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Multispectral VIS-NIR whole-body imaging: Equipment and skin cancer patient data

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Recent trend: remote dermoscopy of large skin areas

← Multi-camera design

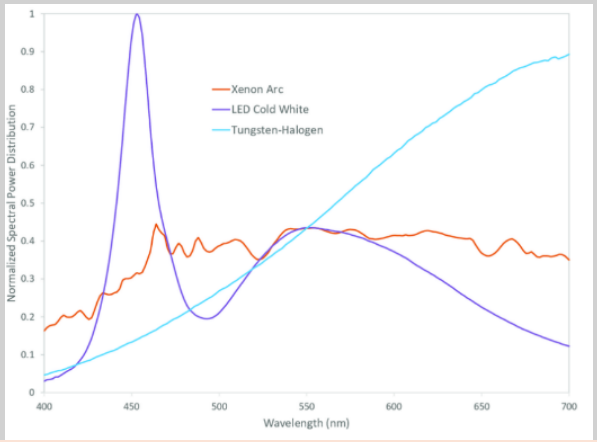
Single camera design →

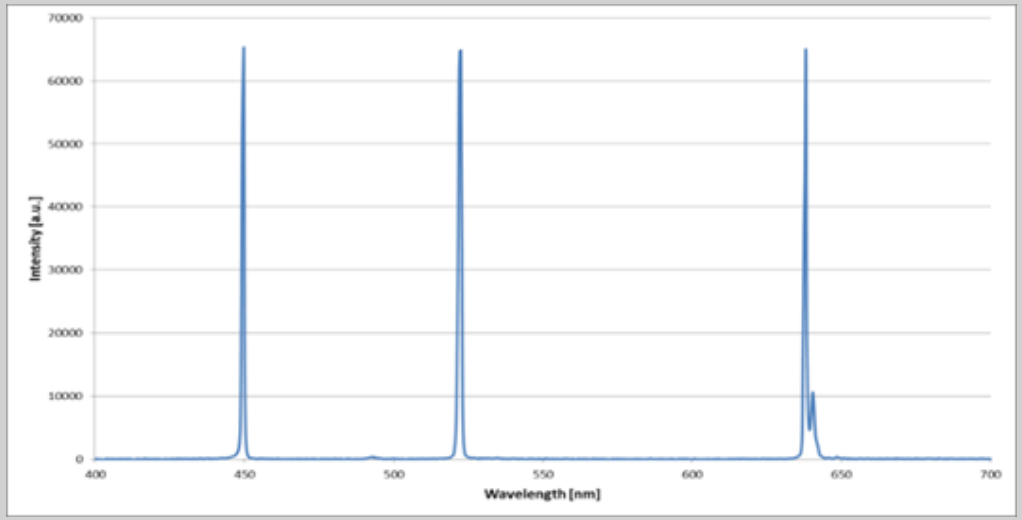
Fotofinder ATBM master 4th Gen

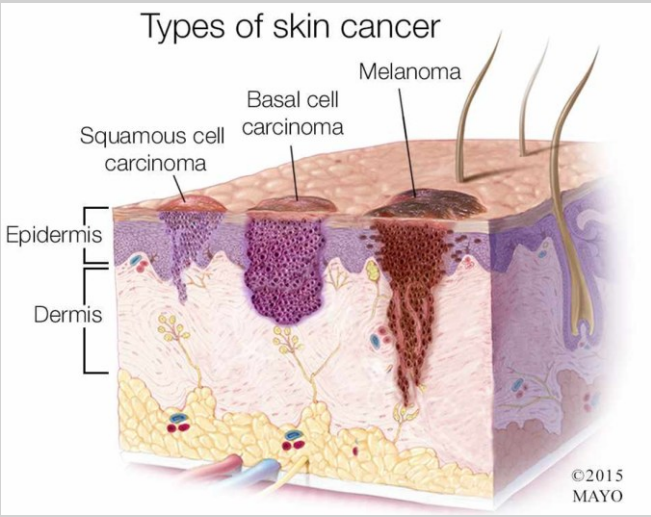
Canfield Vectra WB360 3D

Both systems capture color images under broadband white illumination, which limits acquiring spectral information on skin lesions.

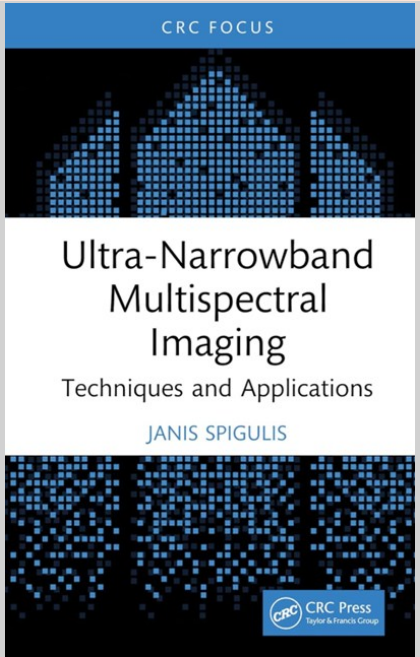
The main idea



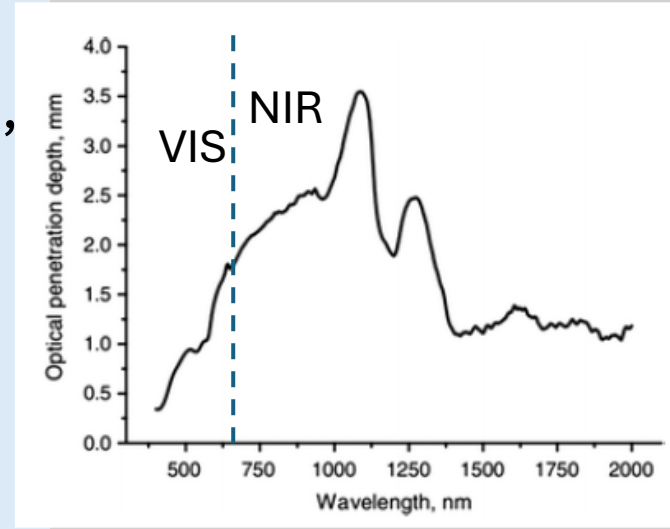




White broadband illumination: halogen lamp, LED or Xe lamp



Previous study: simultaneous spectral line illumination at 450nm, 520nm, 638nm (VIS) → extraction of skin **spectral images** from the camera data set at all working wavelengths → sorting whole-body pigmented and vascular lesions



