A Customized Camera Imaging Pipeline for Dermatological Imaging

ISIC Skin Image Analysis Workshop @ CVPR 2019

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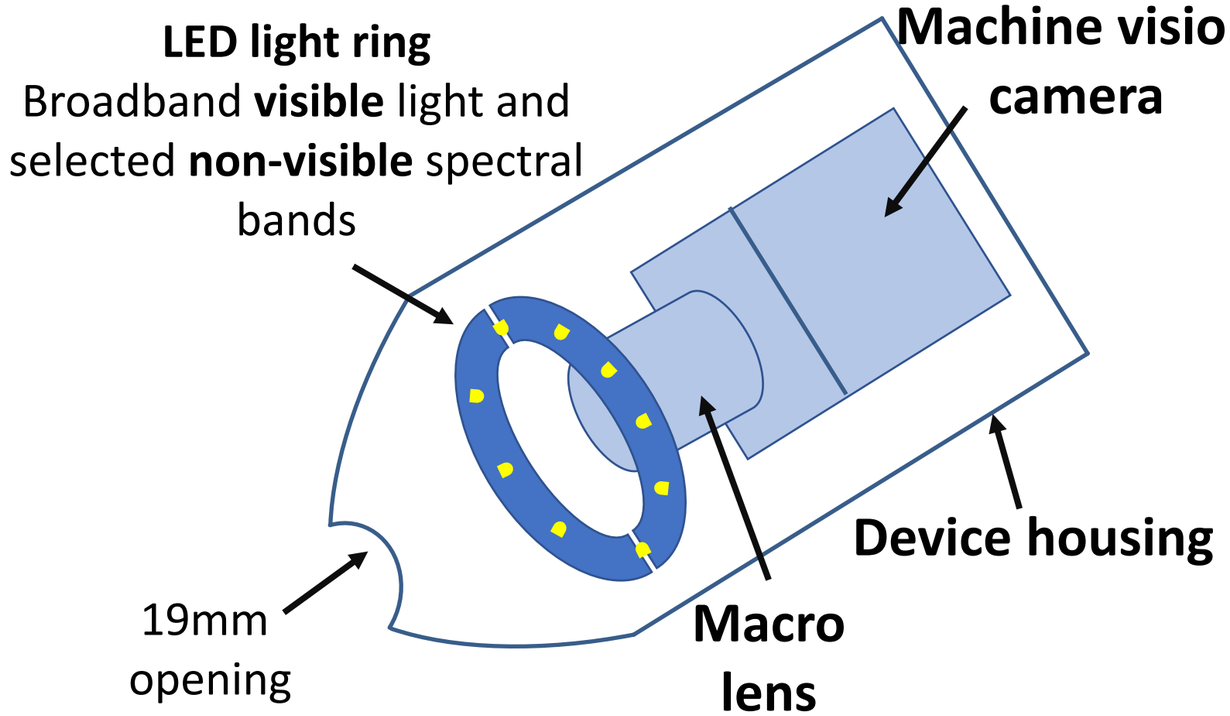
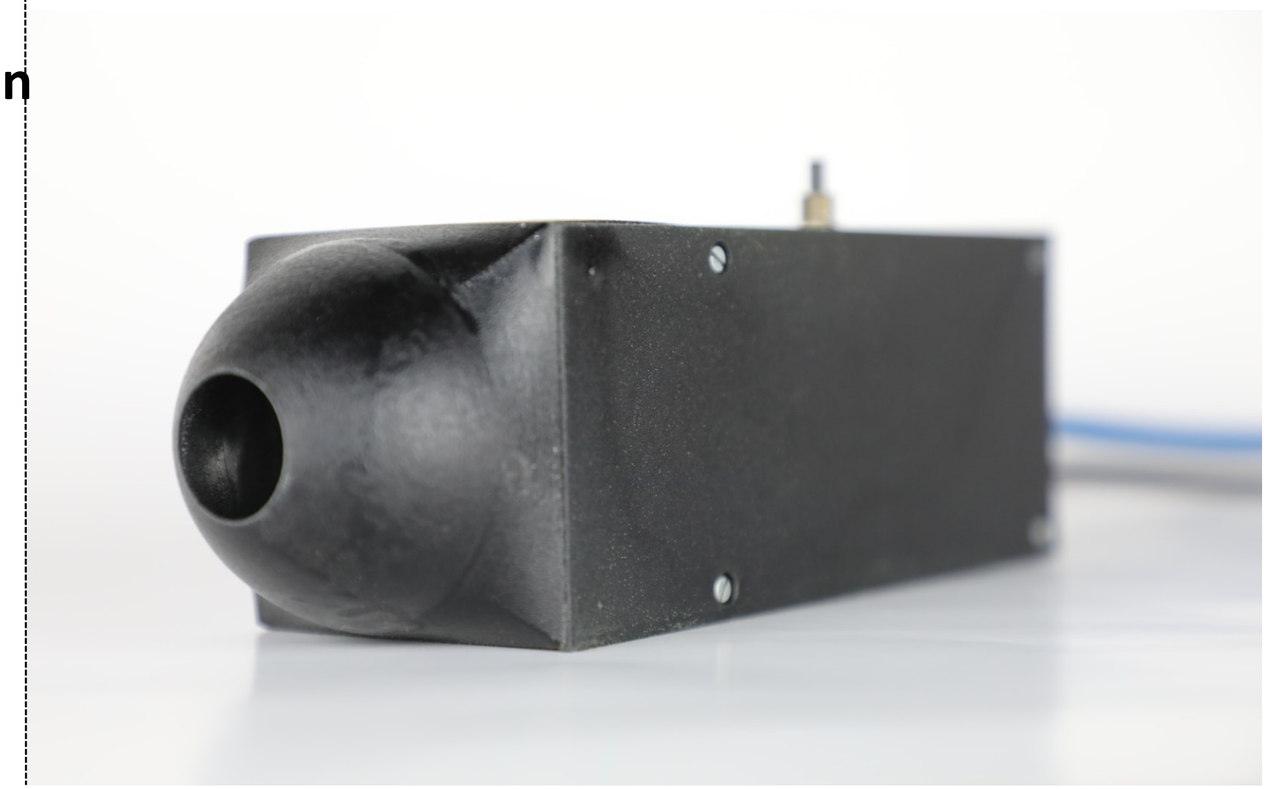
Talk's topic

