

Discussion on the workflow of multispectral imaging systems

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Note: this document is prepared only for the base of discussion in the TC0807 and may contain ambiguous or incorrect descriptions. The author would appreciate any corrections or comments on this document.

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Objective of this document

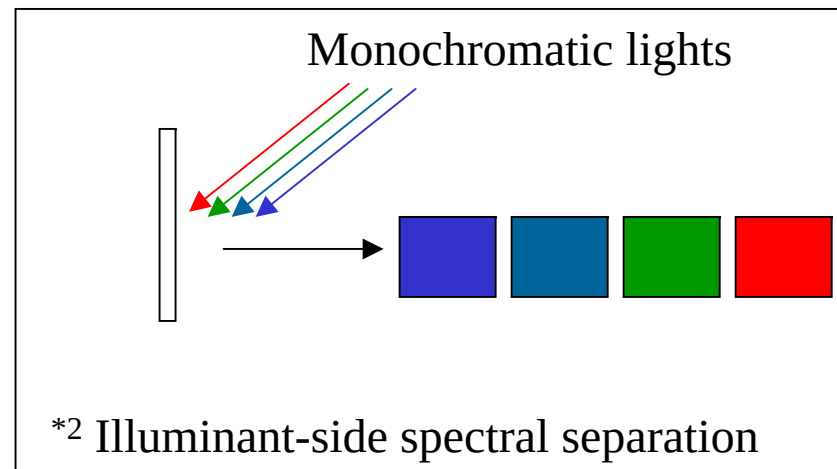
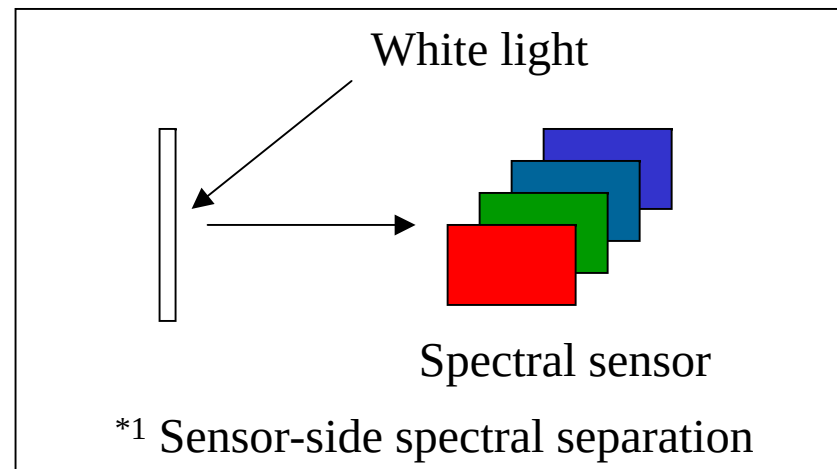
- To make clear the detailed requirements of the multispectral image format, it is important to discuss the workflow of multispectral imaging systems. This document presents the primitives of the multispectral imaging workflow as a base of discussion.
- The presented workflow primitives are still abstract, and the detailed definitions of the primitives are required. The real workflow needs to be the combination of the presented primitives, and the information needed for the image format can be derived from this discussion. These are the issues of further consideration.

Use cases of multispectral images

- Image generation
 - Multispectral Capture
 - Spectral rendering (Computer generated spectral images)
- Image-based measurement
 - Color measurement
 - Spectral measurement
 - Image analysis
- Image processing
 - Image processing without color adjustment (noise reduction, structure enhancement, etc.)
 - Image processing with color adjustment (color enhancement, etc.)
- Color rendering
 - Color rendering (natural)
 - Pseudo-color representation
- Visualization
 - Color reproduction (display)
 - Colorimetric color display
 - Spectral color display
 - Color reproduction (printer)
 - Colorimetric color printing
 - Spectral printing
- Image compression

Multispectral imaging model

- Image generation
 - Captured by a camera or scanner
 - Generated by a computer
- Object
 - Reflection
 - Transmission
 - Emission
- Illuminant
- Spectral separation *
 - Sensor-side *¹
 - Illuminant-side *²
- Sensor device profile
 - Spectral sensitivity
 - Tone curve
- CMF (CIE 1931, 1964, etc.)
- Wavelength range
 - Visible, IR, UV



Legend

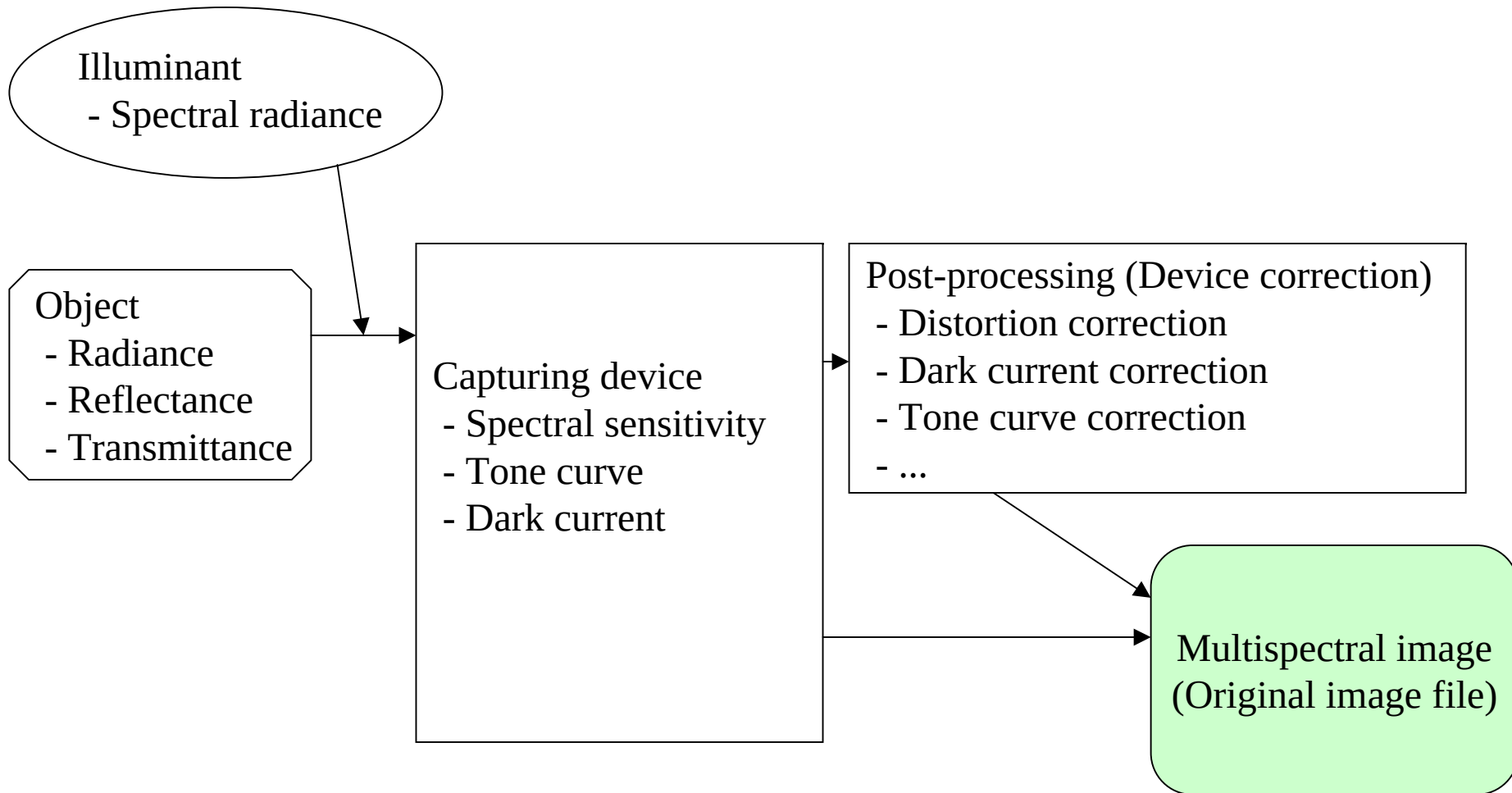
Operation applied to
a multispectral image

