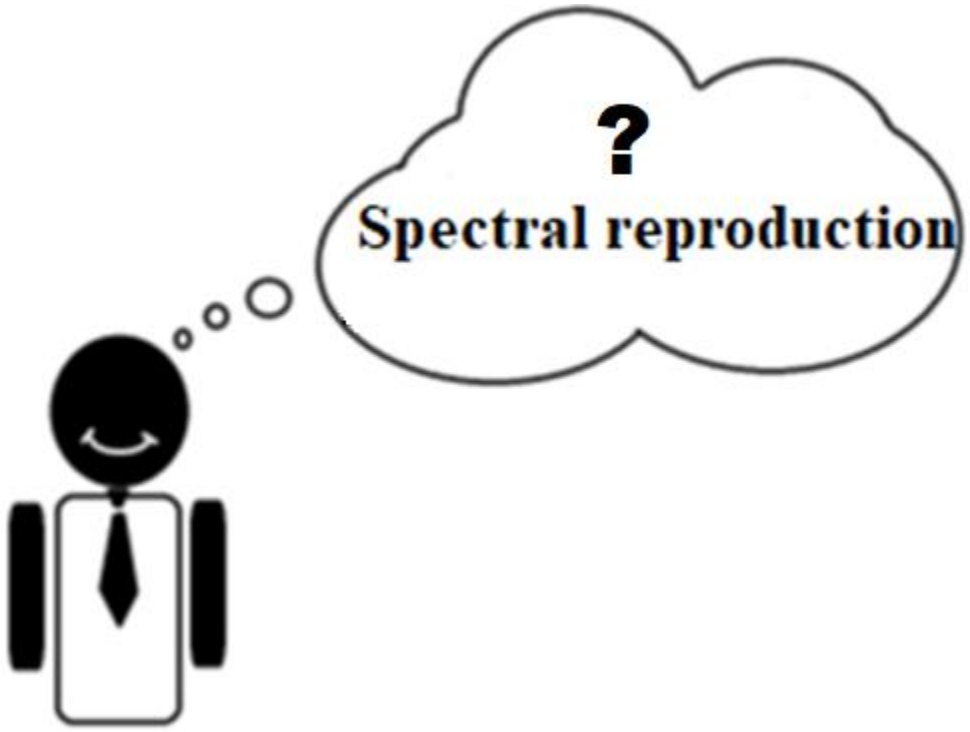
OUTLINE

- Introduction to spectral reproduction
- Spectral acquisition
- Spectral processing
- Spectral reproduction use cases
- Spectral reproduction workflows
- Some metrics for evaluation
- Conclusions

Understanding spectral reproduction

Requirement/Goal	Eg:	Spectral Matching
Spectral data acquisition	Eg:	Acquire Spectral Data
Spectral processing	Eg:	Create model to match spectra
Application	Eg:	Apply the workfkow to match spot colour to process inks



Driver of spectral reproduction

"Increase in the demand for spectral reproduction workflows"

Reasons:

- Surface reflectance represent material property essential in fields like Cultural heritage, computer graphics
- Intermediate processing in the spectral domain helps in colour accuracy, data hiding etc. important in fields like medical imaging, arts and graphics

Driver of spectral reproduction

This demand in return has led to :

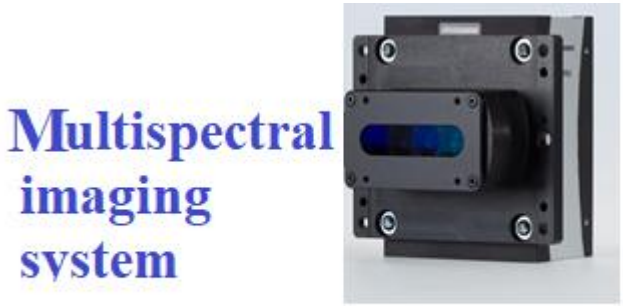
- technological advancements in spectral acquisition devices and processing hardwares
- availability of spectral and multi spectral data today

