Attention!
Is Recycling Artificial Neural Network Effective for Maintaining Renewable Energy Efficiency?

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* speaker

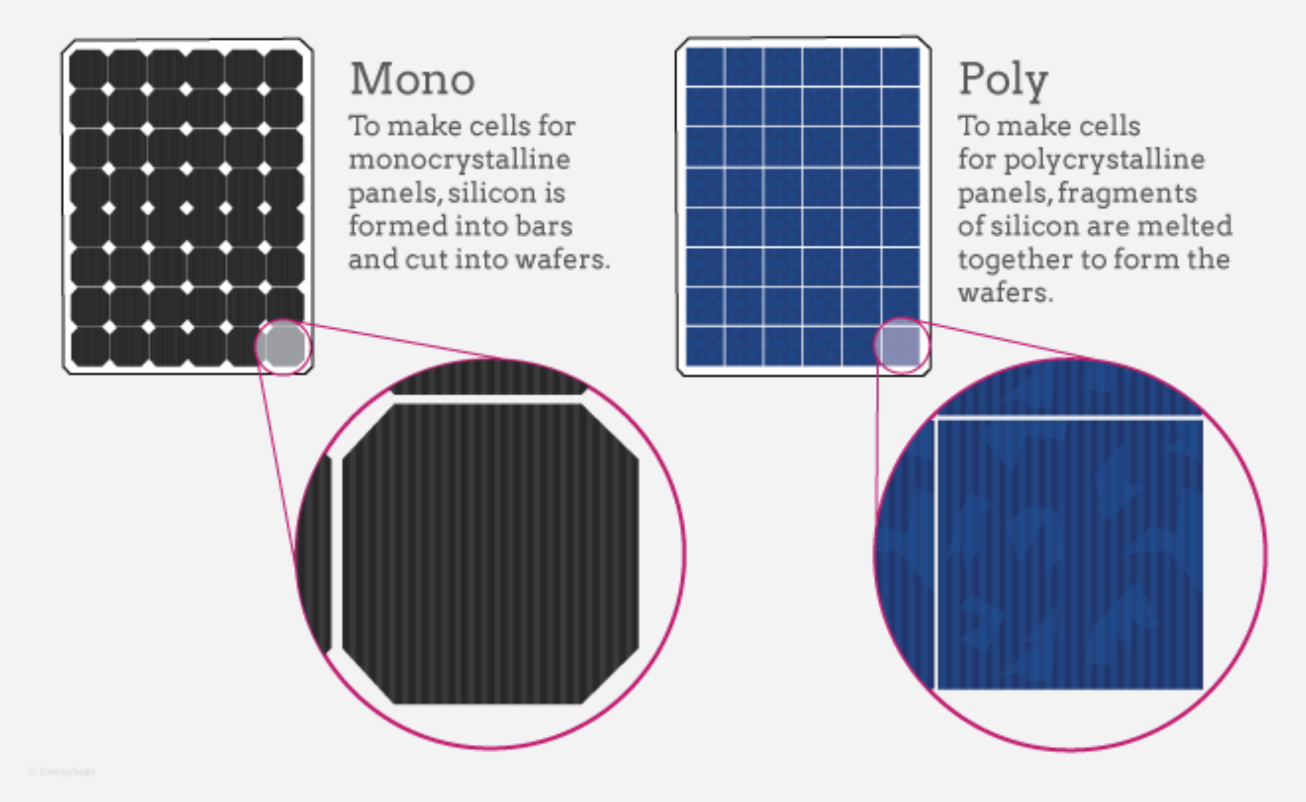
Contents

Introduction

Renewable Energy

In focus: Renewable energy in Europe, *European Commission*, 18 March 2020.

Type of solar panels



Monocrystalline

- Single pure silicon crystal
- Uniform dark squares
- 15~20% of conversion efficiency
- 40 years of lifespan
- More expensive

Polycrystalline

- Different Silicon Fragments
- Irregular blue squares dark squares
- 13~16% of conversion efficiency
- 35 years of lifespan
- Less expensive

Monocrystalline vs Polycrystalline Solar Panels, *American solar energy society*, 20 February 2021.

Efficiency of photovoltaic system

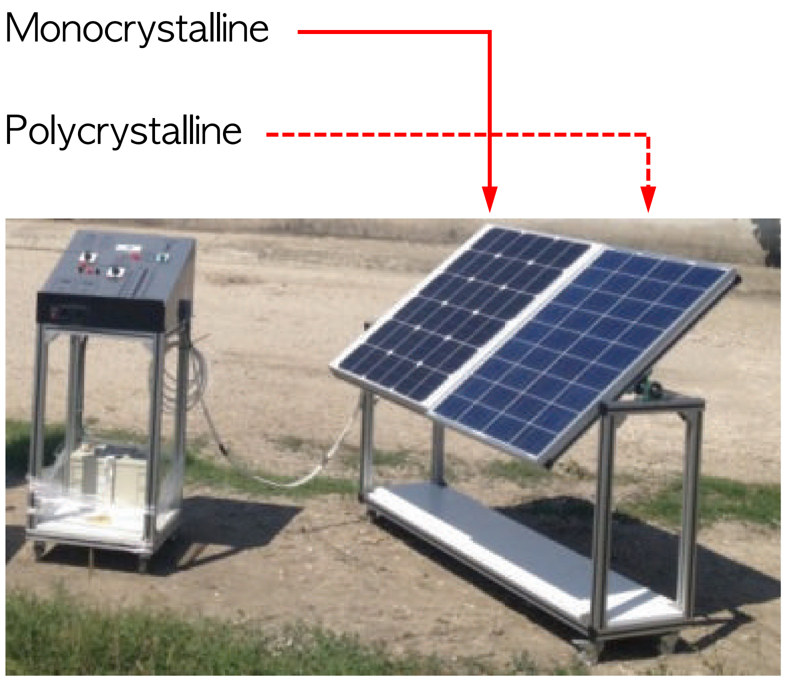


FIGURE 2: Photograph of apparatus.