A customize camera for dermatological analysis

Schematic drawing of the device



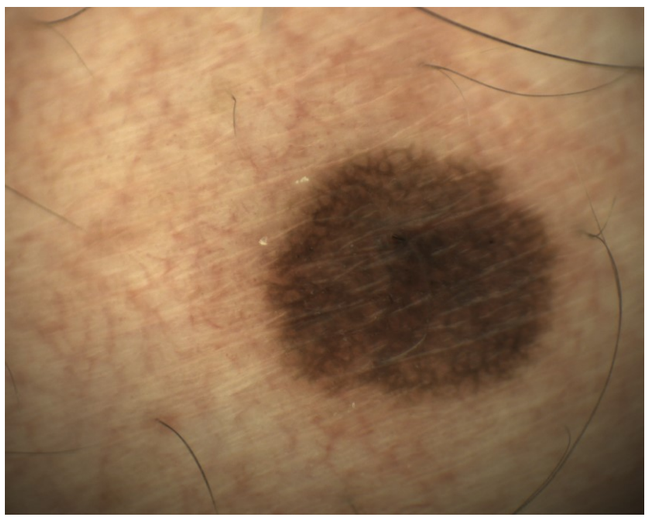
Prototype



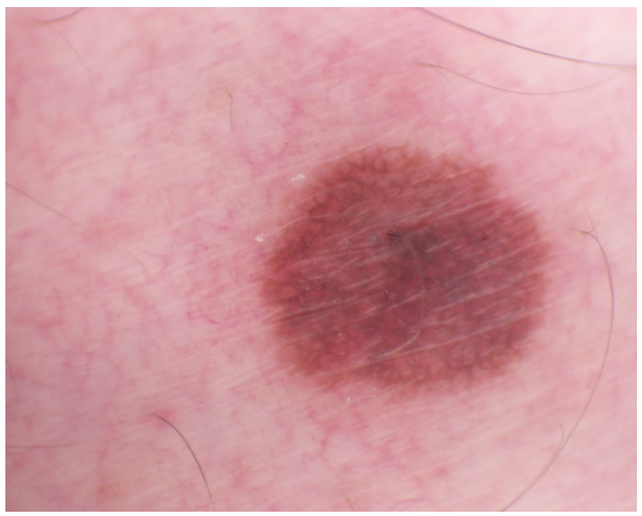
Challenges

1. Machine vision camera vs. consumer camera
2. How to use the visible image with the narrow band spectral image?

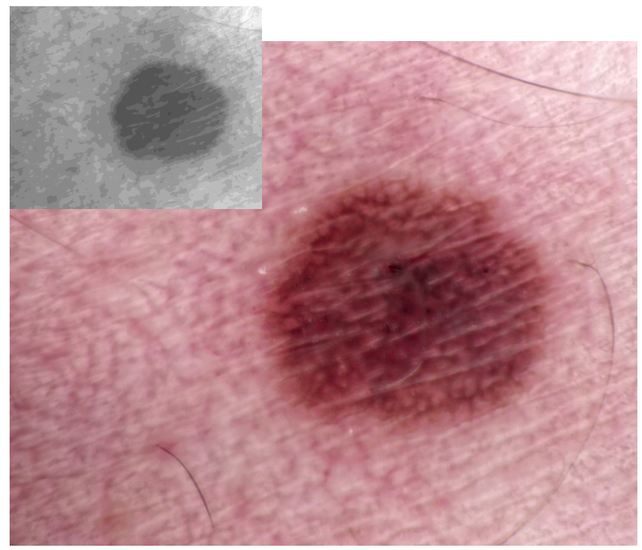
Output from machine vision camera's API



Consumer camera output



Enhanced RGB image using a spectral band

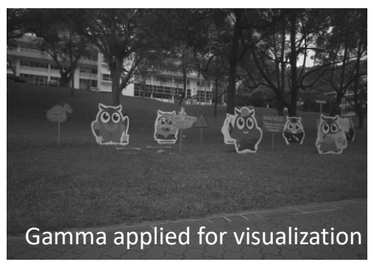


In-camera processing pipeline

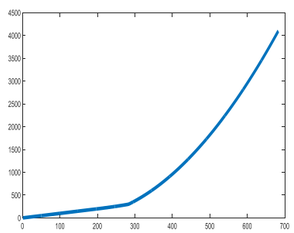
- There are a number of steps onboard a camera that convert the light falling on the camera's sensor image (raw image) to the final R,G,B image output

- These steps are collectively called the "in-camera image processing pipeline"

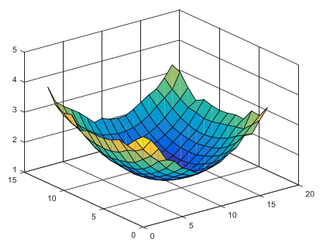
In-camera processing pipeline



1- Reading raw Image

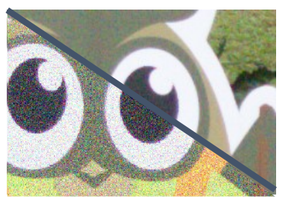


2- Black light subtraction, linearization [Values or 1D LUT]

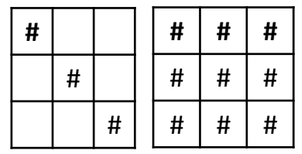


3- Lens correction [2D Array(s)]

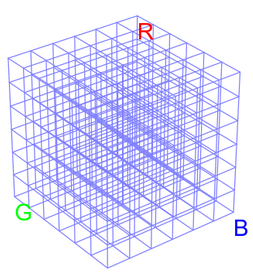
4- Demosaicing [Func]



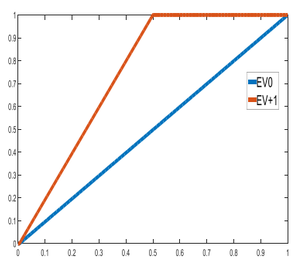
5- Noise reduction [Func]



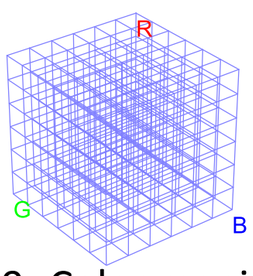
6- White-balancing & color space transform to CIE XYZ [MATs]



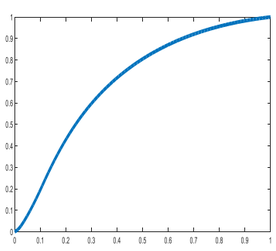
7- Hue/Sat map [3D LUT]



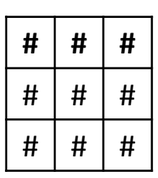
8- Exposure curve [EV value or 1D LUT]



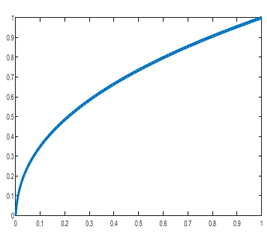
9- Color manipulation [3D LUT]



10- Tone curve application [1D LUT]

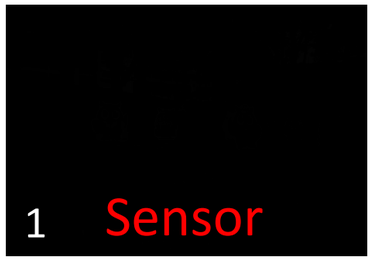


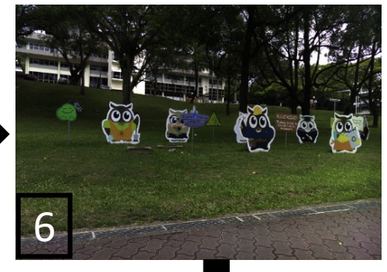
11- Final color-space conversion [Mat]

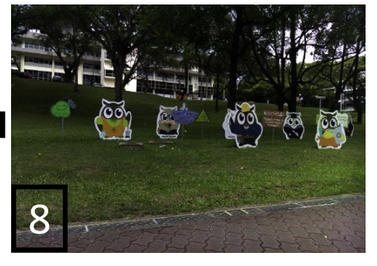


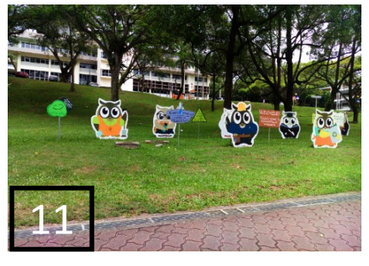
12- Gamma curve application [1D LUT]