Numerical data

Multispectral image
within the scope
of this document

Image data or
sampled points
out of the scope
of this document

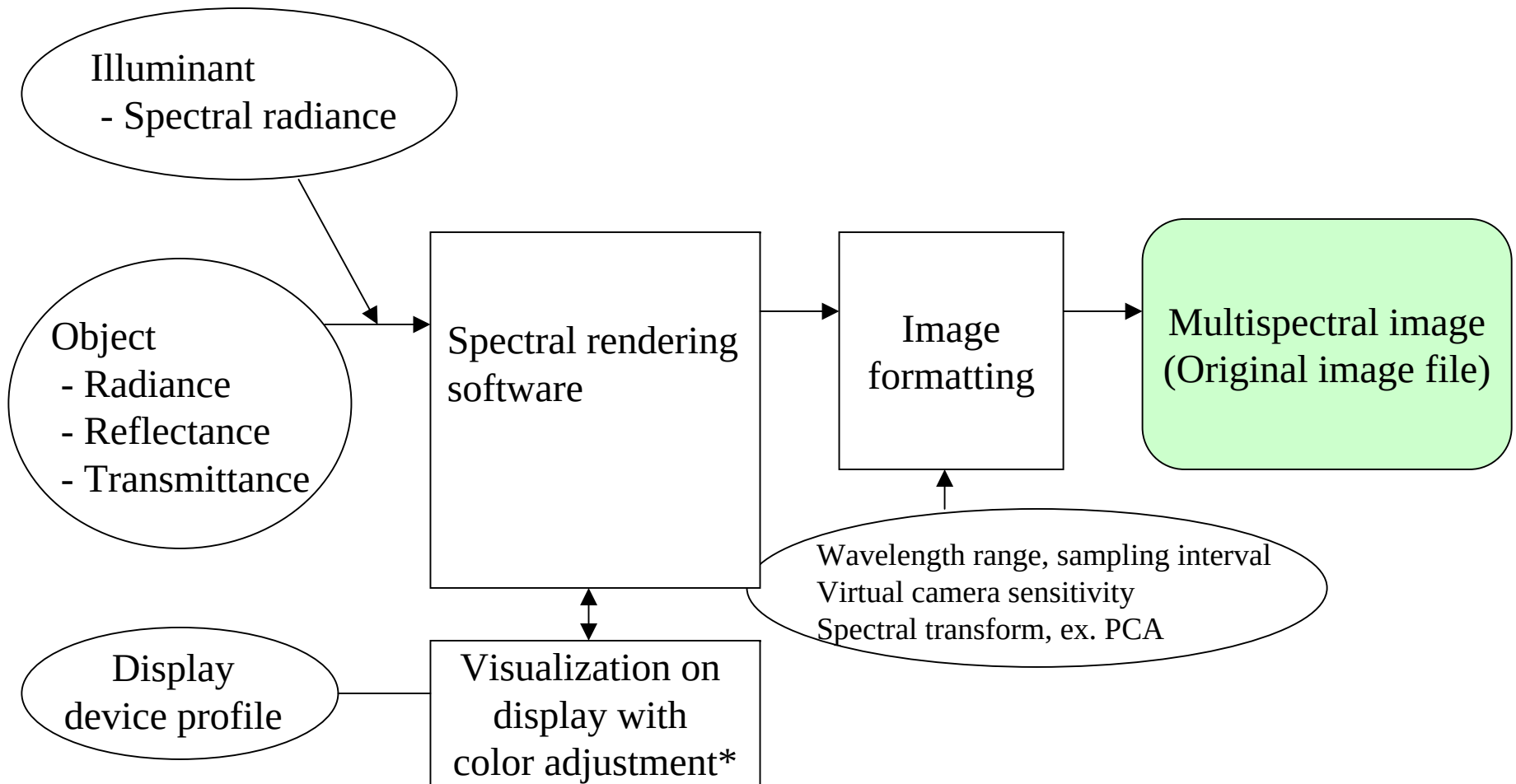
Multispectral capture



*Note: The device independent image representation is not efficient in multispectral imaging; The number of bands varies depending on the devices, and the linear encoding may cause the loss of information by the quantization.

Spectral rendering

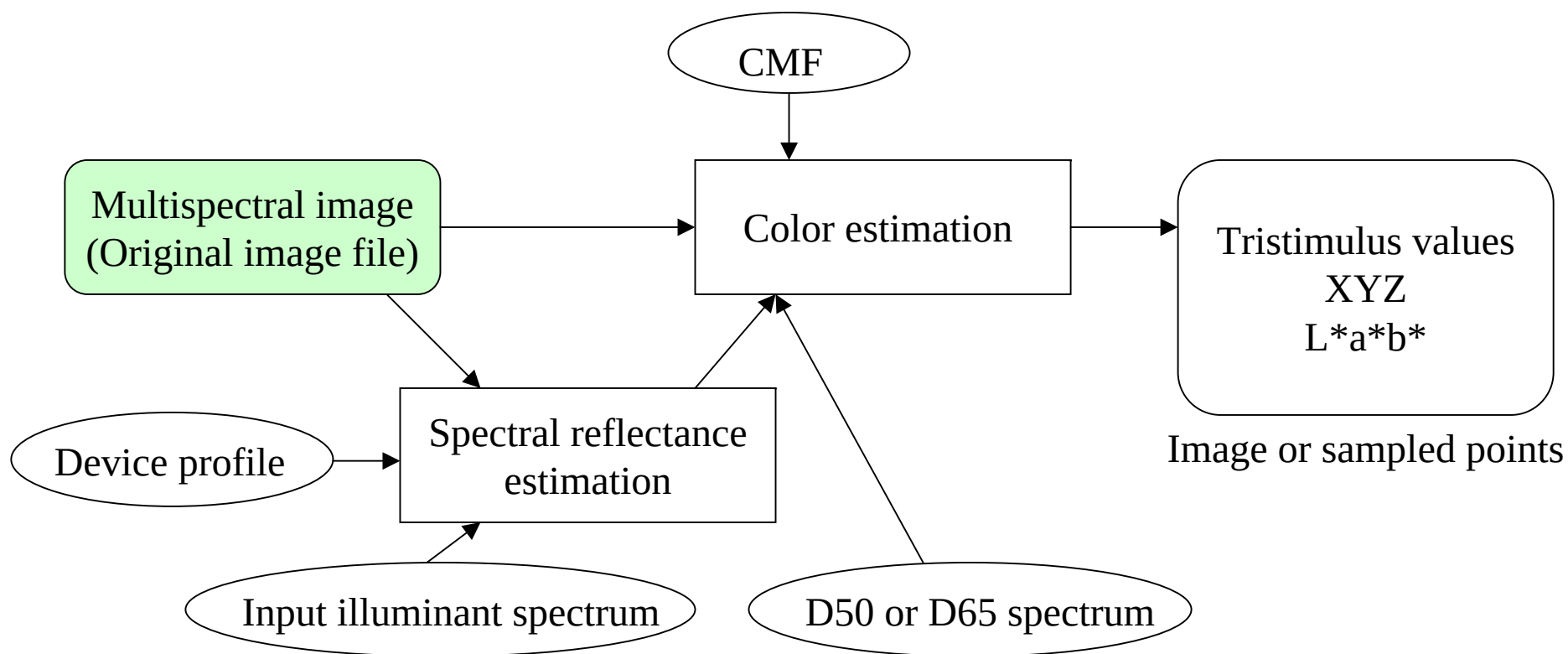
(Computer generated spectral images)