Panel type	Average efficiency
Monocrystalline	6.65%
Polycrystalline	5.38%

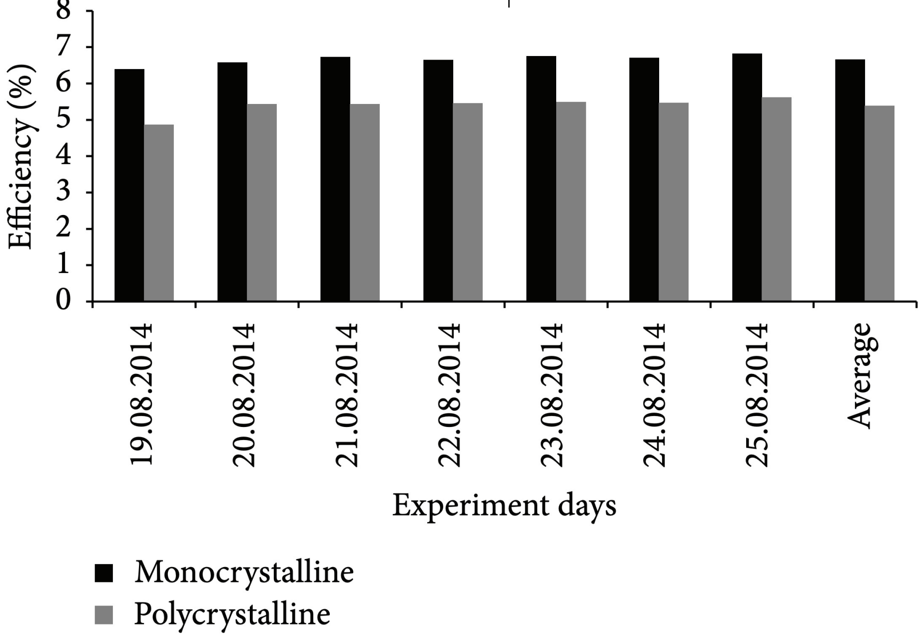
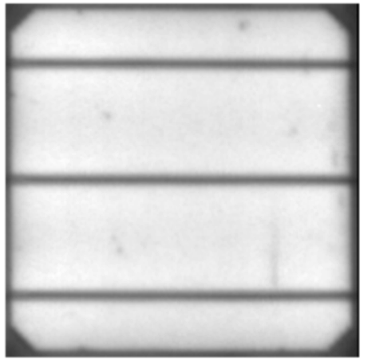


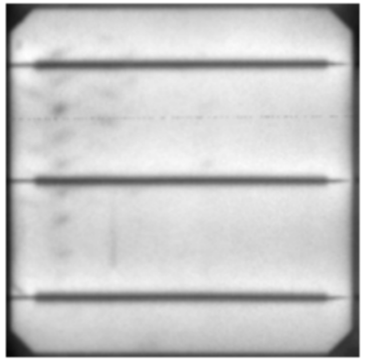
FIGURE 7: Panels efficiencies ratio.

Taşçıoğlu, Ayşegül, Onur Taşkın, and Ali Vardar. "A power case study for monocrystalline and polycrystalline solar panels in Bursa City, Turkey." *International Journal of Photoenergy* 2016.

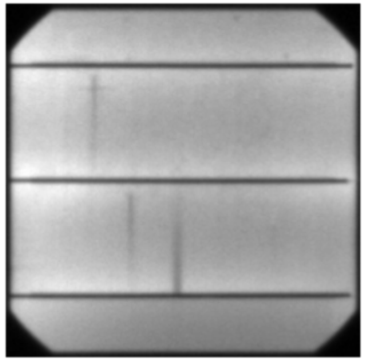
Solar Panels



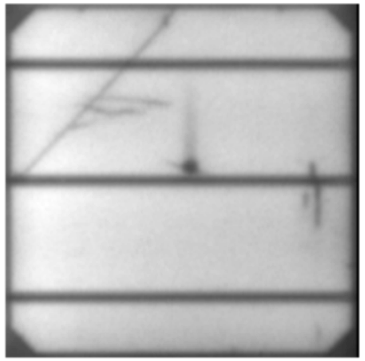
Non-defective



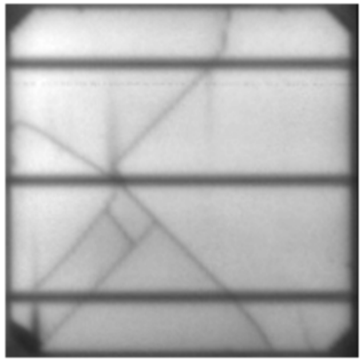
Defective
(1/3-level)



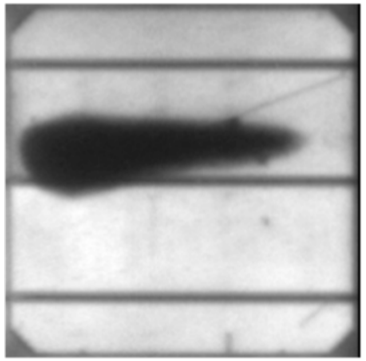
Defective
(2/3-level)



Complete Defective
(Crack)



Complete Defective
(Crack)



Complete Defective
(Contamination)

Buerhop-Lutz, Claudia, et al. "A benchmark for visual identification of defective solar cells in electroluminescence imagery." *35th European PV Solar Energy Conference and Exhibition*, 2018.

