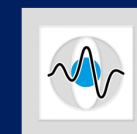# Weakly Supervised Segmentation of Cracks on Solar Cells using Normalized L_p Norm
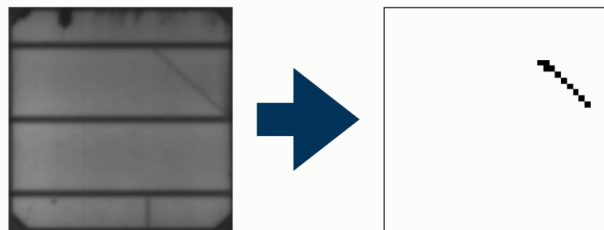
Martin Mayr, Mathis Hoffmann, Andreas Maier, Vincent Christlein

Pattern Recognition Lab, Friedrich-Alexander University Erlangen-Nürnberg, Germany

Motivation / Problem description

Weakly-supervised segmentation [2] of cracks on EL images without pixelwise labels

- Photovoltaics (PV): important part of renewable energy sources
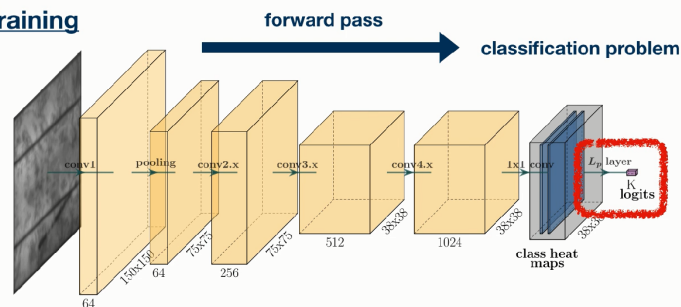- Microcracks can cause severe damage on already installed PV

Data

ELPV dataset [1] augmented with image-level annotations regarding microcracks
- 2426 electroluminescence 8-bit grayscale images of 44 different solar modules
- training/validation: 2126 samples | test: 300 samples
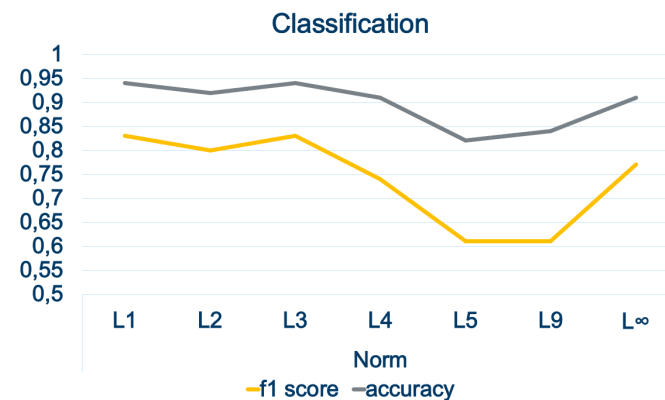
Method overview

Training   forward pass   classification problem

Classification using normalized L_p norm [3]

$$L_p(\vec{y}) = \left(\frac{1}{N} \sum_{i=1}^{N} |y_i|^p \right)^{\frac{1}{p}}$$

$\vec{y}$: flattened activation map Y
N: number of elements in $\vec{y}$
p: scalar for L_p layer

Classification results

Classification

— f1 score — accuracy

Effect of different p values on heat maps

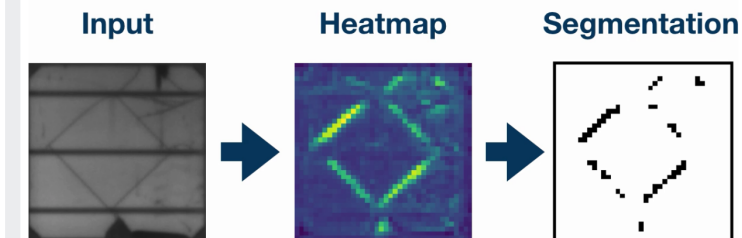| Input	L_1	L_3	L_{inf}

Segmentation rule

$$seg(y_i) = \begin{cases} 1, \text{for } y_i > \frac{\max(Y)}{2} \\ 0, \text{else} \end{cases}$$

Y: activation map
y_i: item/pixel i of Y

Segmentation results with L_∞

Input   **Heatmap**   **Segmentation**

Conclusion

- Coarse segmentation of cracks on EL images possible with only a small number of image-level annotated samples
- No excessive postprocessing necessary

References

[1] https://github.com/zae-bayern/elpv-dataset
[2] Oquab et al. Is object localization for free? – weakly-supervised learning with convolutional neural networks. In CVPR. 2015.
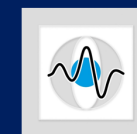[3] Gulcehre et al. Learned-norm pooling for deep feedforward and recurrent neural networks. In ECML PKDD. 2014.