*The color image may be visualized on a display during the image generation, but the generated image is considered to be independent on the display device. The display device calibration is performed within the image generation system in most cases.

Color measurement

- Tristimulus values under standard illuminant, i.e., D50 or D65.
- Scene tristimulus values (reflection objects under input illuminant or emissive objects).



Spectral measurement

- Spectral radiance / reflectance / transmittance.

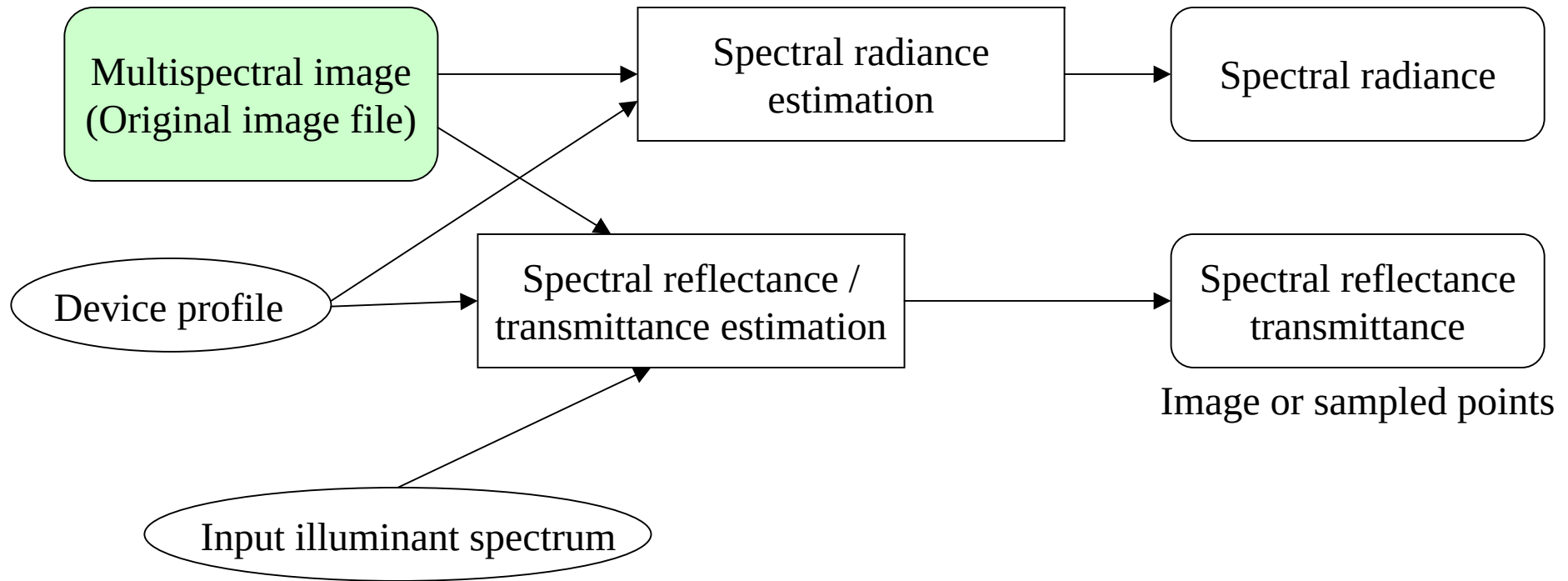


Image processing without color adjustment (noise reduction, structure enhancement, etc.)

- In the image processing operation, such as noise reduction or structure enhancement, the pixel values are modified without the intention of color modification.
- It optionally needs the input device profile.