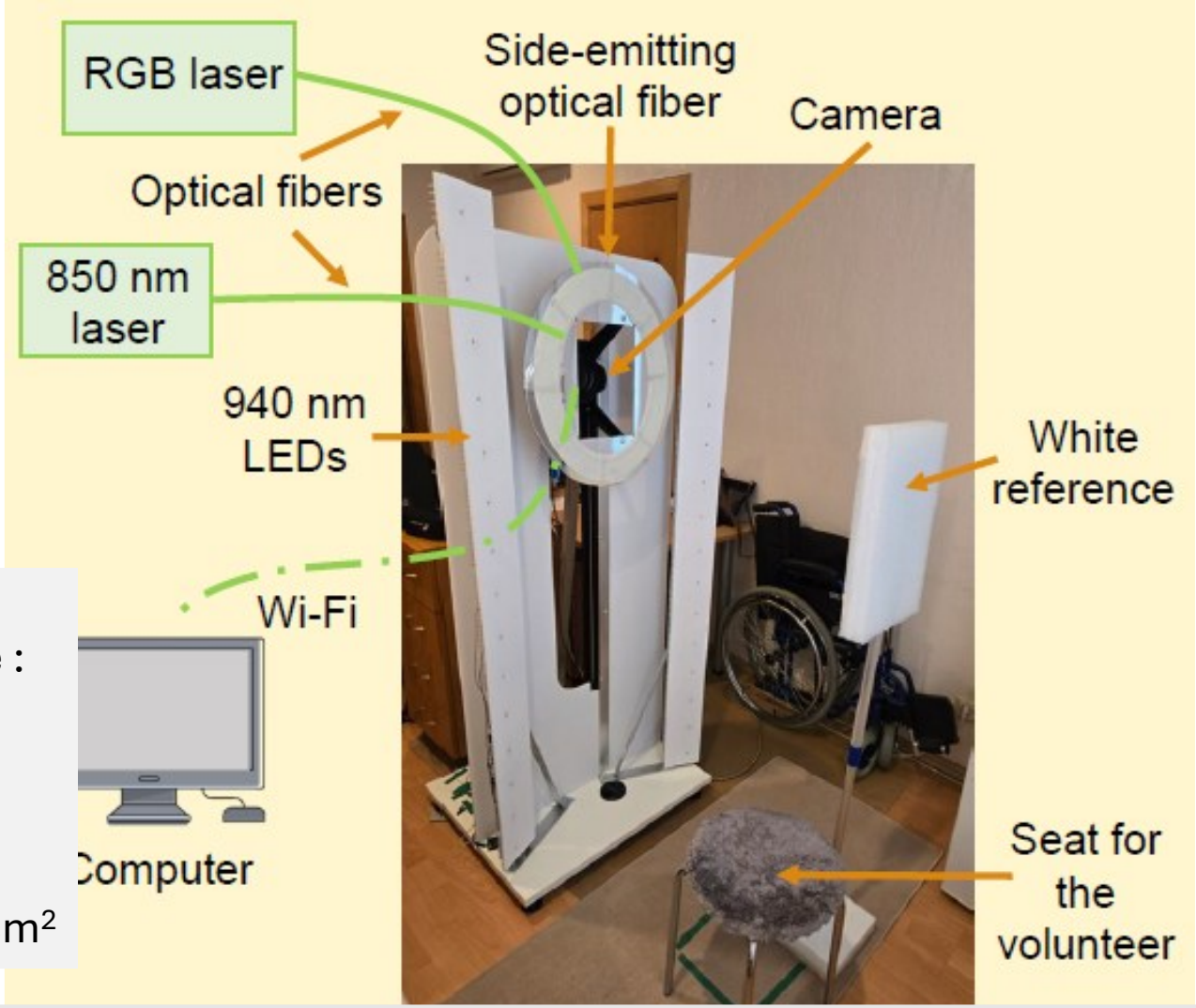
NIR: deeper light penetration in skin

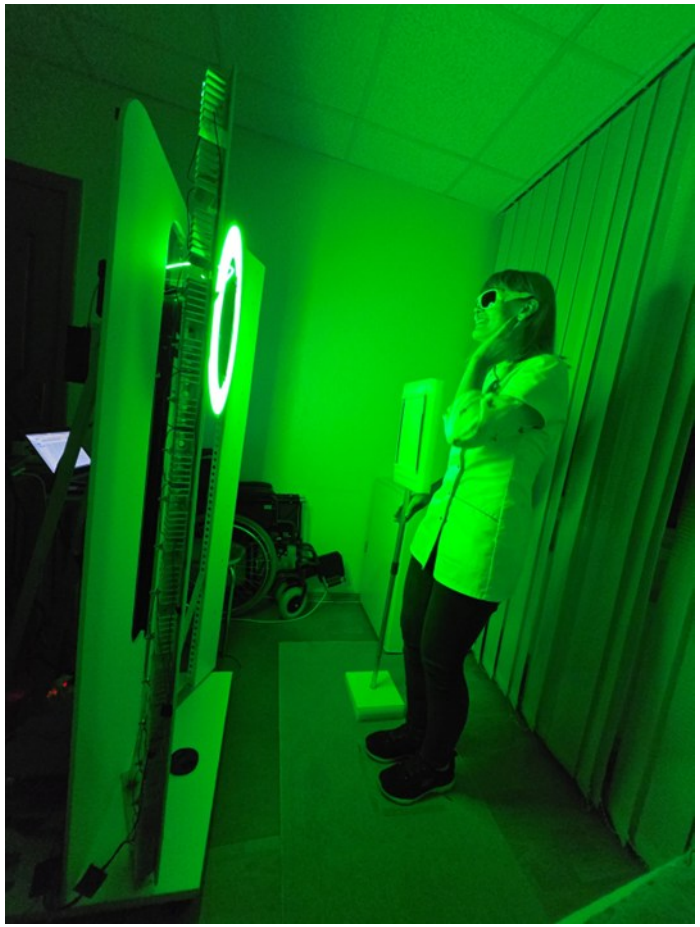
J.Spigulis, et al., **"Triple spectral line imaging of whole-body human skin: equipment, image processing, and clinical data"**, Sensors **24**, 7348 (2024).