Acknowledgement

Weakly Supervised Segmentation of Cracks on Solar Cells using Normalized L_p Norm

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Pattern Recognition Lab, Friedrich-Alexander University Erlangen-Nürnberg, Germany

Motivation / Problem description

Microcrack

- often leads to big cracks or defective regions after a few warm-cold cycles
- hard to detect on polycrystalline solar cells

- Photovoltaics (PV): important part of renewable energy sources
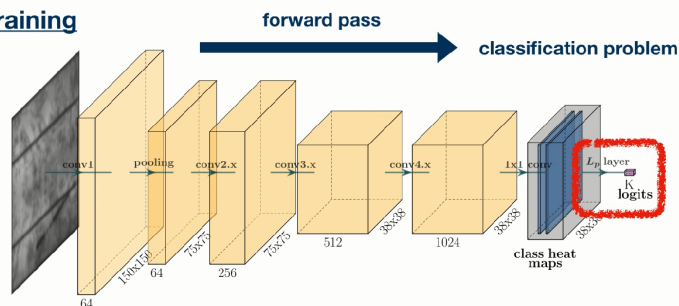- Microcracks can cause severe damage on already installed PV

Data

ELPV dataset [1] augmented with image-level annotations regarding microcracks

- 2426 electroluminescence 8-bit grayscale images of 44 different solar modules
- training/validation: 2126 samples | test: 300 samples

Method overview

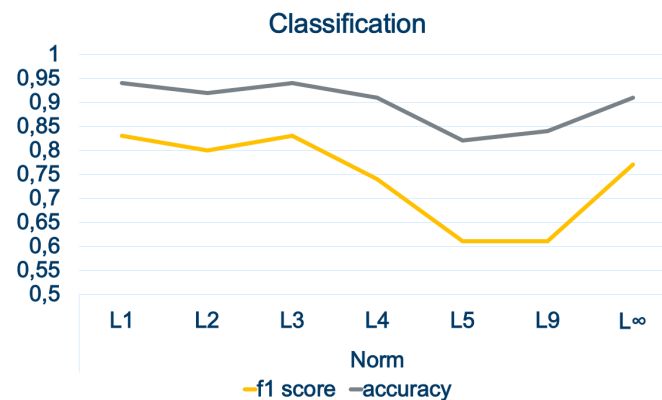## Classification using normalized L_p norm [3]

$$L_p(\vec{y}) = \left(\frac{1}{N} \sum_{i=1}^{N} |y_i|^p \right)^{\frac{1}{p}}$$

$\vec{y}$: flattened activation map Y
N: number of elements in $\vec{y}$
p: scalar for L_p layer

Classification results

Effect of different p values on heat maps
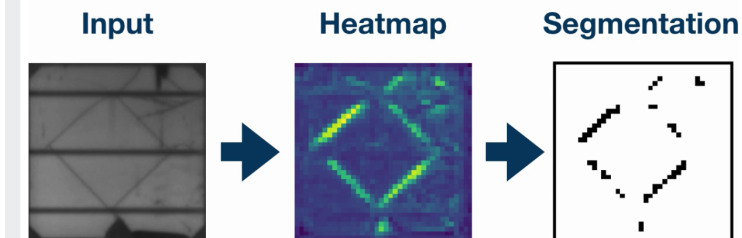

| Input | L_1 | L_3 | L_{inf} |

Segmentation rule

$$seg(y_i) = \begin{cases} 1, \text{for } y_i > \frac{\max(Y)}{2} \\ 0, \text{else} \end{cases}$$