Problem and goal

- Cause of the decrease in efficiency
  - Cracks
  - Contaminations
  - No/slow response to fix the above states
- For maximizing the efficiency
  - Detect the defectives
  - Fix defectives as soon as possible

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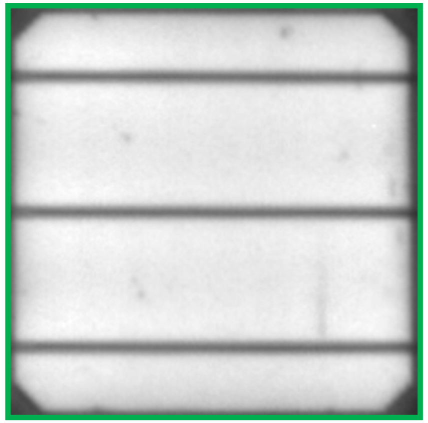
Approach

Limitations of the conventional methods

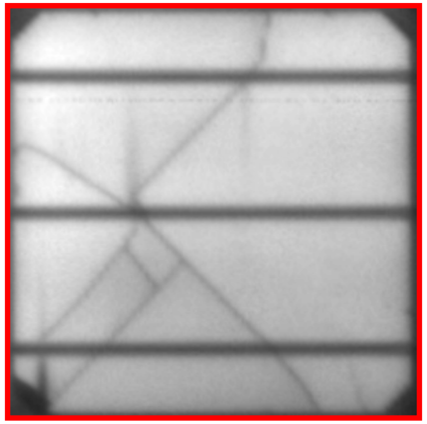
- Deep learning-based Classification method (supervised)
  - Needs one-to-one class label
  - High complexity, high power consumption

- Segmentation method
  - Needs one-to-one segmentation mask
  - Marking the defective area is unnecessary

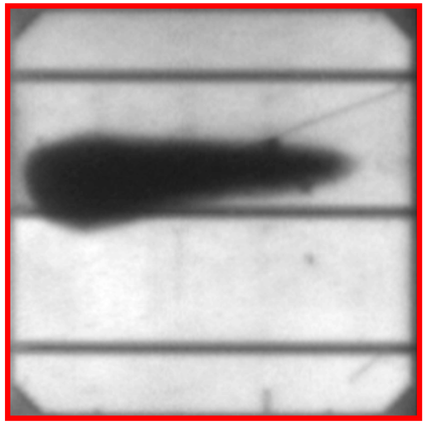
Easy to understand



Non-defective



Defective
(Crack)

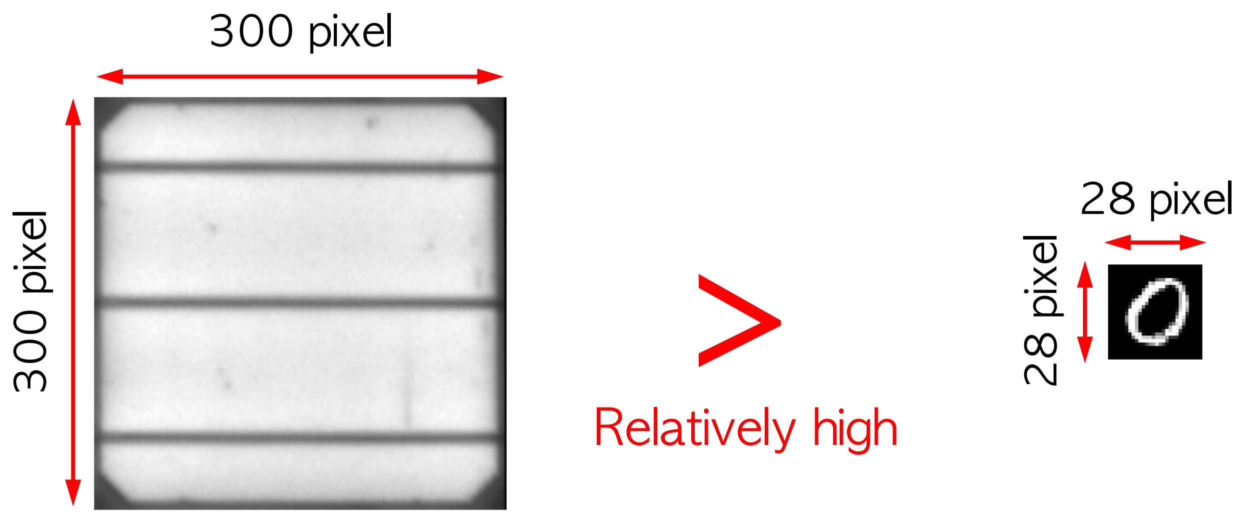


Defective
(Contamination)

- Is the given information sufficient? → Yes
- Do we need high-complex model? → Probably not

Buerhop-Lutz, Claudia, et al. "A benchmark for visual identification of defective solar cells in electroluminescence imagery." *35th European PV Solar Energy Conference and Exhibition,* 2018.