Intermediate images for each stage

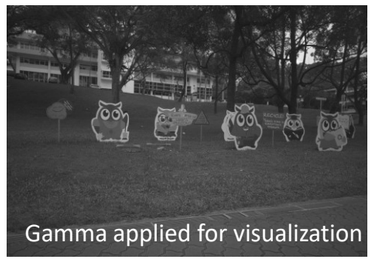








In-camera processing pipeline



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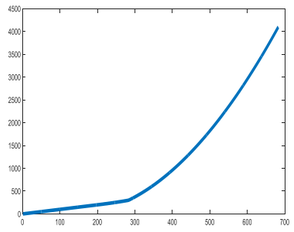

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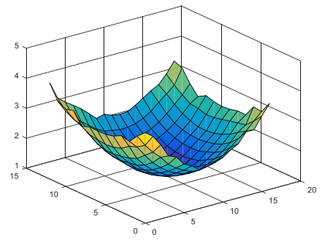
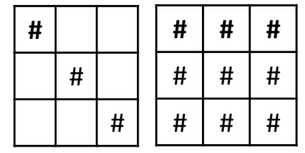


3- Lens correction
[2D Array(s)]

4- Demosaicing
[Func]

5- Noise reduction
[Func]

Color space transform



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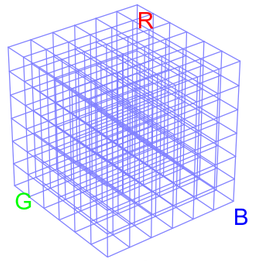

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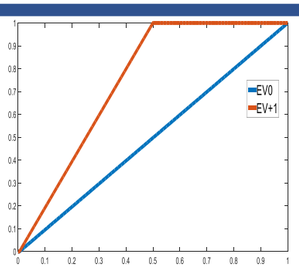
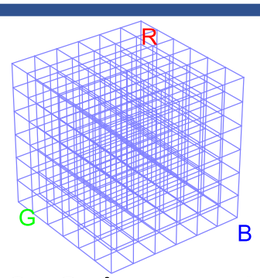
[3D LUT]



8- Exposure curve
[EV value or 1D LUT]



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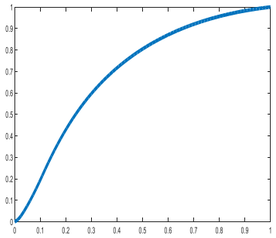

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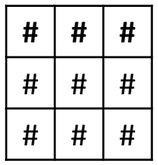

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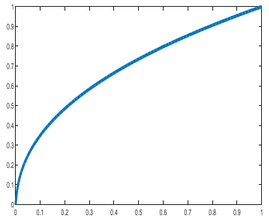
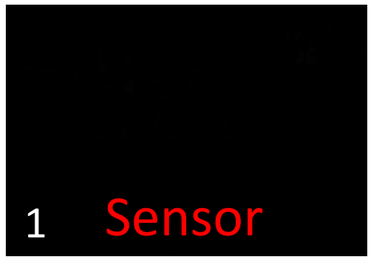
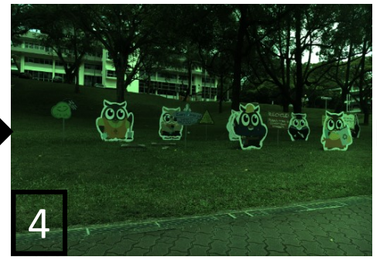


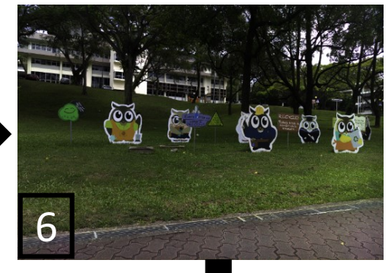
12- Gamma curve application [1D LUT]

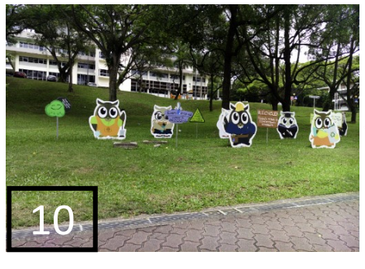
Photofinishing

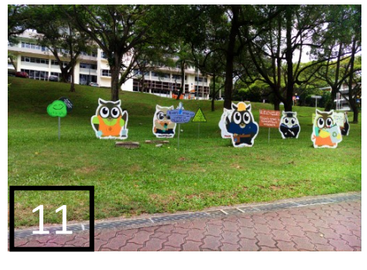
Intermediate images for each stage





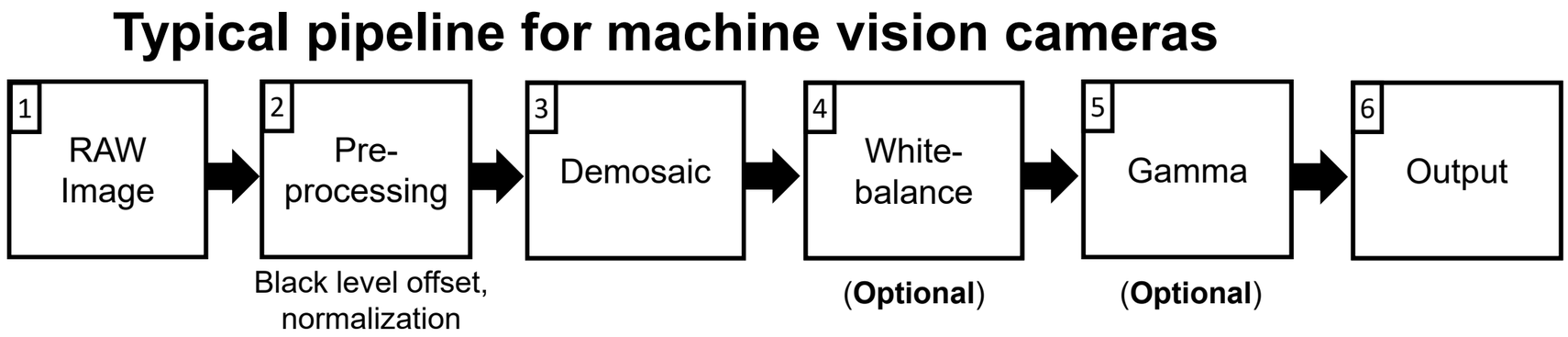






Machine Vision vs. Consumer Camera Pipelines

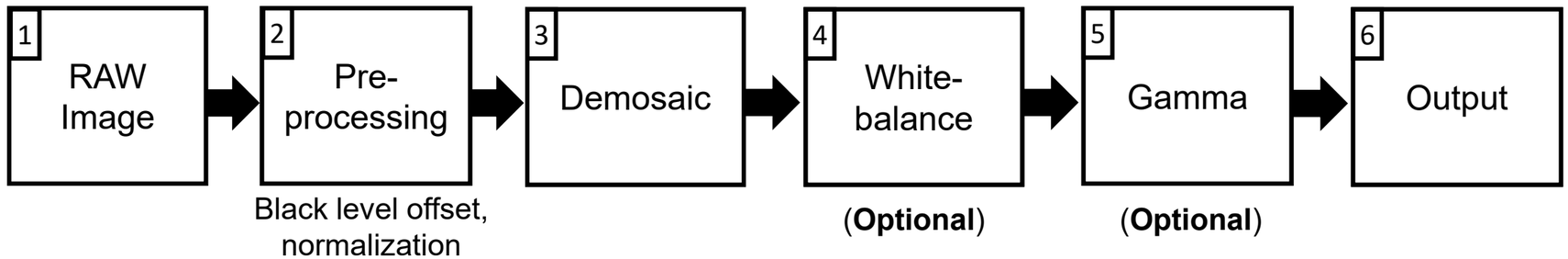
- Why does a machine vision camera's image appear different from consumer camera?



