Automatic fault detection in infrared thermographic images in photovoltaic arrays using deep convolutional neural networks

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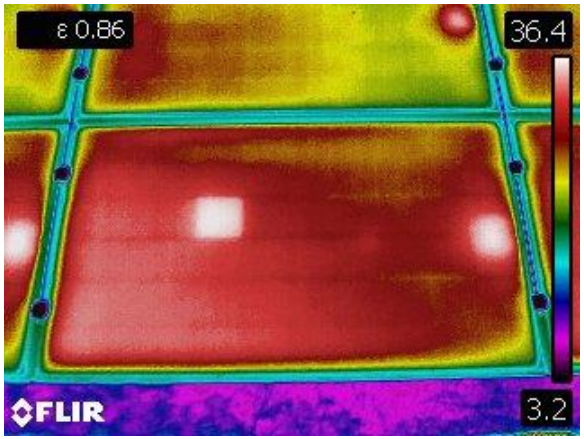
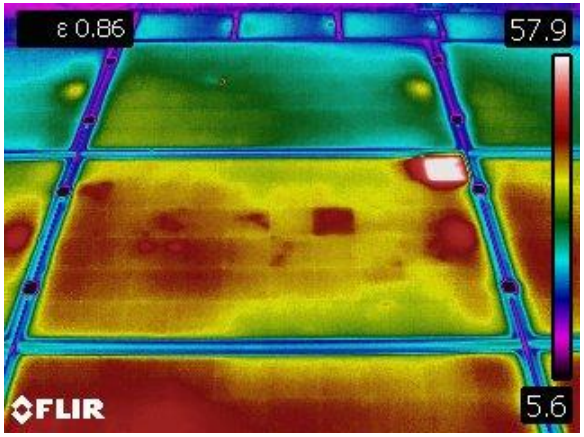
The Problem



Hot Cell



Cracked Panel

- Infrared Thermography: Picture of Temperature of Panels
- Trained Human can Identify Flaws but is Time Intensive