Improvements in spectral acquisition:

- faster, accurate and precise acquisition with available spectrophotometers, TSR, hyperspectral and multispectral imaging systems
- increased repeatability, reproducibility and traceability of devices of spectral and multi spectral data today

Some spectral acquisition devices

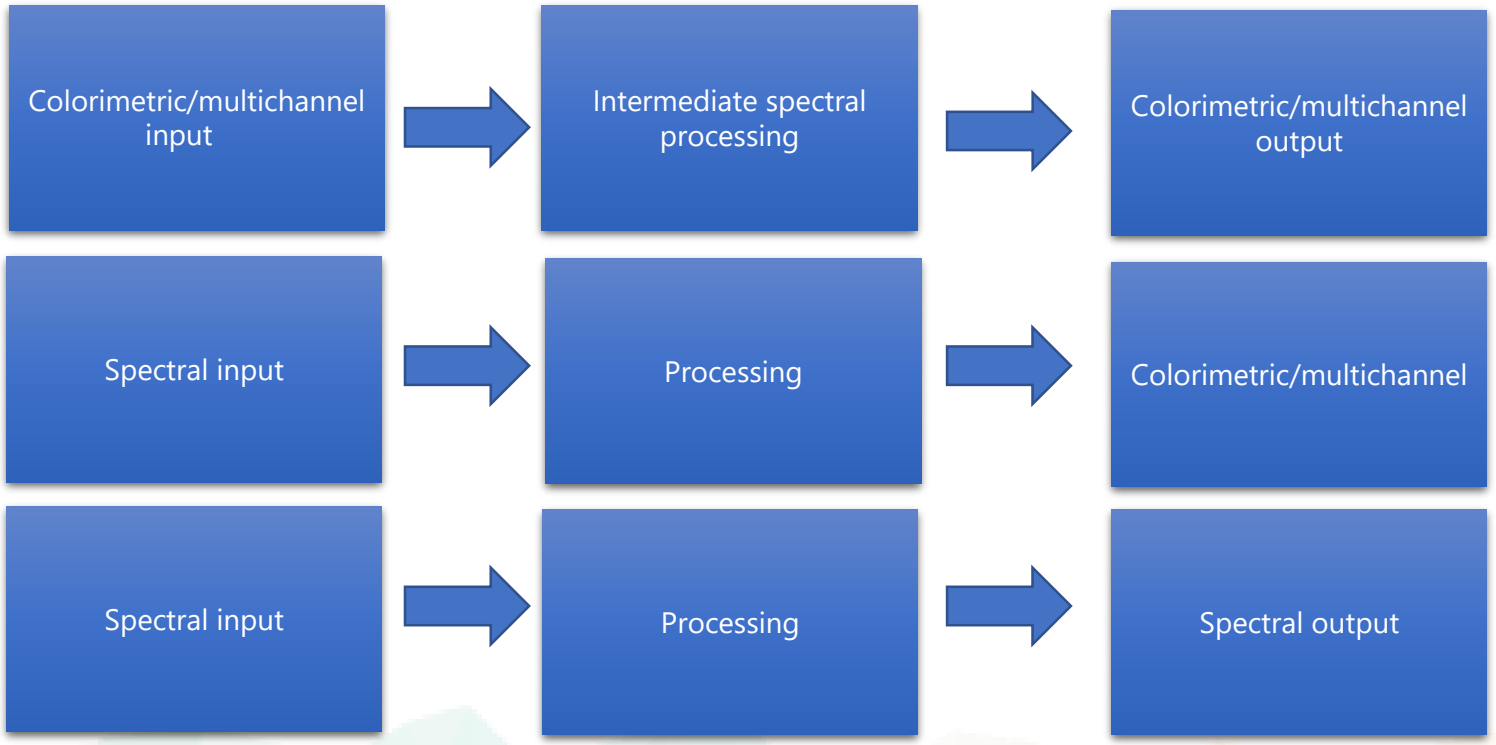
- Hyperspectral imaging output s narrow spectral bands over a continuous spectral range
- Multispectral imaging discrete (3-12) number of channels



https://www.chromasens.de/en/product/multi-spectral-camera-truepixa-pro-compact-6-channel-130dpi

https://applied-infrared.com.au/products/2-hyperspectral-imaging/5-benchtop-hyperspectral-imaging-systems