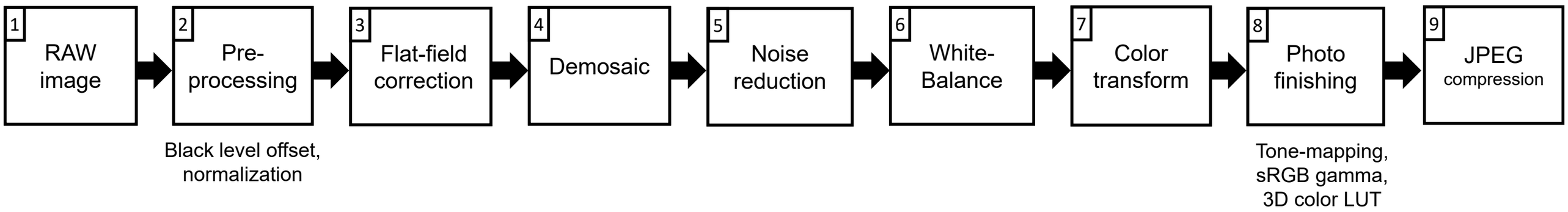
Machine Vision vs. Consumer Camera Pipelines

- Why does a machine vision camera's image appear different from consumer camera?

Typical pipeline for machine vision cameras

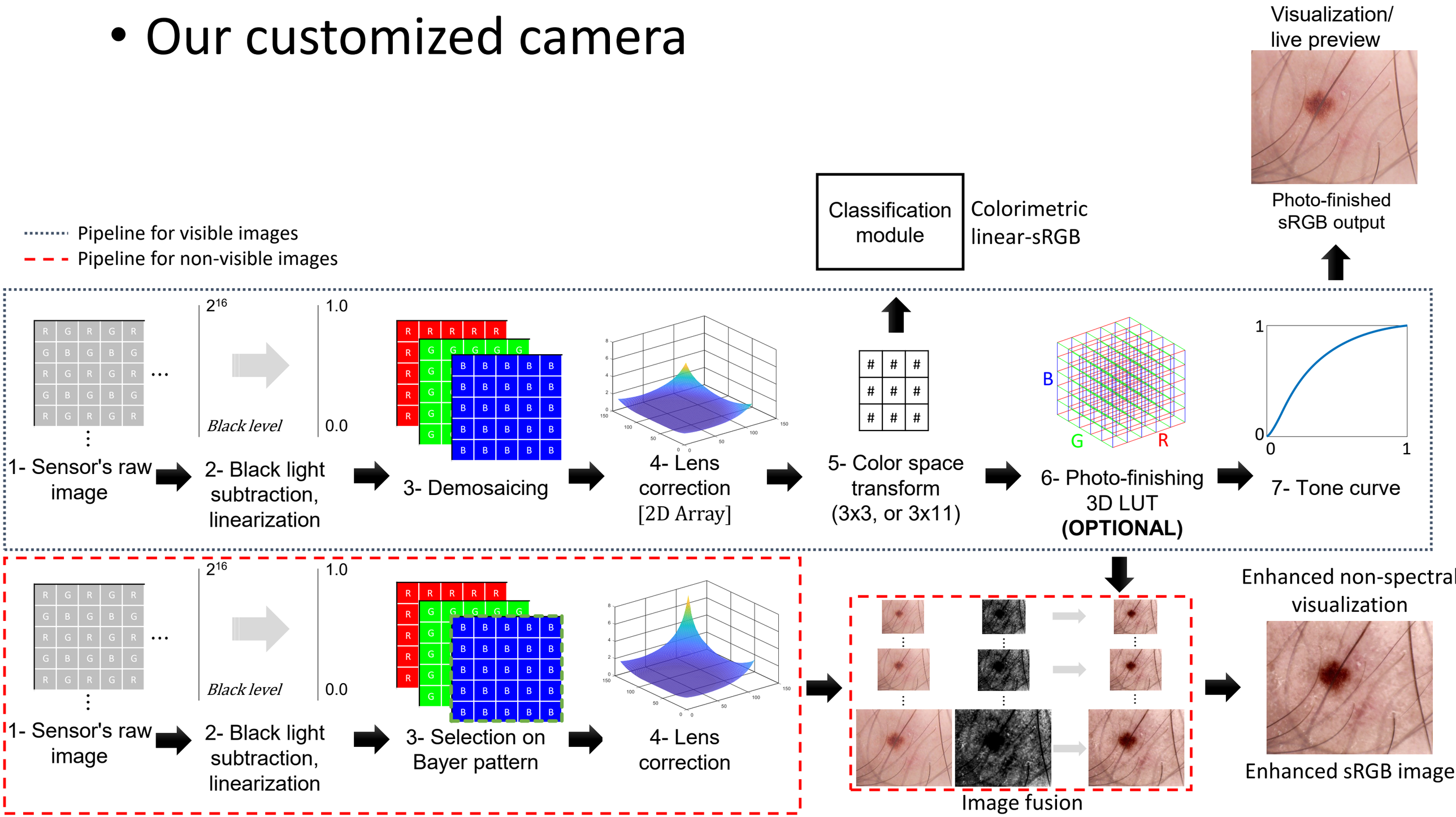


Typical pipeline for consumer cameras



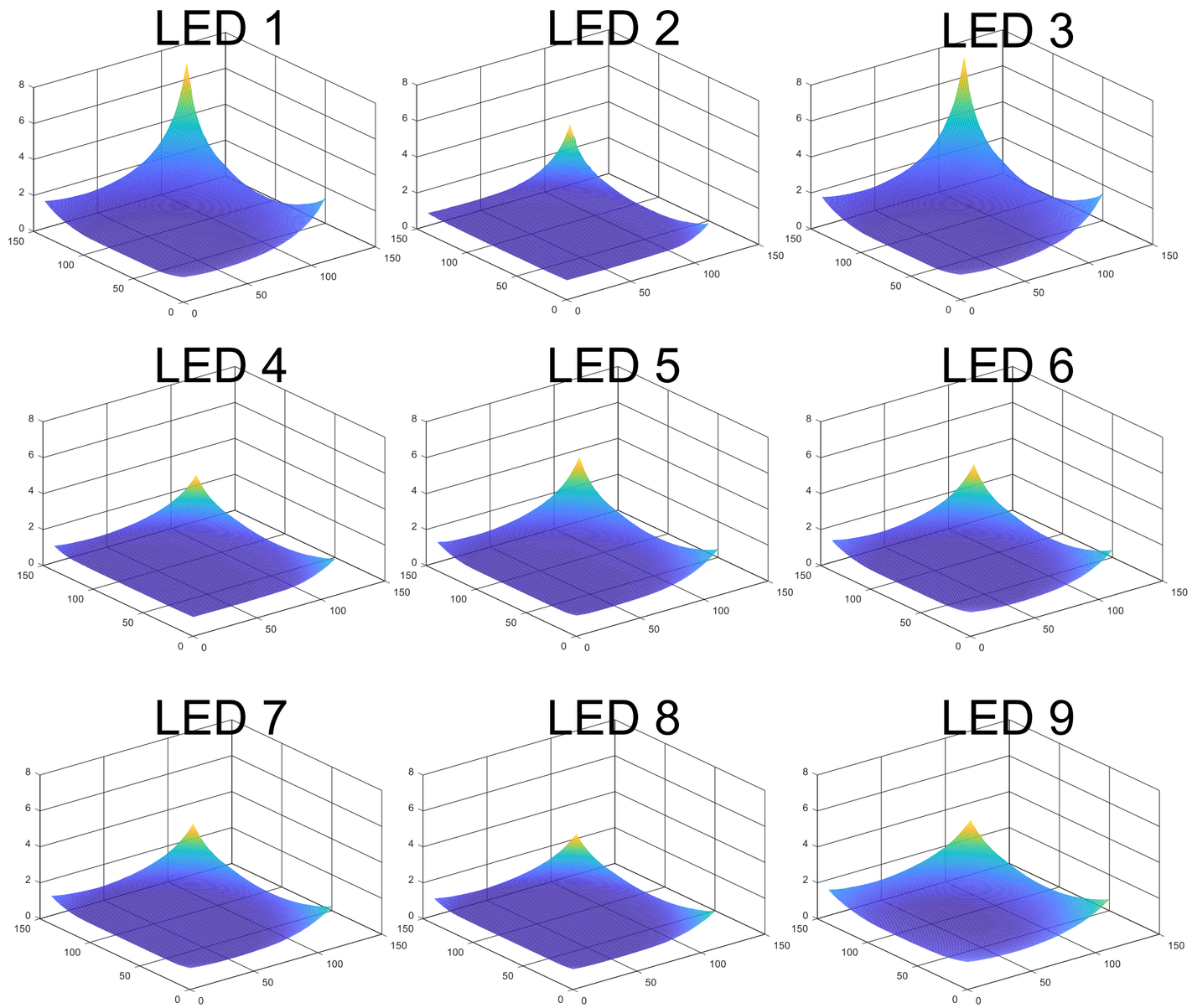
