

SFERA-III

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1st Doctoral Colloquium

WP1 Capacity building and training activities

Odeillo, France, September 11th-13th 2019



Artificial intelligence (AI) driven calibration in solar power plants

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NETWORKING



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Artificial intelligence (AI) driven calibration in solar power plants

Outline

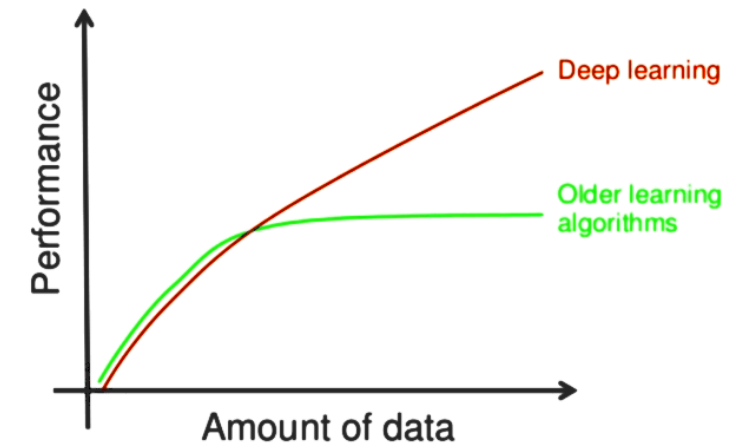
- Why AI models in solar power plants?
- Quick overview to Deep Learning Algorithms
- Heliostat calibration
- Conclusion
- Outlook

Why AI models in solar power plants?

Motivation

- Solar tower plant technology relies on numerical models
 - Design and planning
 - Forward control
 - Feedback control
- Numerical models are limited by the quantity of influencing factors
 - Approximations lead to deviations from reality
 - It's not possible to capture all factors
- Deep learning algorithms improve model behavior through sensor data continuous.
- The use of Deep Learning is conceivable in almost every area in solar power plants

Why deep learning [1]



[1] <http://neuralnetworksanddeeplearning.com/>

Introduction: Deep Learning Systems

Basics

- Deep learning based algorithms are driven by Neural Networks (NN)



[1]

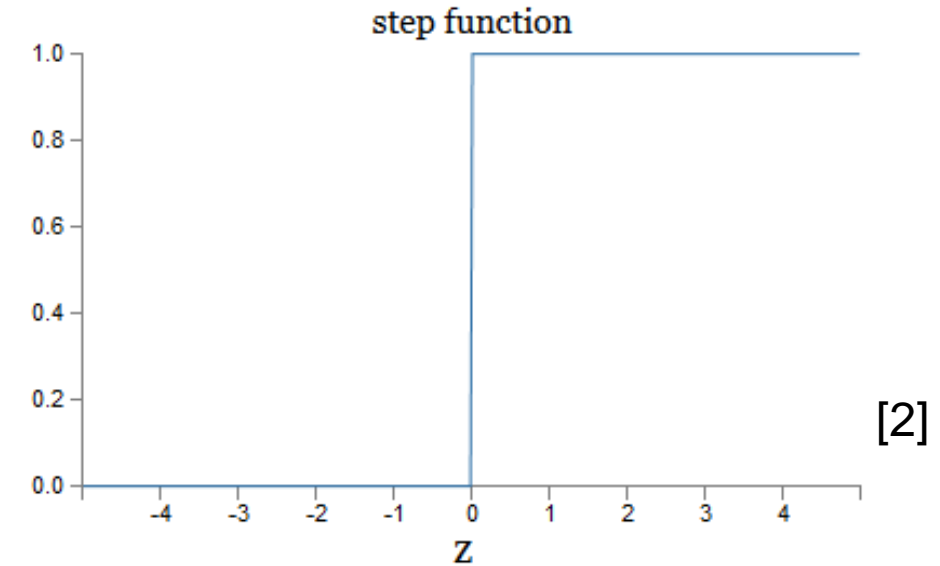
[1] <https://www.shutterstock.com/de/search/neuron?studio=1>

[2] <http://neuralnetworksanddeeplearning.com/>

Introduction: Deep Learning Systems

Basics

- Deep learning based algorithms are driven by Neural Networks (NN)
- Every Node in a Network is described by a mathematical activation function



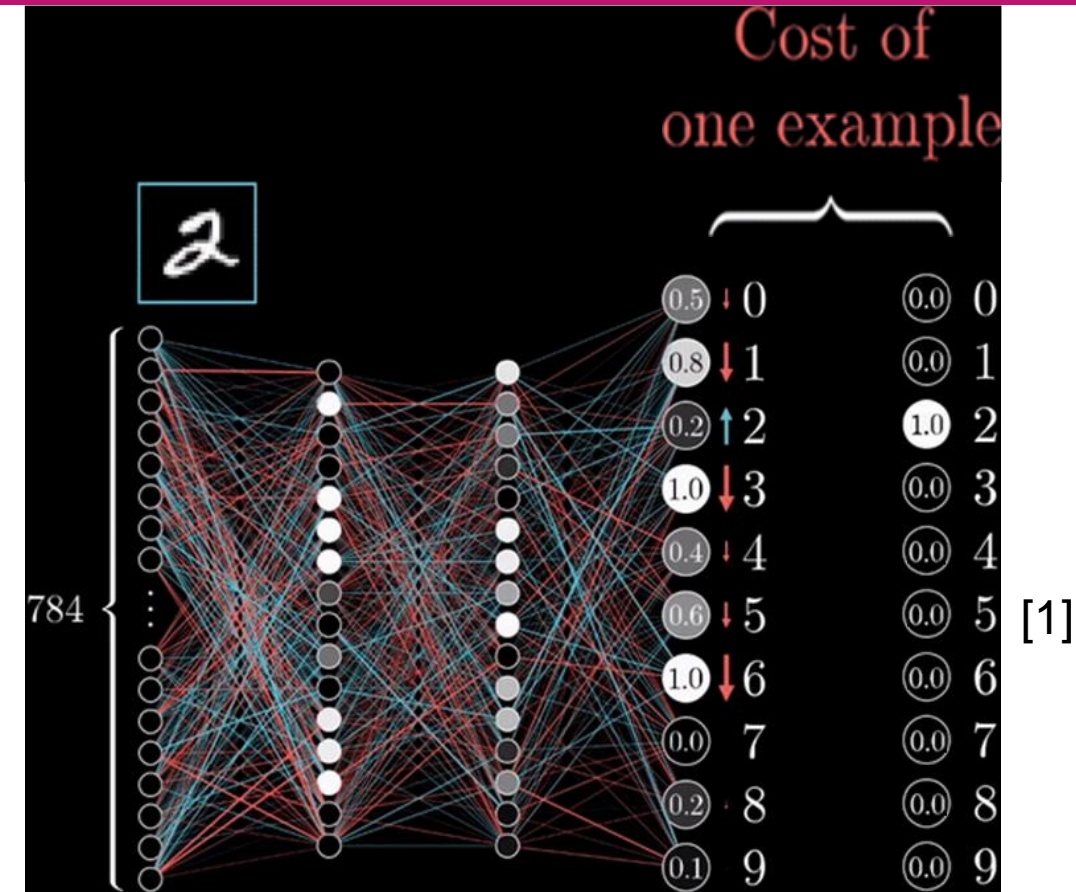
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Introduction: Deep Learning Systems

Basics

- Deep learning based algorithms are driven by Neural Networks (NN)
- Every Node in a Network is described by a mathematical activation function
- The nodes are structured in layers
- The cost describe the difference between the predicted and the correct value