Spectral processing



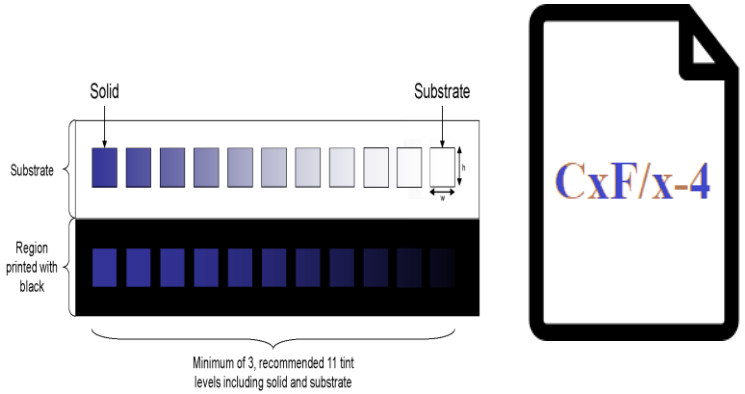
Examples:

- Spectral estimation
- Correcting spectral data
- Spectral BRDF processing
- Colour or other transformation of spectral data

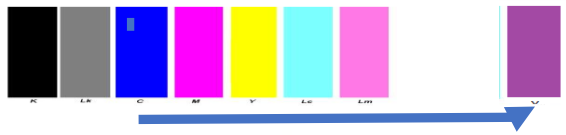
Spectral Reproduction use cases

1. Spot colour reproduction
   - Match process colour to spectra of spot colour

Deshpande, Kiran, and Phil Green. "A simplified method of predicting the colorimetry of spot colour overprints." *colour and Imaging Conference*. Vol. 2010. No. 1. Society for Imaging Science and Technology, 2010.

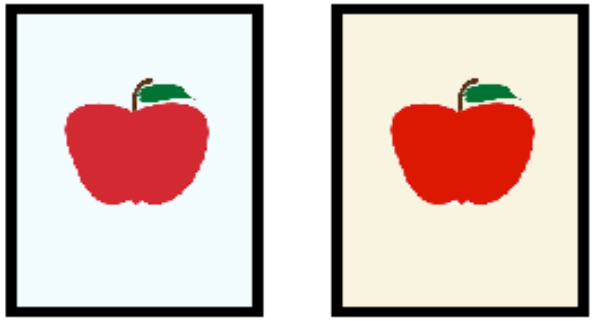


2. Printer characterisation when a ink is switched or sequence is changed
   - Spectral printer characterisation



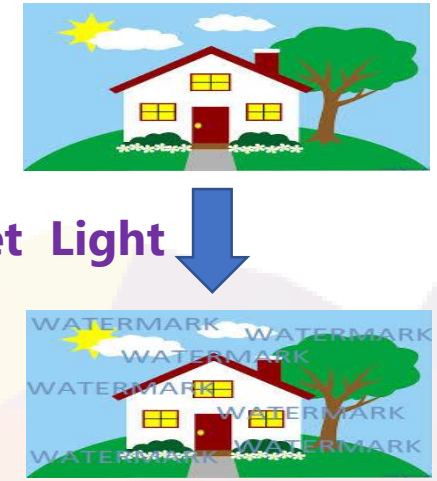
Spectral Reproduction use cases

3. Spectral adjustment for substrate colour
   - ✓ Change characterisation data w.r.t the whitepoint in paper
   - ✓ Correct the data spectrally instead of media relative scaling



