ICC DEVCON 2020

A BRDF Implementation Using iccMAX

by

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THE FUTURE OF COLOR MANAGEMENT

The Norwegian Colour and Visual Computing Laboratory

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OUTLINE

- Introduction to BRDF
- BRDF Model and Appearance
- iccMAX
- BRDF Implementation
- Results
- Conclusions

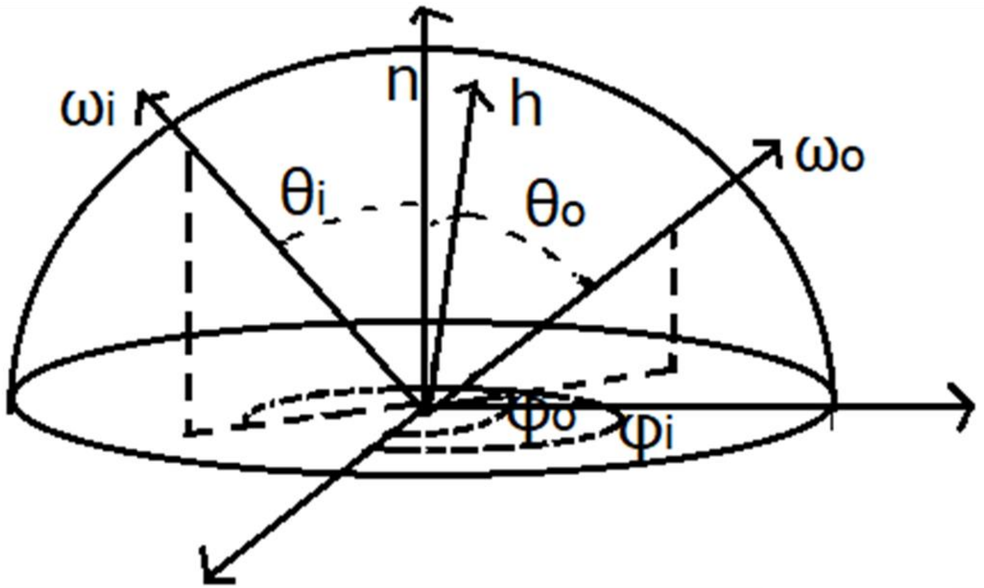
INTRODUCTION

- Reproducing accurate appearance of a scene has always been the goal of colour imaging or computer graphics.
- Optical properties that contribute to an object's appearance are:
  - colour, gloss, translucency and texture

- Bidirectional Reflection Distribution function (BRDF) is widely used for appearance modelling of materials.
- Appearance reproduction in colour management frameworks

BRDF

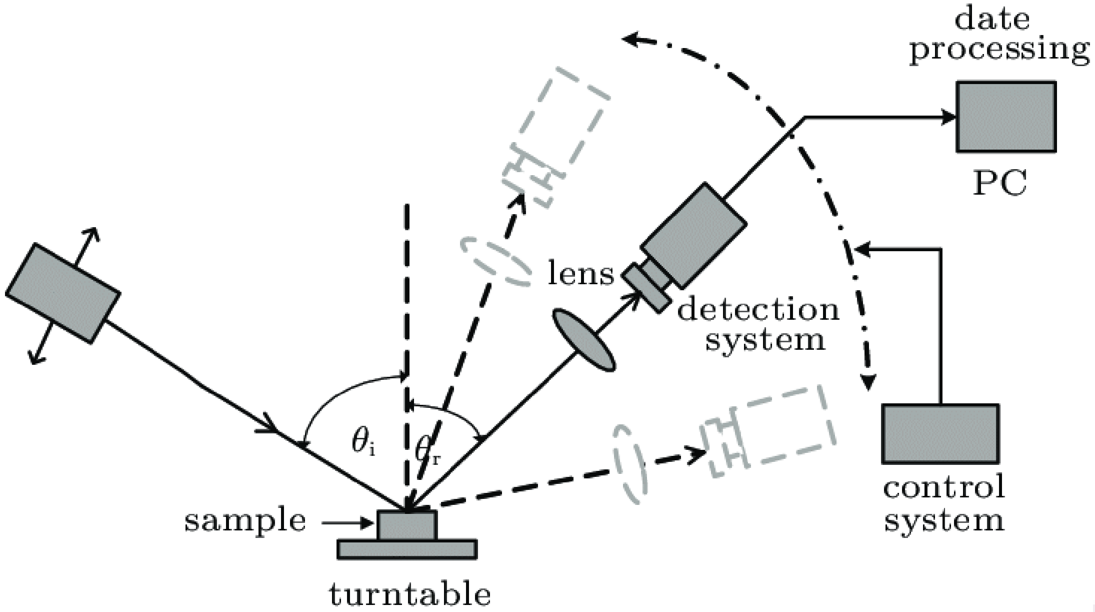
- Represents surface/material reflection characteristics
- Position of the surface
- Direction of incident light
- Direction of reflection
- Amount of light that is reflected