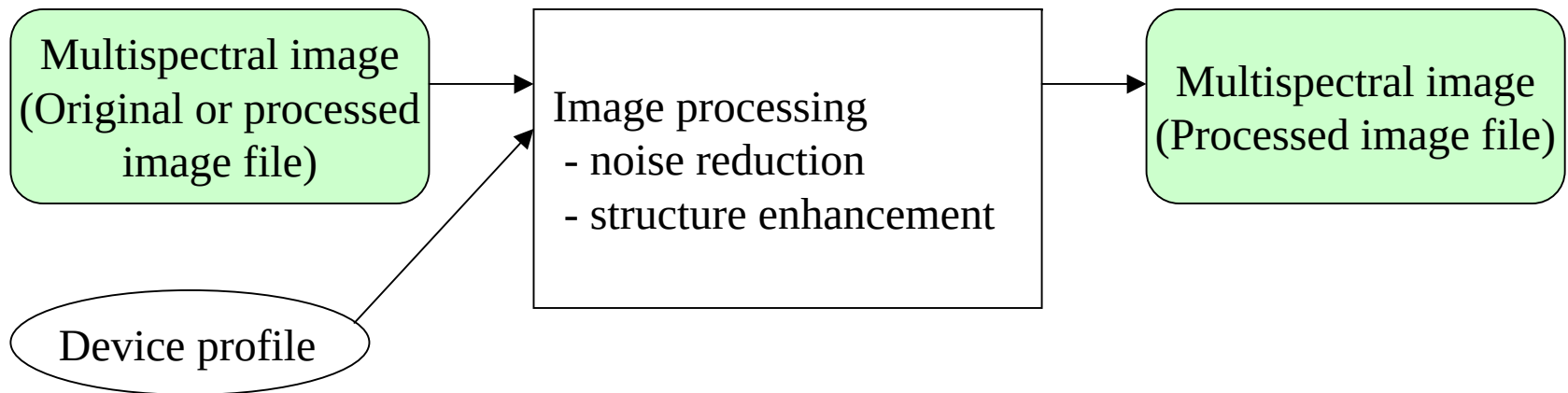
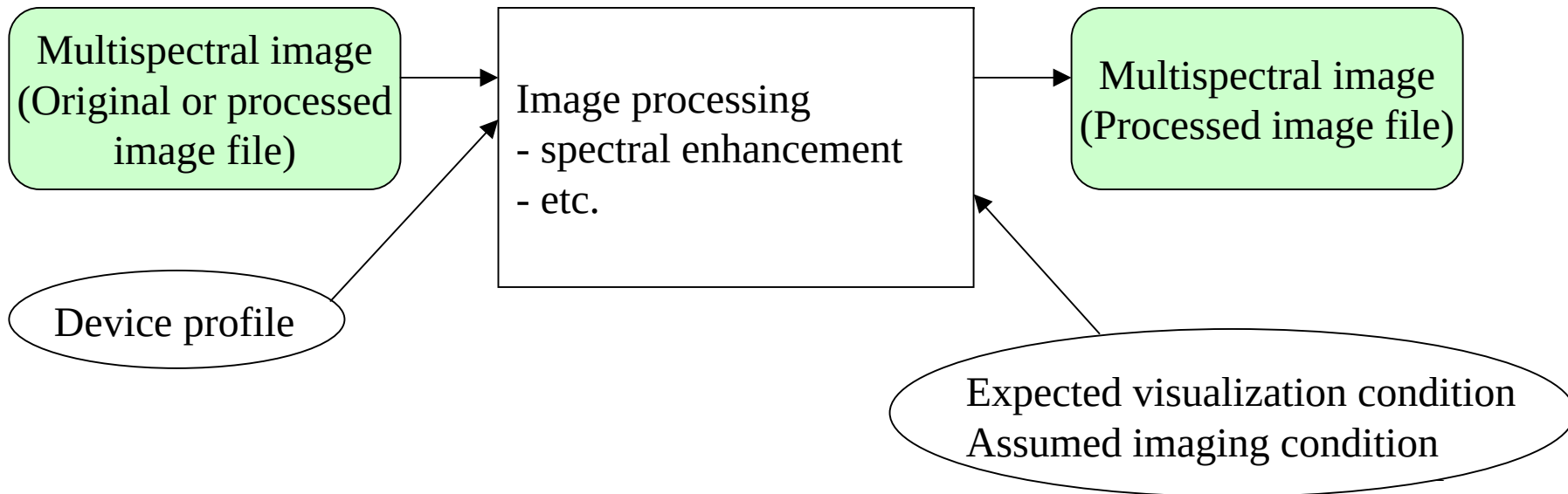


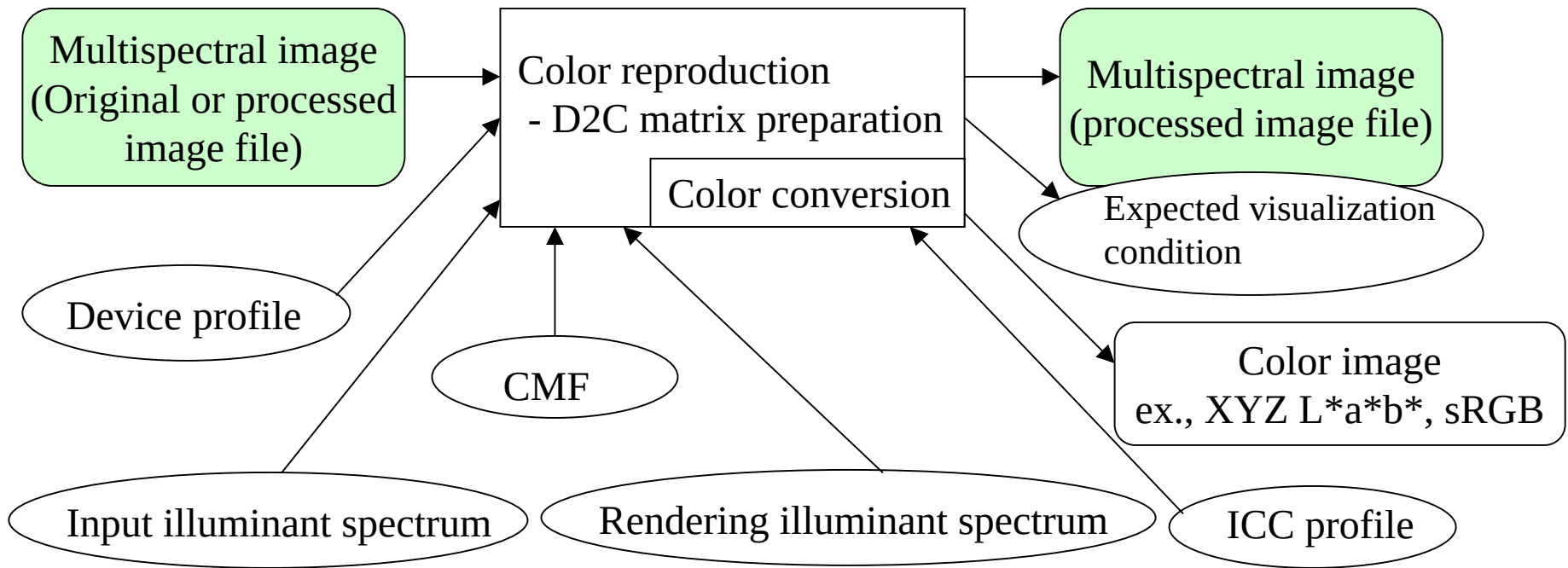
Image processing with color adjustment (color enhancement, etc.)

- In the image processing operation with the intention of color modification, such as color enhancement, it optionally assumes an expected visualization condition or a virtual imaging condition.
- Pixel values are modified in the image processing, and another multispectral image is obtained as the output.
- The color adjustment can be done after the conversion to the tristimulus values or the image for visualization, but they are not addressed in this document, because they are covered by the ICC workflow.