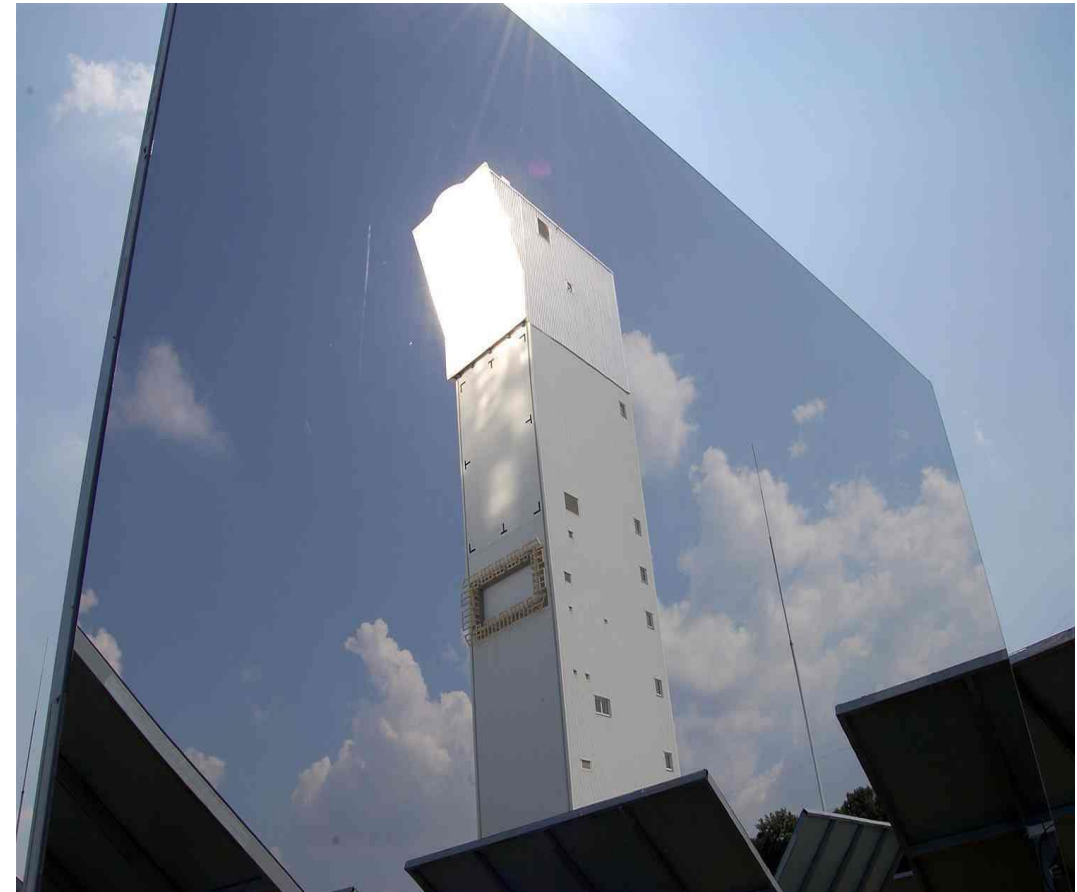


[1] <https://www.youtube.com/watch?v=tIeHLnjs5U8> - ThreeBlueOneBrown

Heliostat calibration

Regression Method

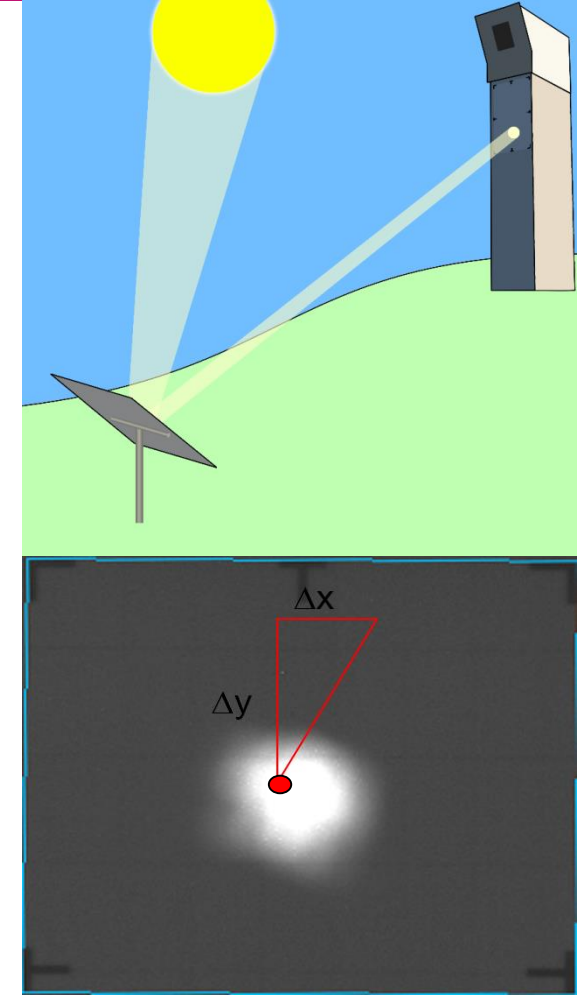
- The efficiency of the power plant depends largely on the ability of the heliostats to precisely align their focal point.
- Highly complex issue



Heliostat calibration

Regression Method

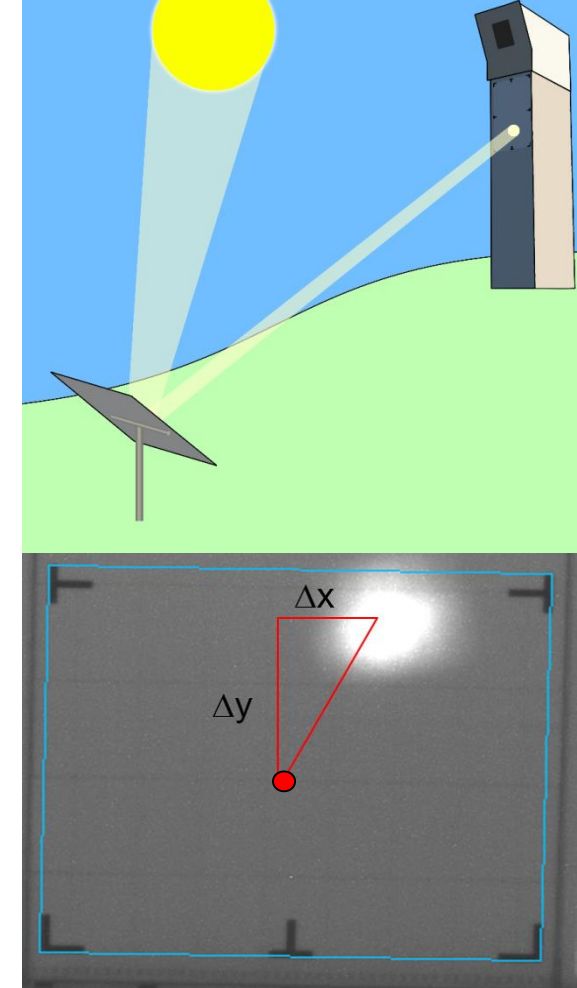
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Heliostat calibration

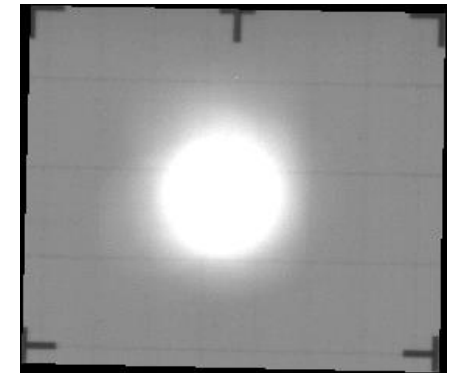
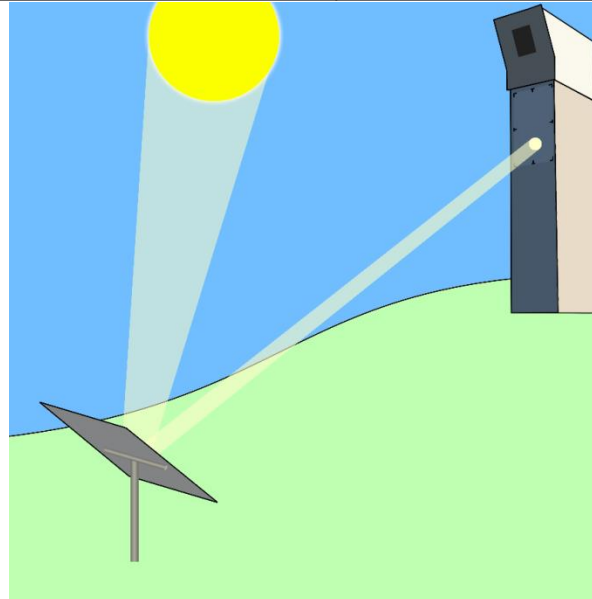
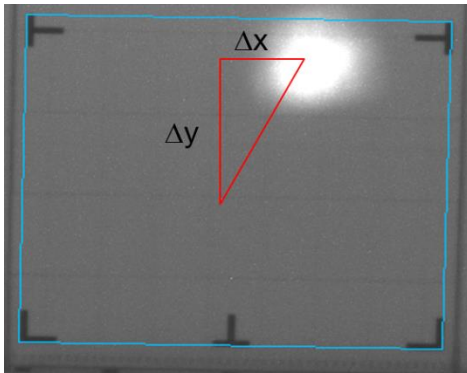
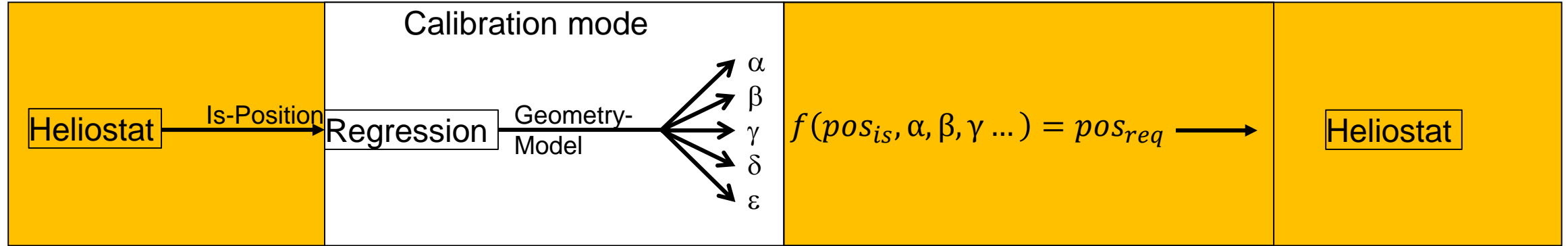
Regression Method