BRDF MODEL AND APPEARANCE

BRDF Measurements

- Samples : Cyan and magenta
- wax-based inks
- matte coated white paper
- OCE ColorWave 600PP
- The radiance factor of these two samples were measured using a Murakami Gonio-Spectrophotometer GCMS
- Incidence angles (θi): 30°, 45° and 60°
- Reflection angles (θr): -80° to 80° in intervals of 5°



Kai, W., Jing-Ping, Z., Hong, L. and Xun, H., 2016. Model of bidirectional reflectance distribution function for metallic materials. *Chinese Physics B*, *25*(9), pp.94201-094201.

BRDF MODEL AND APPEARANCE

Analytical models :

Fits measured data and estimate reflectance data

Eg: Ward BRDF model

Phong Model

Physical models:

Use optics and physics to define the function using micro facets

Eg: Cook Torrance Model

Ward BRDF

$$I_p(\theta_i;\theta_r) = \begin{bmatrix} I_{pX} \\ I_{pY} \\ I_{pZ} \end{bmatrix} = I_i \cos\theta_i \left(\begin{bmatrix} R_{dX} \\ R_{dY} \\ R_{dZ} \end{bmatrix} \frac{1}{\pi} + \frac{k_S}{\sqrt{\cos\theta_i \cos\theta_r}} \frac{e^{[-\tan^2\delta/m^2]}}{4\pi m^2} \right)$$

Sole, A., Farup, I., Nussbaum, P. and Tominaga, S., 2018. Evaluating an image-based bidirectional reflectance distribution function measurement setup. Applied Optics, 57(8), pp.1918-1928.

BRDF MODEL AND APPEARANCE

BRDF Model Optimization

Peter Peers : 'There is more to win by improving the fit than improving the BRDF model.'

- A major part of BRDF rendering accuracy comes from choosing the right optimization method.
- Should balance the error generated in the diffuse component to error generated in rendering the specular peak
- Better metric to fit the model.
- Adaptive metric

[Bieron, J. and Peers, P., 2020, July. An adaptive brdf fitting metric. In Computer Graphics Forum (Vol. 39, No. 4, pp. 59-74).]

BRDF MODEL AND APPEARANCE

BRDF Model Optimization

- Optimized using the Nelder-Mead downhill simplex
- ΔE_{00} colour difference used as the objective function

BRDF Parameters

- K_s, R_{dx}, R_{dY} and R_{dz} and m
- Specular constant
- Diffuse component
- Specular lobe