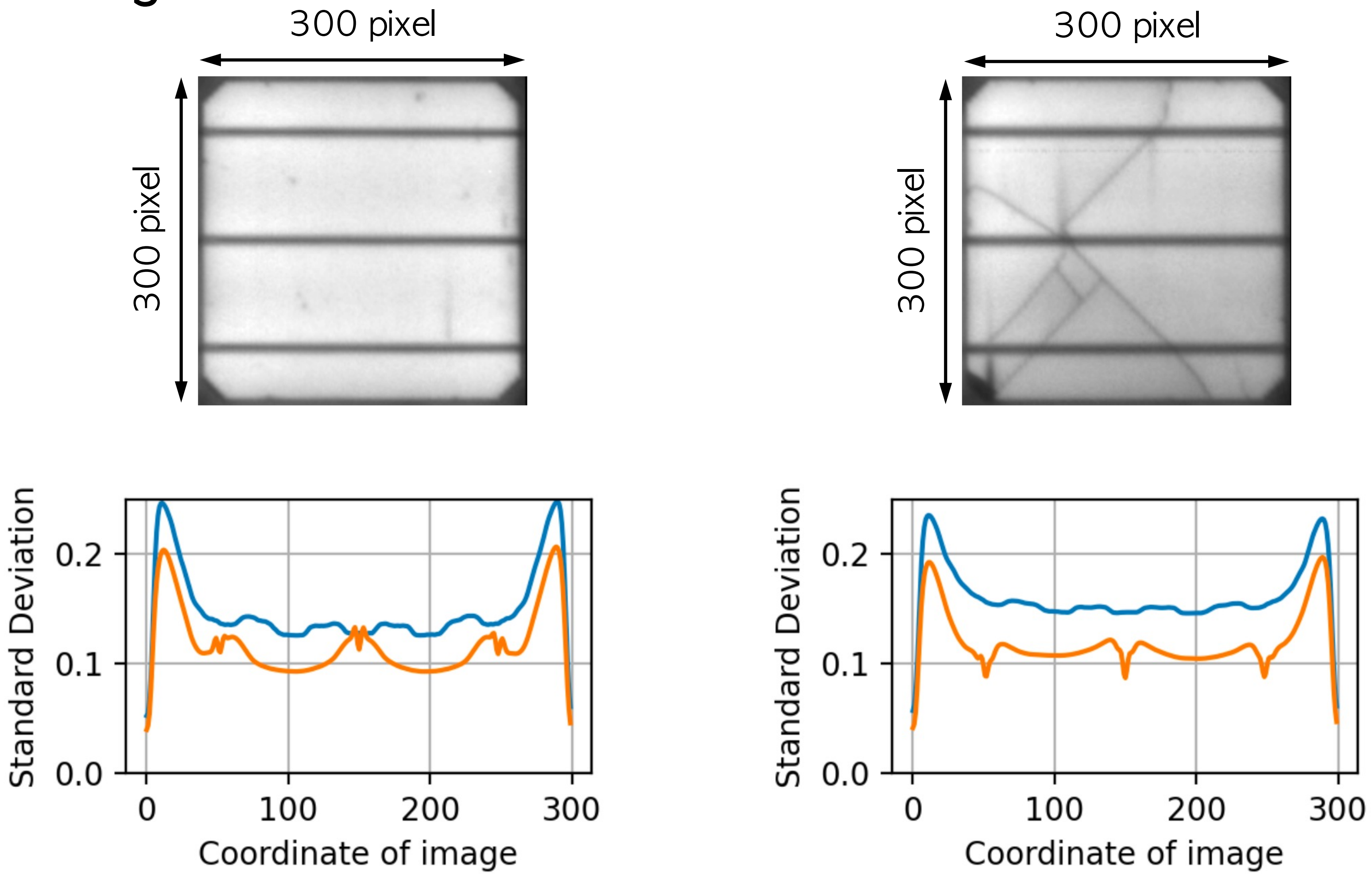
Need to reduce the computational cost



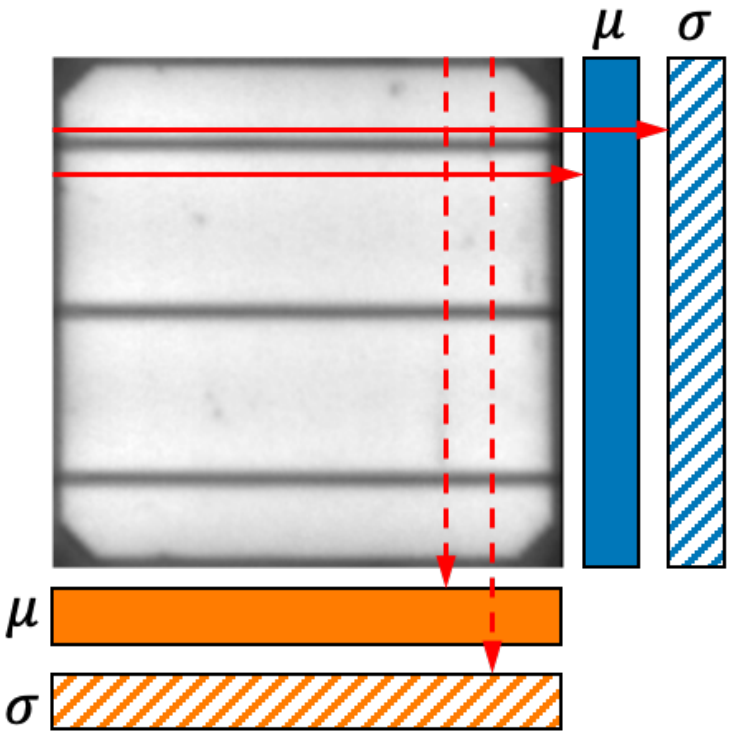
- Training for the high-resolution image requires large computing power.
- Large / high-performance computing is at odds with the concept of renewable energy.