This proof-of-concept study:

- Extended the imaging capabilities of our prototype system to the near-infrared range (850 nm, 940 nm)
- Validated its ability to detect skin cancers on patients of Latvian Oncology Center in Riga

Equipment: prototype system





Illumination max. power density at 70 cm distance :

- 450 nm _ 22 μW/cm^2
- 520 nm _17 μW/cm^2
- 638 nm _15 μW/cm^2
- 850 nm _ 34 μW/cm^2
- 940 nm LED_0.2 mW/cm^2

61-megapixel color camera (Sony a7R IVA), NIR filter removed
Side-emitting optical fiber spirals: 60 m (RGB laser) and 30m (850nm laser)
3 x 1 W RGB laser with SMA output, 450/520/638 nm + 1W 850nm + 940nm LED set
Camera & illuminator up-down movements (0.5m - 1.5 m)
Placed in a light-shielding tent or in a dark room (Latvian Oncology Center patient measurements)

Patients examined in the Oncology Center of Latvia

- Total number: 60 (31 women, 29 men), age 35…93 years, initial diagnosis by onco-dermatologist
- Histologically confirmed malignancies:
  - malignant melanoma (MM, n=7)
  - basal cell carcinoma (BCC, n=33)
- Clinically confirmed: 11 BCC, 62 nevi, 18 hemangiomas, 27 seborrheic keratoses, single cases of lentigo maligna, Bowen's disease and blue nevus.
- Body locations:
  - Melanomas - trunk (50%), head&neck (38%), extremities (13%).
  - Basal cell carcinomas - head&neck (67%), trunk (27%), extremities (6%).
- >100 color RGB images, >400 spectral images of various skin lesions

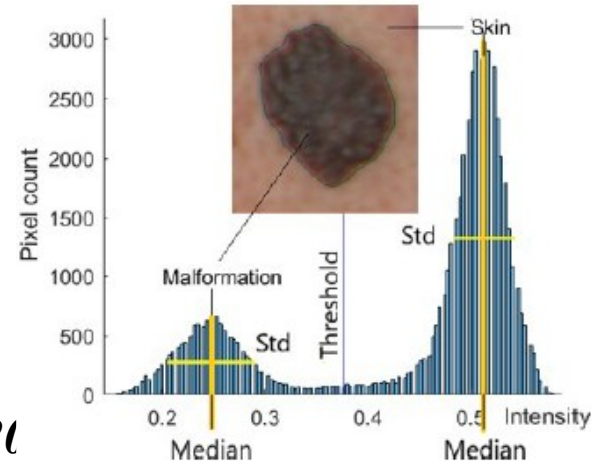
NIR images of skin lesions: specific features

- Wavelength effects:
  - No essential differences between the 850 nm and 940 nm spectral images of skin malformations were observed, so further only 850 nm images will represent the NIR spectral range
- Visibility in NIR:
  - All examined melanomas, as well as ulcerated basal cell carcinomas were clearly visible in the NIR images
  - All examined nevi fully disappeared in the NIR images: the «NIR fading effect»
  - Still, some of seborrheic keratoses and hemangiomas were visible also in the NIR images → extra filtering for out-sorting needed