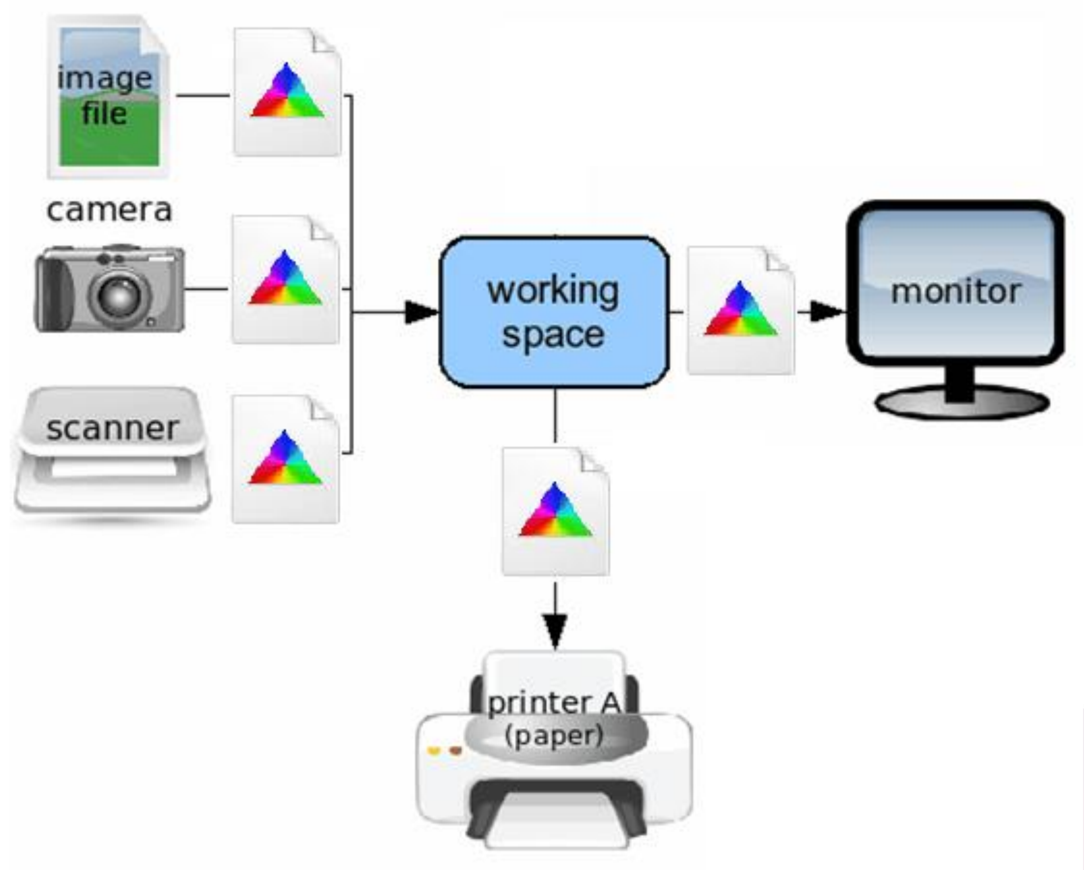
Sole, A., Farup, I., Nussbaum, P. and Tominaga, S., 2018. Evaluating an image-based bidirectional reflectance distribution function measurement setup. Applied Optics, 57(8), pp.1918-1928.

iccMAX

- The ability to use spectral data
- The ability to use different illuminants and observers without the need for chromatic adaptation
- The ability to encode complex transforms, including functional transforms, in the profile
- More support for total colour appearance, including texture and gloss including BRDF

BRDF IN COLOUR MANAGEMENT

- ICC.2 (iccMAX) provides a number of options for BRDF implementation
- BRDFStruct tags and external renderer
- BRDF transforms defined by the profile creator
- We use a multiplex connection space (MCS) for BRDF encoding