Different XYZ but similar appearance

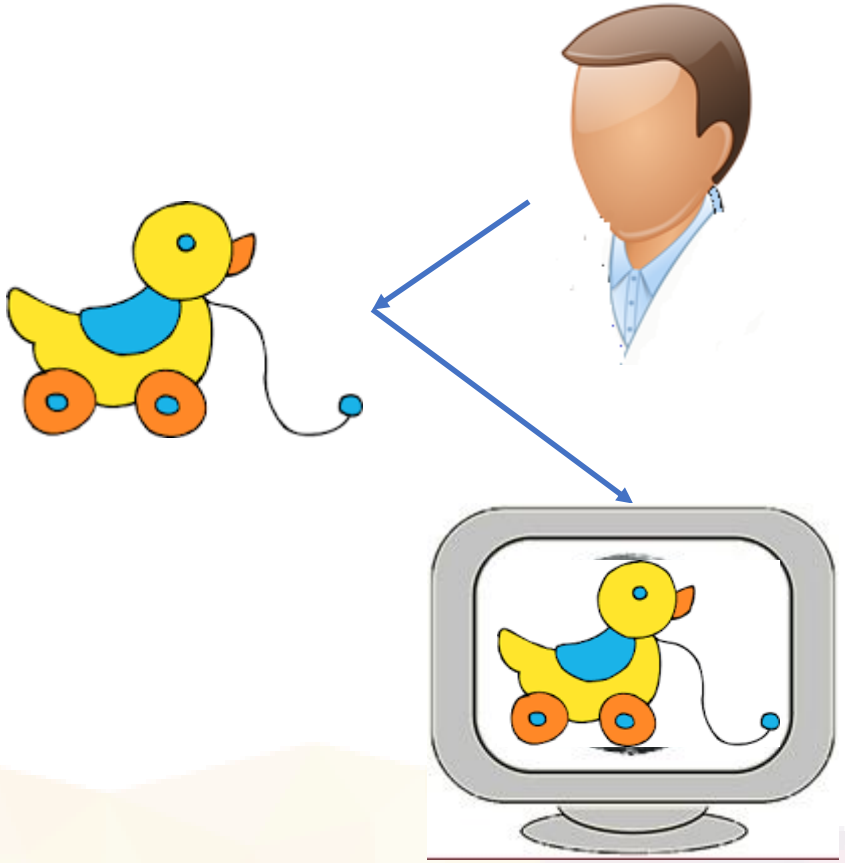
4. Data hiding
   - ✓ Use metameric ink combination to print the watermark



Bala, Raja, Karen M. Braun, and Robert P. Loce. "Watermark encoding and detection using narrowband illumination." colour and Imaging Conference. Vol. 2009. No. 1. Society for Imaging Science and Technology, 2009.

Spectral Reproduction use cases

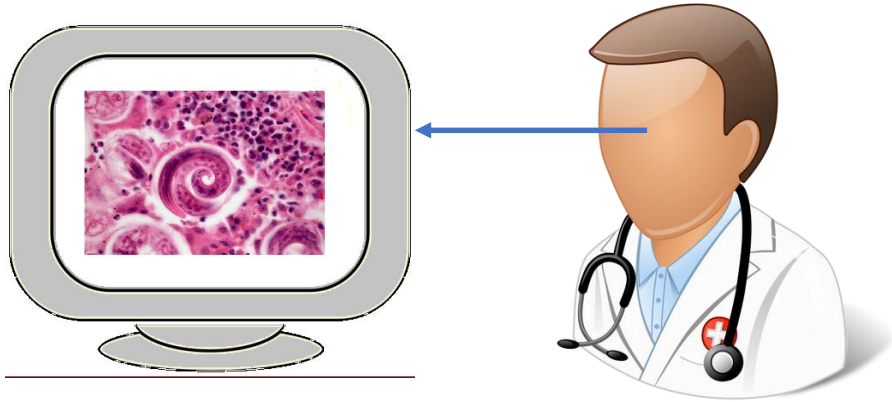
5. Scene-referred spectral reproduction
   - ✓ Spectral estimation using object specific reflectance database
   - ✓ Match estimated spectra to natural spectra i.e. smooth
   - ✓ Reproduction of accurate colour that resembles the perceived scene (Photorealistic rendering system)