Clinical criteria considered in this study

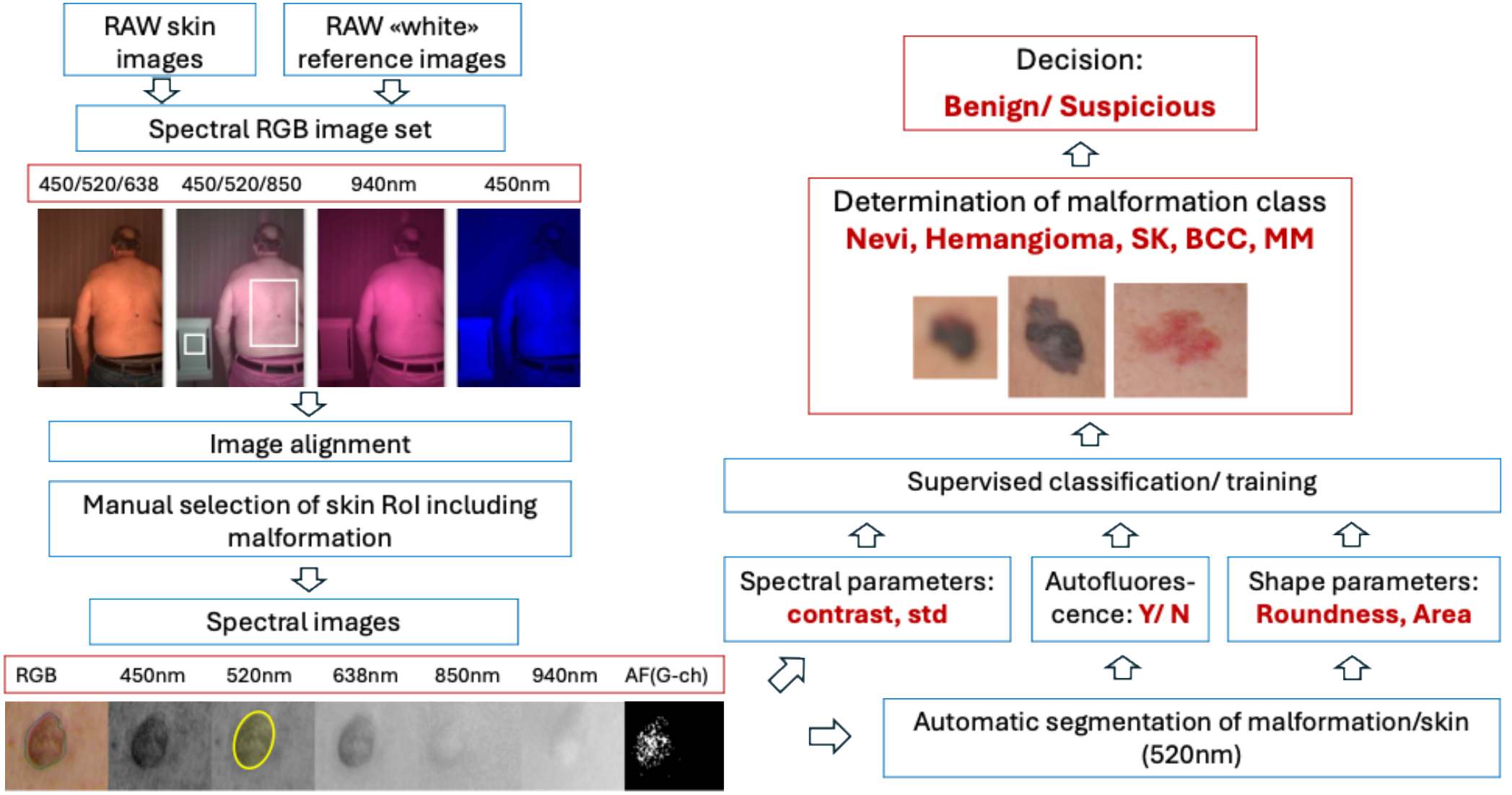
- If visible in NIR image: suspected malignancy; further analysis needed
- By shape - roundness : $\boldsymbol{R = 4\pi A/P^2}$, A – area of lesion, P - perimeter
- By contrast in the spectral images (λ): $\boldsymbol{C = \overline{I_{skin}}\,/\overline{I_{malf}}}$
- Standard deviation (pixels): $\boldsymbol{STD_{malf} = std\left(I_{malf}\right)/\overline{I_{malf}}}$
- Combined VIS-NIR parameters:

$$\boldsymbol{p_{450} = \frac{C_{638}\cdot C_{850}}{C_{450}}} \quad \boldsymbol{p_{520} = \frac{C_{638}\cdot C_{850}}{C_{520}}} \quad \boldsymbol{C_{850}/R_{520}} \quad \boldsymbol{STD_{850}/R_{52}}$$

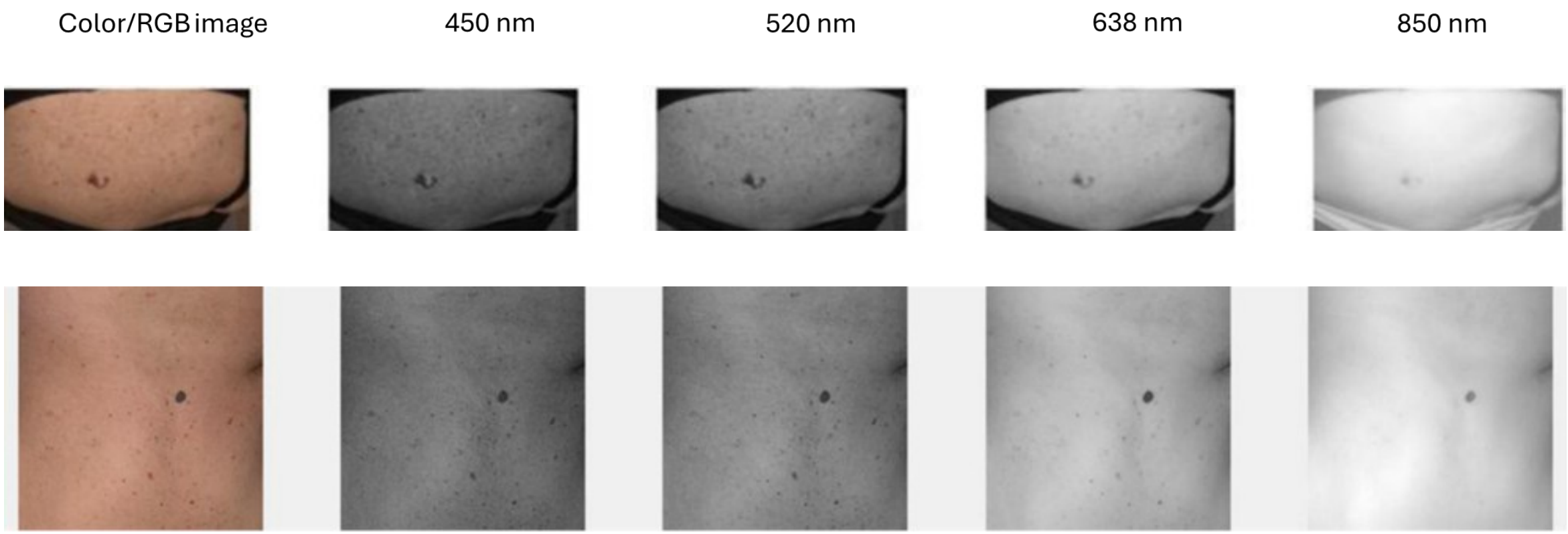


- Fluorescing or not at 450 nm illumination: to out-sort seborrheic keratoses
- Attempt to classify automatically using AI (Matlab *classificationLearner*)