CALCULATOR ELEMENT PROGRAMMING

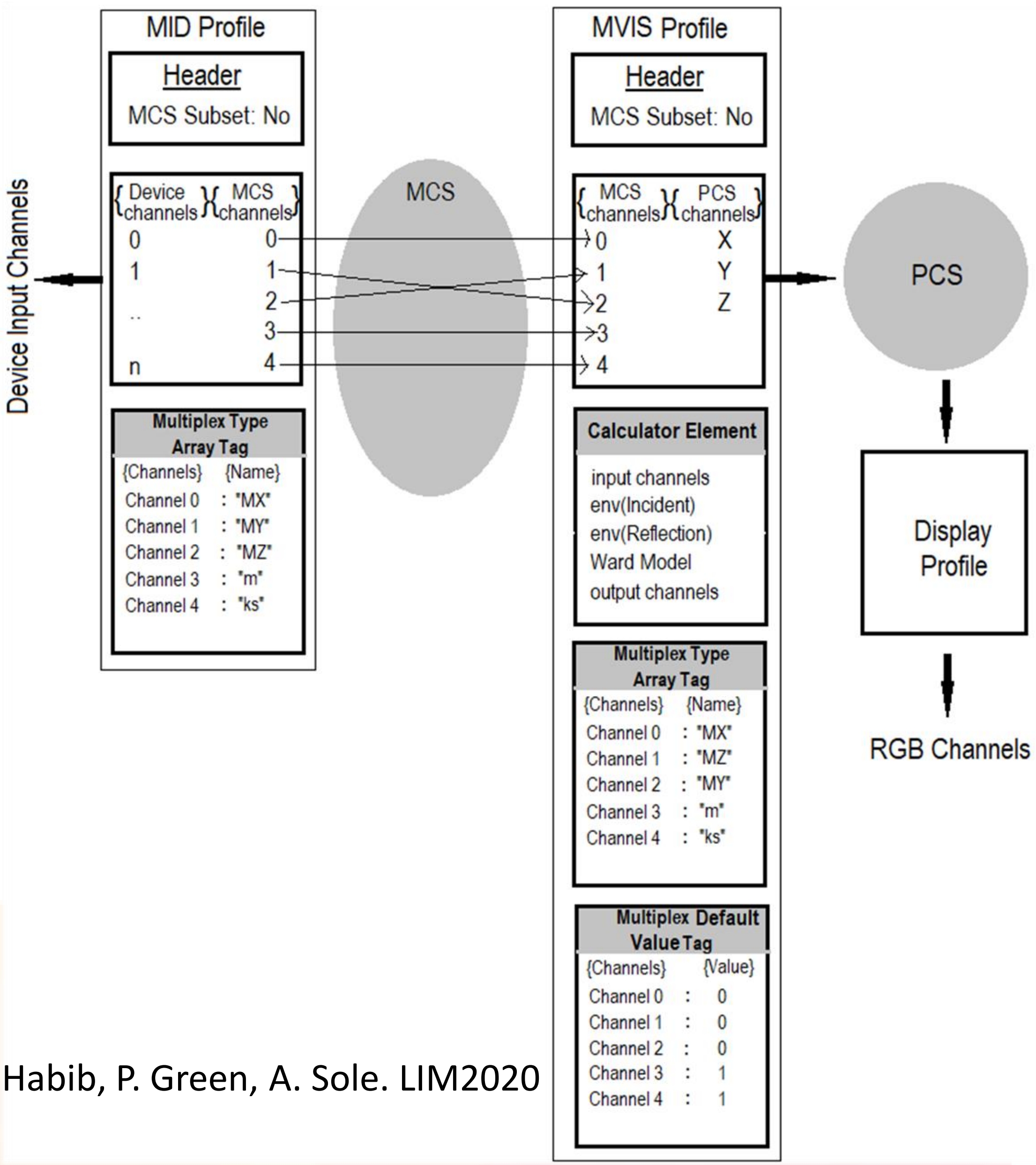
- ICC.2 (iccMAX) provides calculator element programming
- Stack based programming
- XML representation of iccMAX profiles

Operators	2	3	add	11	mul	1	add
Stack	2	3 2	5	11 5	55	1 55	56

```
<MultiProcessElements InputChannels="3" OutputChannels="3">
    <CalculatorElement InputChannels="3" OutputChannels="3">
     <MainFunction>
    {
    in(0,3)
    2.1991875 gama(3)
    2 3 add
    11 mul
    1 add
    sum(2)
    out(0,3)
    }
    </MainFunction>
    </CalculatorElement>
</MultiProcessElements>
```

iccMAX BRDF WORKFLOW

- Input – TIFF file with BRDF coefficients
- An MID profile to read input and pass to the MCS
- An MVIS profile to use MCS as input and apply the encoded BRF model
- The incidence and viewing angles supplied at runtime
- Output – TIFF containing XYZ values at a new geometry



