Infrared Thermographic Fault Detection using Deep Convolutional Neural Networks on Building-Mounted Photovoltaics

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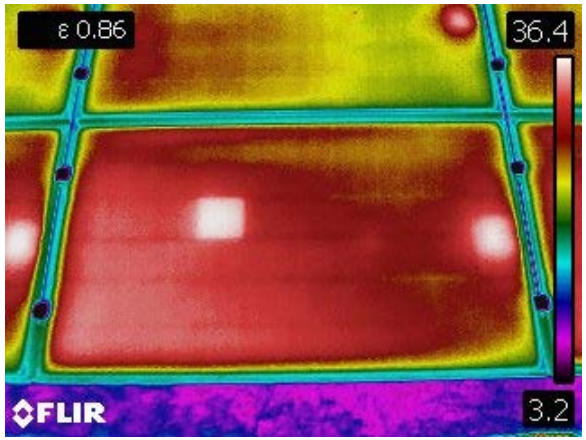
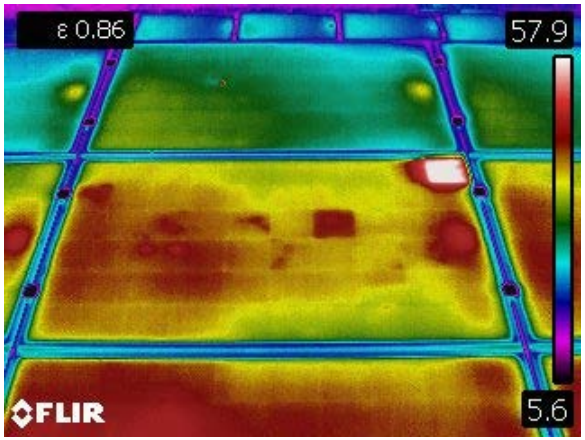
The Problem