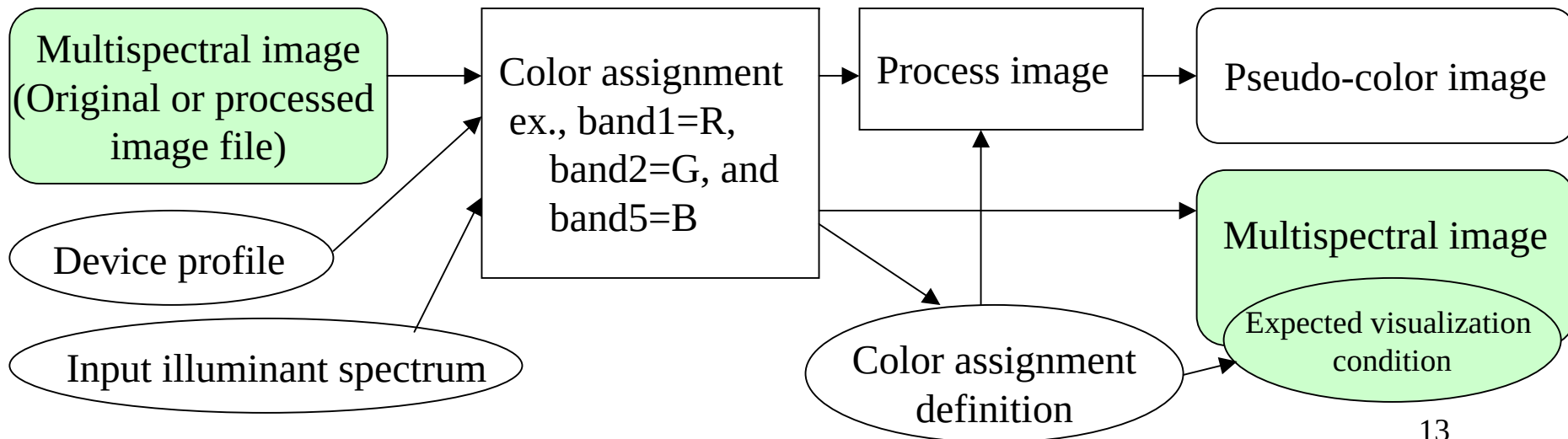
Color rendering

- Two cases considered:
 - The original multispectral image is persistent, the information on the color reproduction is kept as metadata.
 - Color image is generated, and will be dealt with conventional color management system, such as the format within the ICC workflow, sRGB, adobeRGB, sYCC, sc-RGB, or xvYCC.



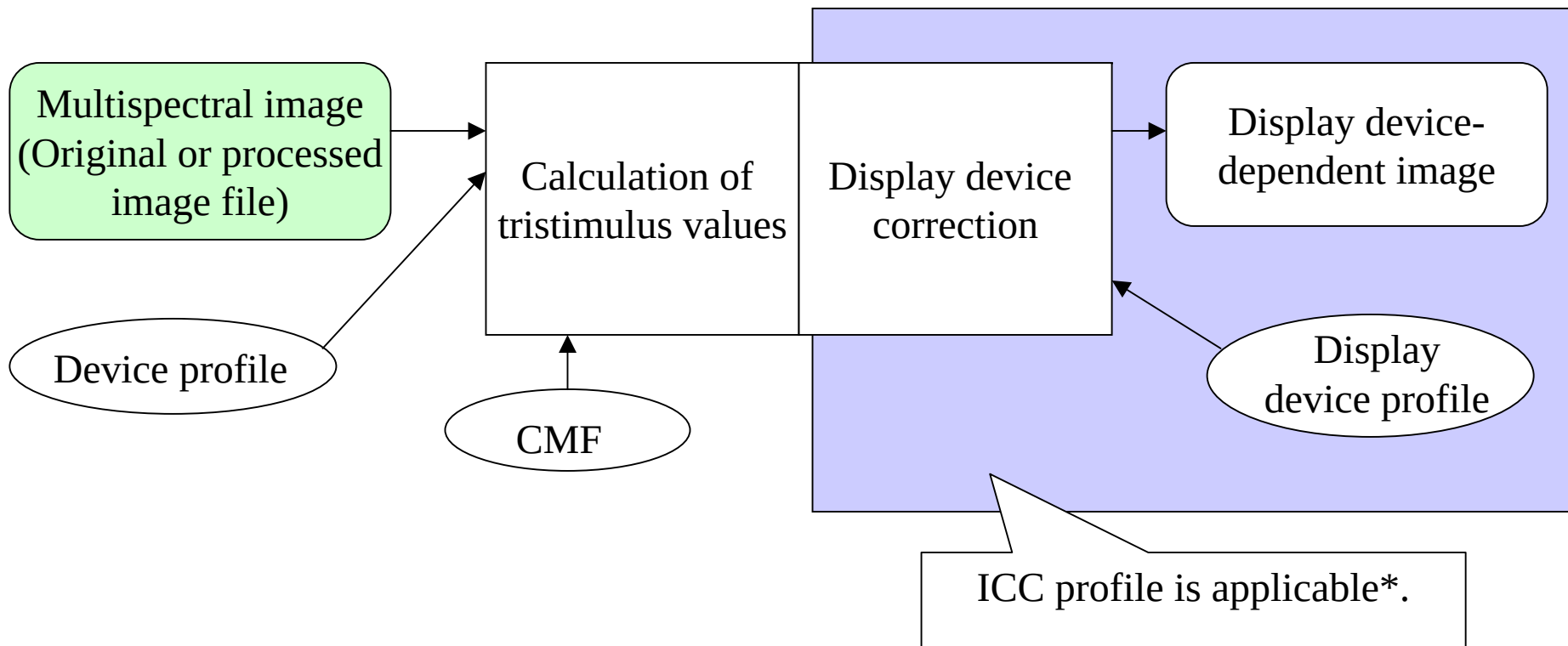
Pseudo-color representation

- Colors are assigned to the image data but it is not intended to reproduce the natural color.
- In the color assignment, the spectral profile of the imaging device is needed in most cases.
- Two cases considered:
 - The original multispectral image is persistent, the information on the color assignment definition is kept as metadata
 - Pseudo-color image is generated, and will be dealt with conventional color management system.



Colorimetric color reproduction (display)