- The efficiency of the power plant depends largely on the ability of the heliostats to precisely align their focal point.
- Highly complex issue
- Standard calibration is done by regression algorithms



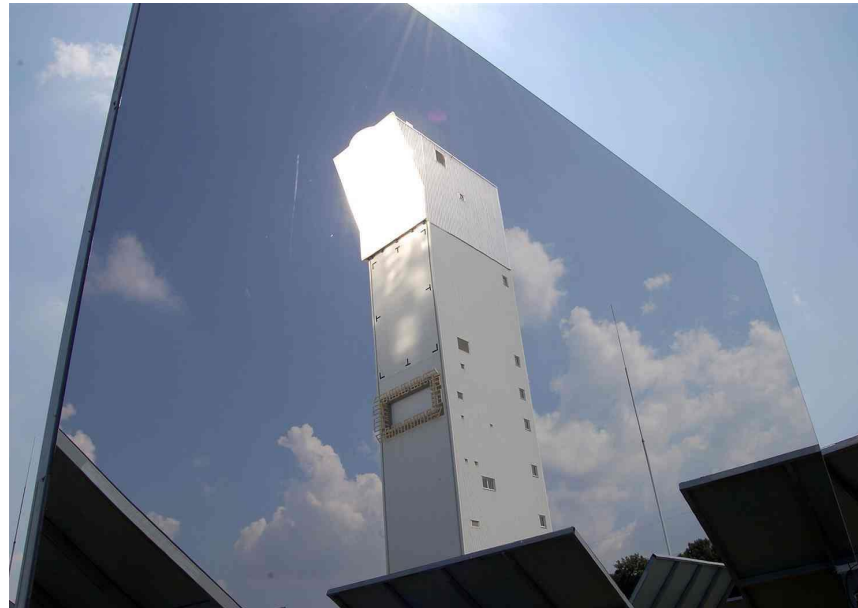
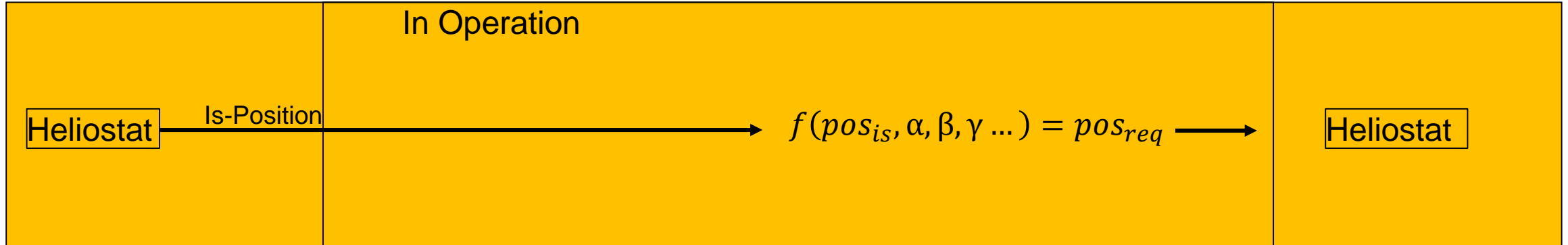
Heliostat calibration

Regression Method



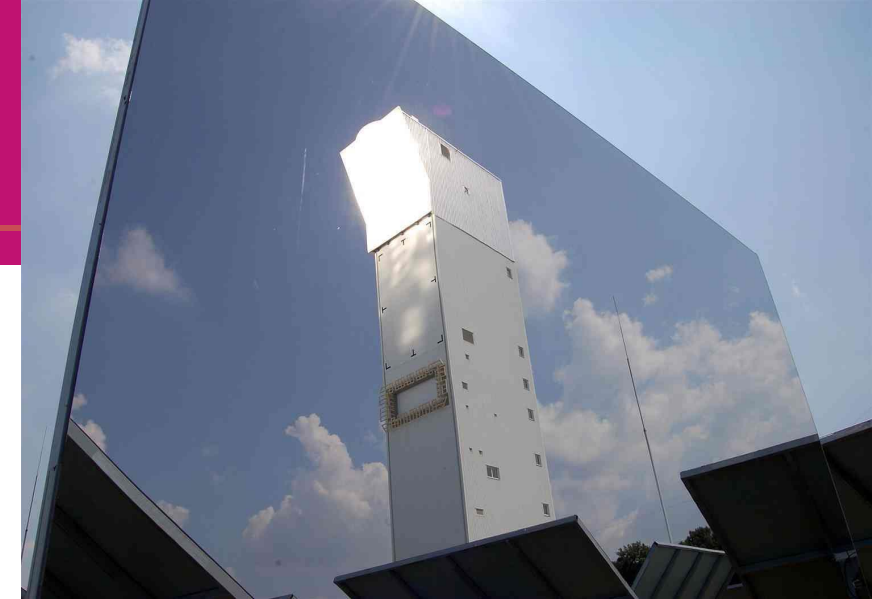
Heliostat calibration

Regression Method



Heliostat calibration

Regression Method



- Regression Method:

- Solver stops working when parameters are linearly dependent

$$f(pos_{is}, \alpha, \alpha, \gamma \dots) = pos_{not\ req}$$

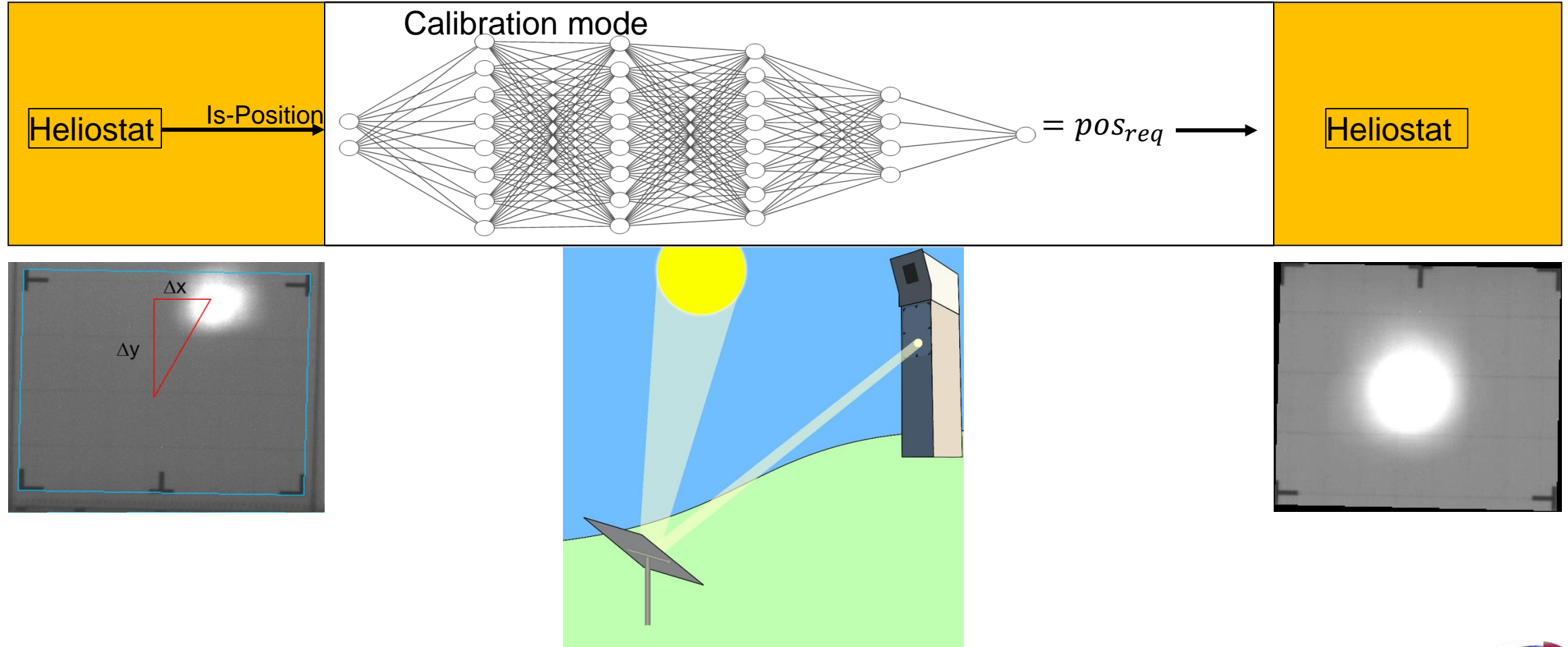
- Geometry Model with 8 Parameters is not sufficient
- It's not given, that the accuracy gets better over time