Hot Cell

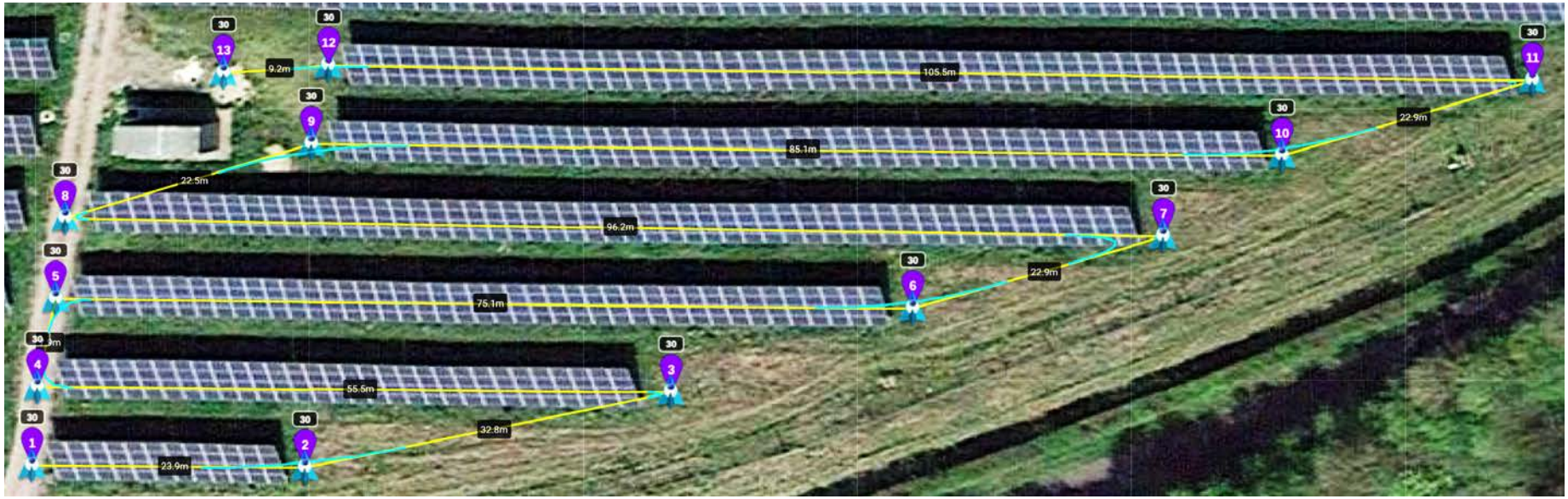


Cracked Panel

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

Utility-Scale Capturing the Images

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



Building-Mounted Capturing the Images

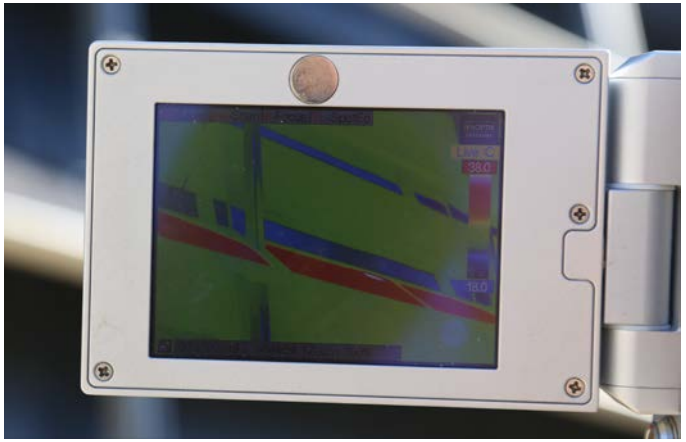
- UK drone regulations make flying difficult in developed areas
- Drone is expensive
- Requires skilled operator (commercial license costs £1000+)
- Not economical for building-mounted PV
- New cheap cameras may allow building managers to self-diagnose

InfraTec VarioCAM (£10,000)

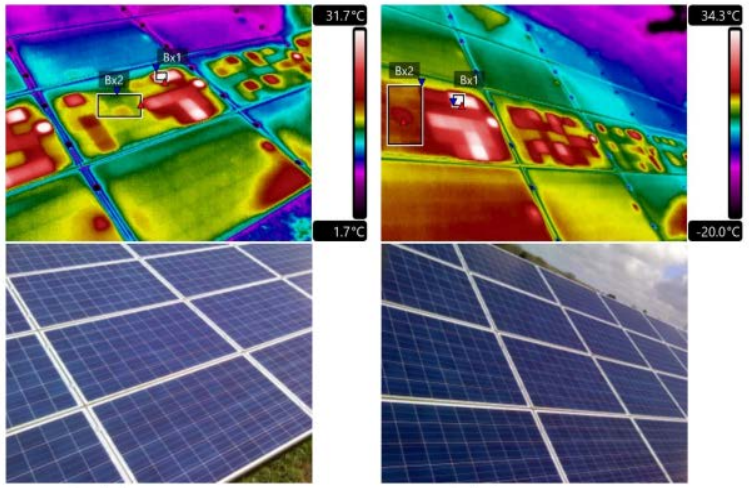
FLIR Pro ONE (£300)