Customized imaging pipeline

- Our customized camera



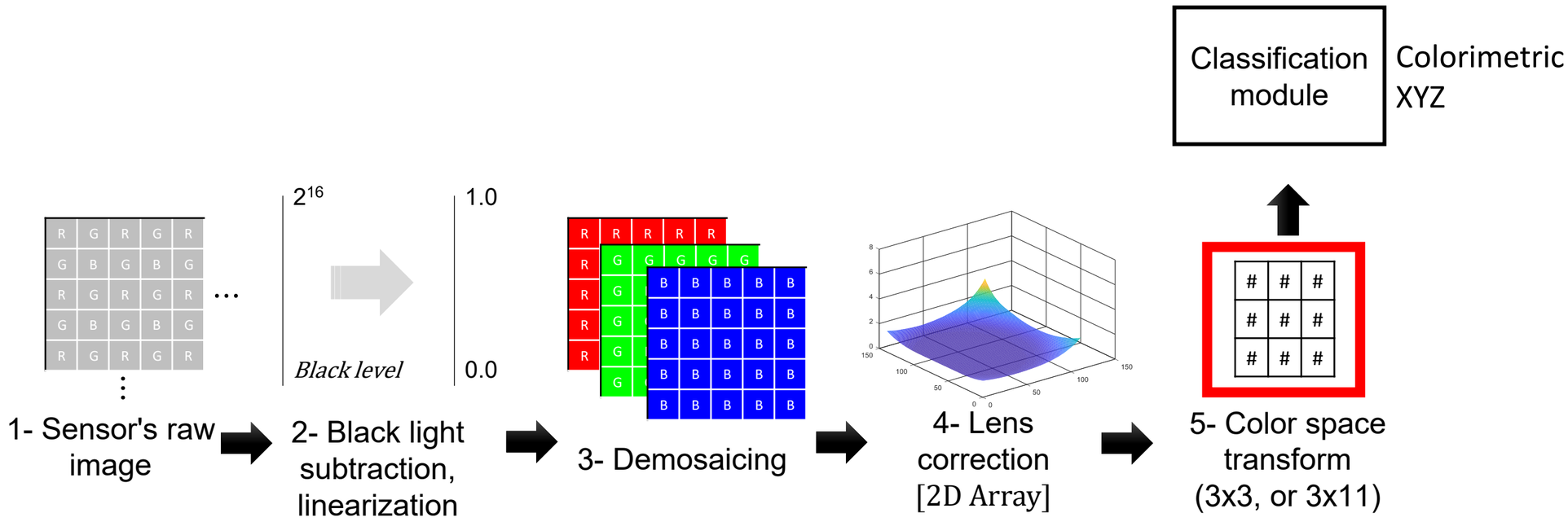
LED flat-field correction

- A flat-field correction for each LED



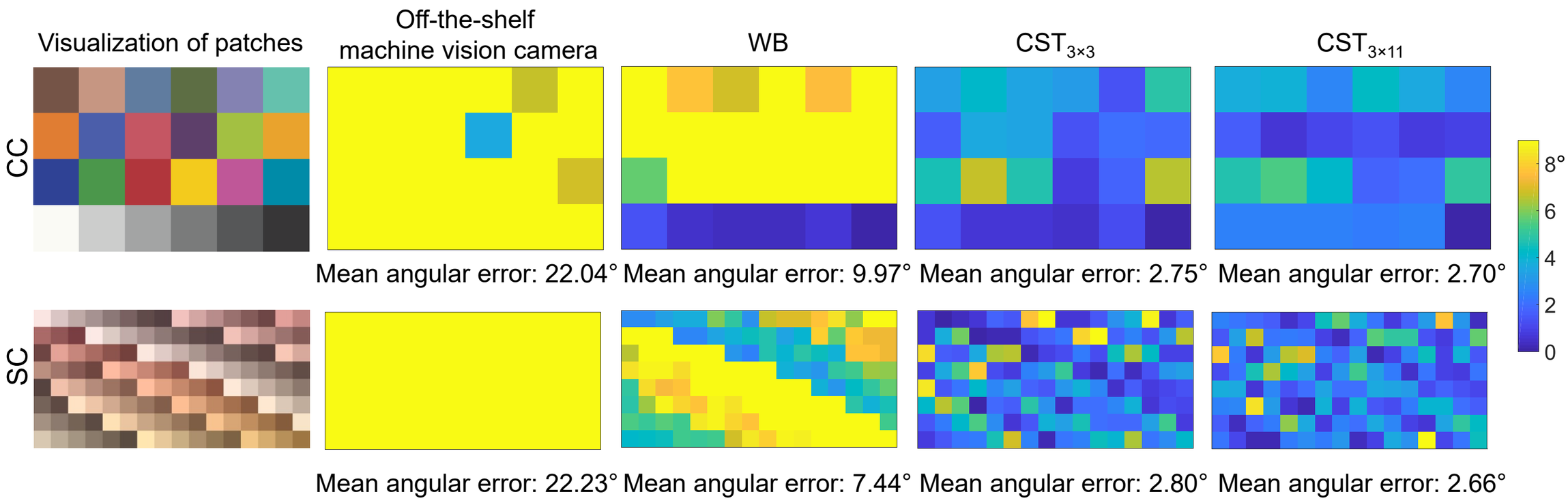
In-camera processing pipeline

- Sensor needs to be colorimetrically calibrated
- Color space transform (CST) to map raw-RGB values to the CIE XYZ color space