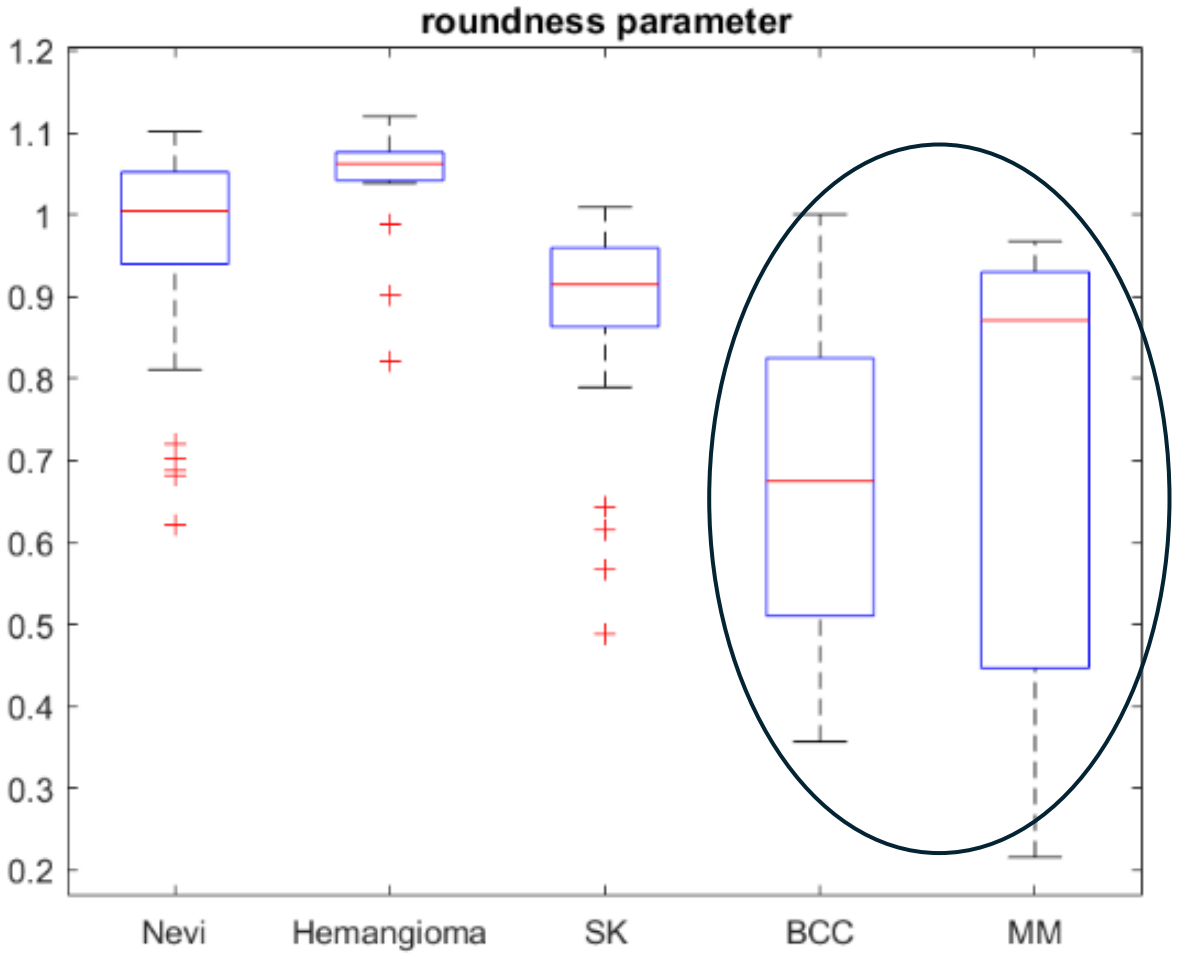
Image processing

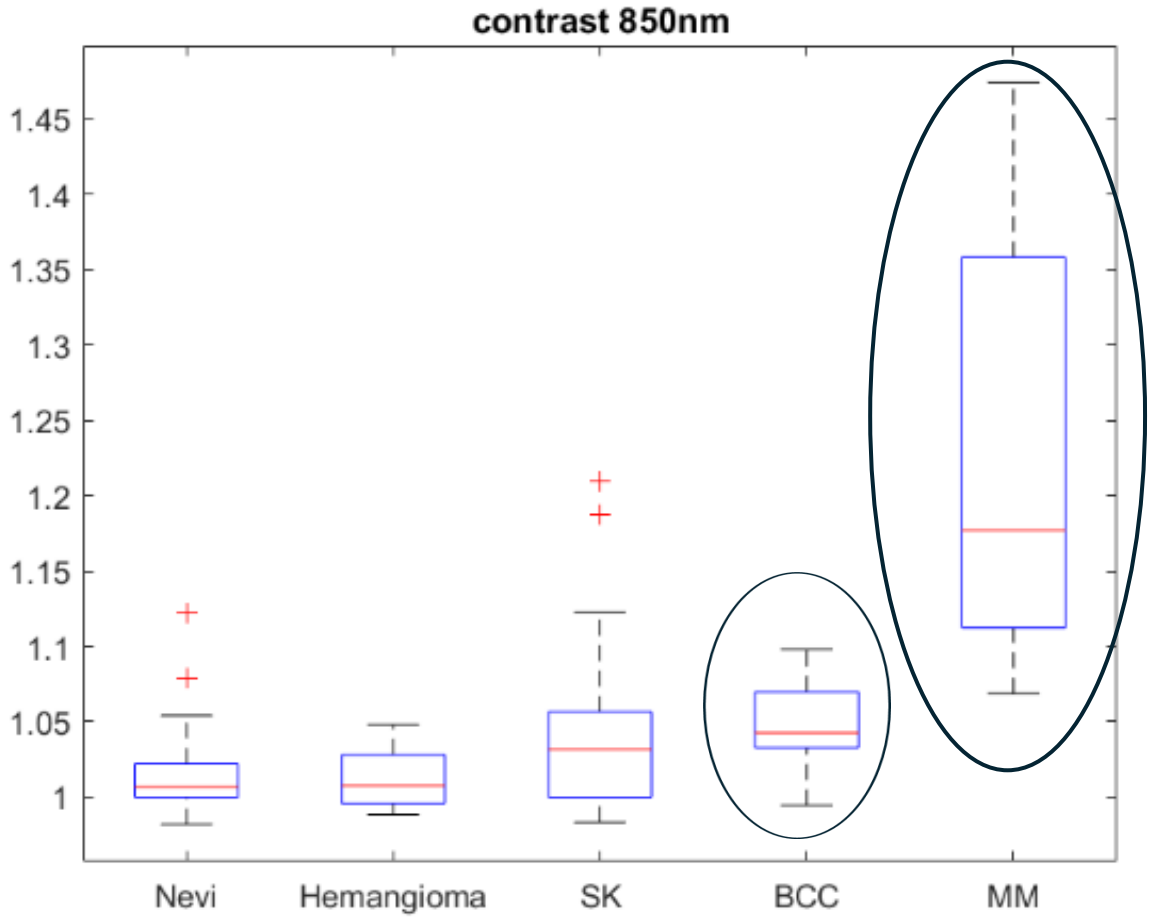


Examples of the «NIR-fading» effect (melanoma)



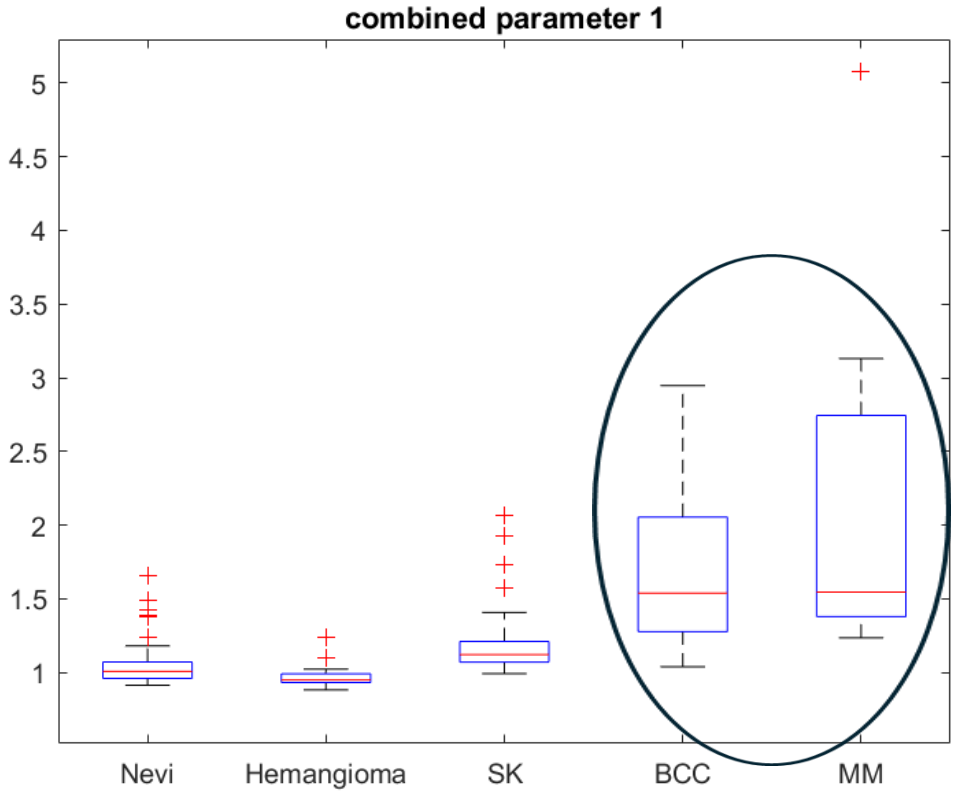