Image by Daniel Barker, used under cc-by-2.0 license

Capturing the Images

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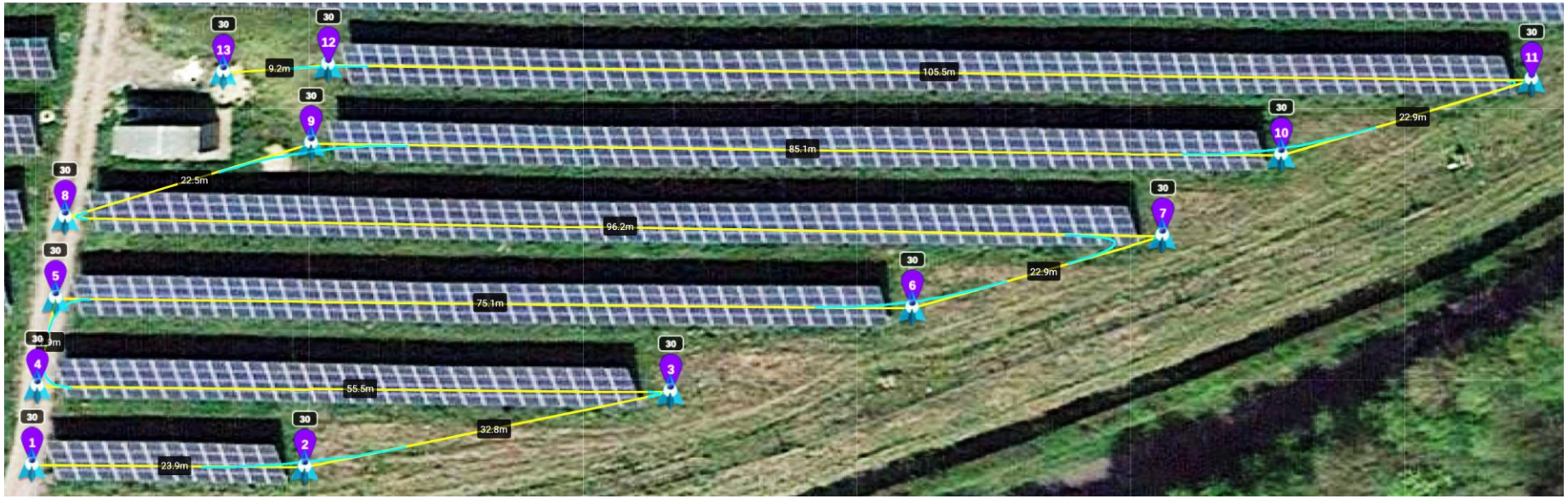
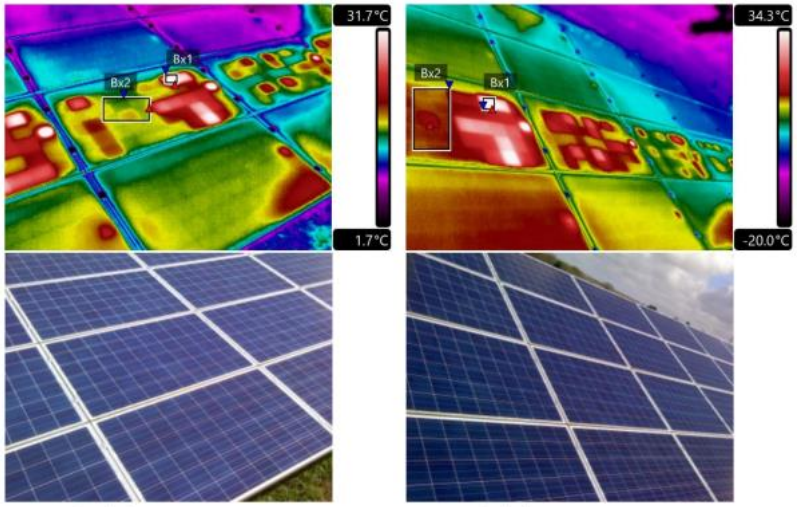
Capturing the Images

- Drone-based Imagery
- Drone flight-path planned in advanced
- Camera currently controlled manually



Creating the Data

- Manual conversion of data from historic PDF reports to CSV tables and raw files



FLIR8384.jpg | 26/04/2018 11:02
114° SE

FLIR8385.jpg | 26/04/2018 11:03
84° E

Sector	B	Sector	B
Row	1	Row	1
Location (East, West, Middle)	W	Location (East, West, Middle)	W
Vertical Panel Position	C	Vertical Panel Position	C

Image Camera Model	FLIR T420 (incl Wi-
Object Emissivity	0.86
Object Distance	1.0 m
Atmospheric Temperature	20.0 °C

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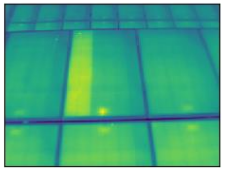
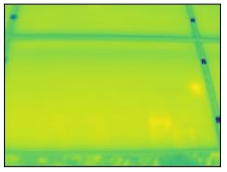
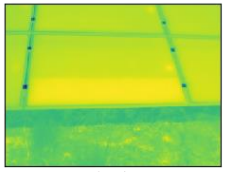
Acceptance Criteria		**Acceptance Criteria**	
Issue	**Hot String**	**Issue**	**Hot String**

	A	B	C
1	FILE	SEVERITY	ISSUE_CATEGORY
2	FLIR8382.jpg	Green	Hot Spot
3	FLIR8383.jpg	Green	Random - PID
4	FLIR8384.jpg	Yellow	Hot String
5	FLIR8385.jpg	Yellow	Hot String
6	FLIR8386.jpg	Yellow	Hot String
7	FLIR8387.jpg	Yellow	Rev: Hot String
8	FLIR8388.jpg	Yellow	Hot String
9	FLIR8389.jpg	Yellow	Rev: Hot String
10	FLIR8390.jpg	Yellow	Hot String
11	FLIR8391.jpg	Green	Hot Row