- Blue line: height-axis
- Orange line: width-axis

Easy to distinguish



Feature Extraction



Feature	Description
μ_{image}	Mean of whole pixel values
σ_{image}	Standard deviation (SD) of whole pixel values
R	Outlier rate that deviate from the threshold, $\mu \pm 1.5\sigma$, among image
S	Skewness of whole pixel values
$S(\mu_{height})$	Skewness of the pixel mean along the height axis
$S(\mu_{width})$	Skewness of the pixel mean along the width axis
$S(\sigma_{height})$	Skewness of the pixel SD along the height axis
$S(\sigma_{width})$	Skewness of the pixel SD along the height axis
K	Kurtosis of whole pixel values
$K(\mu_{height})$	Kurtosis of the pixel mean along the height axis
$K(\mu_{width})$	Kurtosis of the pixel mean along the width axis
$K(\sigma_{height})$	Kurtosis of the pixel SD along the height axis
$K(\sigma_{width})$	Kurtosis of the pixel SD along the height axis

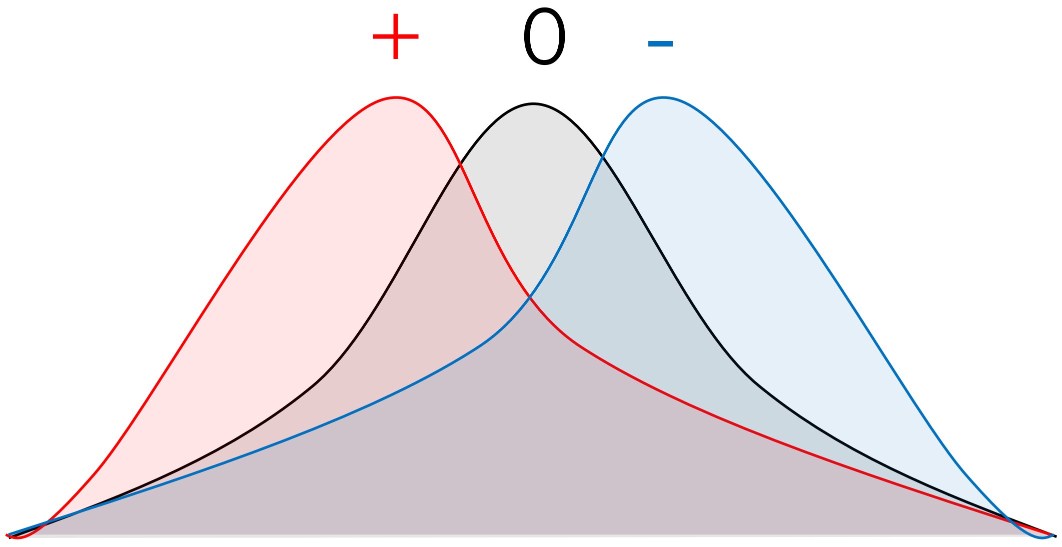
300 x 300 pixel values → 13 statistical features

Computational cost is reduced by 0.014%-level.

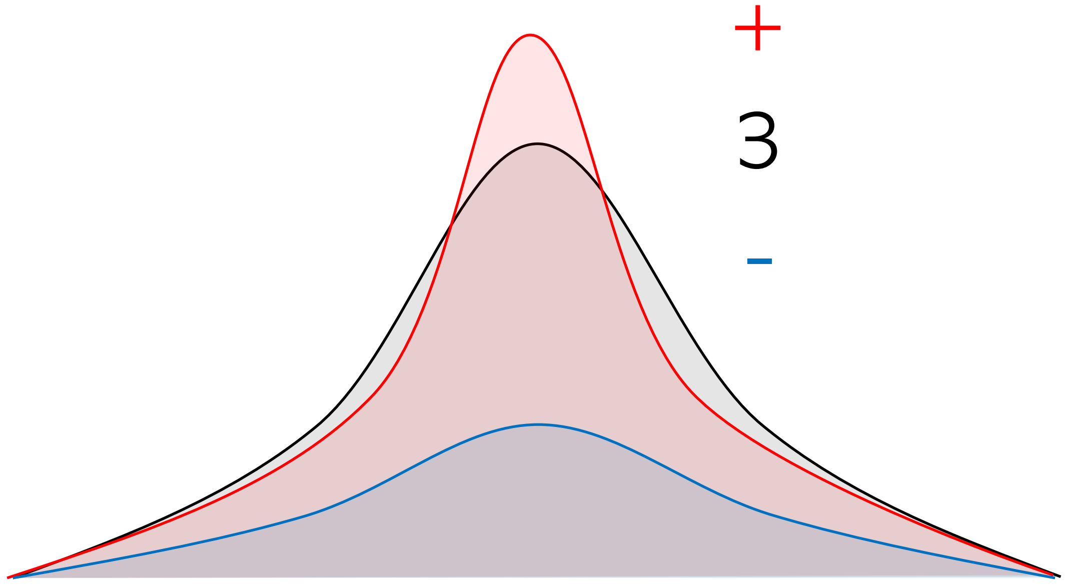
- Black: Reference
- Blue: Negative (or small)
- Red: Positive (or large)

Skewness and Kurtosis

Data (Matrix / Vector) → Histogram (Vector) → Skewness / Kurtosis (Scalar)



Skewness



Kurtosis

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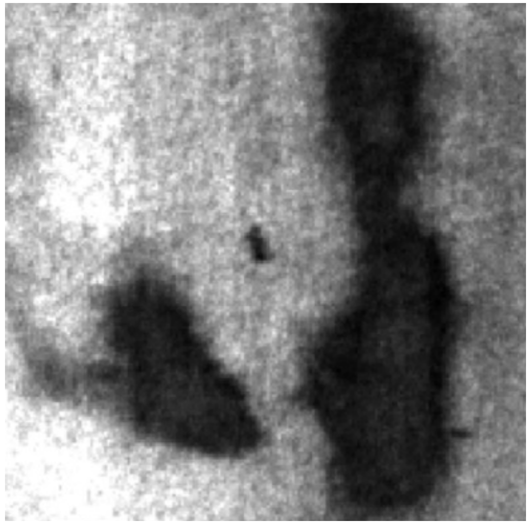
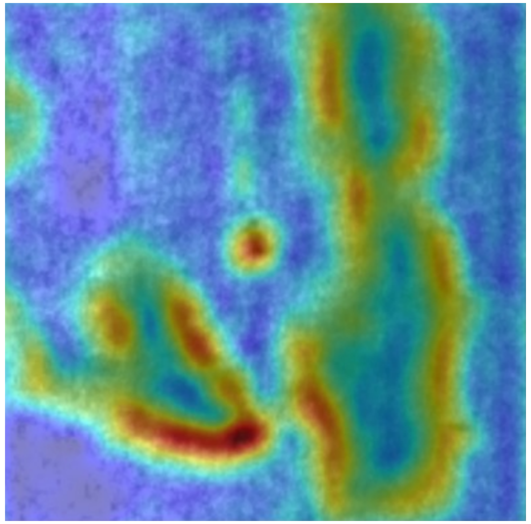
Information emphasizing will be helpful

Information Emphasizing!