Roundness R(520 nm) and NIR image contrast C(850 nm)





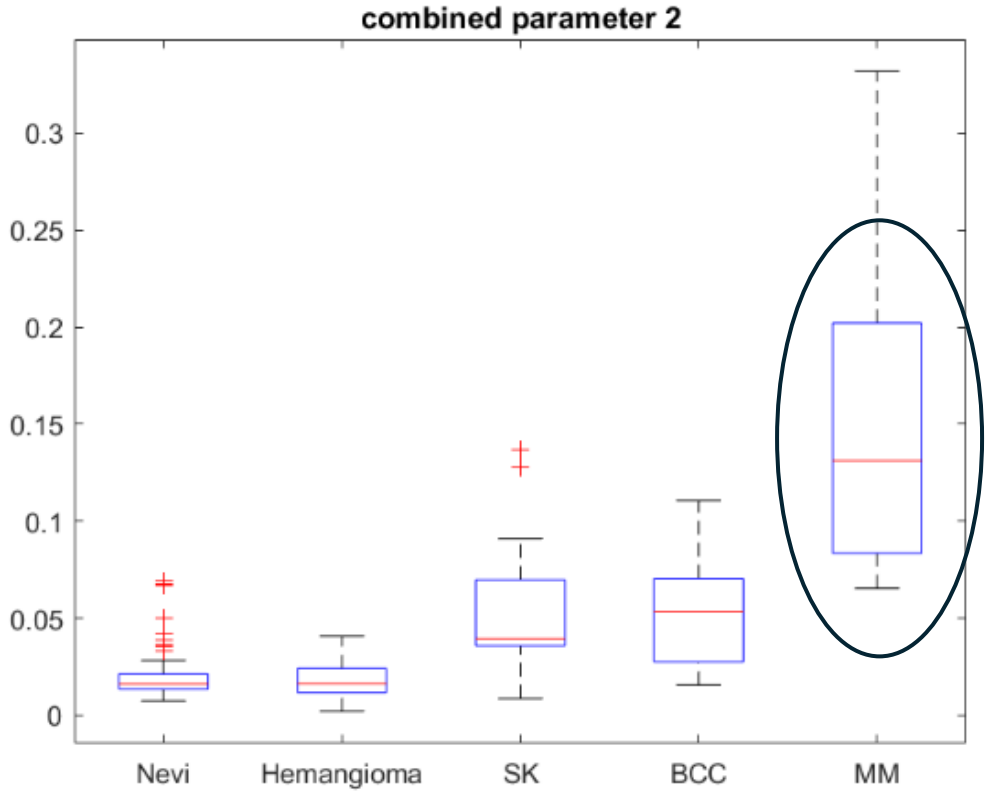
Malignances clearly stand-out in terms of roundness; MM and BCC differ by NIR contrast