Hot Row

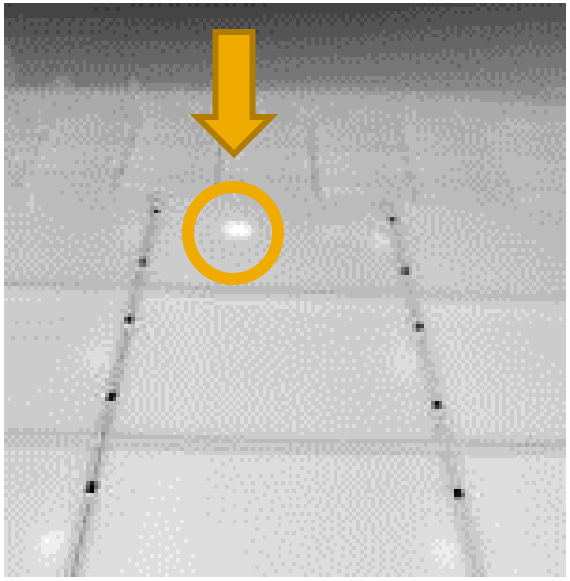

Hot Spot

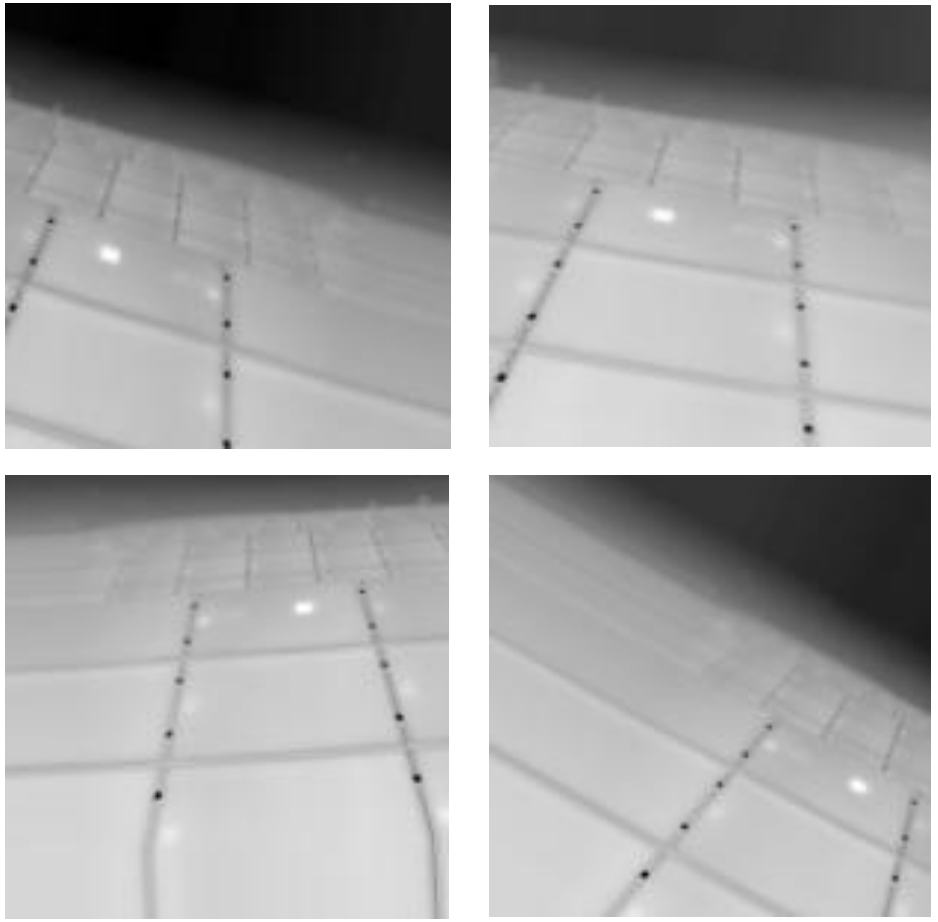

Substring

Data Augmentation

Rotation, Crop, Flip, Zoom, Skew, Brightening

Fault – Hot Cell

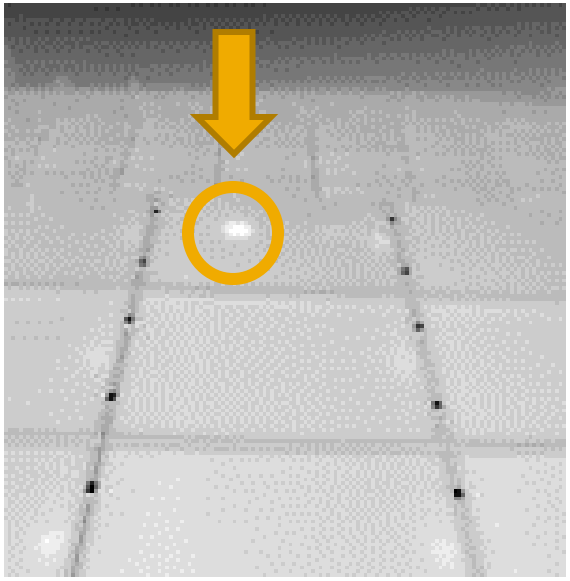


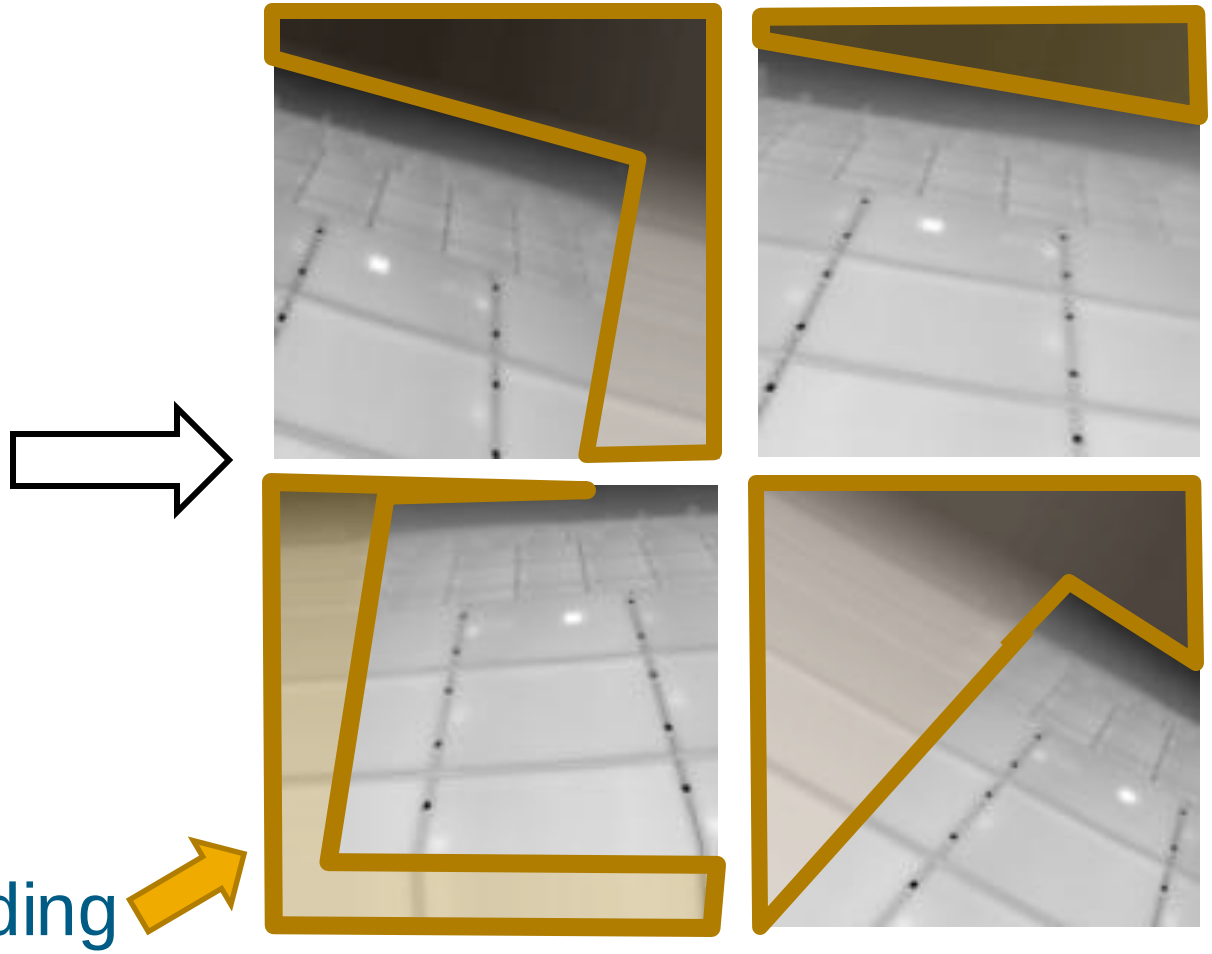


Data Augmentation