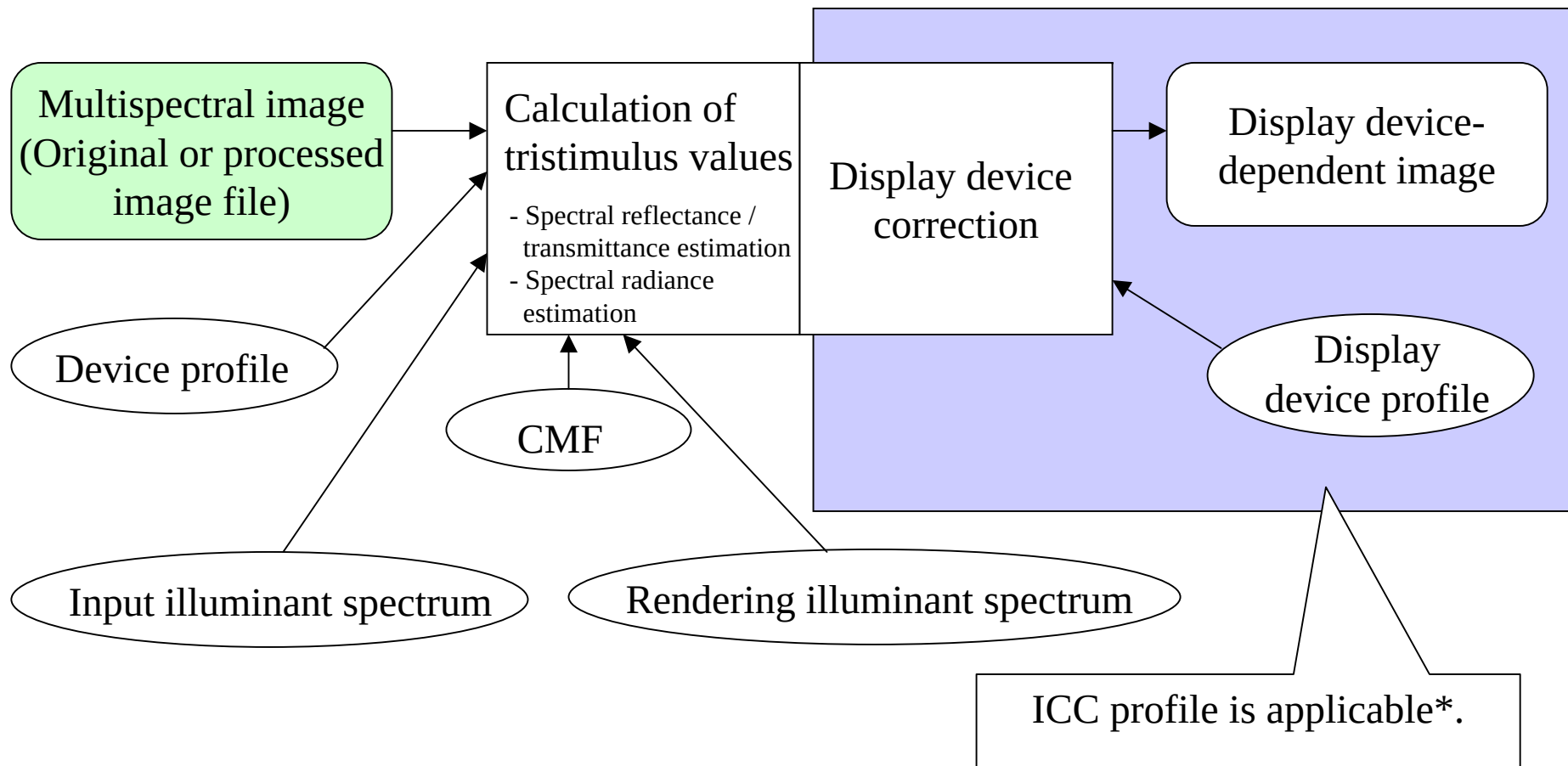
- Reproduction of scene tristimulus values (reflection objects under input illuminant or emissive objects).



*Note: Some extension will be needed for ICC profile specification in the case of multiprimary color displays.

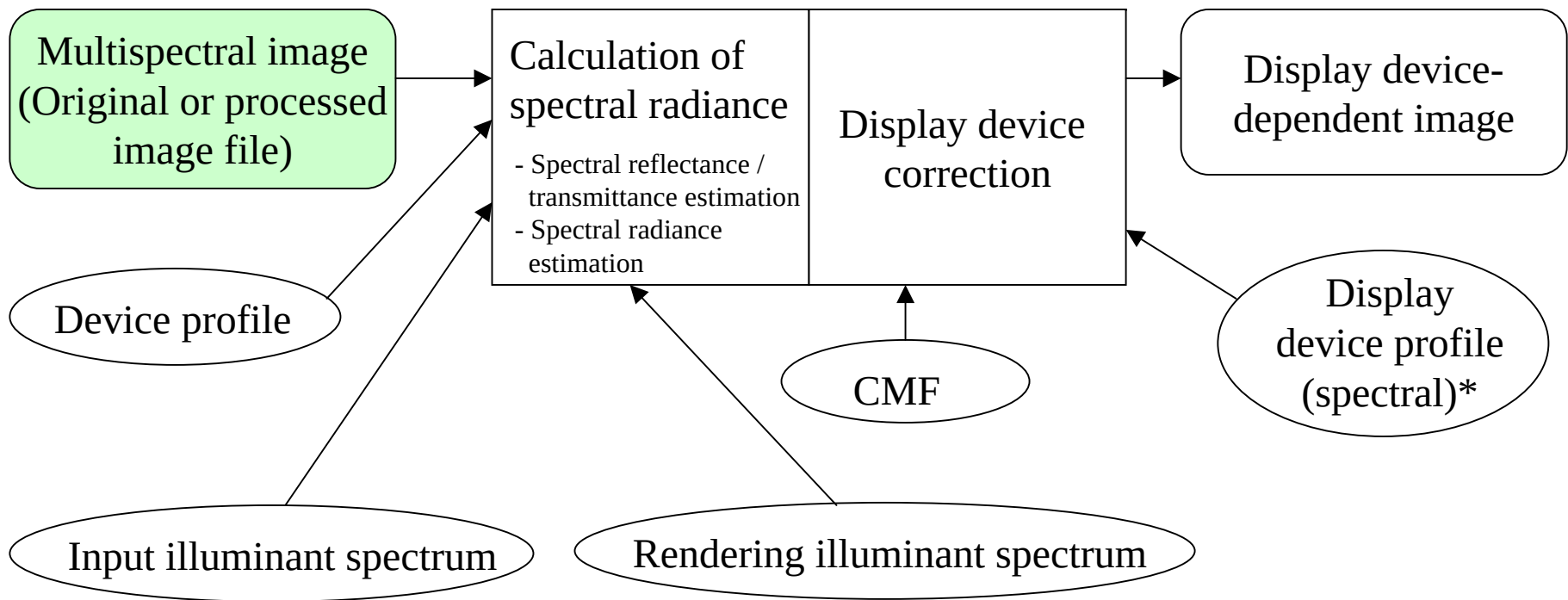
Colorimetric color reproduction (display)

- Reproduction of tristimulus values under a specific rendering illumination.



Spectral color reproduction (display)