Creating the Dataset

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



- Must convert from 'closed' format using expensive software



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

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

Data Augmentation

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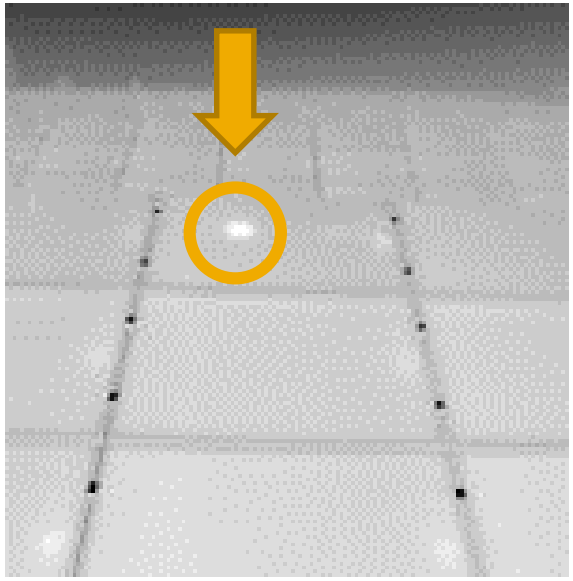
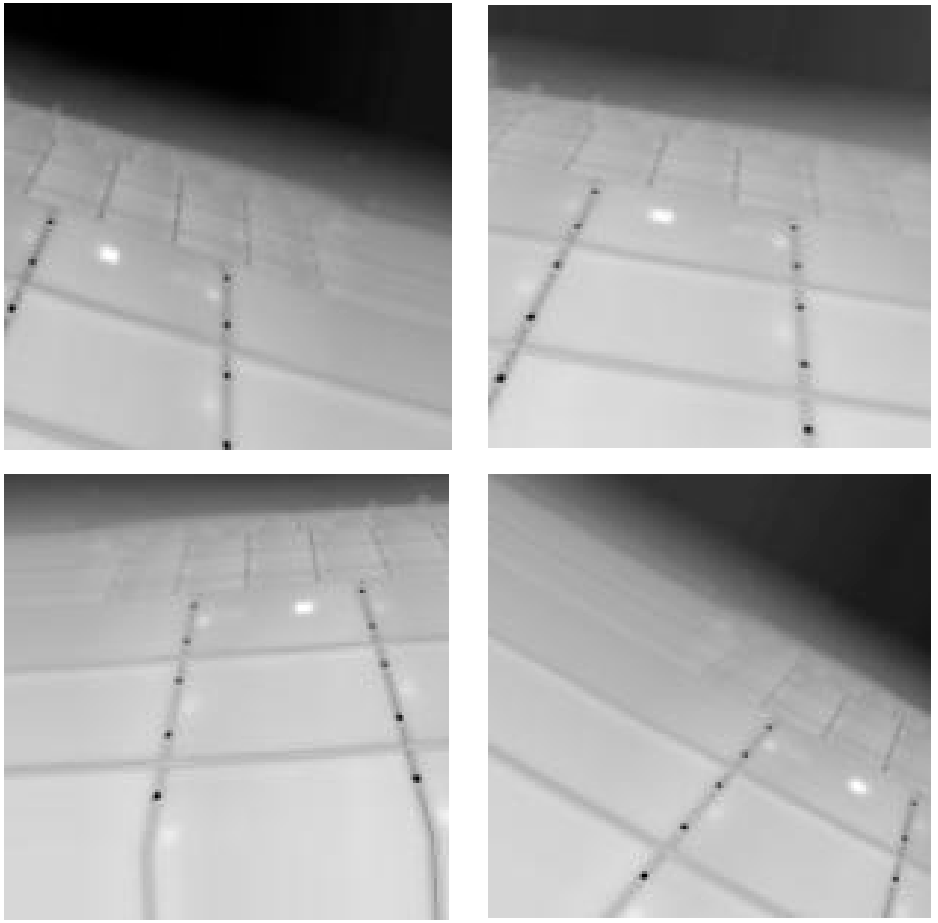
Rotation, Crop, Flip, Zoom, Skew, Brightening