In-camera processing pipeline

- Errors with and without sensor calibration



CC: Macbeth color checker chart
SC: Skin colors from *the Munsell Book of Color*

Photo-finishing

- Photo-finishing to make the images look *visually-pleasing*

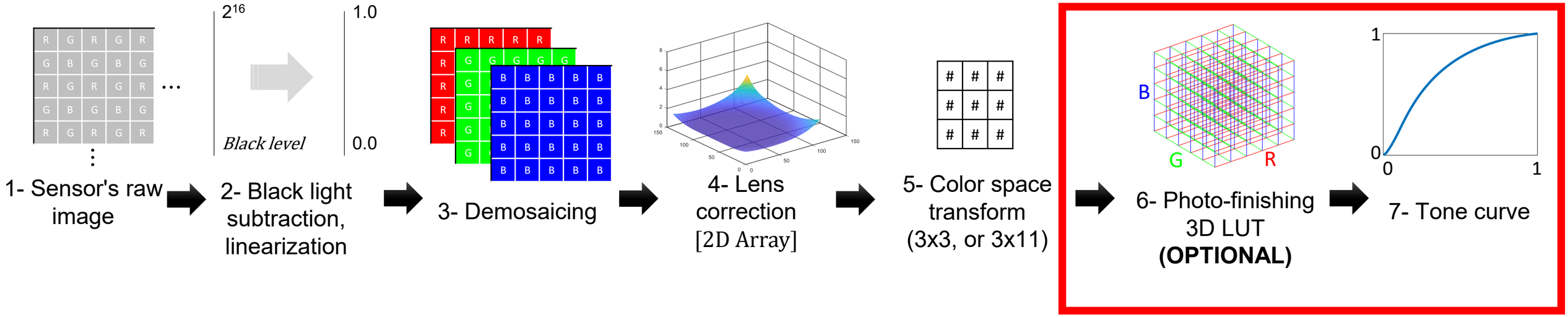
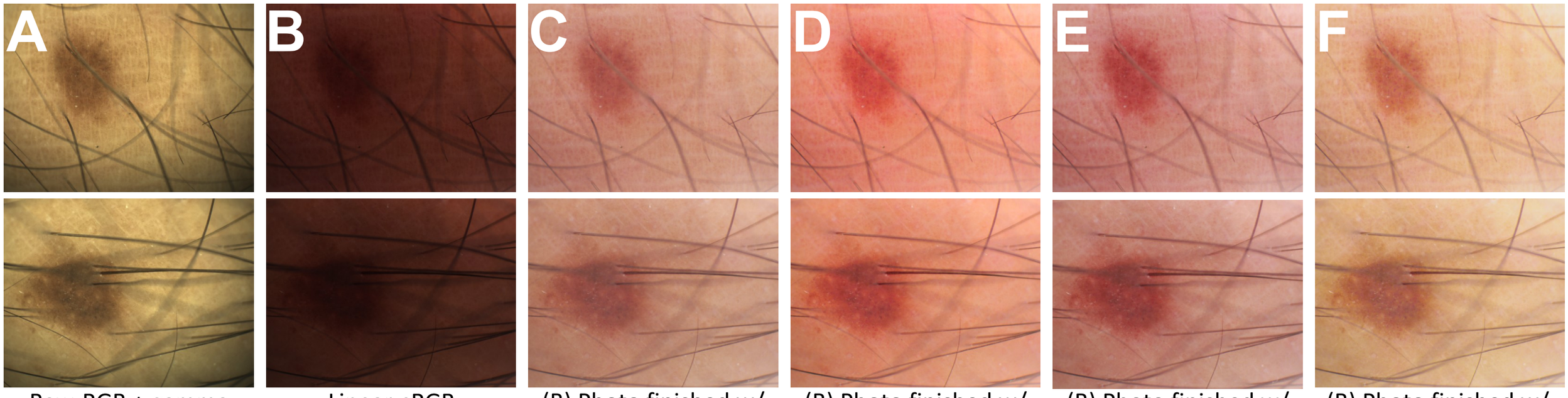


Photo-finishing

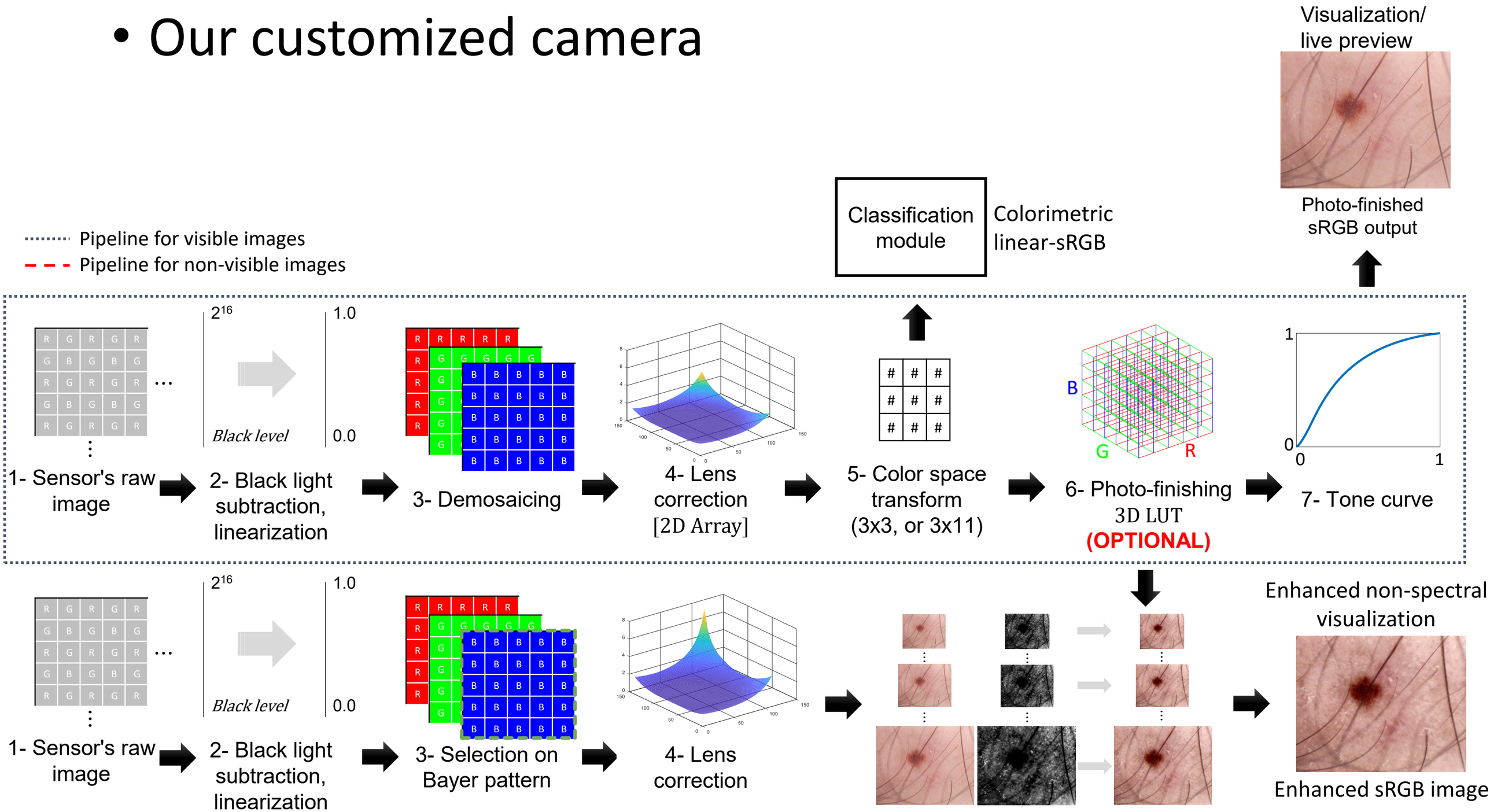
- Photo-finishing to make the images look visually-pleasing
- We can mimic different consumer cameras