Implementing directional reflectance in a colour managed workflow. T Habib, P. Green, A. Sole. LIM2020

MATERIAL IDENTIFICATION

- MID profile reads these channels from the TIFF file and passes them to the MCS.

```
<multiProcessElementType>
  <TagSignature>A2M0</TagSignature>
  <MultiProcessElements InputChannels="5" OutputChannels="5">
    <CalculatorElement InputChannels="5" OutputChannels="5">
        <SubElements/>
        <MainFunction>
        {
            in(0,5)
            out(0,5)
        }
        </MainFunction>
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  </MultiProcessElements>
</multiProcessElementType>
```
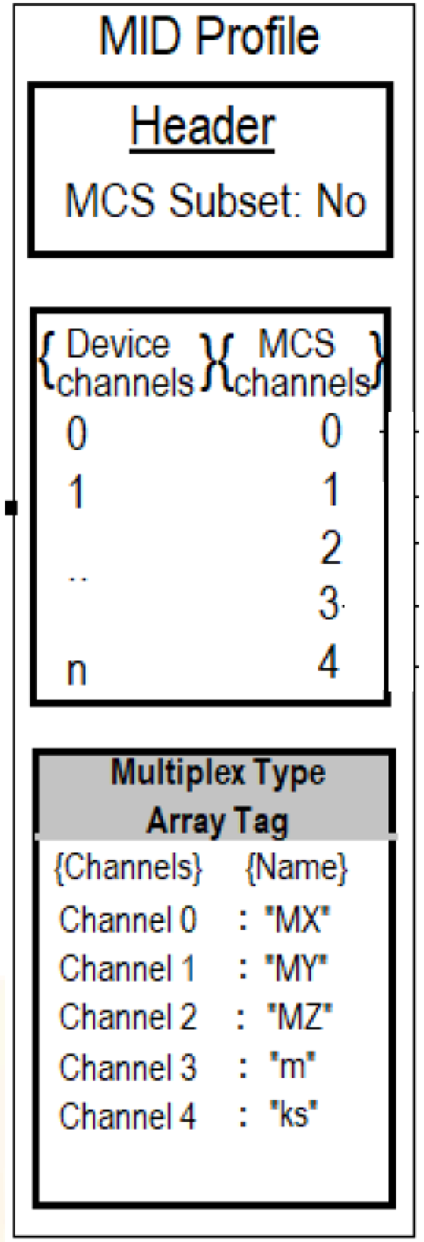
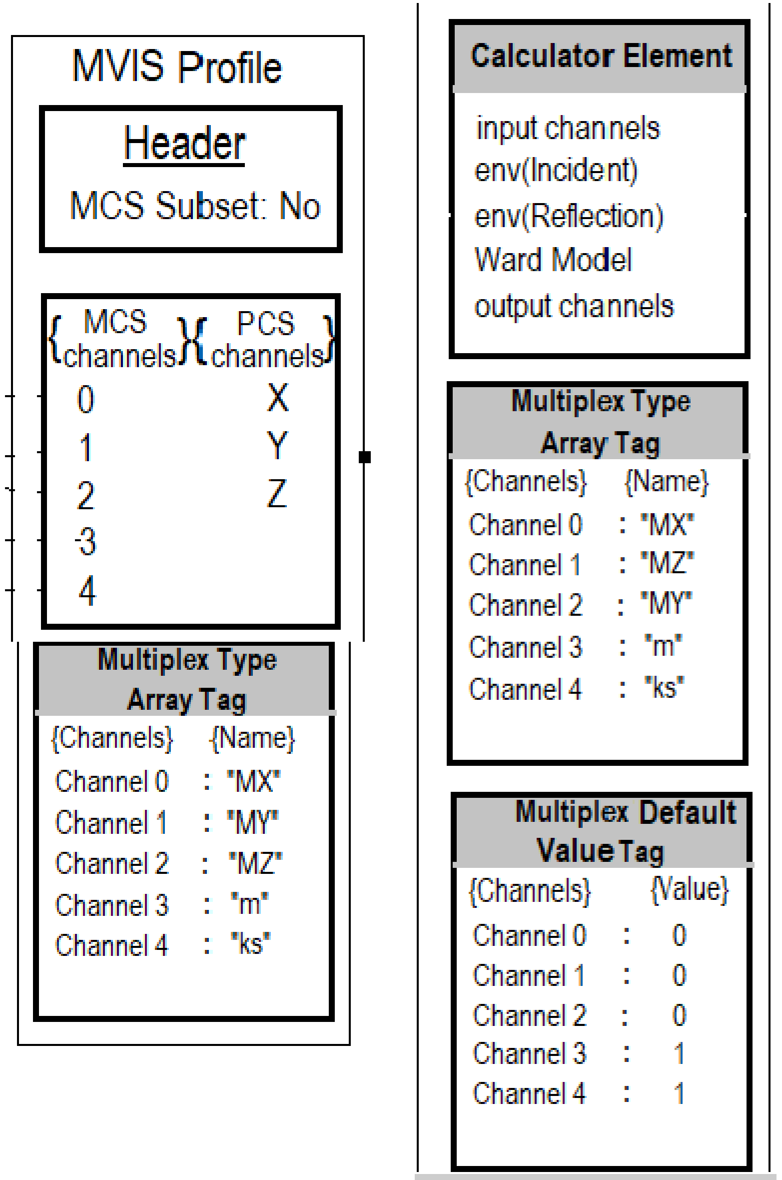
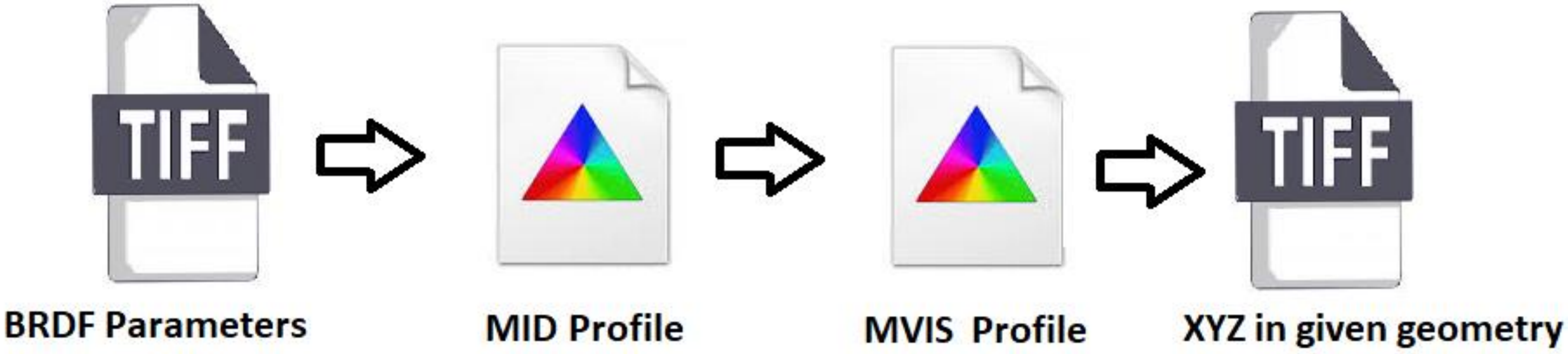