Fault – Hot Cell





Data Augmentation

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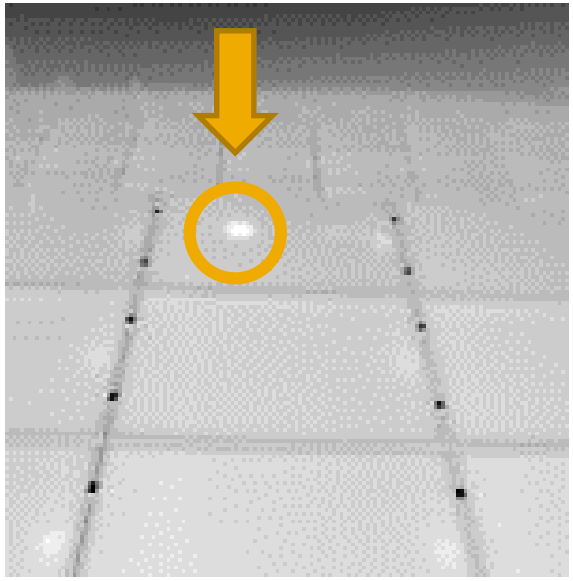
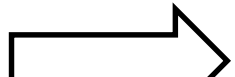
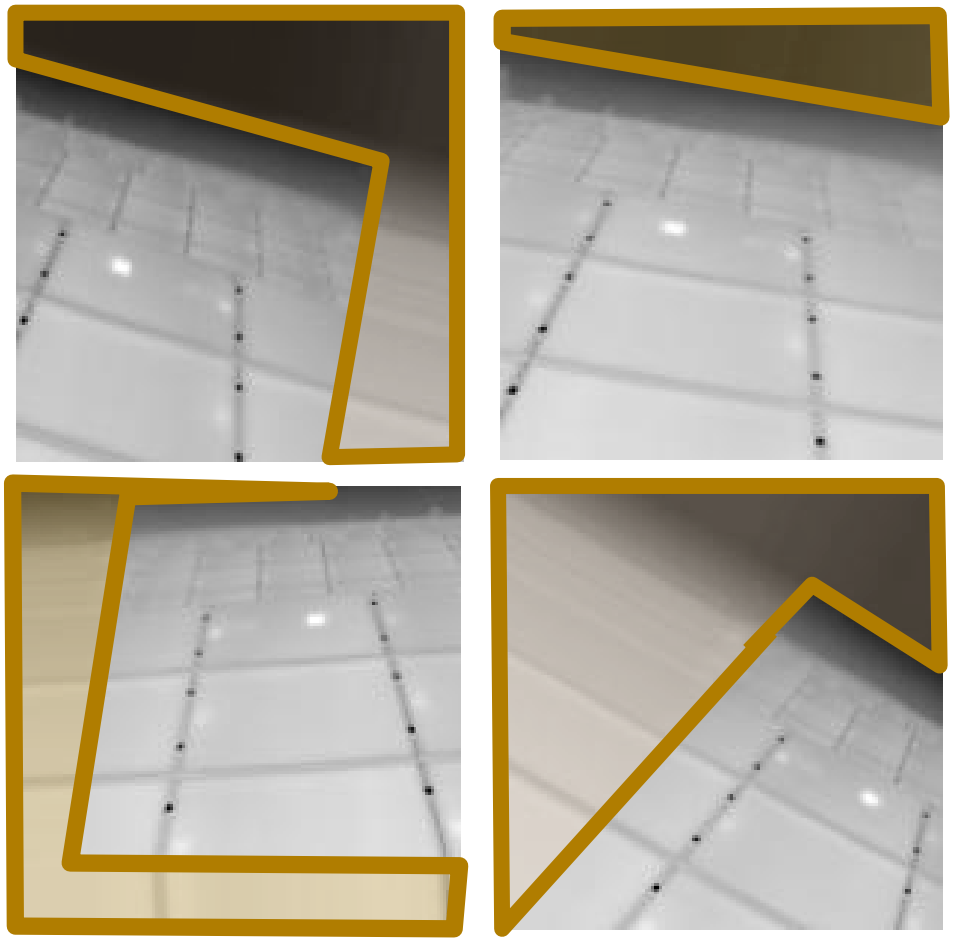
Fault – Hot Cell







Padding

Deep Learning

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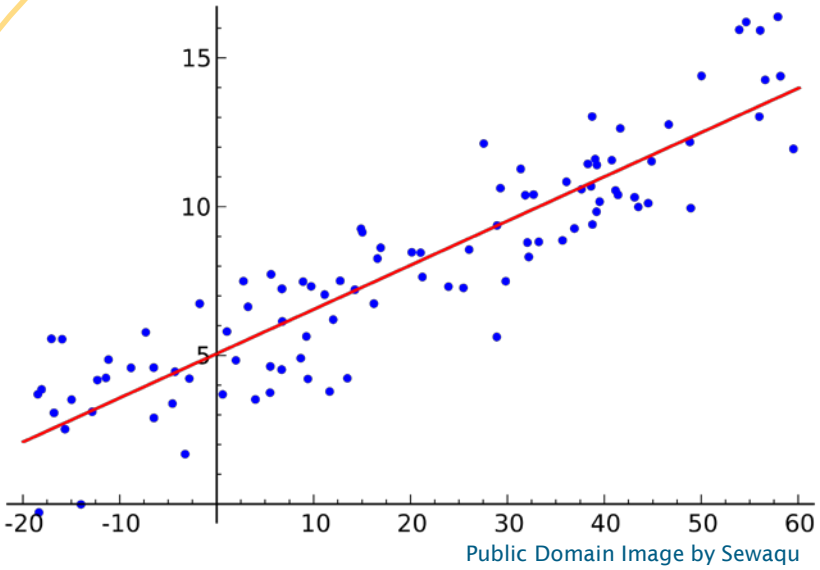
- Machine Learning
  - Artificial Neural Networks
    - Deep Learning
      - Convolutional Neural Networks