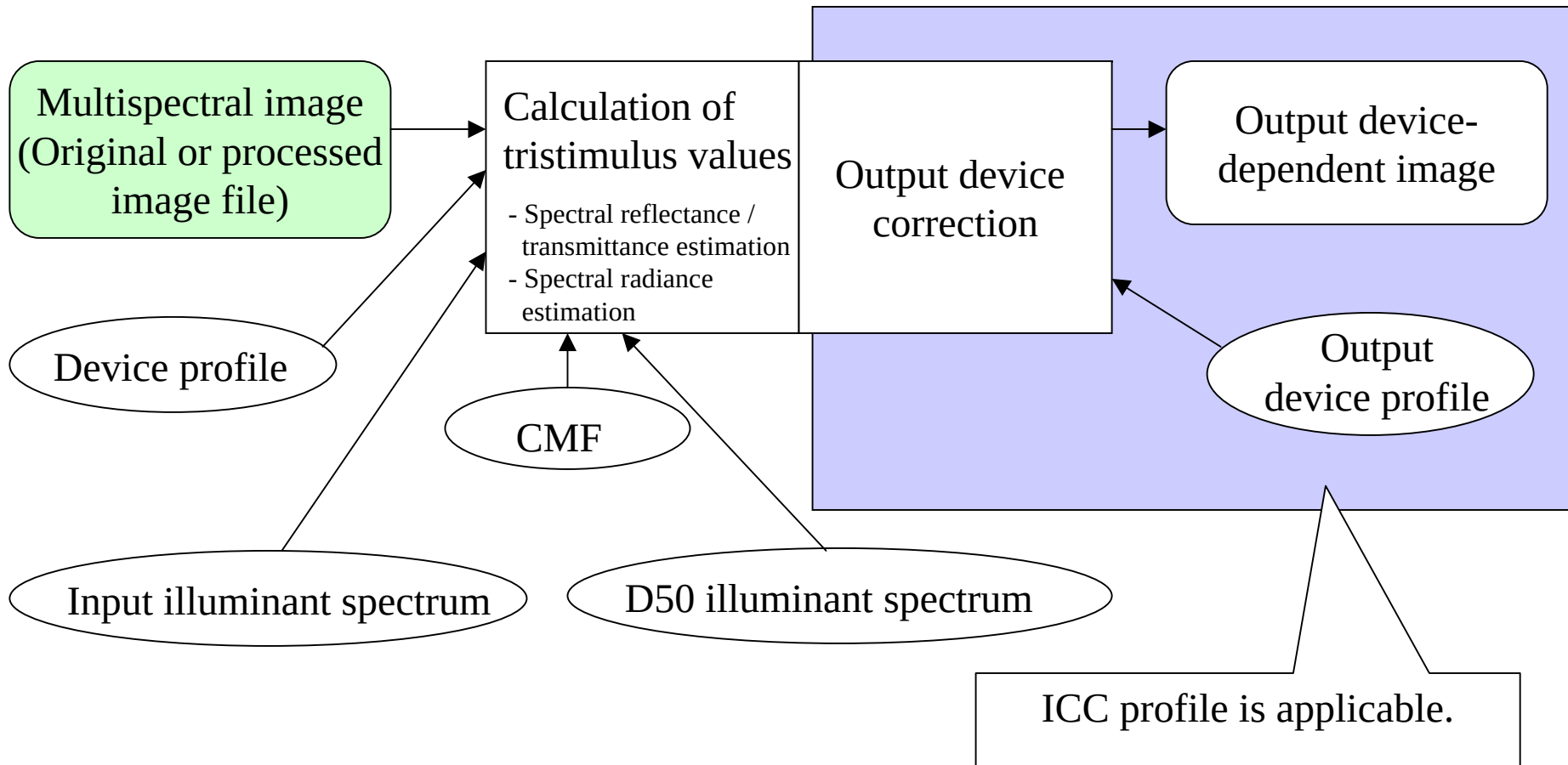
- Reproduction of approximated spectral radiance using multiprimary color display.
- Optional constraint of colorimetric match.



*Note: Spectral profile of display device needs to be defined for this application.

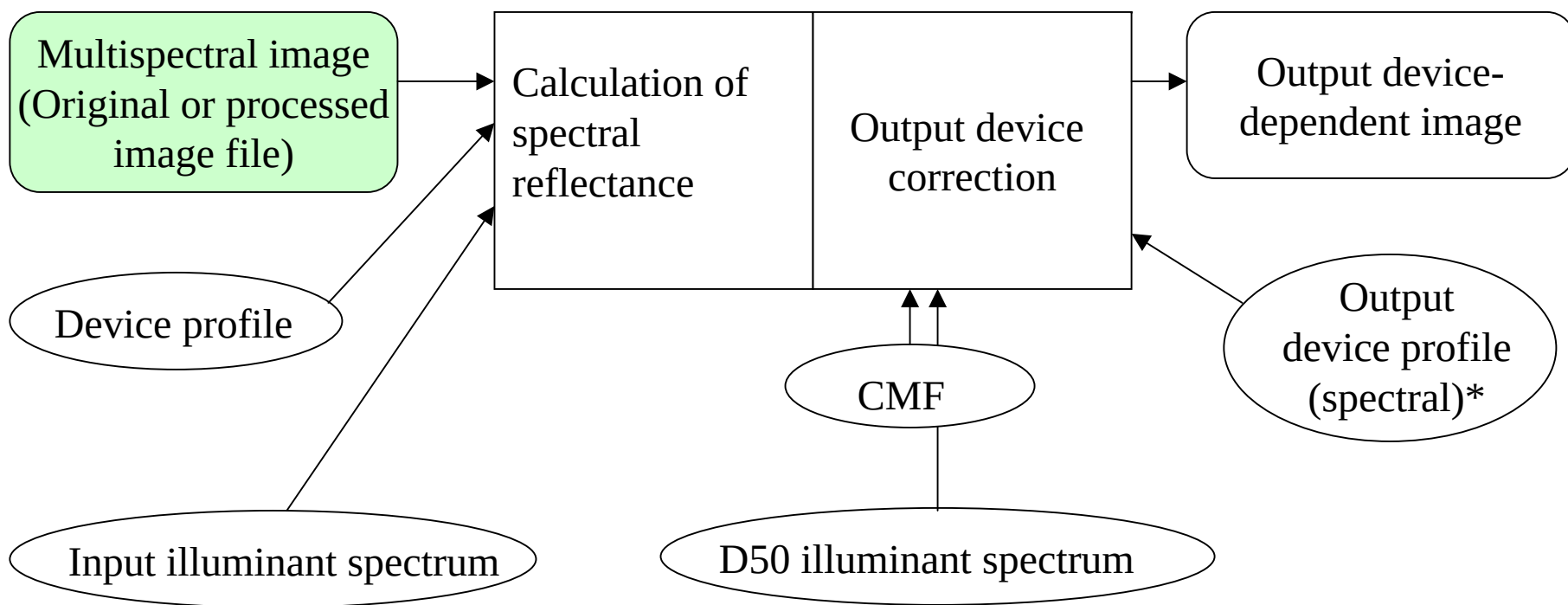
Colorimetric color reproduction (printer)

- Reproduction of tristimulus values under a D50 rendering illumination.



Spectral color reproduction (printer)