Meng, Johannes, et al. "Physically meaningful rendering using tristimulus colours." Computer Graphics Forum. Vol. 34. No. 4. 2015.

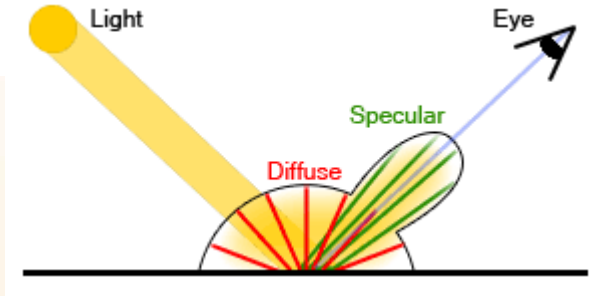
Spectral Reproduction use cases

6. Hi-fidelity colour reproduction and spectral information in medical imaging.
   - ✓ Multispectral images to display (wider colour gamut can display accurately)
   - ✓ Can use spectrum to detect or quantify diseases etc.



Yamaguchi, Masahiro, et al. "High-fidelity video and still-image communication based on spectral information: Natural vision system and its applications." Spectral Imaging: Eighth International Symposium on Multispectral Color Science. Vol. 6062. International Society for Optics and Photonics, 2006.

7. Spectral BRDF to render synthetic images at different orientations



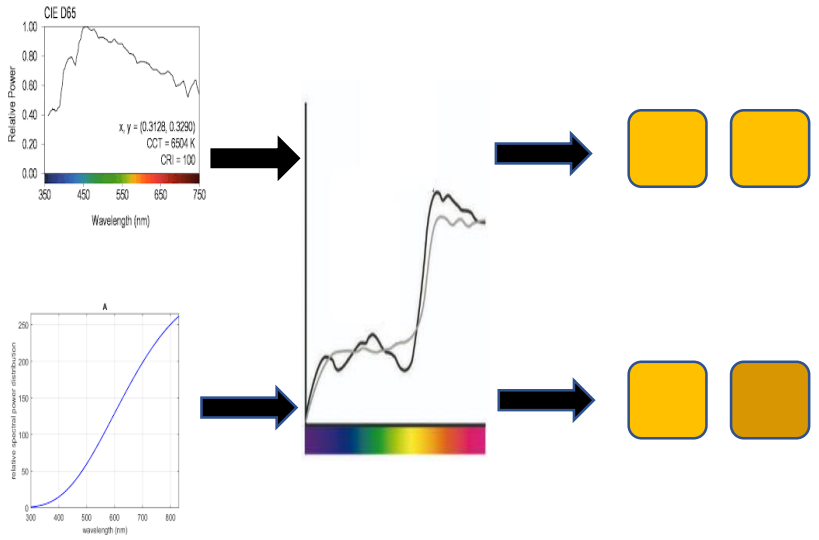
Ďurikovič, Roman, and Andrej Mihálik. "Modeling the BRDF from spectral reflectance measurements of metallic surfaces." Applied surface science 312 (2014): 87-90.

Spectral Reproduction use cases

8. Minimizing metamerism under different illuminants
   - ✓ Spectral Input (Target) -> Ink combination under illuminant 1 and same ink combination under illuminant 2 should have the lowest colour difference with the target.