Public Domain Image by Sewaqu

Automatically predicting data

Deep Learning

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Machine Learning

Artificial Neural Networks

Deep Learning

Convolutional Neural Networks

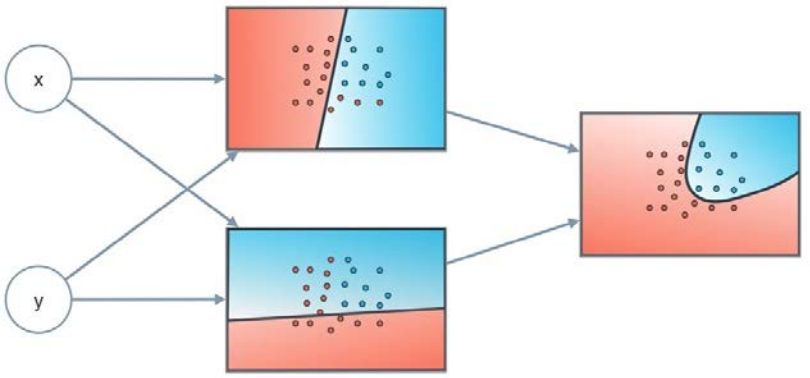

Image by Luis Serrano

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

Deep Learning

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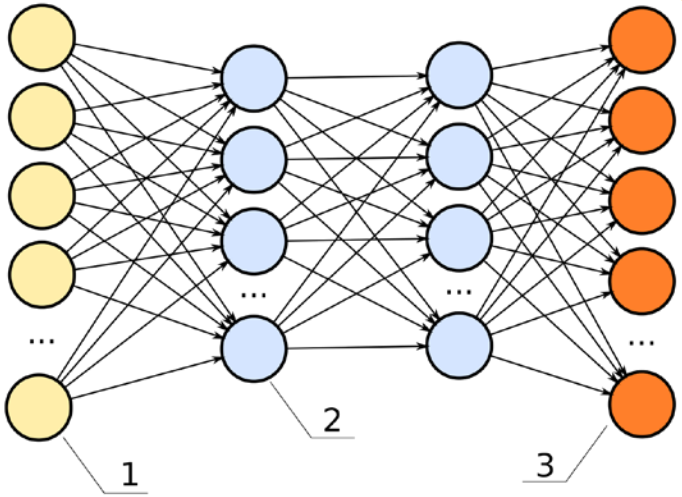
- Machine Learning
- Artificial Neural Networks
- **Deep Learning**
- Convolutional Neural Networks



