Microscopic Image Analysis of Printed Structures Without a Microscope: A Deep Learning Approach

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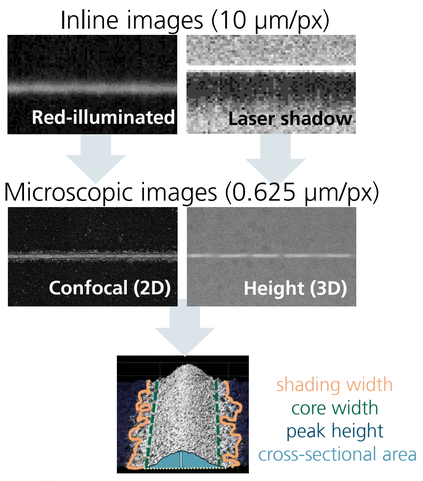
Motivation

- Knowledge of finger geometry crucial for print quality inspection
- High-resolution finger profile obtained via offline microscopic measurements
  - But: additional time and effort
- AOI tools provide low-resolution images of solar cells → Affects quality inspection
  - Critical for very thin printed structures

→ Derive microscopic-like finger geometry directly from inline optical images

Approach

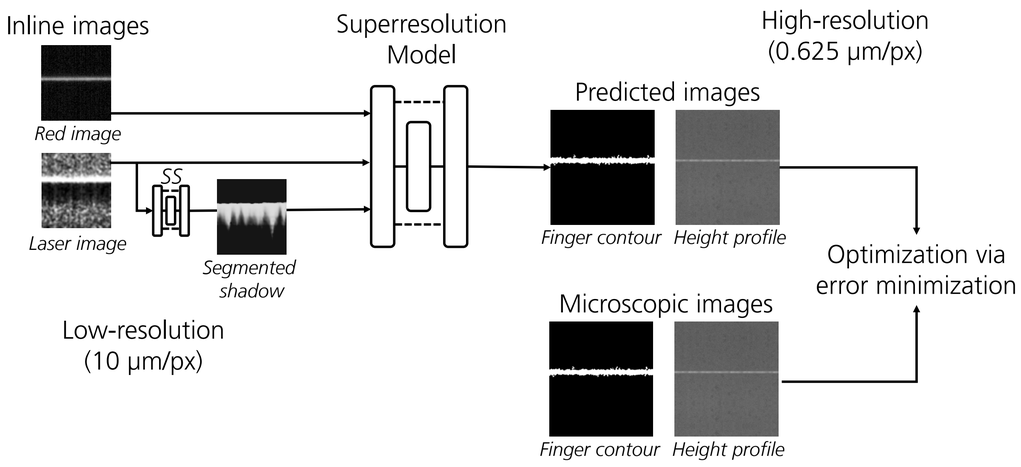
1. Superresolution model to predict high-resolution images from inline images
2. DeepFineUp model to predict the geometrical statistics from the generated high-resolution images
3. User-friendly geometrical quality maps



Finger geometry estimation

Superresolution model

- CNN learns to predict the microscopic-like high-resolution images
  - Used for geometrical parameter prediction
- Input: Cropped inline optical images
  - Red-illuminated image
  - Laser projected shadow image
  - Shadow contour image obtained by shadow segmentation 'SS' model
- Optimization by pixel-wise error minimization via microscopic reference data

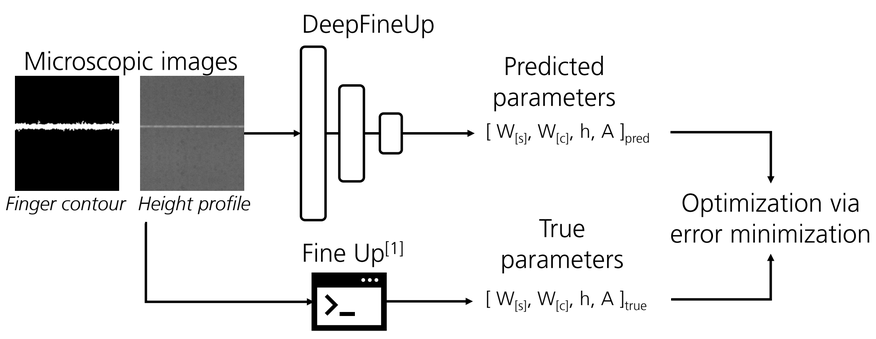


Superresolution model. Given inline input images, our model predicts high-resolution images.

DeepFineUp model

- Image processing-based analysis tools[1] estimates the finger geometry from high-resolution images
- But: time expensive at whole cell level

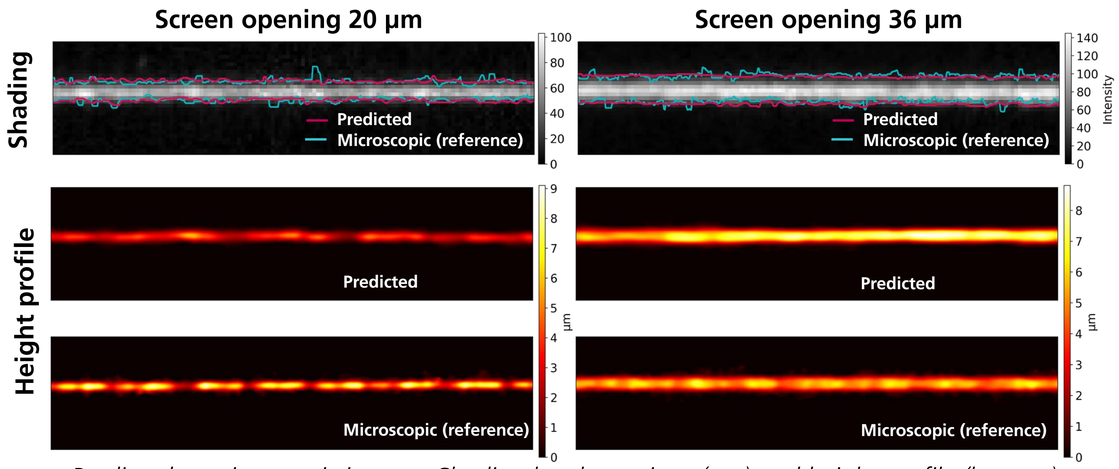
→ We implement a CNN[2] to predict the geometrical parameters
  - Input: high-resolution images containing 2D and 3D information
  - Target parameters obtained by applying FineUp on the images
  - Optimized via supervised learning using paired data