Y: activation map
y_i: item/pixel i of Y

Segmentation results with L_∞

Input → Heatmap → Segmentation

Conclusion

- Coarse segmentation of cracks on EL images possible with only a small number of image-level annotated samples
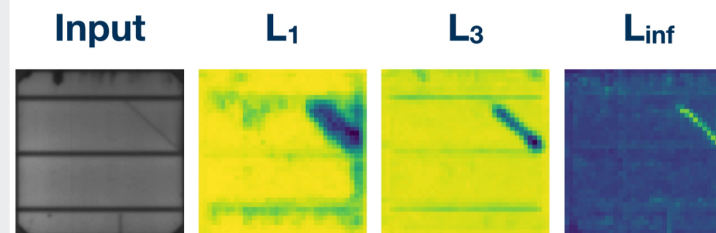- No excessive postprocessing necessary

References

[1] https://github.com/zae-bayern/elpv-dataset
[2] Oquab et al. Is object localization for free? – weakly-supervised learning with convolutional neural networks. In CVPR. 2015.
[3] Gulcehre et al. Learned-norm pooling for deep feedforward and recurrent neural networks. In ECML PKDD. 2014.

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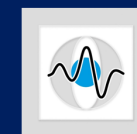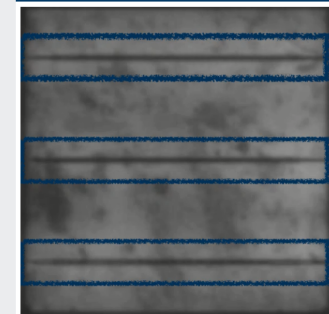
Weakly Supervised Segmentation of Cracks on Solar Cells using Normalized L_p Norm

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Pattern Recognition Lab, Friedrich-Alexander University Erlangen-Nürnberg, Germany

Motivation / Problem description

Busbars

- important for the conduction of the direct current
- 2 - 5 busbars per cell
- should not be classified as crack

- Photovoltaics (PV): important part of renewable energy sources
- Microcracks can cause severe damage on already installed PV
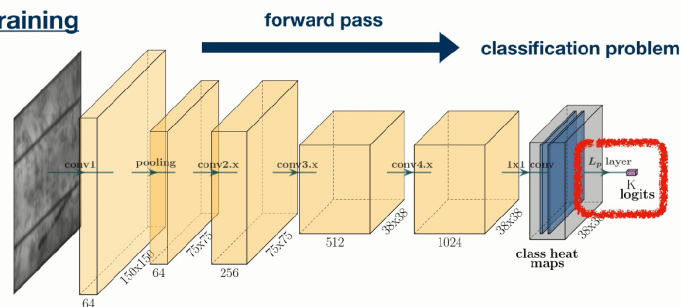
Data

ELPV dataset [1] augmented with image-level annotations regarding microcracks

- 2426 electroluminescence 8-bit grayscale images of 44 different solar modules
- training/validation: 2126 samples | test: 300 samples
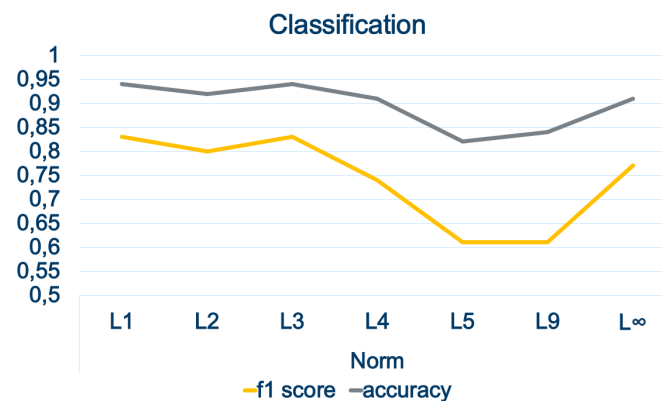
Method overview

Training — forward pass — classification problem

Classification using normalized L_p norm [3]

$$L_p(\vec{y}) = \left(\frac{1}{N} \sum_{i=1}^{N} |y_i|^p \right)^{\frac{1}{p}}$$

$\vec{y}$: flattened activation map Y
N: number of elements in $\vec{y}$
p: scalar for L_p layer