Public Domain Image by Zufzzi

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

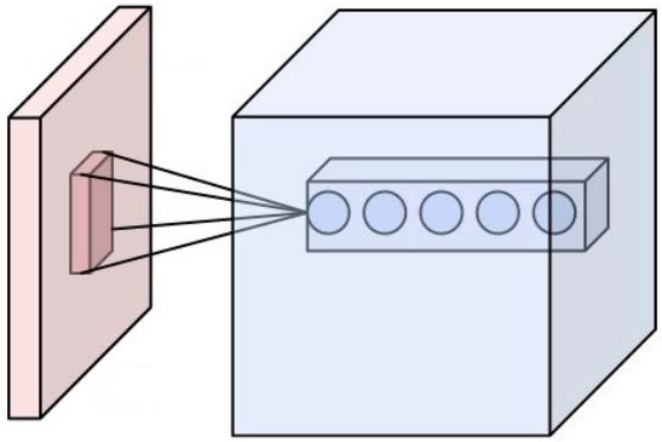
Deep Learning

Machine Learning

Artificial Neural Networks

Deep Learning

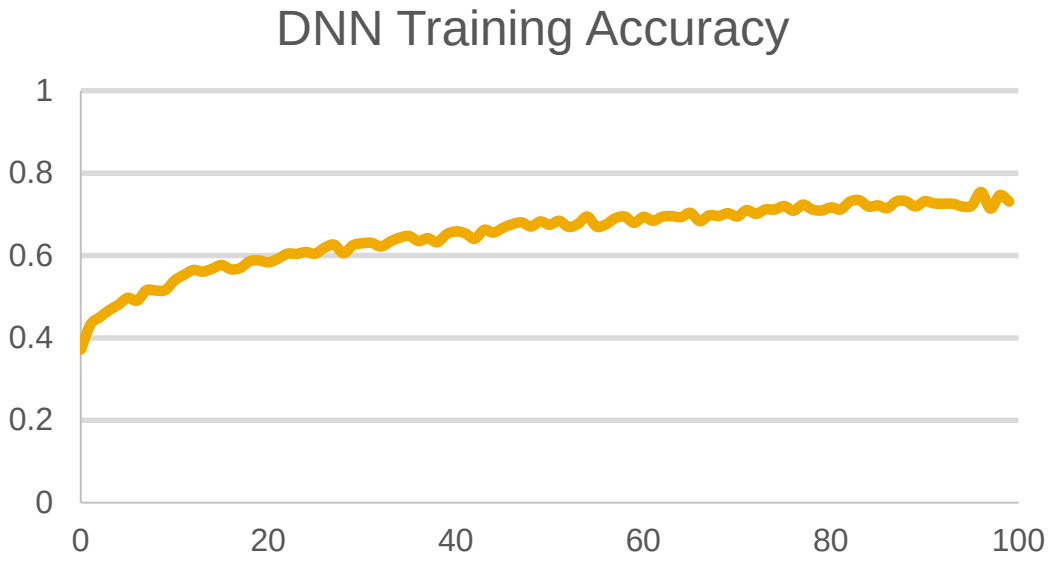
Convolutional Neural Networks

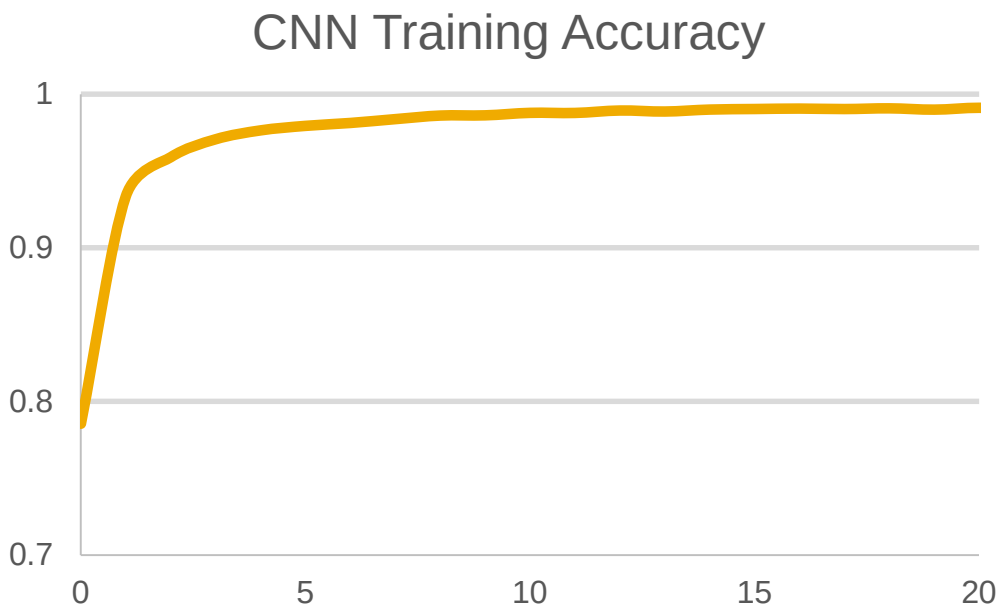


- Neural Network for Images
- Good for classification
- Often better than humans

Utility Scale Results

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





Building-Mounted Initial Results