Cancer-sensitive NIR spectral image parameters



C_{850} / R_{520}

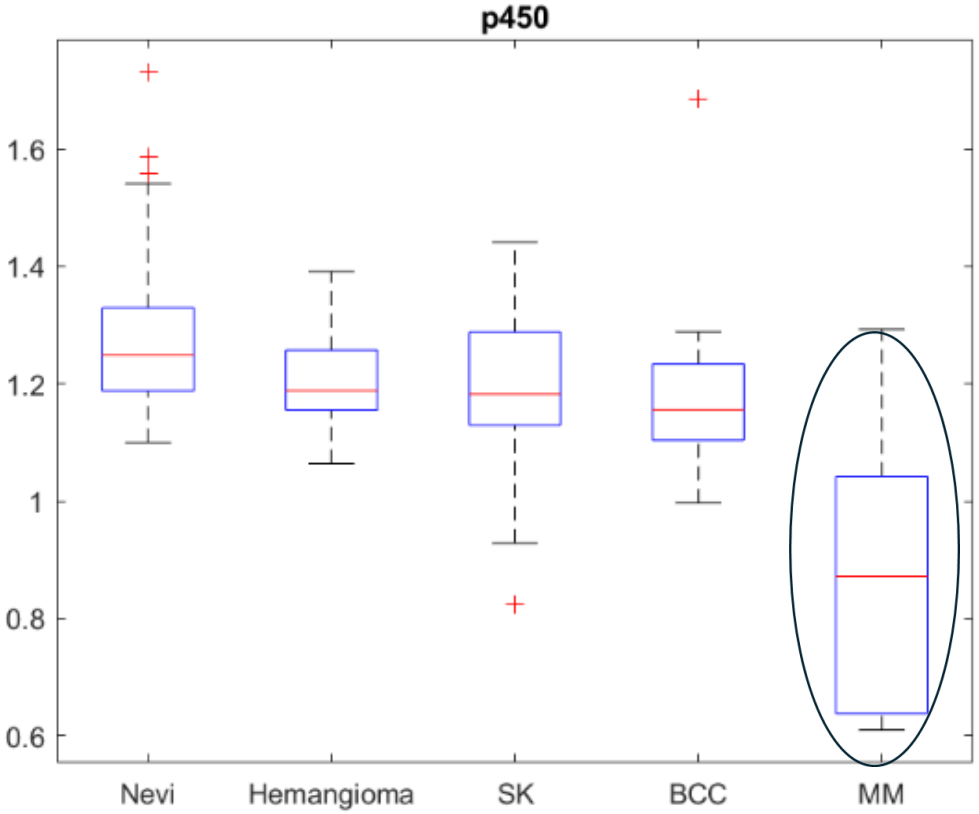
Both malignancies stand out

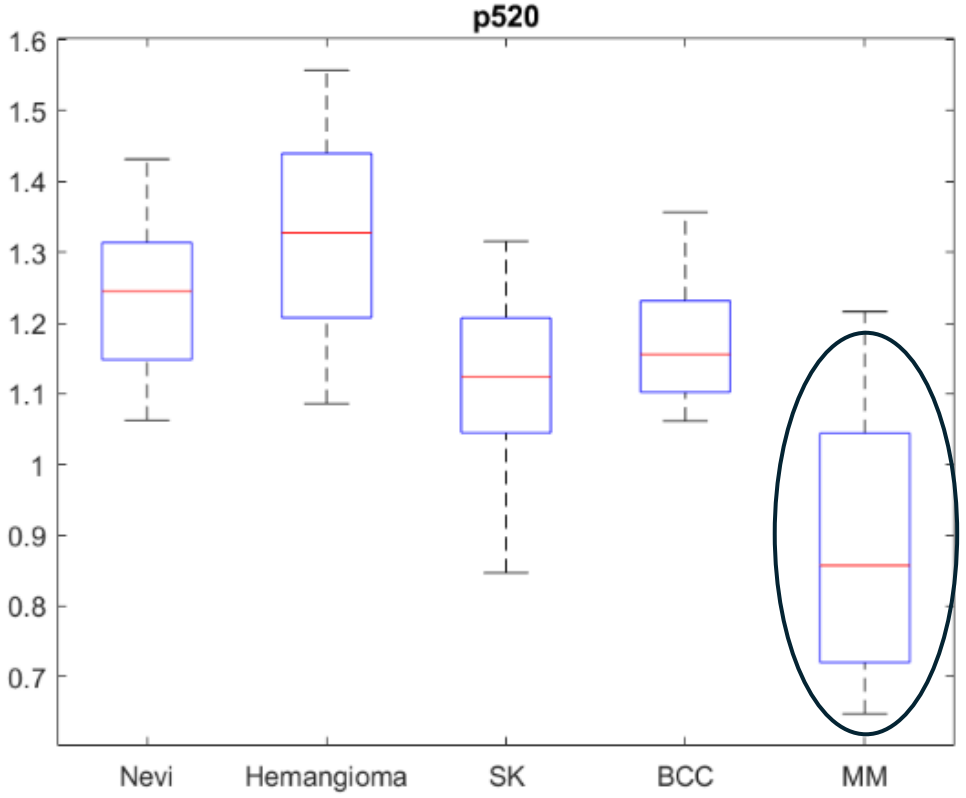


STD_{850} / R_{520}

Melanomas stand out

Combined NIR-VIS spectral image contrasts





$$p_{450} = \frac{C_{638} \cdot C_{850}}{C_{450}}$$

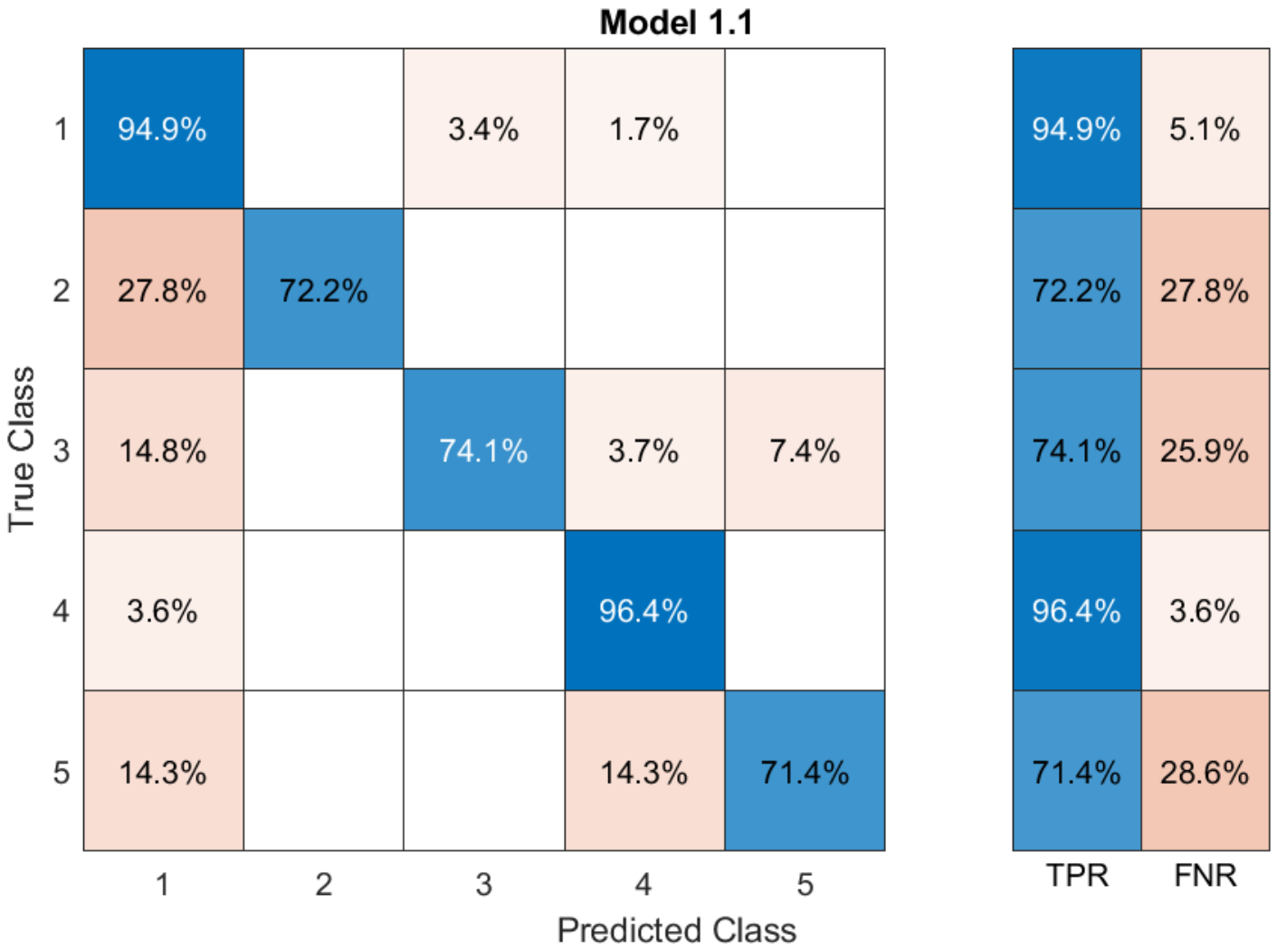
$$p_{520} = \frac{C_{638} \cdot C_{850}}{C_{520}}$$

Melanomas clearly stand out in both VIS-NIR spectral image contrast ratios

Results of AI-calculated classification: TPR ~ 71-96%

Diagnostic parameters:

1 – I_{malf} (0-1)
2 – I_{skin} (0-1)
3 – Std_{malf} (0-1)
4 – Std_{skin} (0-1)
5 – A (0-Inf)
6 – R (0-Inf)
7 – AF (false/true)



Classes:

1 – nevi
2 – hemangiomas
3 – SK
4 – BCC
5 - MM

Data of 450 nm, 520 nm, 638 nm, and 850 nm spectral images (in total **19 parameters**)

Summary

- The developed **prototype device and image processing software** proved to be **efficient** for remote detection of skin malignancies.
- **Melanomas, ulcerated basal cell carcinomas**: clearly exhibited in **NIR spectral images** (thanks to deeper skin invasion and hemoglobin absorption of the comprised blood).
- **Nevi**: fully disappeared in the NIR spectral images **(«NIR-fading» effect).**
- **Hemangiomas, seborrheic keratoses**: out-sorted by roundness / fluorescence at 450 nm
- Potential **cancer-sensitive clinical criteria** extracted from VIS-NIR spectral **i**mages:
  - **Single snapshot** under 450/520/850 nm illumination: $\mathbf{C_{850}/R_{520}}$, $\mathbf{STD_{850}/R_{520}}$
  - **Double snapshot**, 450/520/638 nm + 850 nm illumin.: $\mathbf{C_{638}*C_{850}/C_{450}}$, $\mathbf{C_{638}*C_{850}/C_{520}}$
- **AI automatic classification of VIS-NIR image sets:** true positive ratios 71-96% for five lesion groups; more clinical data needed to improve sensitivity and specificity.
- **Take-home message:** *remote VIS-NIR multispectral imaging technology is opening new prospects for skin cancer detection and screening*

Acknowledgments

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Thank You!

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