- AI Method:

- No linear dependence between parameters
- Thousands of parameters able to fit high complex problems
- Accuracy gets better every time the calibration is done

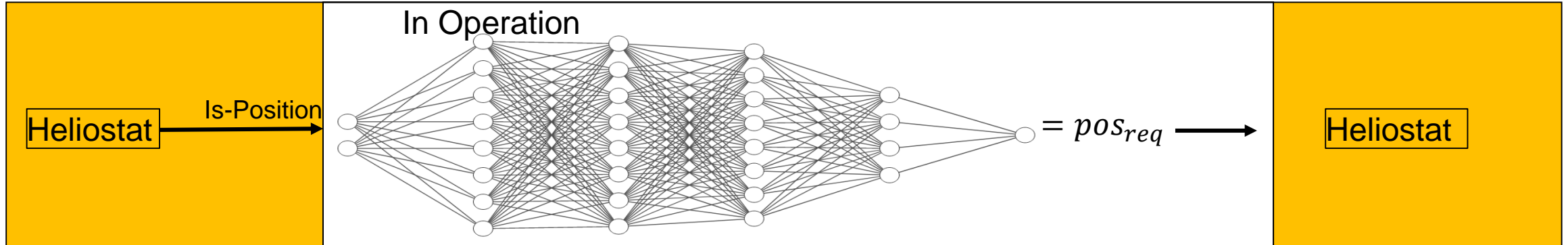
Heliostat calibration

Neural Network



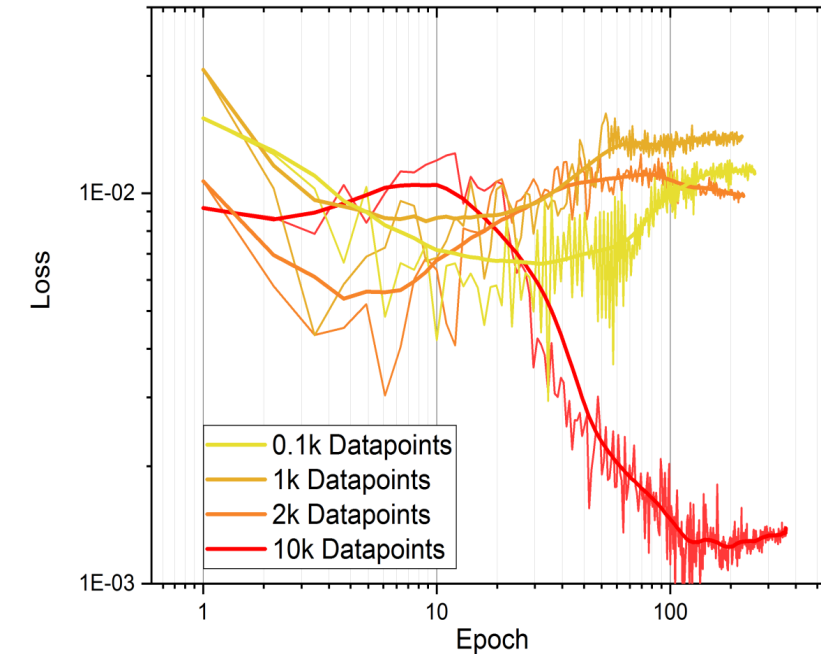
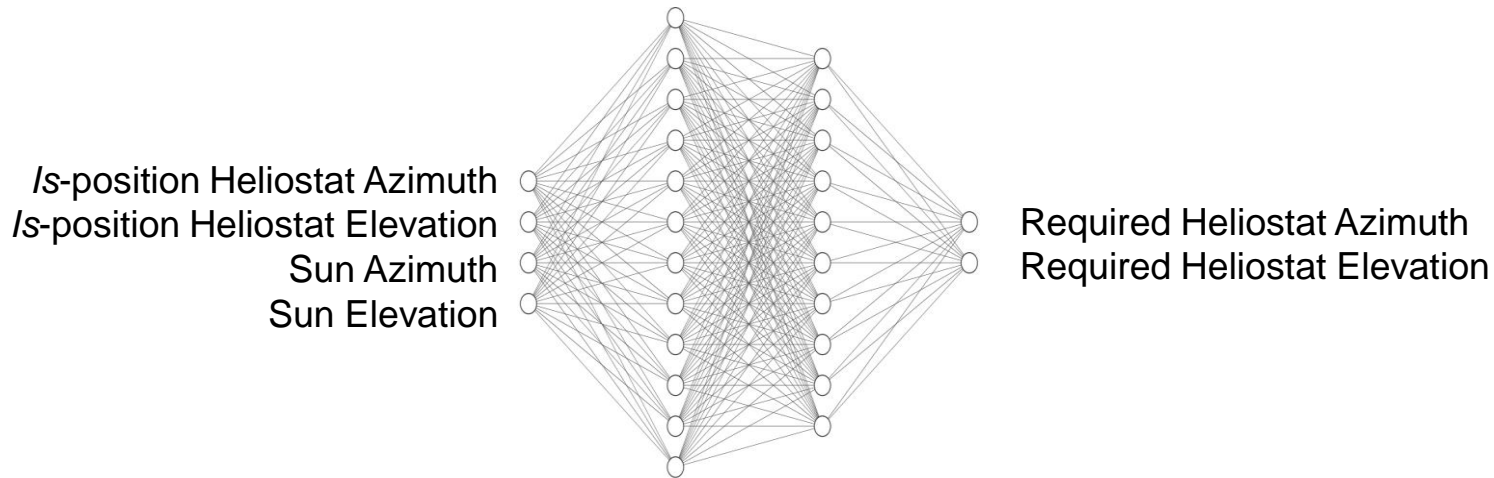
Heliostat calibration

Neural Network



Heliostat calibration

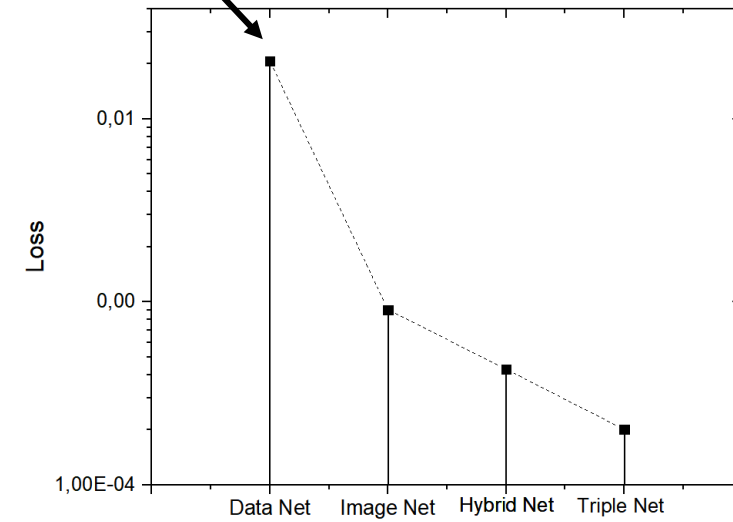
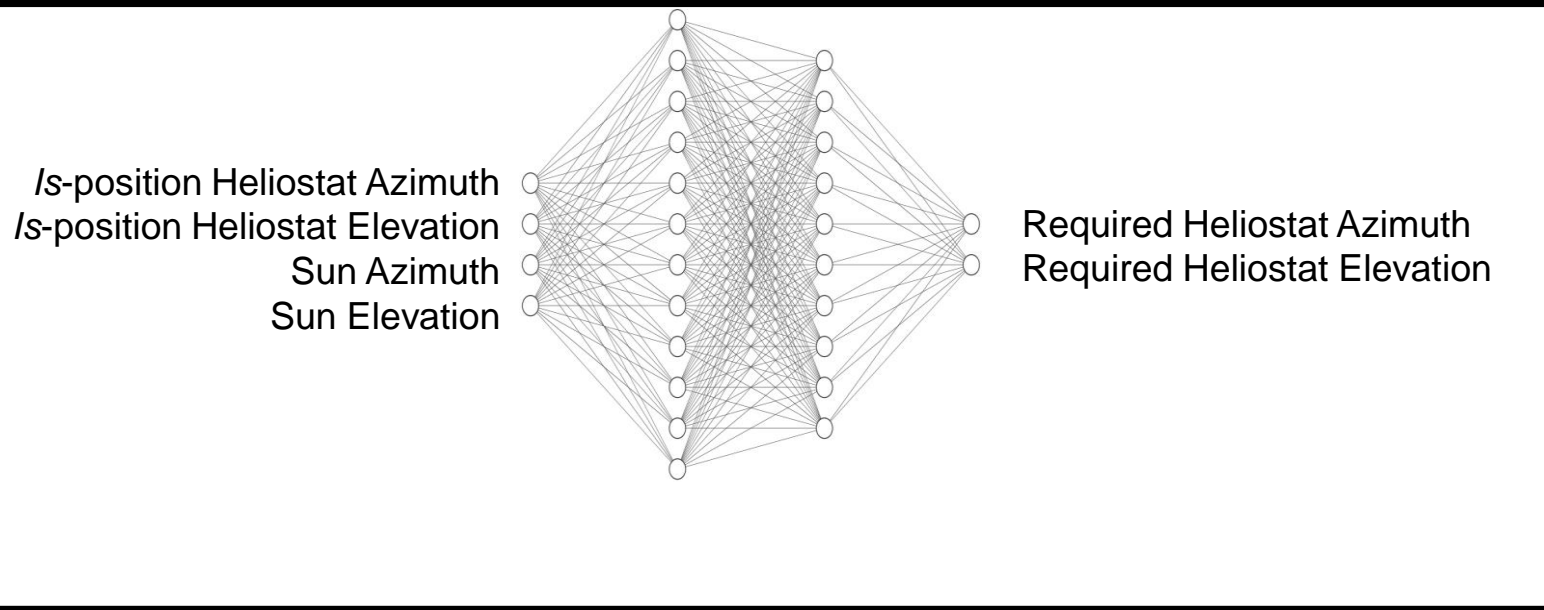
Neural Network