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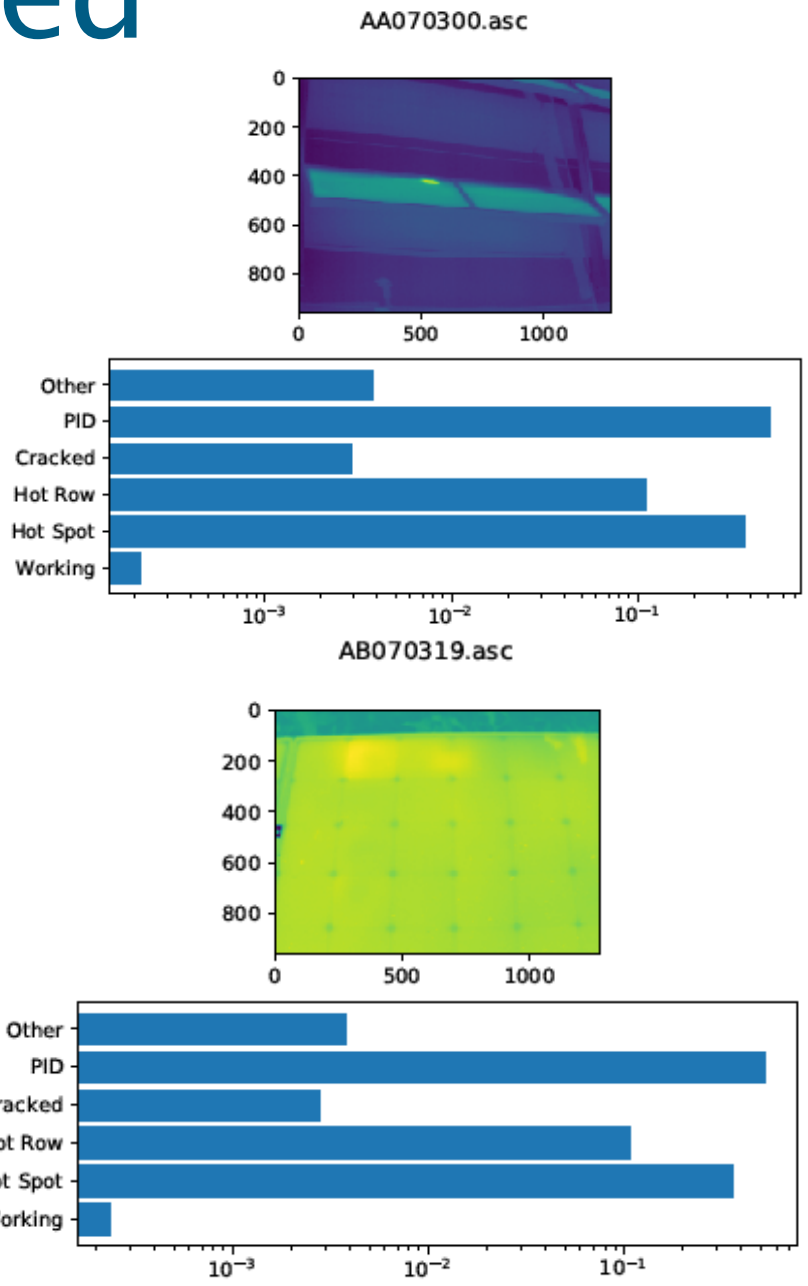
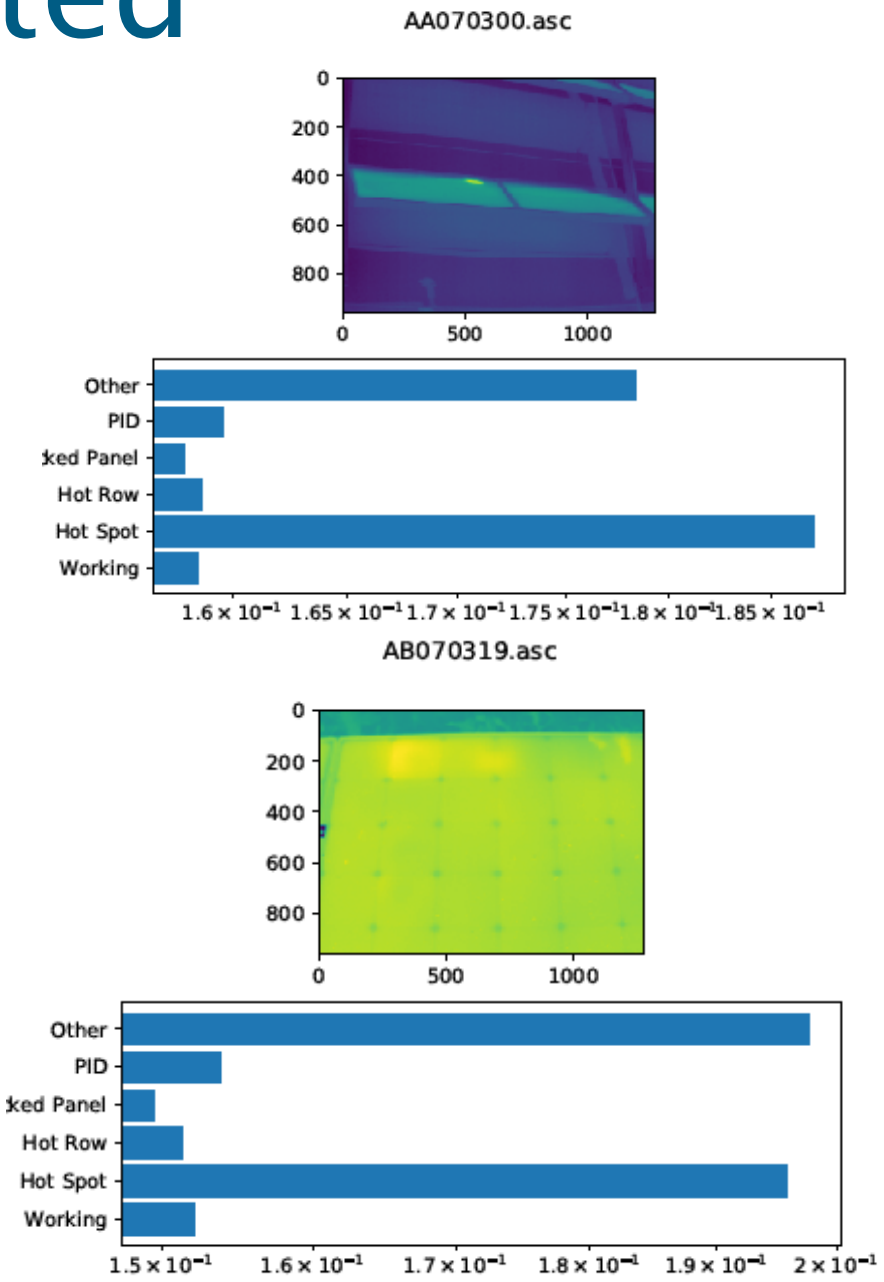
- Results are not good. Predictions for all building-mounted PV images are very similar.
- Algorithm was only trained on drone images, therefore confused by non-drone images.



Building-Mounted Results after Training

- Large increase in prediction
- "Other“: dirt, plant shading, bird droppings, visible to human eye
  - Small portion of utility-scale data
  - Large portion of building-mounted data



Summary

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- Infrared Thermography (image of heat)
  - Can be used to cheaply find faults in PV solar modules
- Convolutional Neural Network
  - Can predict likely fault type of solar panel when 'trained' from known data
  - Designed for images and achieved 76% on test data.
- Building-Mounted PV images
  - Adding only a few images to the dataset added good prediction for faults in PV

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Thank you

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