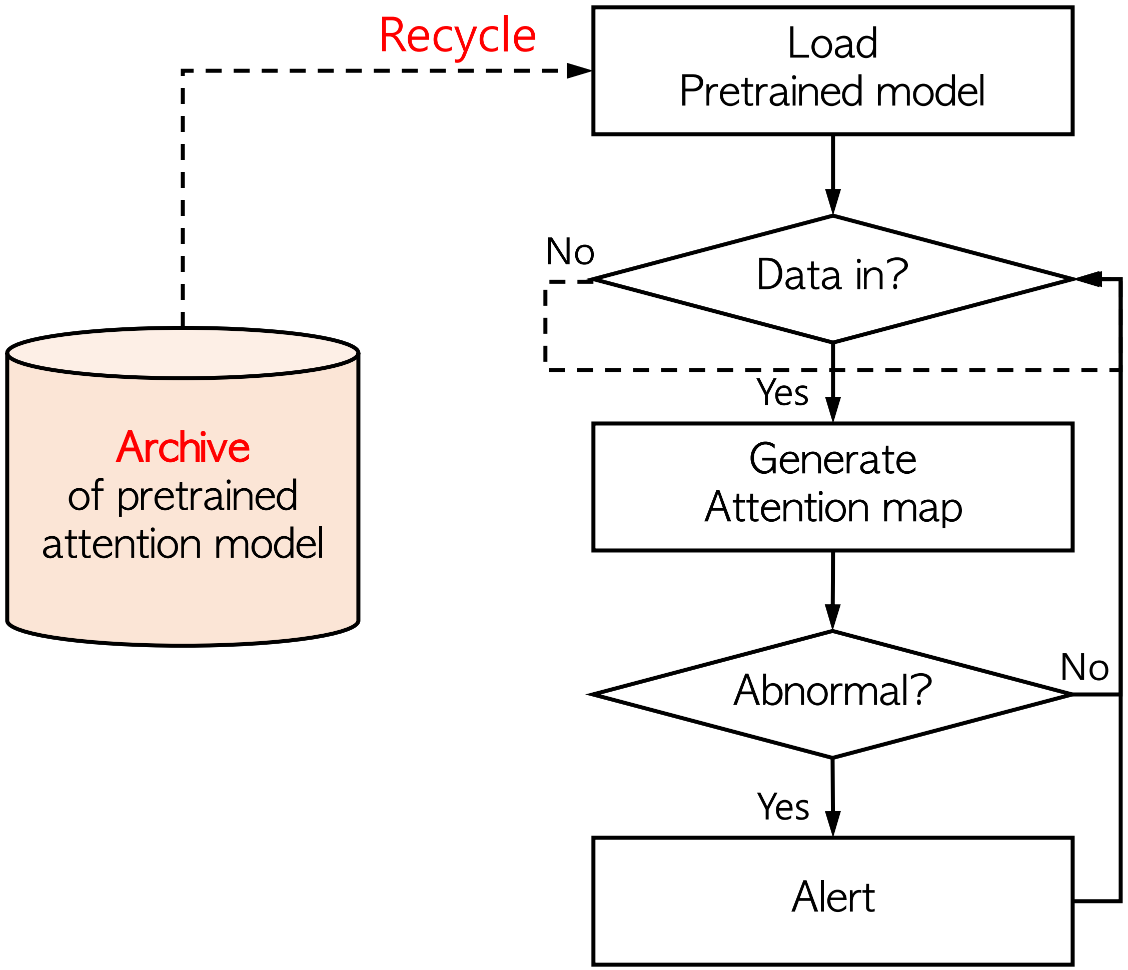
CAM / AM



	Class Activation Map (CAM)	Attention Map (AM)
Task	Discrimination	Discrimination / Generation
Training Manner	Supervised	Supervised / Unsupervised
Label	Necessary	Optional