- **Problem:** With 4 Inputs the network starts giving relevant results only after feeding >10K (simulated) Sun and Heliostat positions (per Heliostat) thorough it
→ Reality is more complex and has fewer data points
- **Solution 1: GET MORE DATA** (Thats what i'm working on right now)
- **Solution 2:** Try to get more information out of the data you already have

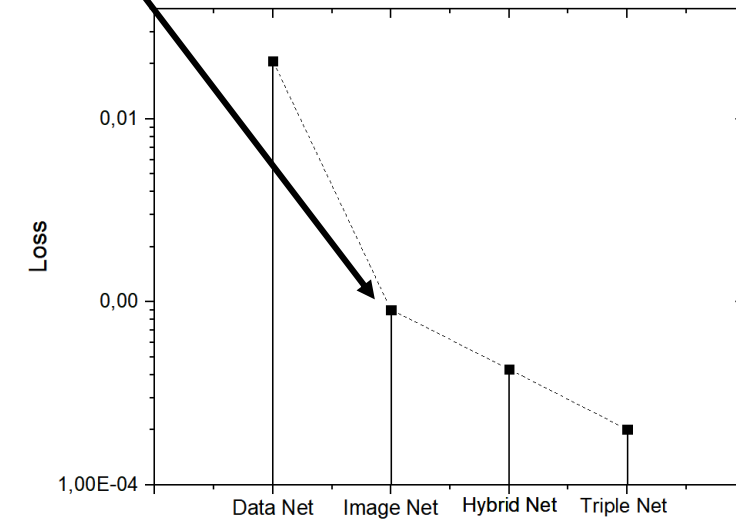
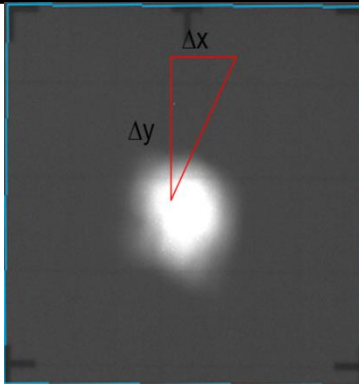
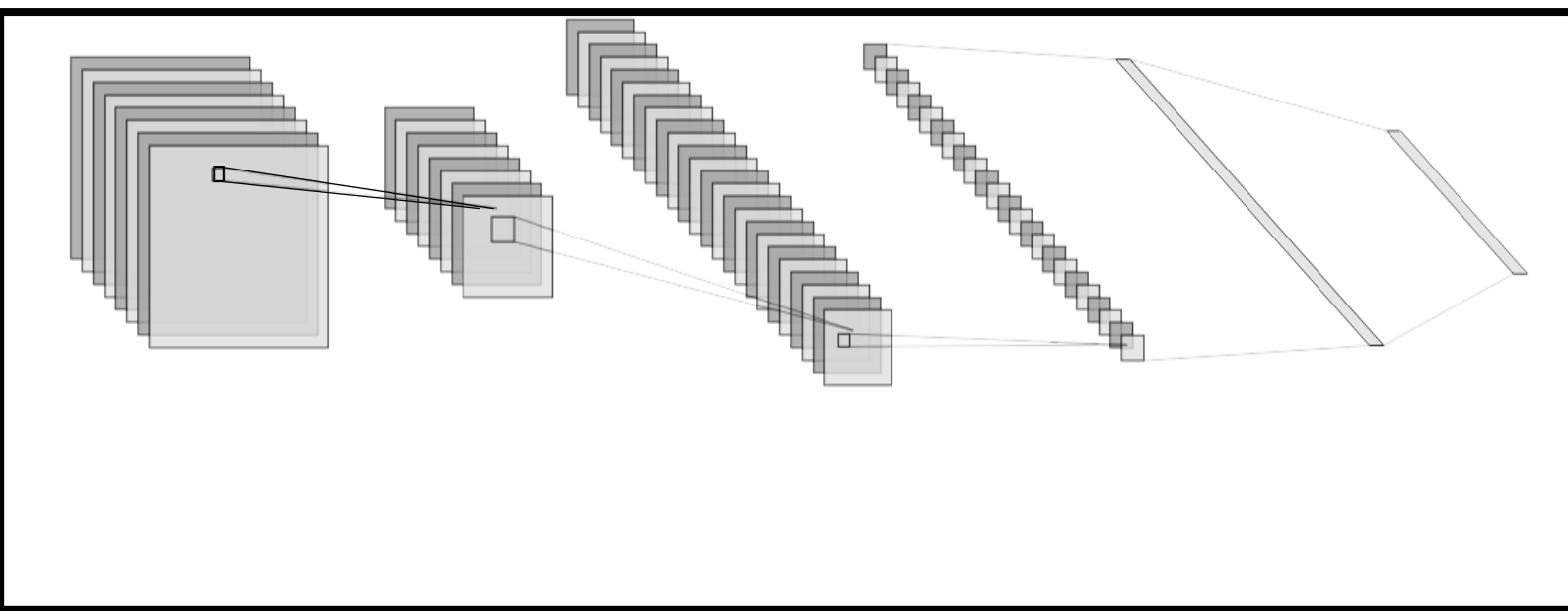
Heliostat calibration