Classification results

Classification — f1 score, accuracy — Norm: L1, L2, L3, L4, L5, L9, L∞

Effect of different p values on heat maps
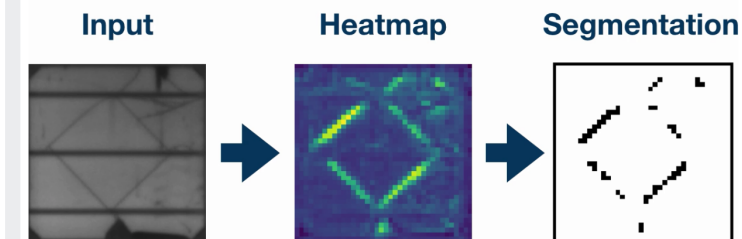

Input — L_1 — L_3 — L_{inf}

Segmentation rule

$$seg(y_i) = \begin{cases} 1, \text{for } y_i > \frac{\max(Y)}{2} \\ 0, \text{else} \end{cases}$$

Y: activation map
y_i: item/pixel i of Y

Segmentation results with L_∞

Input — Heatmap — Segmentation

Conclusion

- Coarse segmentation of cracks on EL images possible with only a small number of image-level annotated samples
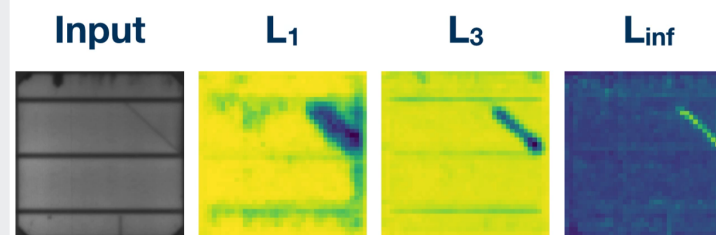- No excessive postprocessing necessary

References

[1] https://github.com/zae-bayern/elpv-dataset
[2] Oquab et al. Is object localization for free? – weakly-supervised learning with convolutional neural networks. In CVPR. 2015.
[3] Gulcehre et al. Learned-norm pooling for deep feedforward and recurrent neural networks. In ECML PKDD. 2014.
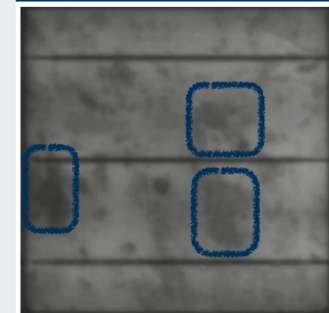
Acknowledgement

Weakly Supervised Segmentation of Cracks on Solar Cells using Normalized L_p Norm

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Pattern Recognition Lab, Friedrich-Alexander University Erlangen-Nürnberg, Germany

Motivation / Problem description

Noisy regions

- polycrystalline solar cells consist of many fragments melted together
- should not be classified as crack

- Photovoltaics (PV): important part of renewable energy sources
- Microcracks can cause severe damage on already installed PV
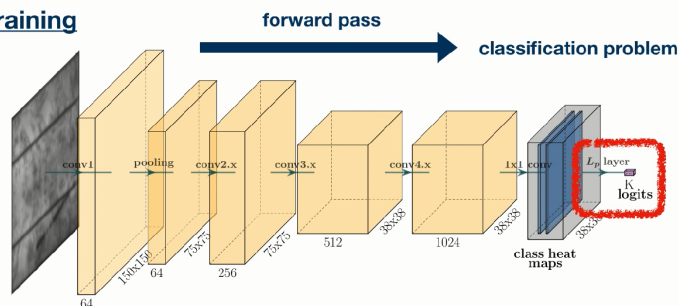
Data

ELPV dataset [1] augmented with image-level annotations regarding microcracks
- 2426 electroluminescence 8-bit grayscale images of 44 different solar modules
- training/validation: 2126 samples | test: 300 samples
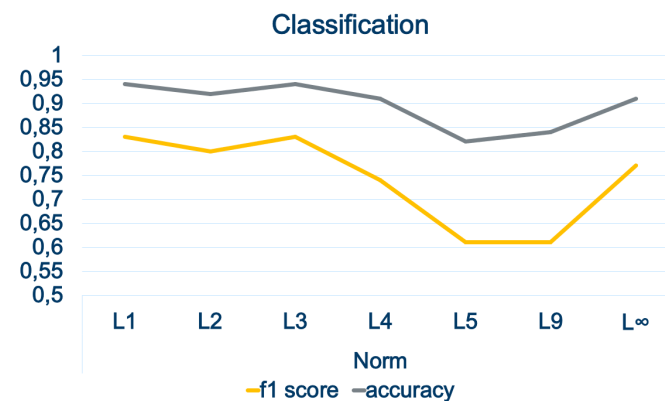
Method overview