MATERIAL VISUALIZATION

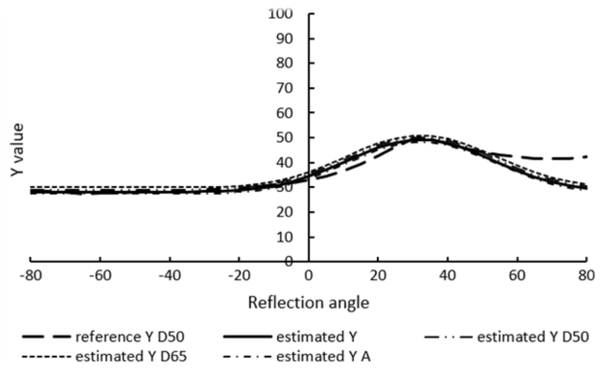
- MVIS profile then takes the channels from the MCS and applies the BRDF ward model using the parameters pixelwise
- A new TIFF file is created with the estimated XYZ values for the given incidence and viewing angles



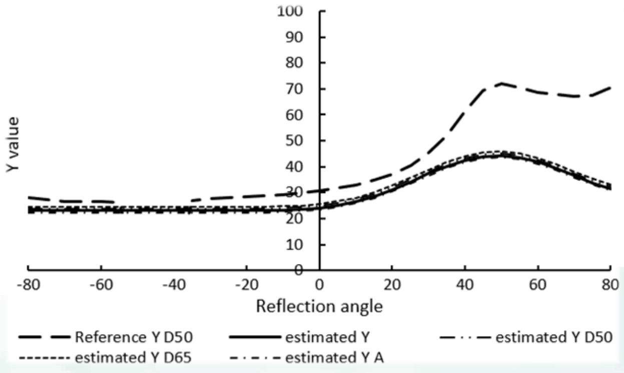
APPLICATION



RESULTS

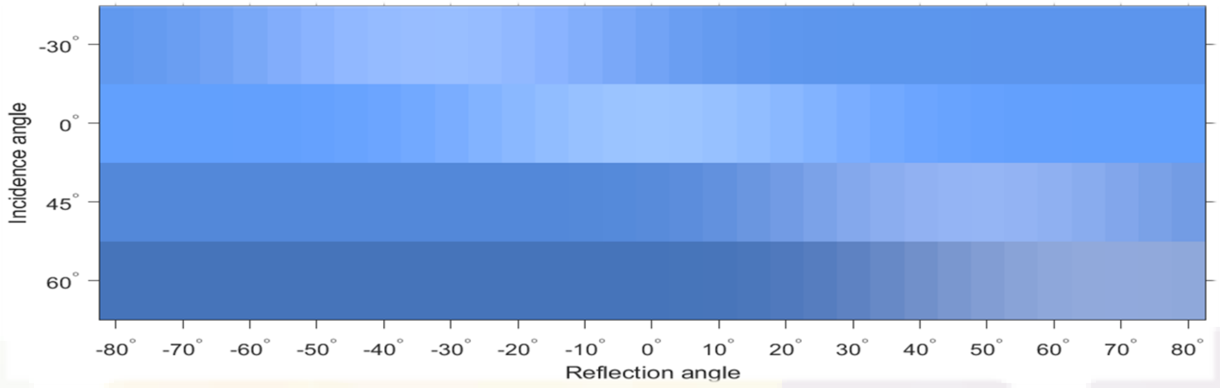


Y value
Reflection angle
reference Y D50
estimated Y
estimated Y D50
estimated Y D65
estimated Y A



Y value
Reflection angle
Reference Y D50
estimated Y
estimated Y D50
estimated Y D65
estimated Y A