Neural Network



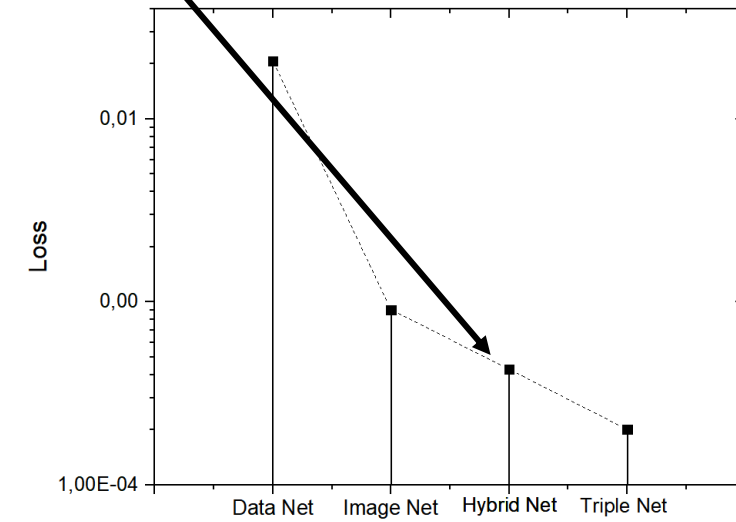
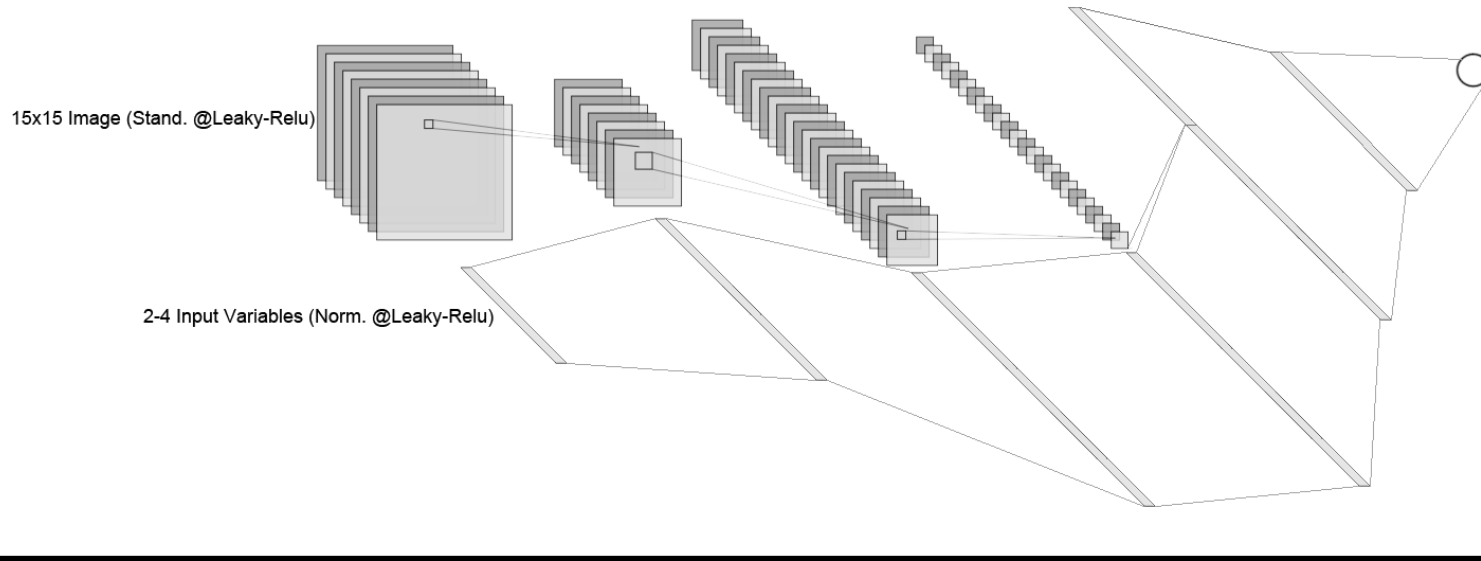
Heliostat calibration

Neural Network

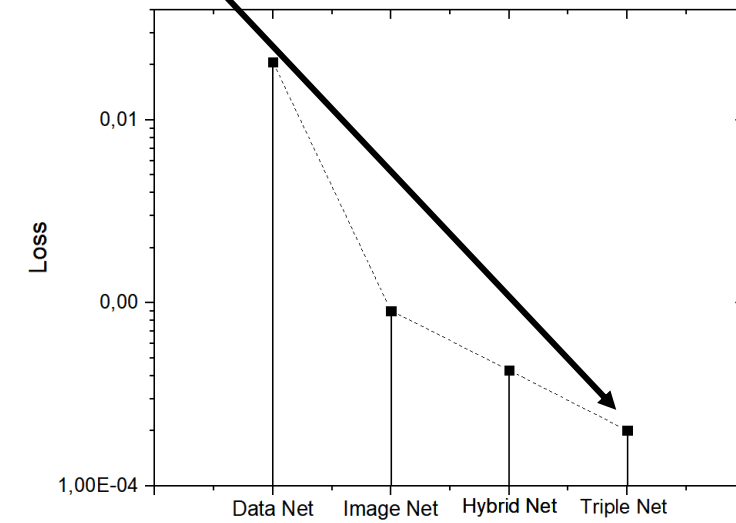
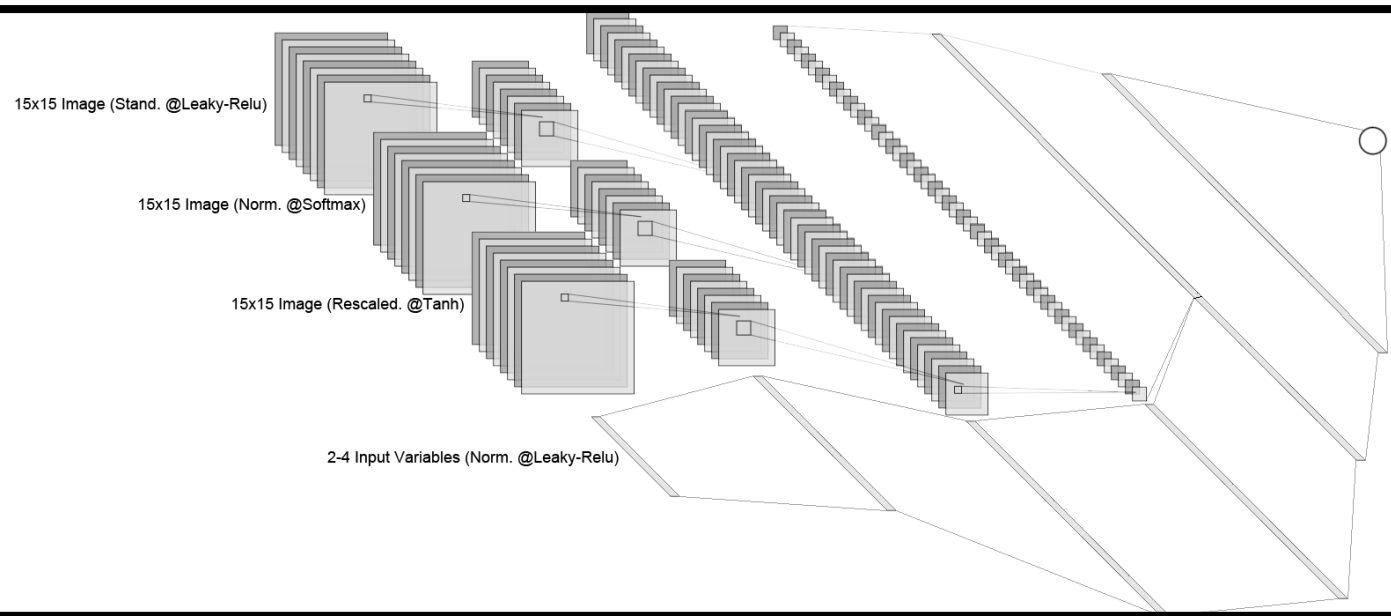


Heliostat calibration

Neural Network



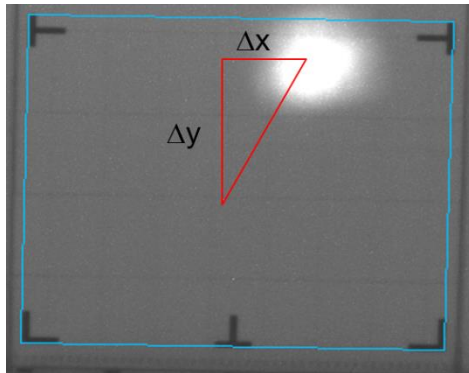
Heliostat calibration Neural Network



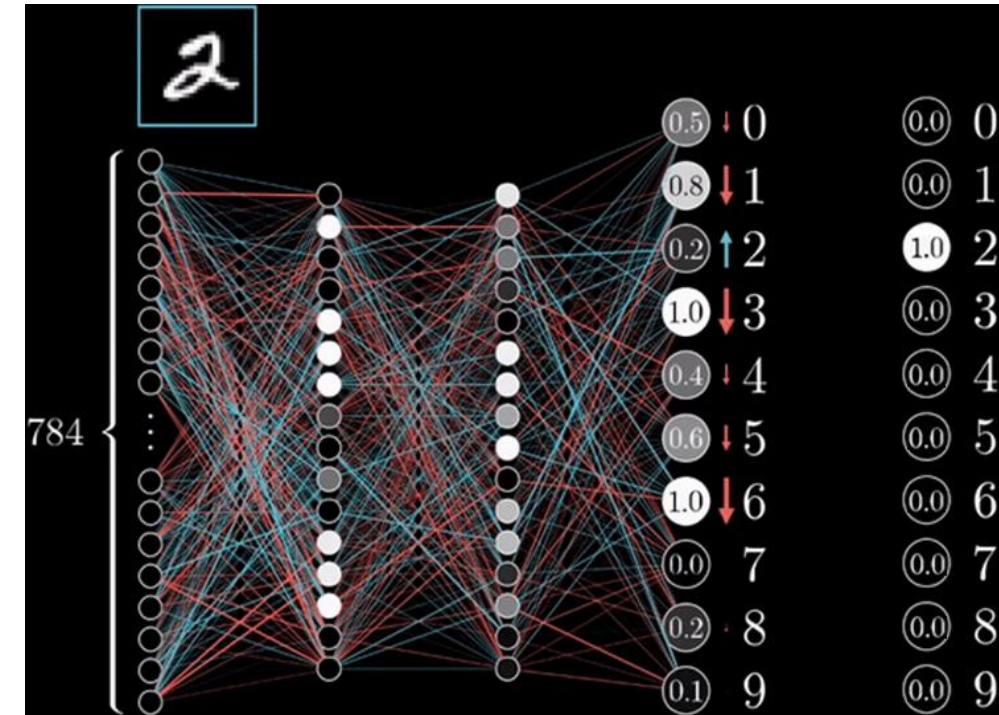
Heliostat calibration

Neural Network

Another Problem: Pictures can only produced and used in calibration mode. Outside the calibration mode we have only the heliostat and the sun position