Training — forward pass — classification problem

Classification using normalized L_p norm [3]

$$L_p(\vec{y}) = \left(\frac{1}{N} \sum_{i=1}^{N} |y_i|^p \right)^{\frac{1}{p}}$$

$\vec{y}$: flattened activation map Y
N: number of elements in $\vec{y}$
p: scalar for L_p layer

Classification results

Classification

f1 score — accuracy

Norm: L1, L2, L3, L4, L5, L9, L∞

Effect of different p values on heat maps
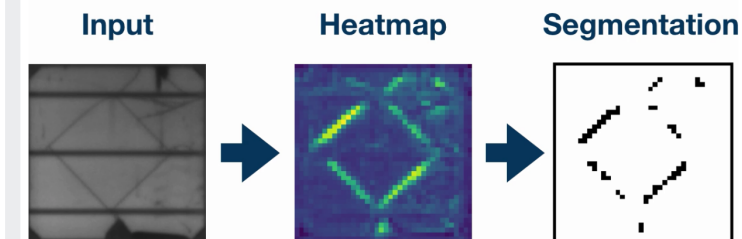

Input — L_1 — L_3 — L_{inf}

Segmentation rule

$$seg(y_i) = \begin{cases} 1, \text{for } y_i > \frac{\max(Y)}{2} \\ 0, \text{else} \end{cases}$$

Y: activation map
y_i: item/pixel i of Y

Segmentation results with L_∞

Input — Heatmap — Segmentation

Conclusion

- Coarse segmentation of cracks on EL images possible with only a small number of image-level annotated samples
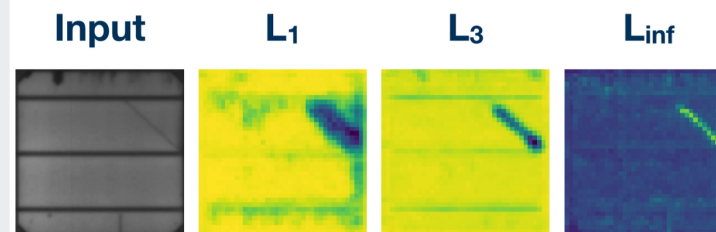- No excessive postprocessing necessary

References

[1] https://github.com/zae-bayern/elpv-dataset
[2] Oquab et al. Is object localization for free? – weakly-supervised learning with convolutional neural networks. In CVPR. 2015.
[3] Gulcehre et al. Learned-norm pooling for deep feedforward and recurrent neural networks. In ECML PKDD. 2014.

Acknowledgement
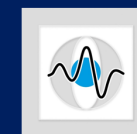
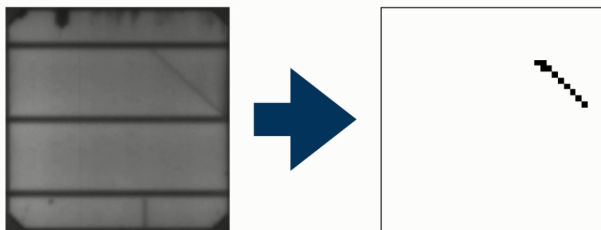# Weakly Supervised Segmentation of Cracks on Solar Cells using Normalized L_p Norm

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FAU FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG
TECHNISCHE FAKULTÄT

Motivation / Problem description

Weakly-supervised segmentation [2] of cracks on EL images without pixelwise labels

- Photovoltaics (PV): important part of renewable energy sources
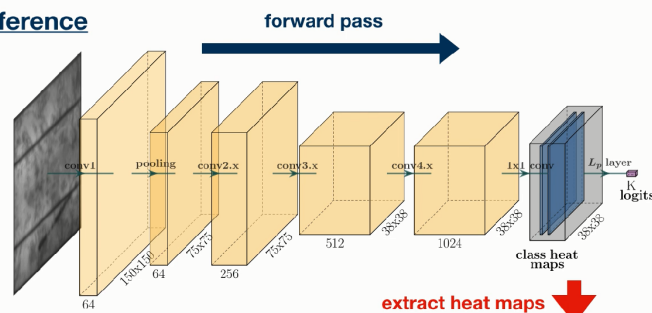- Microcracks can cause severe damage on already installed PV