Rotation, Crop, Flip, Zoom, Skew, Brightening

Fault – Hot Cell





Padding

Deep Learning

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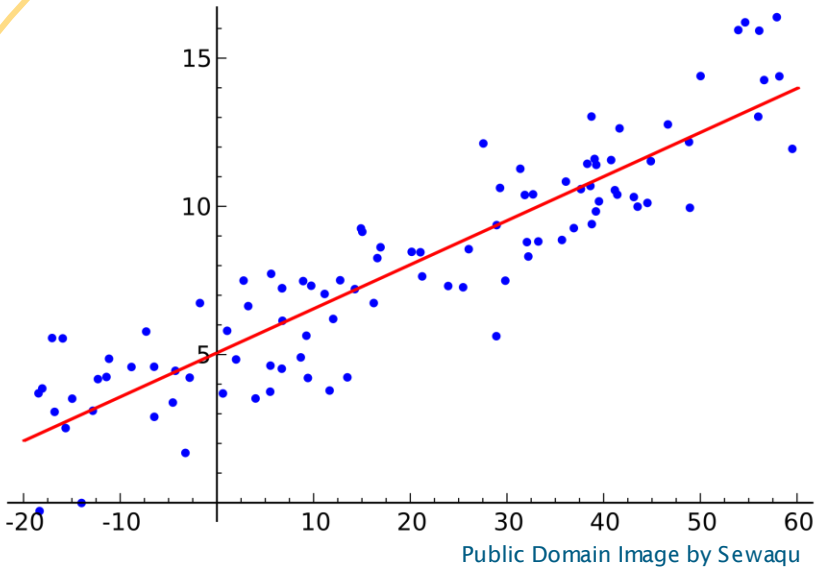
- Machine Learning
- Artificial Neural Networks
- Deep Learning
- Convolutional Neural Networks



Public Domain Image by Sewaqu