Raw-RGB + gamma | Linear-sRGB | (B) Photo finished w/ **Adobe** tone-curve | (B) Photo finished w/ **Nikon's** Vivid mode | (B) Photo finished w/ **Canon's** Portrait mode | (B) Photo finished w/ **Olympus's** Natural mode

Non-visible spectral images

- Our customized camera



Non-visible spectral images

- Next: Enhancement using narrow band spectral images

Visualization/
live preview

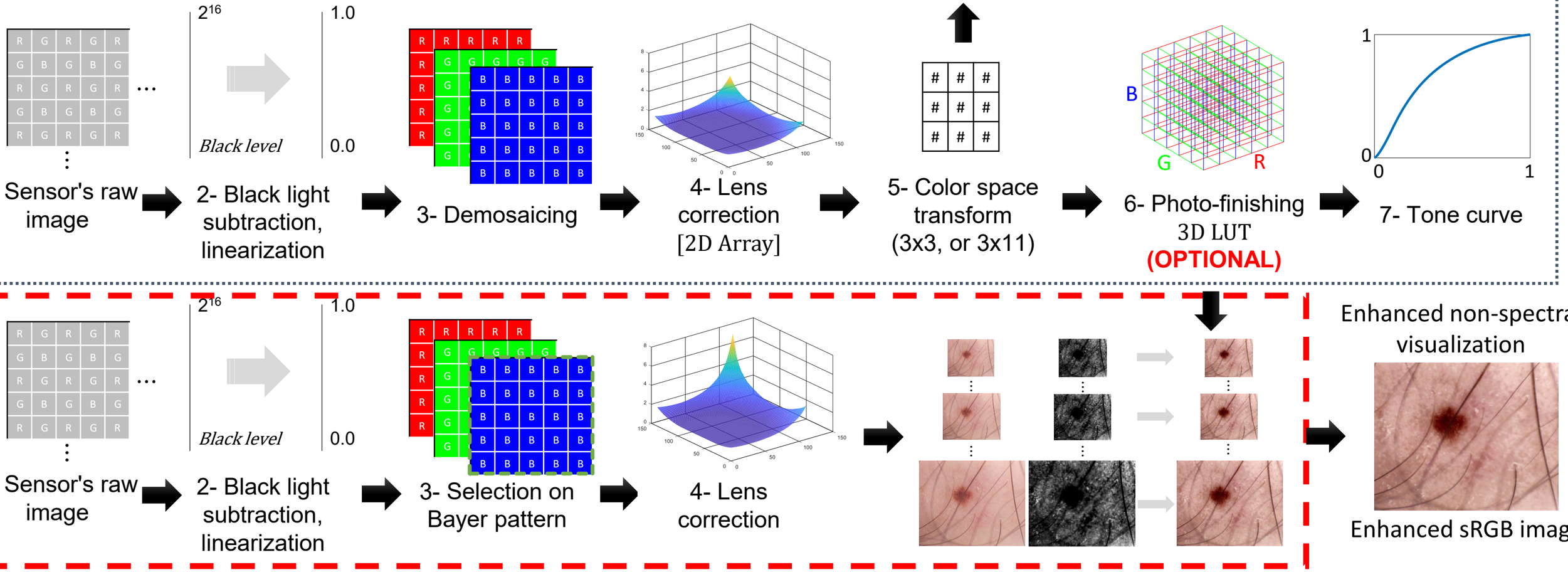
Photo-finished
sRGB output

Classification module

Colorimetric linear-sRGB

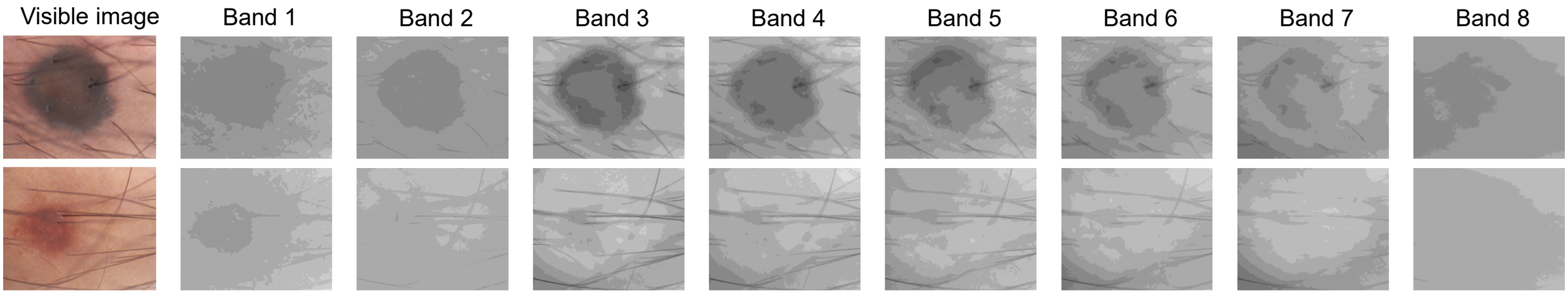
Pipeline for visible images

Pipeline for non-visible images



Non-visible spectral images

- Narrow band spectral images



Spectral data fusion

- Three methods:
  - Modified bilateral filtering [1]
  - Modified local Laplacian filter [2]
  - Wavelet-based fusion [3]