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ELPV dataset [1] augmented with image-level annotations regarding microcracks
- 2426 electroluminescence 8-bit grayscale images of 44 different solar modules
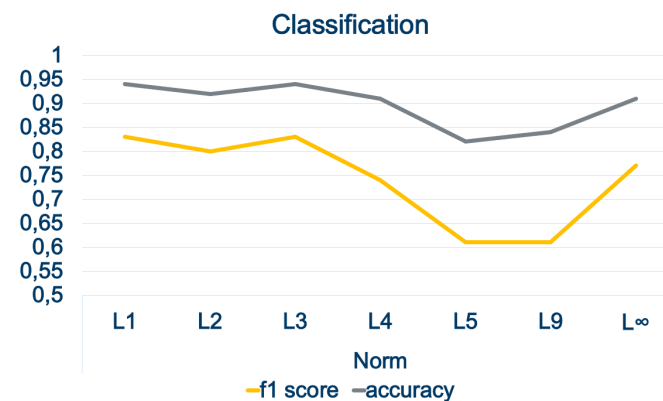- training/validation: 2126 samples | test: 300 samples

Method overview

Classification using normalized L_p norm [3]

$$L_p(\vec{y}) = \left(\frac{1}{N} \sum_{i=1}^{N} |y_i|^p \right)^{\frac{1}{p}}$$

$\vec{y}$: flattened activation map Y
N: number of elements in $\vec{y}$
p: scalar for L_p layer

Classification results

Classification

—f1 score —accuracy

Effect of different p values on heat maps
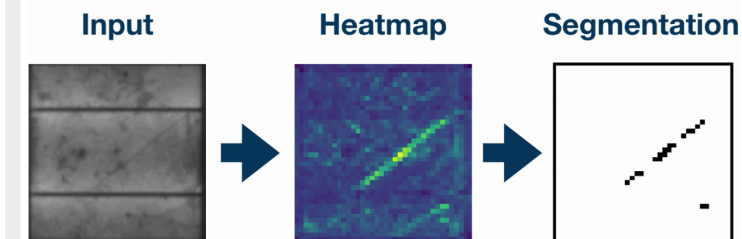
Input	L_1	L_3	L_{inf}

Segmentation rule

$$seg(y_i) = \begin{cases} 1, \text{for } y_i > \frac{\max(Y)}{2} \\ 0, \text{else} \end{cases}$$

Y: activation map
y_i: item/pixel i of Y

Segmentation results with L_∞

Input	Heatmap	Segmentation

Conclusion

- Coarse segmentation of cracks on EL images possible with only a small number of image-level annotated samples
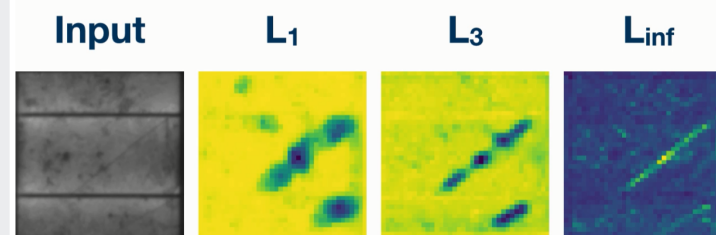- No excessive postprocessing necessary

References

[1] https://github.com/zae-bayern/elpv-dataset
[2] Oquab et al. Is object localization for free? – weakly-supervised learning with convolutional neural networks. In CVPR. 2015.
[3] Gulcehre et al. Learned-norm pooling for deep feedforward and recurrent neural networks. In ECML PKDD. 2014.