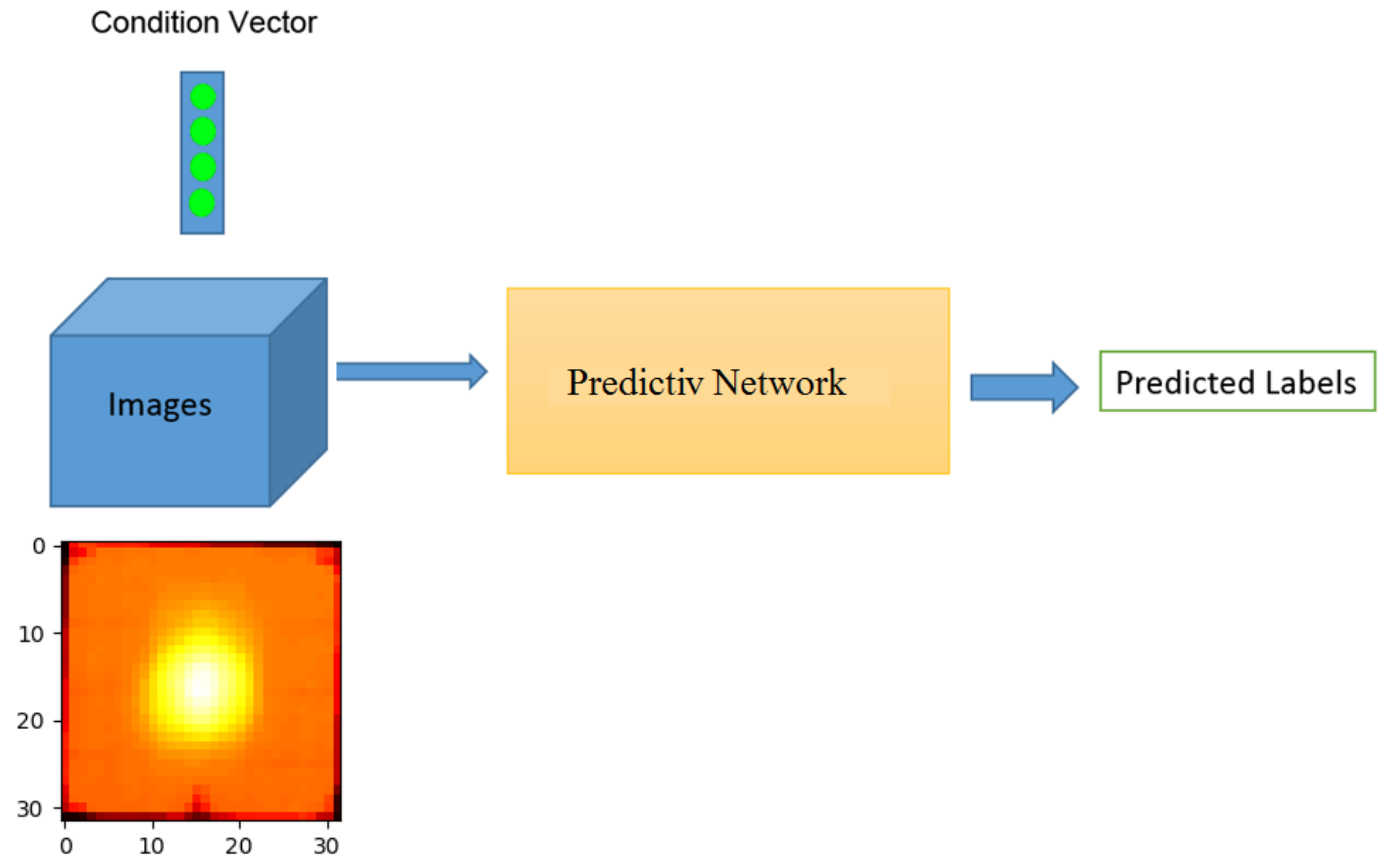


Another Solution: Data Imputation



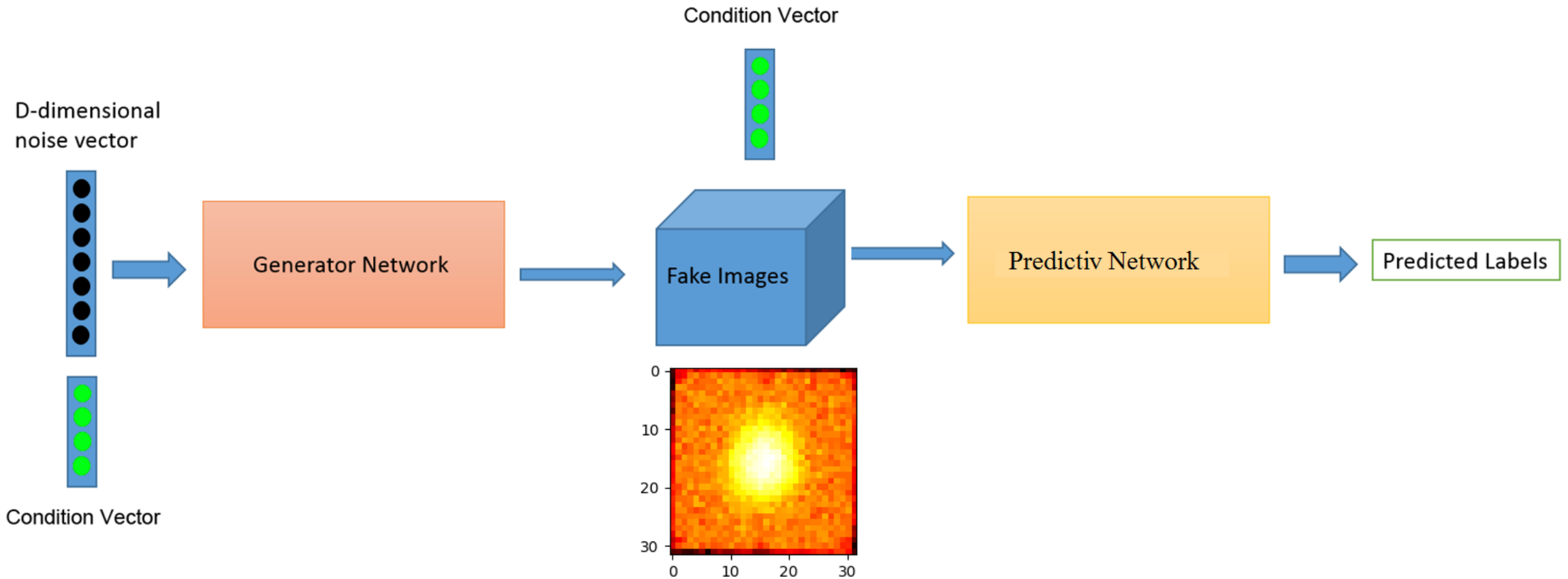
Generativ Adversarial Network (GAN)

The Solution



Generativ Adversarial Network (GAN)