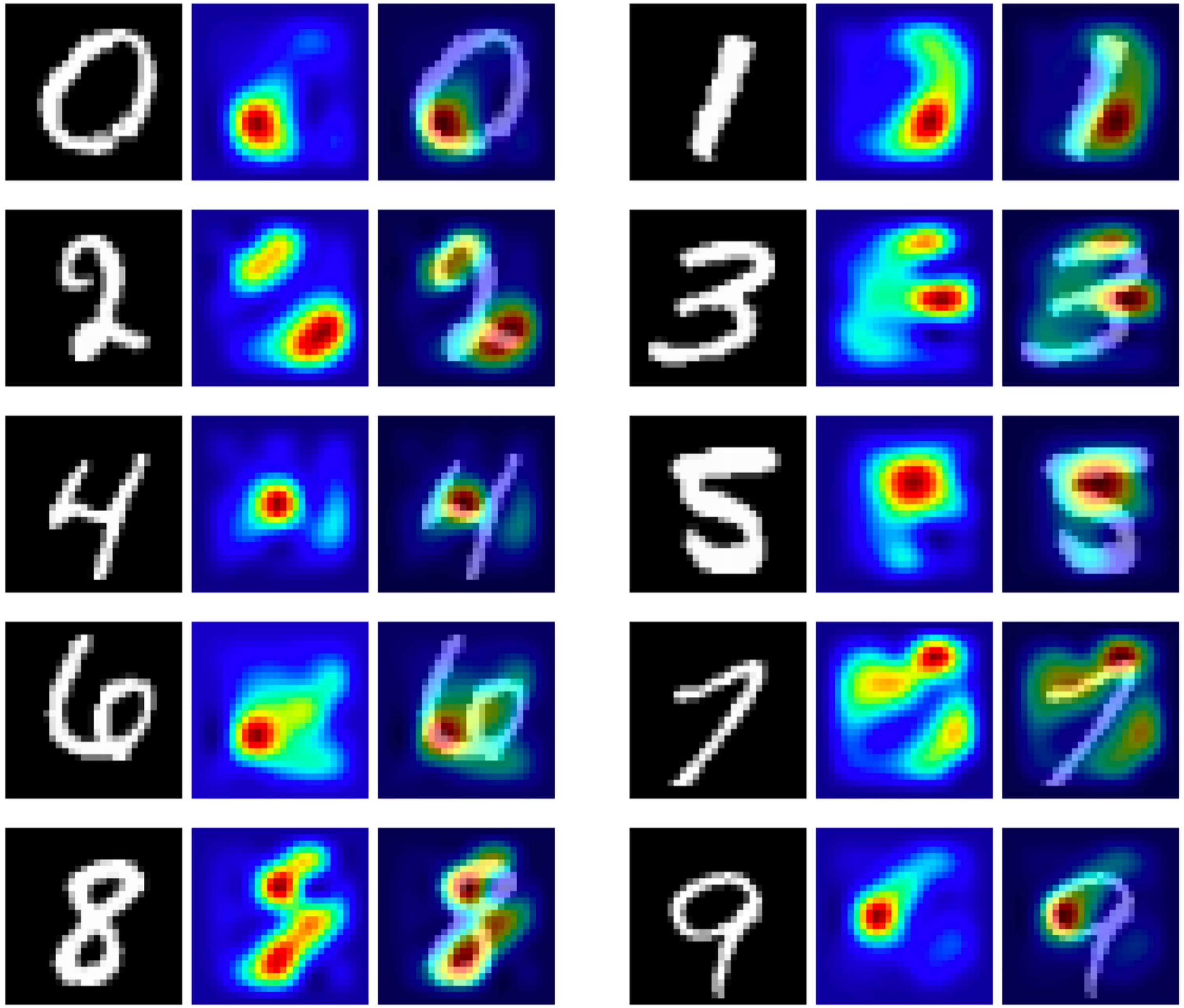
Lee, Soo Young, et al. "Steel surface defect diagnostics using deep convolutional neural network and class activation map." *Applied Sciences,* 2019.
Chen, Liang-Chieh, et al. "Attention to scale: Scale-aware semantic image segmentation." *Proceedings of the IEEE conference on computer vision and pattern recognition.* 2016.