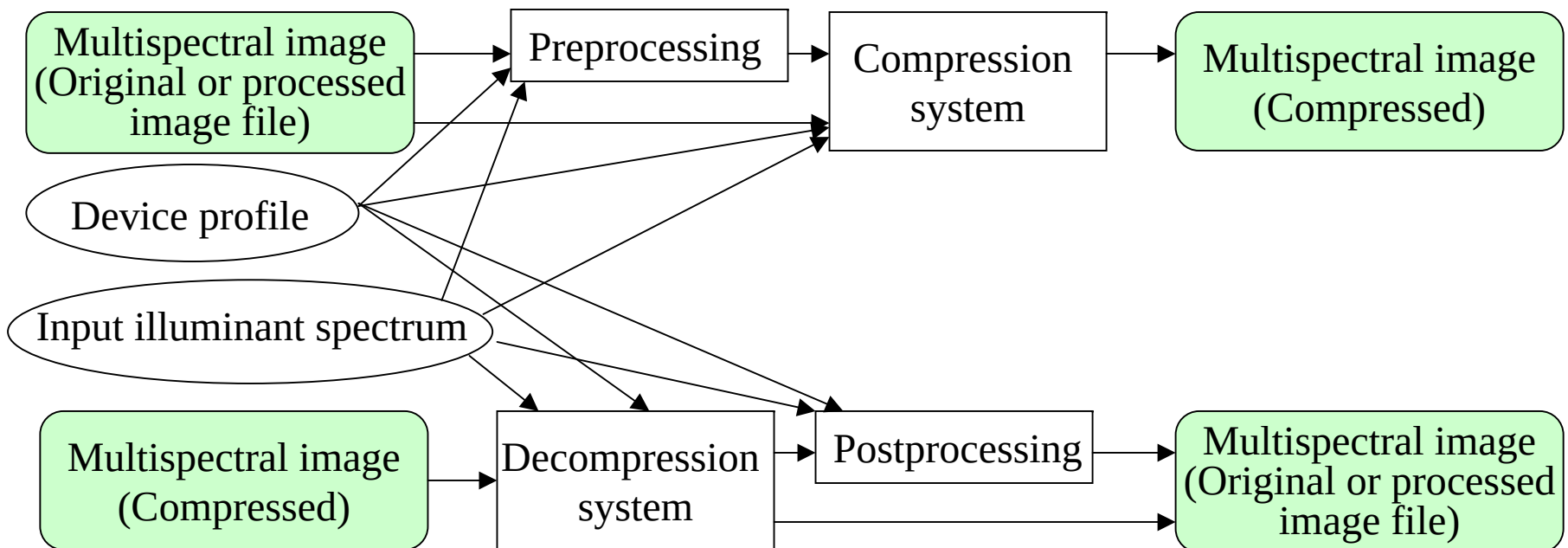
- Reproduction of approximated spectral reflectance.
- Optional constraint of colorimetric match.



*Note: Spectral profile of output device needs to be defined for this application.

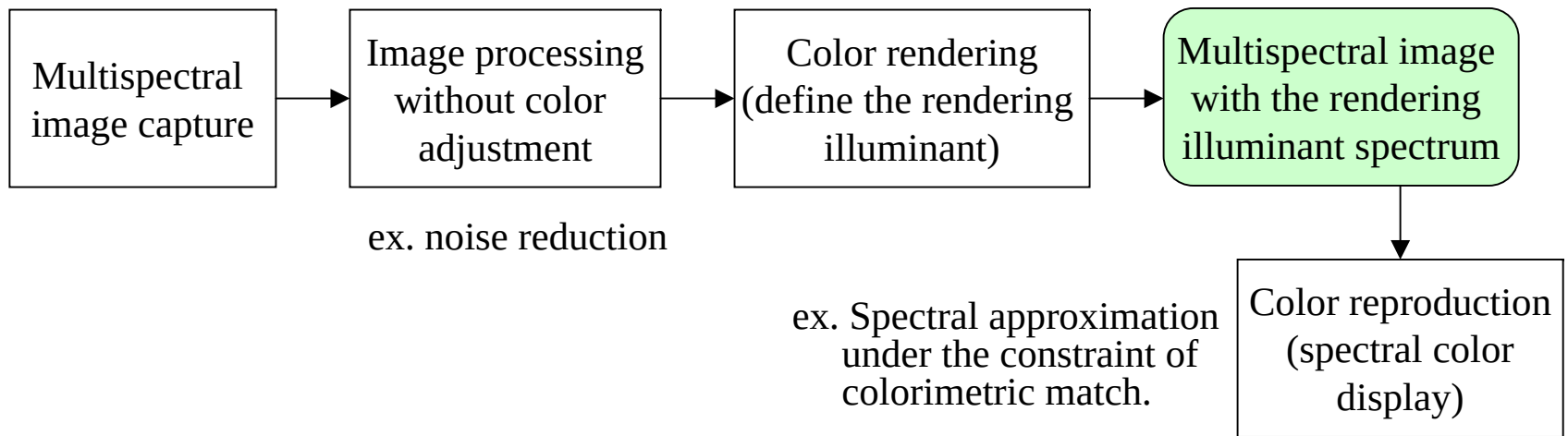
Image compression

- Spectral transform is a key issue in multispectral image compression.
- Two cases considered:
 - Spectral transform is attained in the compression / decompression system.
 - Spectral transform is performed before the compression and after the decompression system.

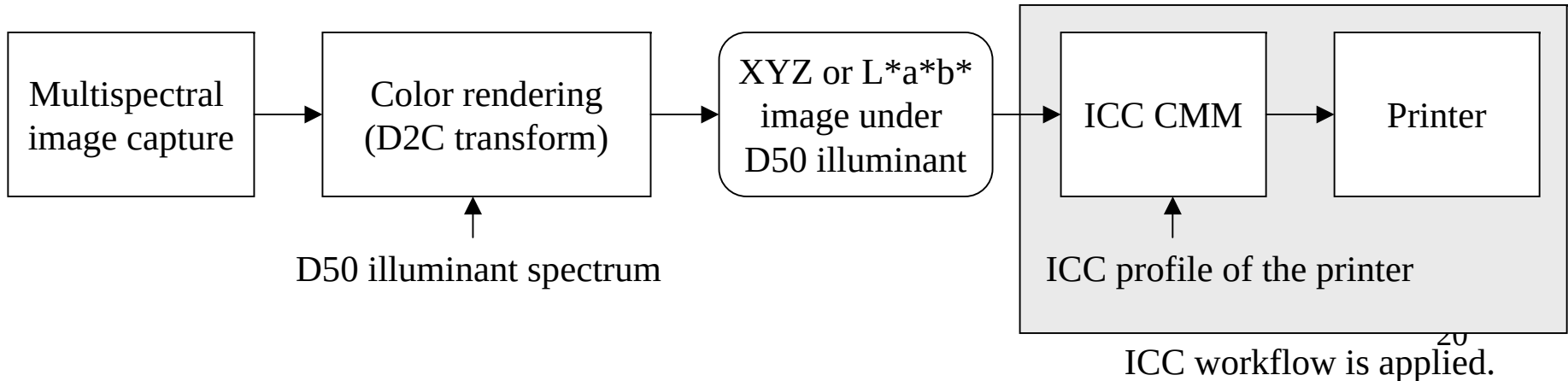


Examples

- Spectral color reproduction with multiprimary color display



- Colorimetric color printing using multispectral camera or scanner



Discussion on the scope of multispectral image format

- The spectral profile is a most important in the workflow of multispectral imaging.
- If the definition of spectral profile is available, some conventional image formats that support multichannel images can be employed, ex., TIFF, JPX, HDF
- Importance and simplicity: category $1 > 2 > 3$.
 - Category 1
 - Original multispectral image
 - Processed multispectral image
 - Category 2
 - Multispectral image with expected visualization condition
 - Category 3
 - Image data for multichannel display
 - Image data for spectral printing

Corresponds baseline, advanced, archival in the requirements?

- The comparison with the requirements discussed in this TC is needed.