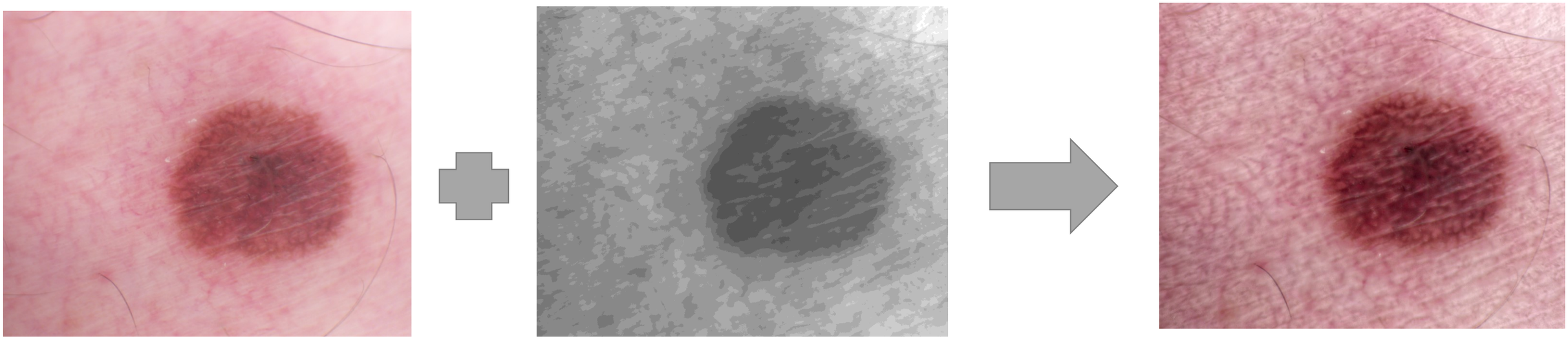


Photo-finished image

A narrow band spectral image

The result of the fusion

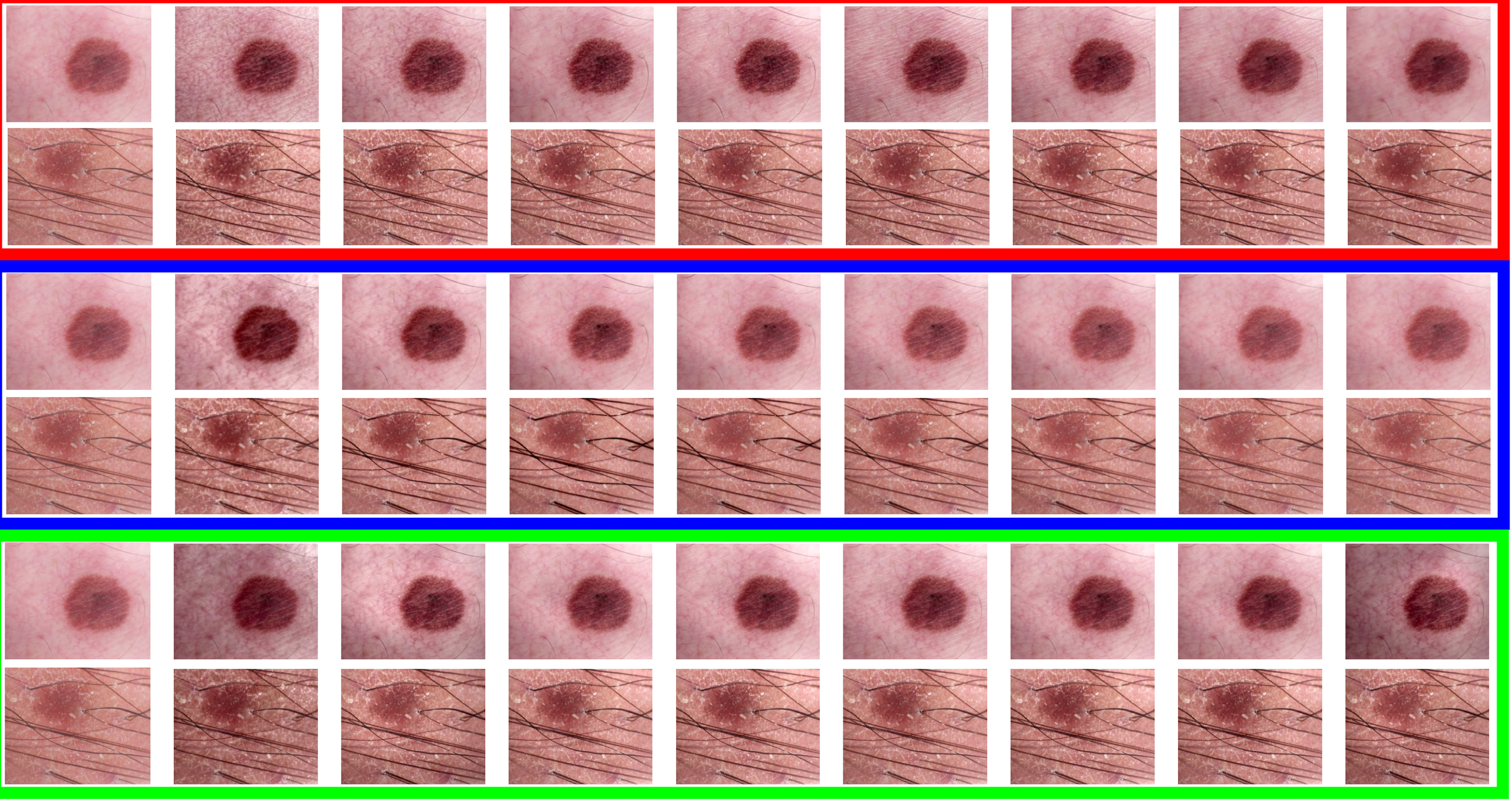
[1] Clement Fredembach, Nathalie Barbuscia, and Sabine Süsstrunk. Combining Visible and Near-Infrared Images for Realistic Skin Smoothing. In *Color and Imaging Conference*, 2009.

[2] Mathieu Aubry, Sylvain Paris, Samuel W. Hasinoff, Jan Kautz, and Fredo Durand. Fast Local Laplacian Filters: Theory and Applications. In *SIGGRAPH*, 2014.

[3] Michel Misiti, Yves Misiti, Georges Oppenheim, and Jean-Michel Poggi. *Wavelets and Their Applications*. Newport Beach, CA: Wiley-ISTE.

Examples of data fusion

Visible image | Band 1 | Band 2 | Band 3 | Band 4 | Band 5 | Band 6 | Band 7 | Band 8



Modified bilateral filter method [1]

Modified local Laplacian filter method [2]

Wavelet-based image fusion [3]

Feedback from clinicians

- Is there a preference between the methods and the different spectral bands?
    - Among the three methods used to perform spectral image fusion, do you have a preferred method?
    - Is there a particular spectral image that you feel provides the most information?
    - Do you feel this type of fusion is useful for you in a clinical setting (i.e., would it help you make a more informed decision)?

Clinician feedback

- The most preferred:
  - Wavelet-based method
  - Spectral band 8 (NIR - 1100 nm)
- Comments from our participants include:
  "Yes, I think that the fusion is very helpful"
  "I could see the pattern of each lesion much better (reticular, dots, borders)."
- A dermatologist who was neutral commented:
  "Only in certain cases."

Still an area of active research.

Conclusion

- **Presented a customize camera pipeline for dermatological imaging**
  - Modified machine-vision camera
  - Based on understanding of consumer camera pipelines
  - Useful for the design of similar devices
- **Spectral data fusion**
  - Older methods shouldn’t be ruled out
  - Open problem, room for more research

Thank you!