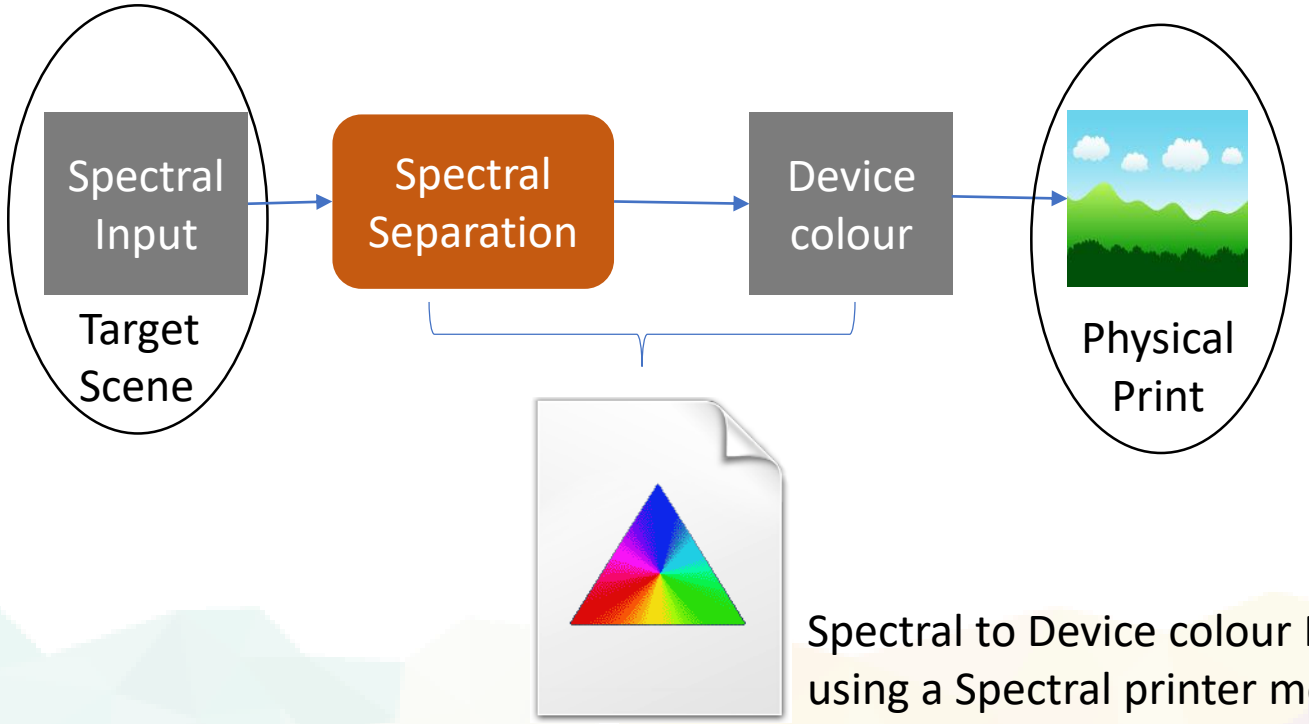
L. G. Coppel, S. Le Moan, P. Z. S. R. Elıas and J. Y. Harderberg, "Next generation printing-Towards spectral proofing," Advanced in Printing and Media Technology, vol. 41, pp. 19-24, 2014.