DeepFineUp model. Given the high-resolution images, the model predicts the finger parameters.

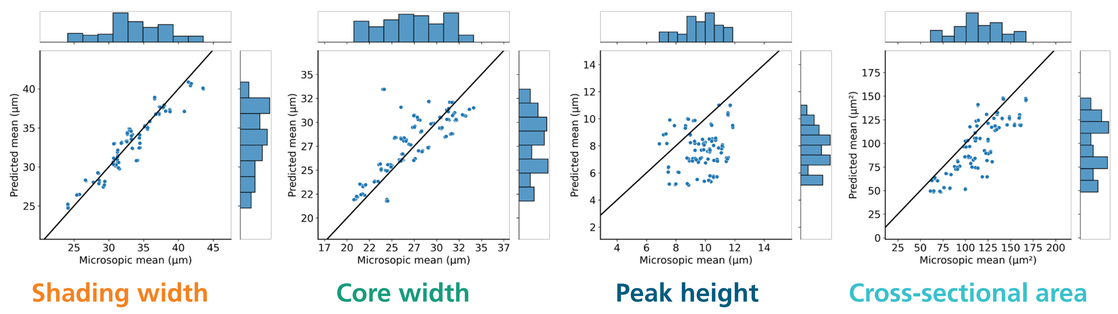
Results

Superresolution



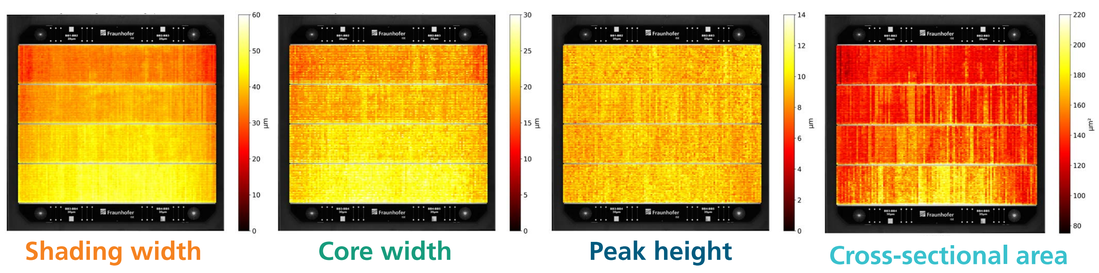
Predicted vs.microscopic images. Shading border regions (top) and height profile (bottom)

Correlation for each finger parameter

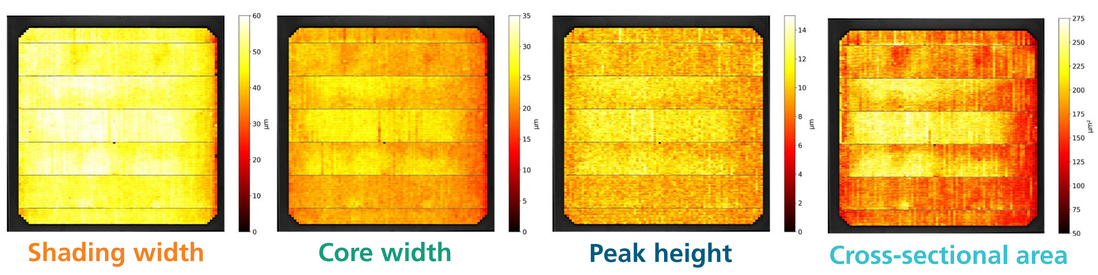


Correlation between predicted and microscopic mean parameter for each finger image patch

Q-maps: Reduced to statistically relevant quality parameters



Quality map of a flatbed screen-printed sample with screen openings of varying widths[3]



Quality map of rotatory screen-printed sample with a screen opening of 40 µm

Conclusion

- Tool to generate quality maps from inline optical images without the need of offline microscopic measurements
- Superresolution model generates respective high-resolution images
- DeepFineUp model successfully predicts geometrical parameters from generated high-resolution images
- Quality maps revealing the geometrical finger profile are generated
- Applicable on different metallization layouts, different printing methods

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1 Trötschler, T. et al . (2014). Two Image Processing Tools to Analyse Alkaline Texture and Contact Finger Geometry in Microscope Images.
2 Bengio, Y. & Lecun, Yann. (1997). Convolutional Networks for Images, Speech, and Time-Series.
3 Pingel, S. et al. (2020). Low-temperature Ag-paste Screening for Silicon Heterojunction Solar Cells And Modules.

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link to Fraunhofer ISE contributions of the 40th EU PVSEC
https://ise.link/eupvsec2023
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