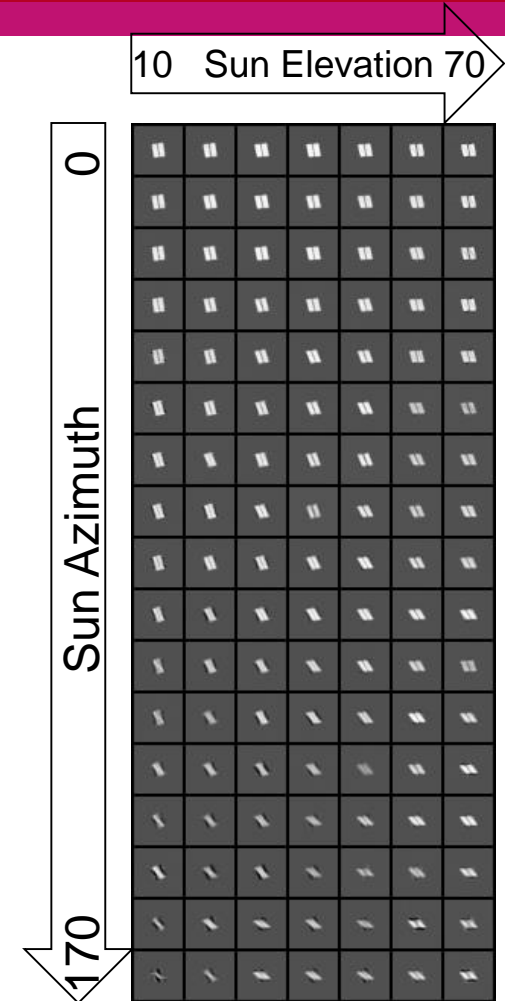
The Solution



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Conclusion

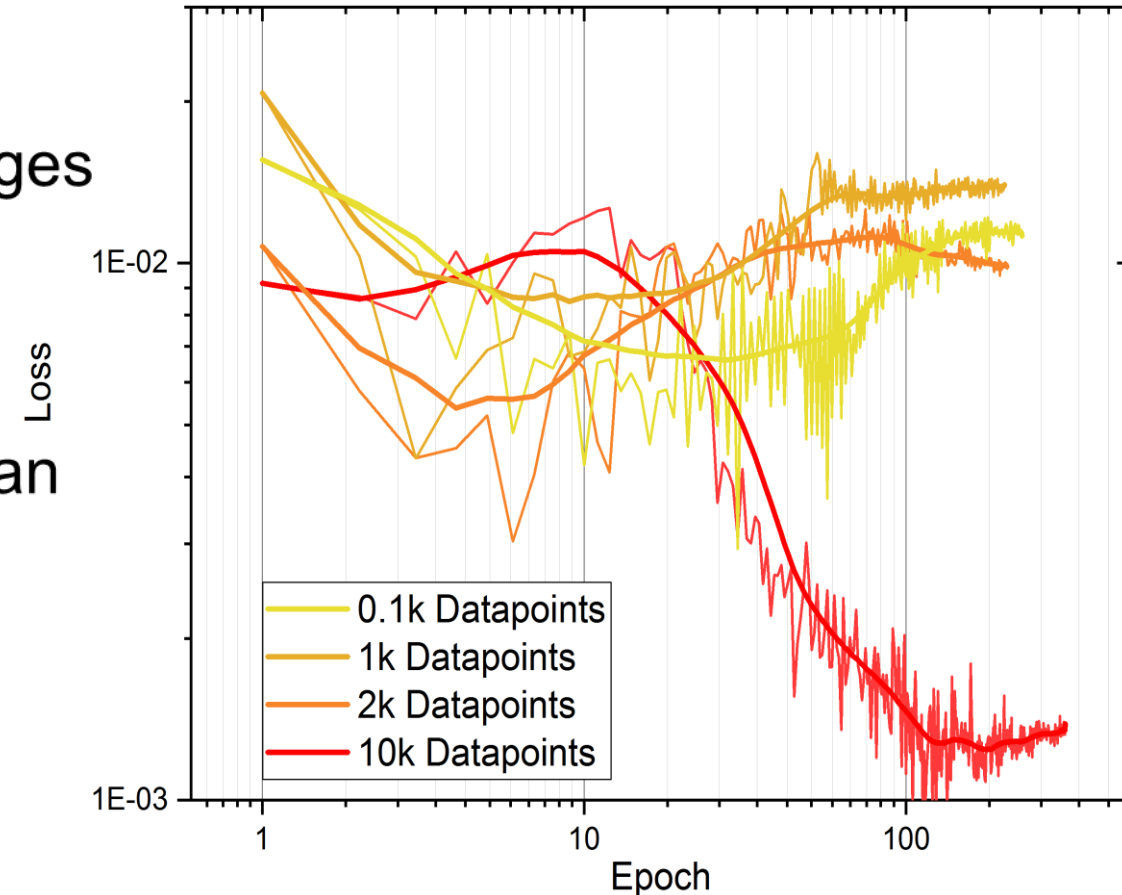
- **We have shown:**
 - GANs are able to produce raytracer Images with high accuracy but including real heliostat errors



Artificial intelligence (AI) driven calibration in solar power plants

Conclusion

- **We have shown:**
 - GANs are able to produce raytracer Images with high accuracy but including real heliostat errors
 - It is possible to calibrate Heliostats with an AI only with the Axis Position of the Heliostats if you have enough Data

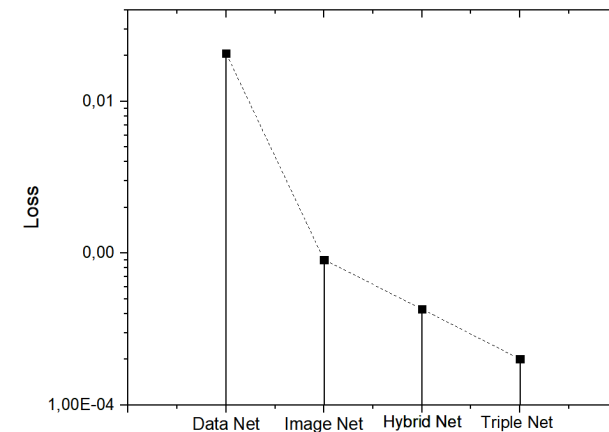
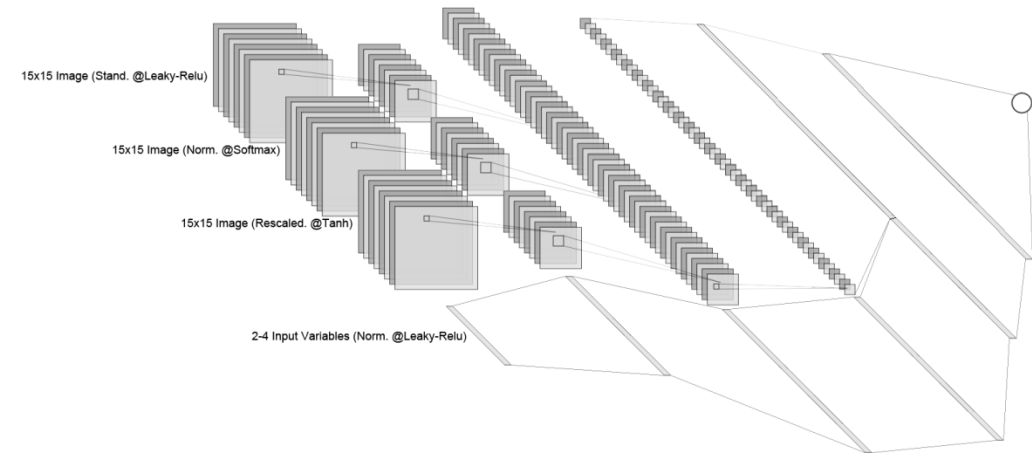


Artificial intelligence (AI) driven calibration in solar power plants

Conclusion

- **We have shown:**

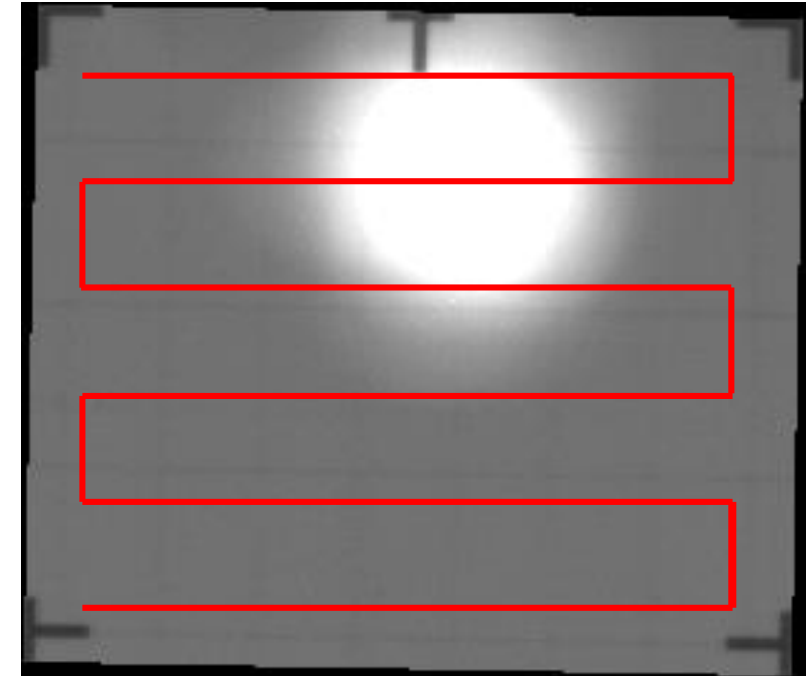
- GANs are able to produce raytracer Images with high accuracy but including real heliostat errors
- It is possible to calibrate Heliostats with an AI only with the Axis Position of the Heliostats if you have enough Data
- Also with a small amount of data you can calibrate the heliostats if you use the target pictures as a support.



Artificial intelligence (AI) driven calibration in solar power plants

Outlook

- Setting up the Generator-Predictor Network System
- GET MORE DATA
- Test the calibration method at the solar tower plant in Jülich



Thanks for your attention!



Knowledge for Tomorrow