Overall flow



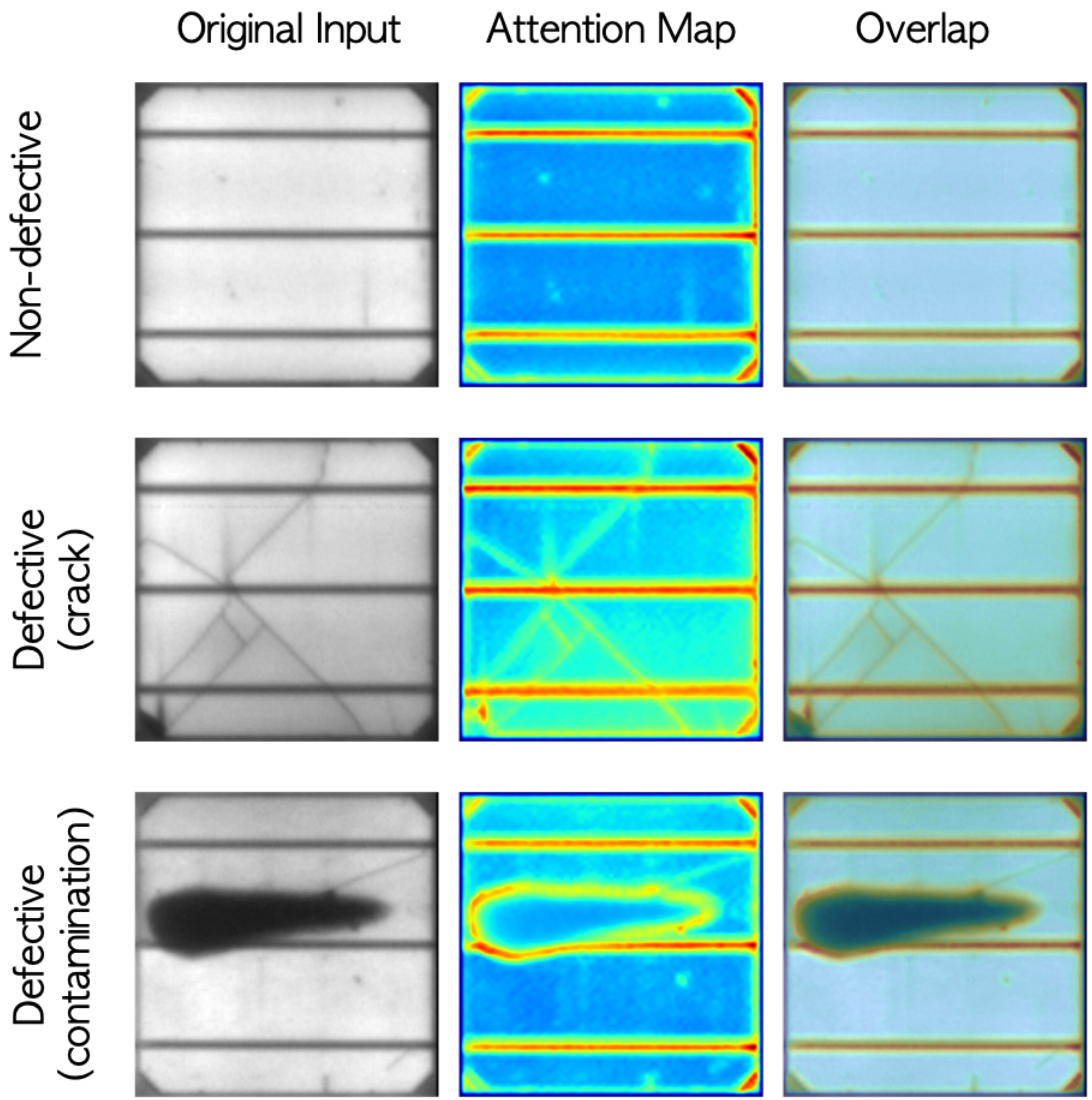
Experiments

Pretrained Attention Model



LeCun, Yann, et al. “Gradient-based learning applied to document recognition.” Proceedings of the IEEE, 1998.

Attention Maps



Comparison - 1

Correlation coefficients between labels and extracted features

	Value	Original	Attention
Sign	Min	-0.937	-0.948
	Max	0.889	0.815
	Avg	0.403	0.447
	SD	0.288	0.280
Absolute	Min	0.010	0.014
	Max	0.937	0.948
	Avg	0.027	**0.023**
	SD	0.494	**0.527**

High maximum coefficient → Setting the threshold to determine defective or not is easier.

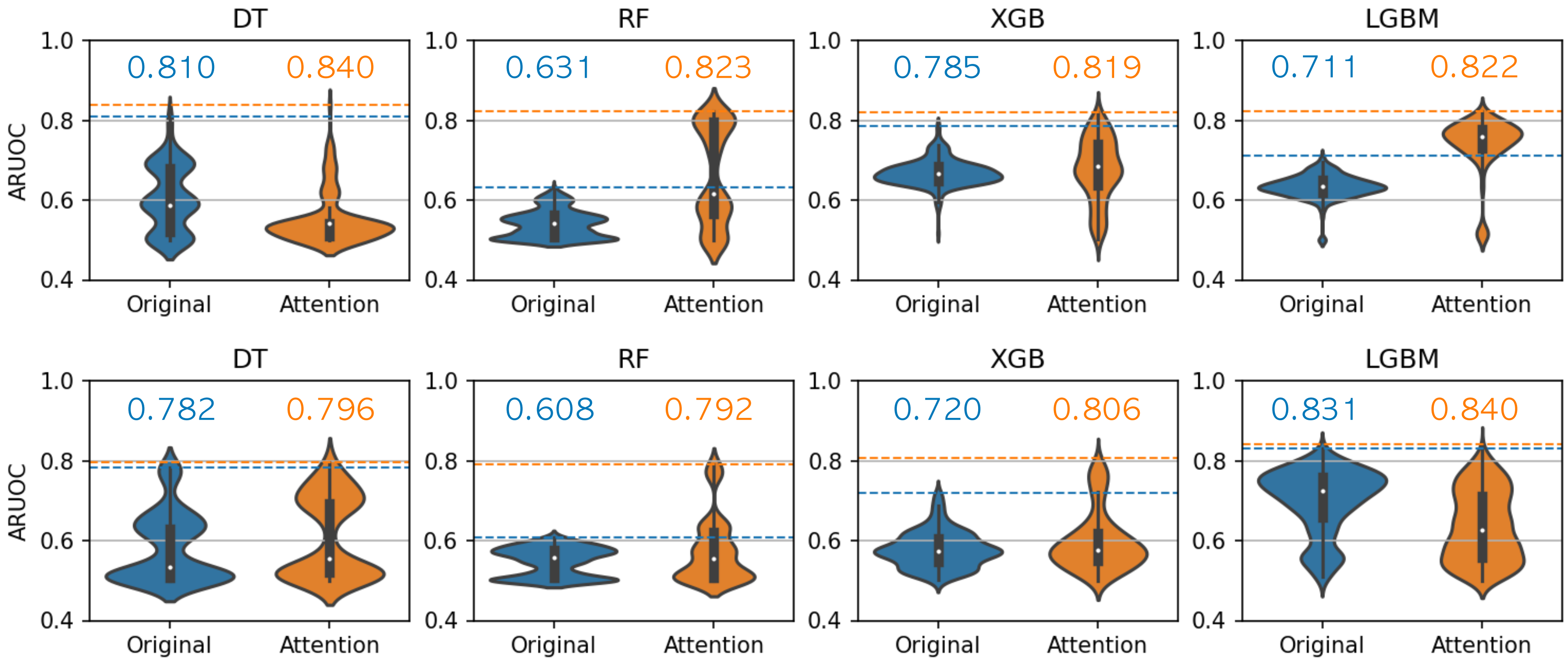
Low average coefficient → Each feature value is independent and meaningful info.

Comparison - 2

- DT: decision tree
- RF: random forest
- XGB: extreme gradient boosting
- LGBM: light gradient boosting machine

Clear non-defective
VS
Complete defective

Complete non-defective
VS
Various defectives
(including small defective)



- Control variable
  - Feature extraction method: 13 statistical features

- Independence variable
  - Input type: original image or attention map
  - Model: decision tree, random forest, or other lightweight machine learning models

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Conclusion

Conclusion

- We highly reduce the computational cost.
  - Through the proposed feature extraction method.
  - 300 x 300 pixel values → 13 statistical features

- We propose an attention map utilization for information emphasis.

- We eliminated the cost of training a new attention model by recycling the model trained on public datasets.
  - This approach is very meaningful in the context of maximizing renewable energy efficiency.

Thank you!