Automatically predicting data

Deep Learning

- Machine Learning
- **Artificial Neural Networks**
- Deep Learning
- Convolutional Neural Networks

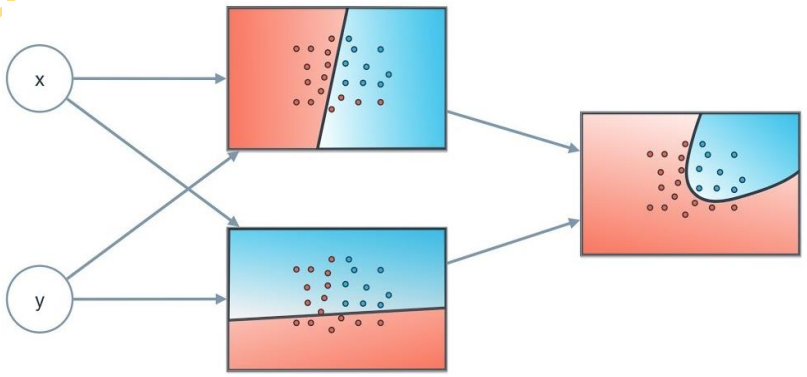


Image by Luis Serrano

- Built out of Neurons
- Follows human brain
- Can form complex shapes with simple addition/multiplication