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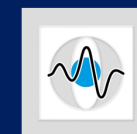
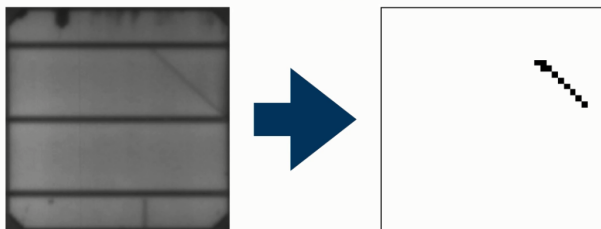# Weakly Supervised Segmentation of Cracks on Solar Cells using Normalized L_p Norm

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TECHNISCHE FAKULTÄT

Motivation / Problem description

Weakly-supervised segmentation [2] of cracks on EL images without pixelwise labels

- Photovoltaics (PV): important part of renewable energy sources
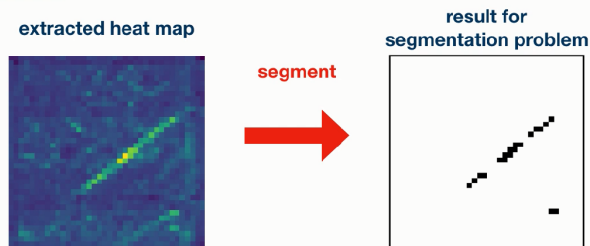- Microcracks can cause severe damage on already installed PV

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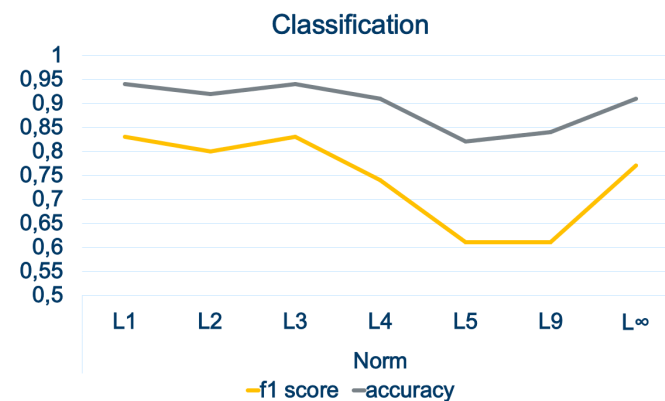
Method overview

Inference

extracted heat map

segment

result for segmentation problem

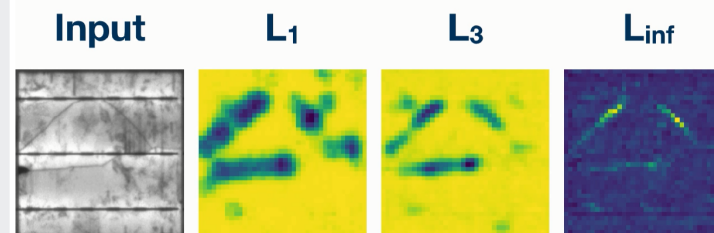## Classification using normalized L_p norm [3]

$$L_p(\vec{y}) = \left(\frac{1}{N} \sum_{i=1}^{N} |y_i|^p \right)^{\frac{1}{p}}$$

$\vec{y}$: flattened activation map Y
N: number of elements in $\vec{y}$
p: scalar for L_p layer

Classification results

Classification

— f1 score — accuracy

Effect of different p values on heat maps

Input	L_1	L_3	L_{inf}

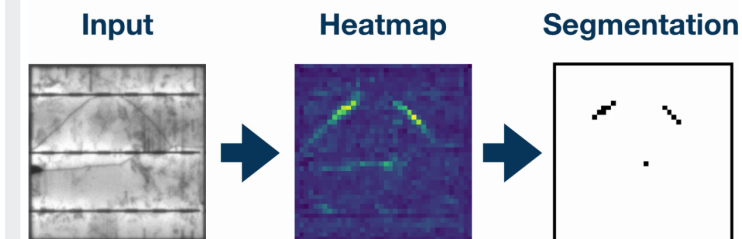## Segmentation rule

$$seg(y_i) = \begin{cases} 1, & \text{for } y_i > \frac{\max(Y)}{2} \\ 0, & \text{else} \end{cases}$$

Y: activation map
y_i: item/pixel i of Y

Segmentation results with L_∞

Input   **Heatmap**   **Segmentation**

Conclusion

- Coarse segmentation of cracks on EL images possible with only a small number of image-level annotated samples
- No excessive postprocessing necessary

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[1] https://github.com/zae-bayern/elpv-dataset
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