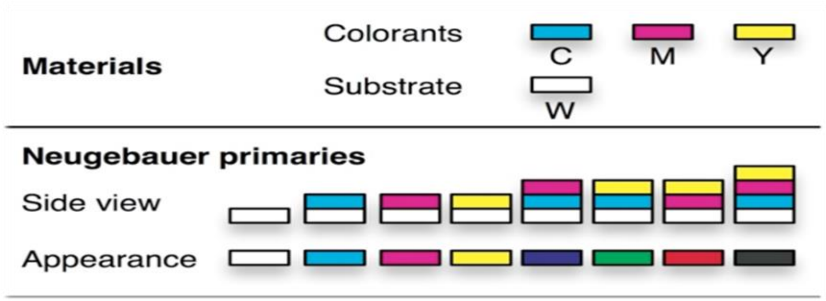
40/0
40/40



Incidence angle
Reflection angle

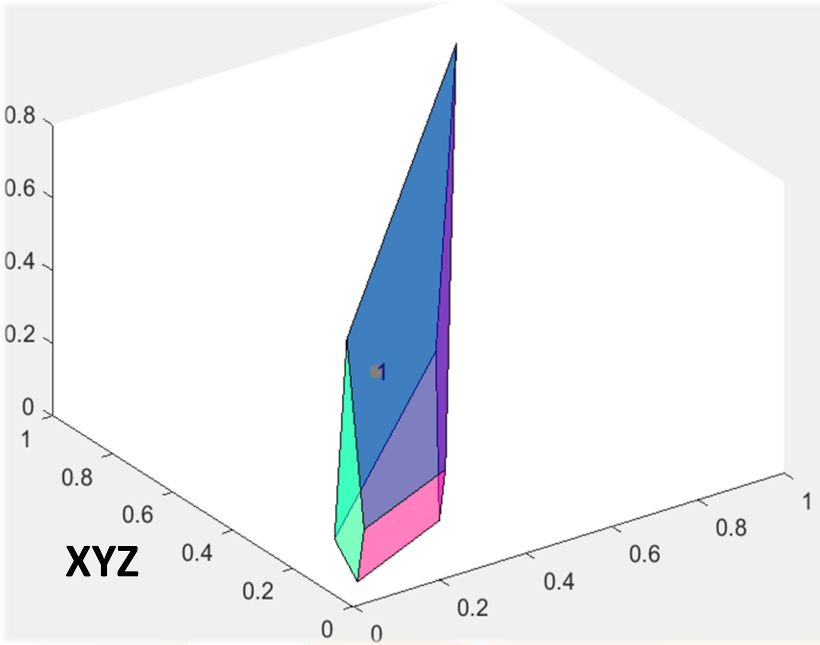
BRDF INTERPOLATION METHOD

Neugebauer Primaries



Shepard Interpolation

$$y = \frac{\sum_i^n y_i D_i^{-\mu}}{\sum_i^n D_i^{-\mu}}.$$

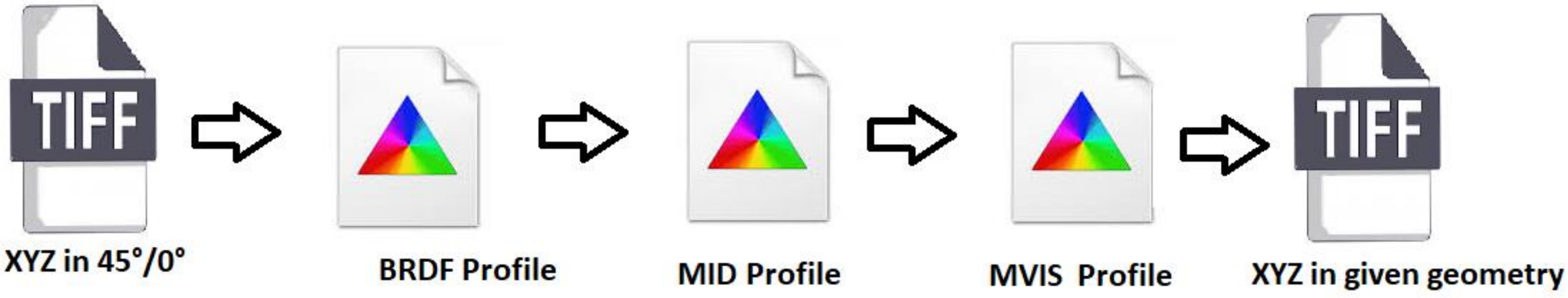


BRDF values

Five dimensional and Irregular

Westland, S., Ripamonti, C. and Cheung, V., 2012. *Computational colour science using MATLAB*. John Wiley & Sons.

Application



CONCLUSIONS

- ✓Using MCS an efficient rendering framework can be achieved.
- ✓Framework should be tested on other BRDF models.
- ✓This lays the ground to develop a more robust framework that can map input XYZ to BRDF coefficients and through MCS to XYZ in another geometry.
- ✓For this the Interpolation Method can be used
- ✓Normal map can be used to further decode light and viewing directions and make worflow model robust

Limitations:

- Cannot handle spatial locations

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Thank You

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