Deep Learning

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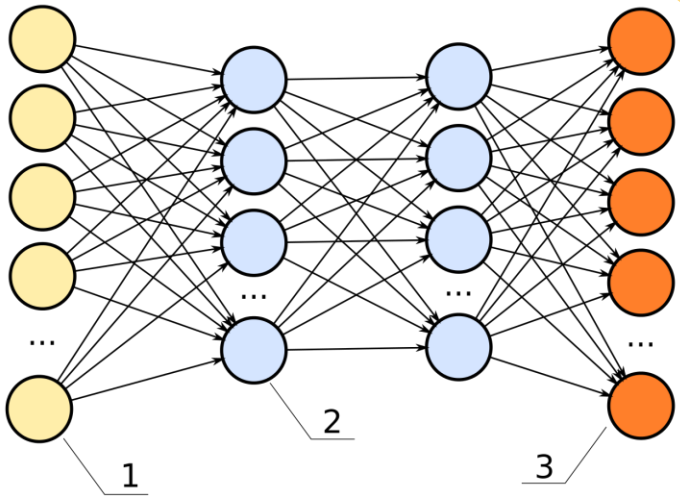
- Machine Learning
- Artificial Neural Networks
- Deep Learning
- Convolutional Neural Networks



Public Domain Image by Zufzzi

- Many layers of Neurons
- Needs more data
- Can model complex non-linear relationships

Deep Learning

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- Machine Learning
- Artificial Neural Networks
- Deep Learning
- **Convolutional Neural Networks**

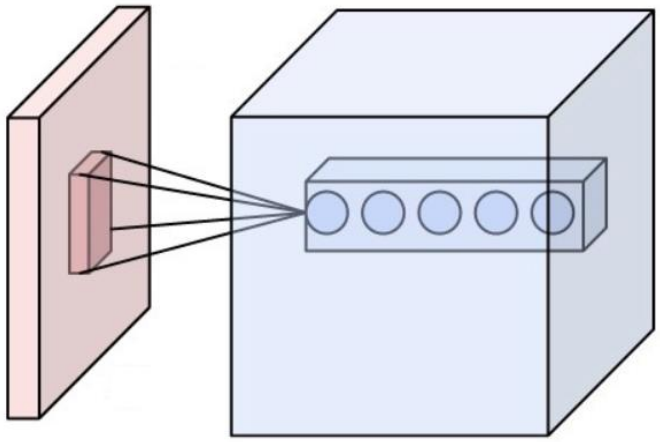
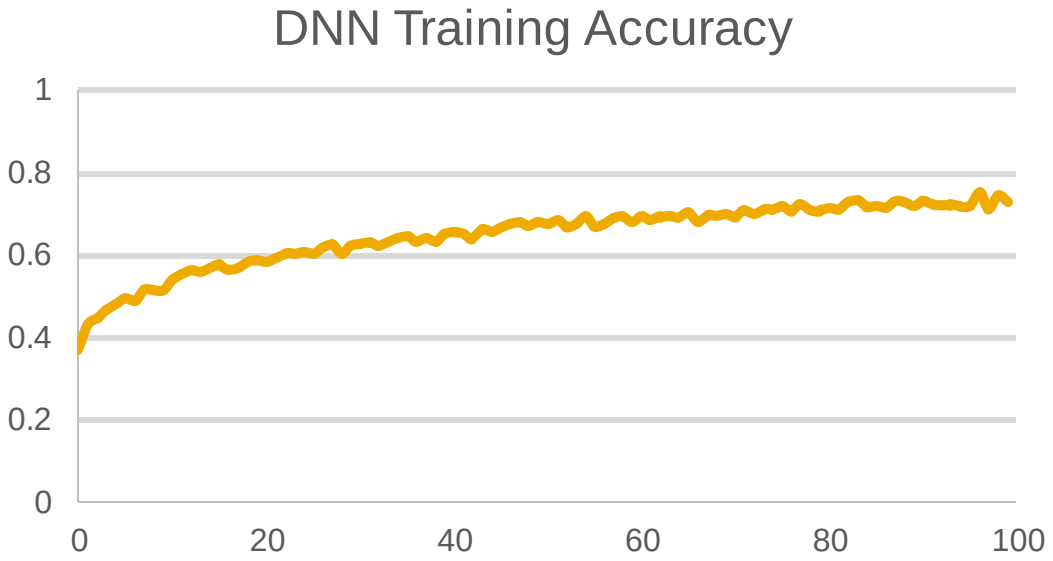