9. Softproofing with custom observers
   - ✓ Matching XYZ using custom observer1 to XYZ using custom observer 2



Spectral Reproduction workflow

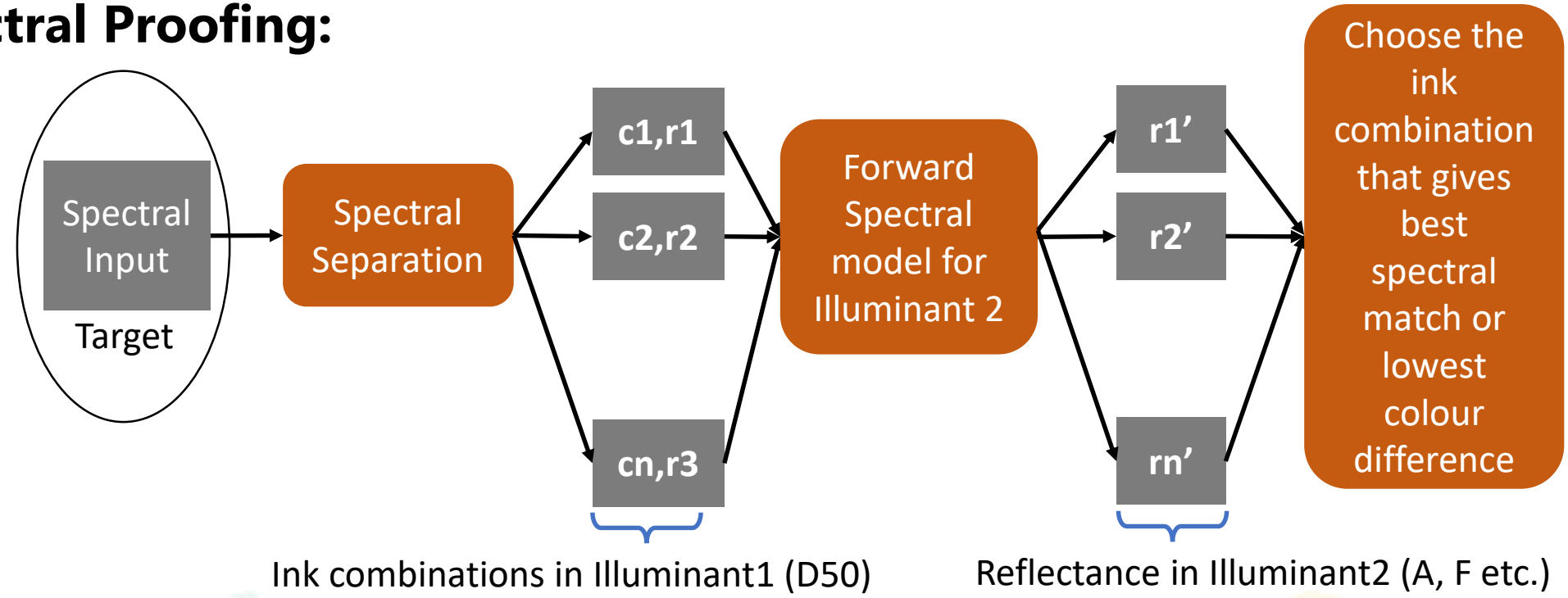
Spectral Proofing:



Spectral to Device colour Profile using a Spectral printer model

Spectral Reproduction workflow

Spectral Proofing:

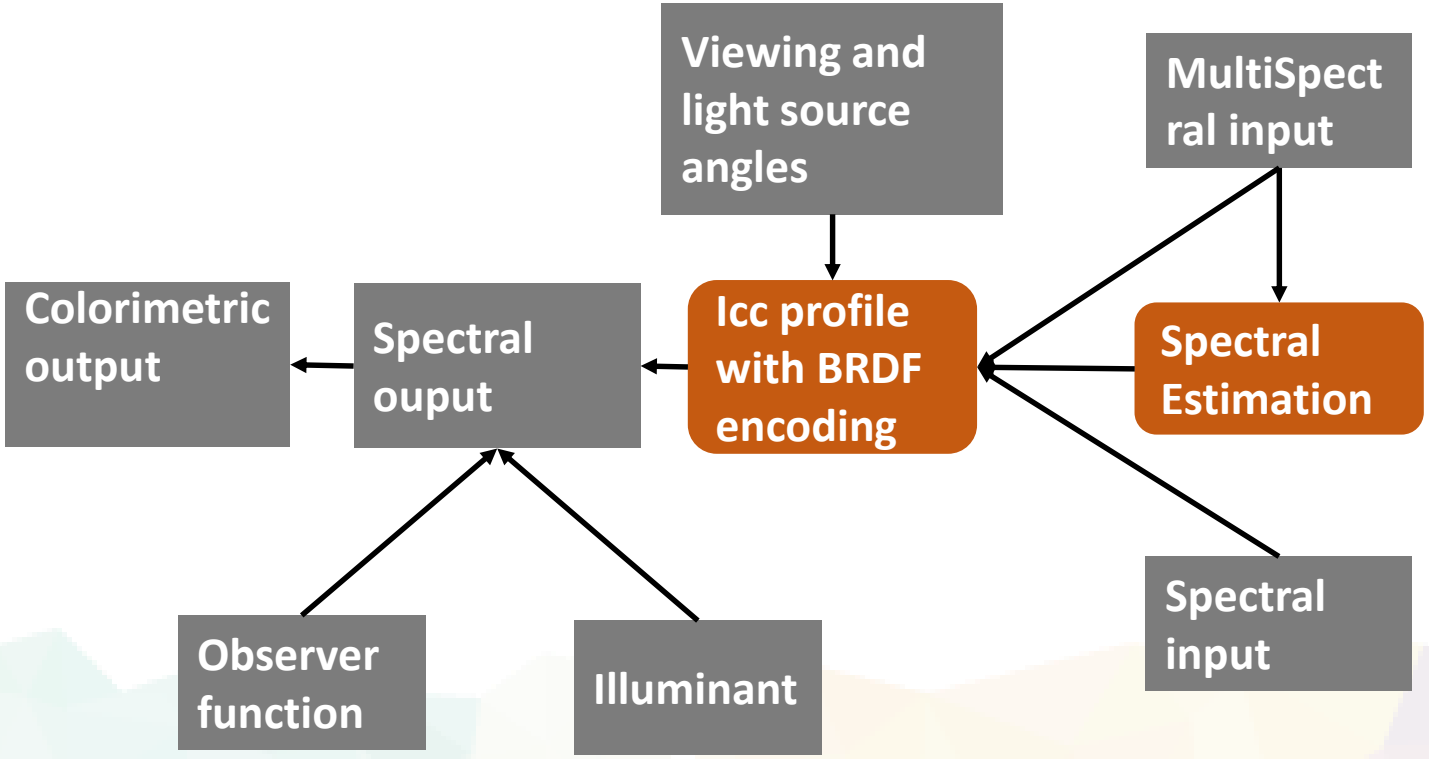


Coppel, Ludovic Gustafsson, et al. "Next generation printing-Towards spectral proofing. "*Advanced in Printing and Media Technology*. Vol. 41. 2014. 19-24.

Urban, Philipp, and Roy S. Berns. "Paramer mismatch-based spectral gamut mapping." *IEEE transactions on image processing* 20.6 (2010): 1599-1610.

Spectral Reproduction workflow

BRDF encoding:



Metrics to assess spectral reproduction

- ✓Colour Difference (CIEDE 2000)
- ✓Root Mean Square Error (RMSE)
- ✓Goodness of Fit Coefficient (GFC)
- ✓Smoothness (Green, 2008)
- ✓Metamerism Index (MI) (CIE, 1986)
- ✓Special Metamerism Index (CIE, 1989)
- ✓Color Inconstancy (Luo, Hunt 2003)(Derhak, Luo, Berns, 2020)
- ✓Hue Constancy (Derhak, Luo, Berns)
- ✓Spectral Comparison Index (Viggiano, 2002)

Conclusions

- ✓Spectral reproduction workflows can be integrated with colour management
- ✓Possible BRDF rendering using spectral ICC profile
- ✓Possibility of achieving complete spectral colour management
- ✓Need object specific spectral database
- ✓Need metrics to assess the quality of spectral reproduction
- ✓Need increased support for multichannel profiles in existing graphic editors

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Thank You