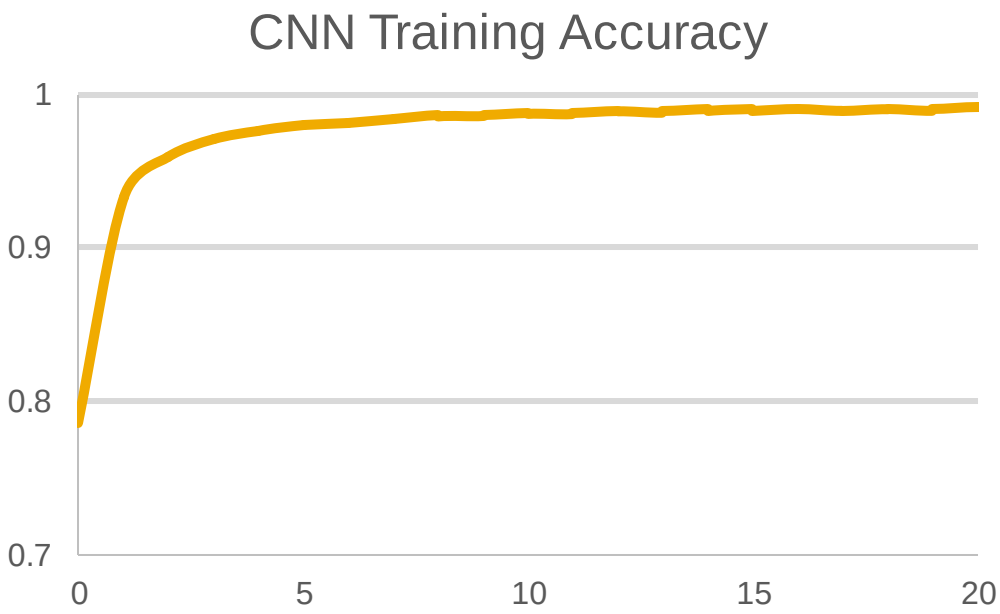
Image by Aphex34 licensed under CC by-sa 4.0

- Neural Network for Images
- Good for classification
- Often better than humans

Results

- Deep Neural Network Accuracy
  - 75% training
  - 54% on test data
- Convolutional Neural Network Accuracy
  - 99% training
  - 76% on test data





Summary

- Infrared Thermography (image of heat):
  - ✓ Can be used to cheaply find faults in PV solar modules

- Deep Learning: complex automated computer prediction
  - ✓ Can be 'trained' with known data
  - ✓ Not designed for images, but achieved 54% accuracy on test data

- Convolutional Neural Network
  - ✓ Can predict likely fault type of solar panel
  - ✓ Designed for images, and achieved 76% on test data.

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Thank you

This work is part of the activities of the Energy and Climate Change Division at the University of Southampton and supported by Energy Programme of RCUK, UKRI and Engineering and Physical Sciences Research Council, Newton Fund, UK. Special thanks to ThermoSurvey in assisting with project images.