EPRI-CV: Computer Vision as Inventory Tool

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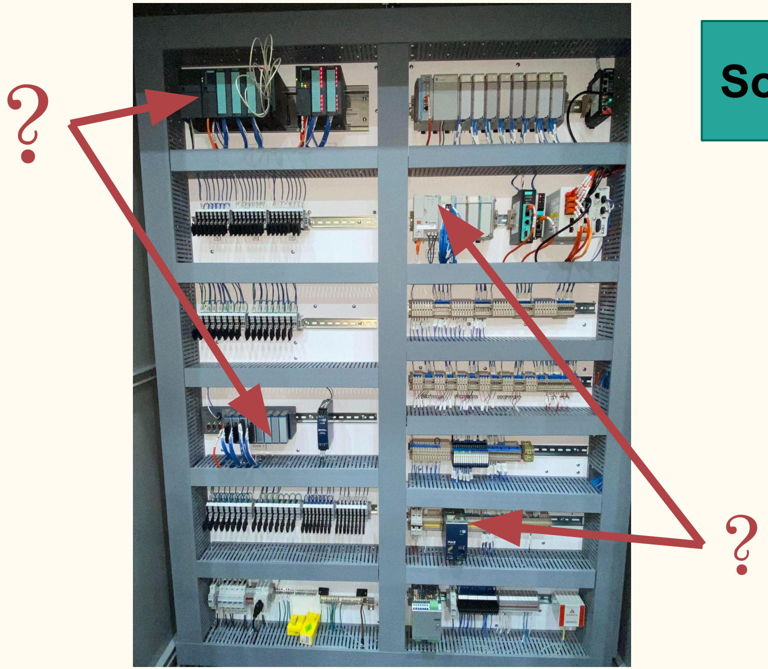
sea visionaries

Problem Statement

Control panels in power plants are not well-inventoried; in-person inspections time consuming



Solution

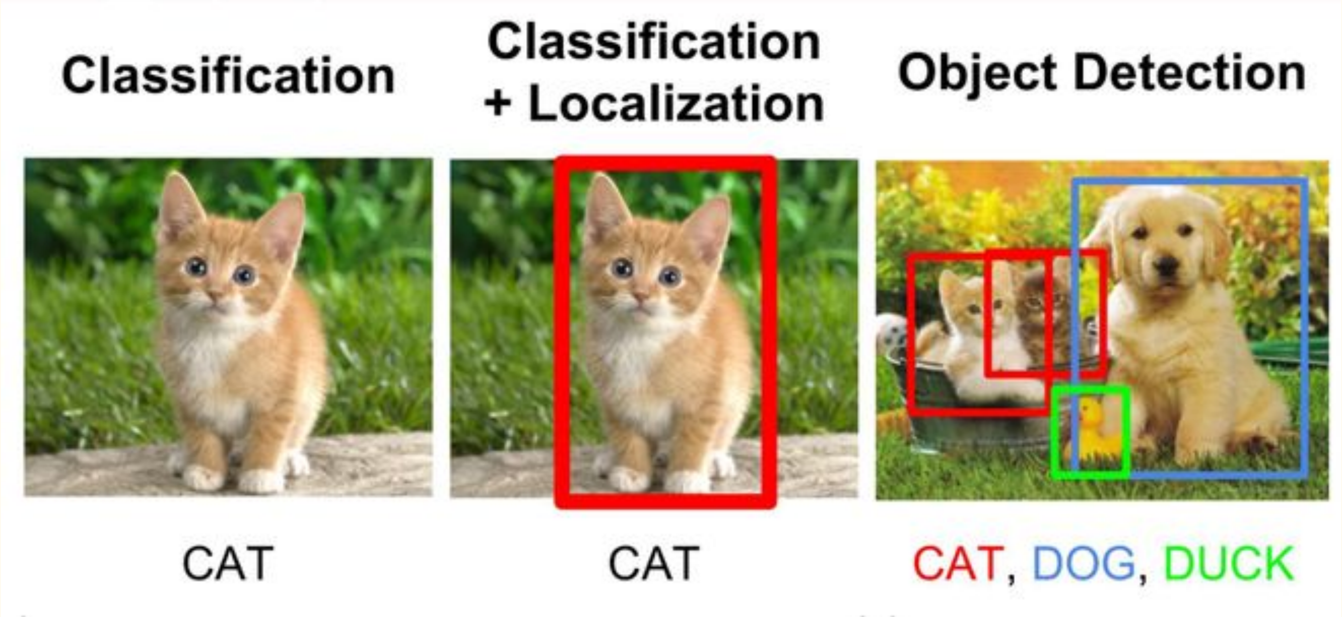
Develop a computer vision model to identify specific cyber-security modules

Inspector takes a photo of the cabinet...

... runs photo through inference with the model

... inventory!

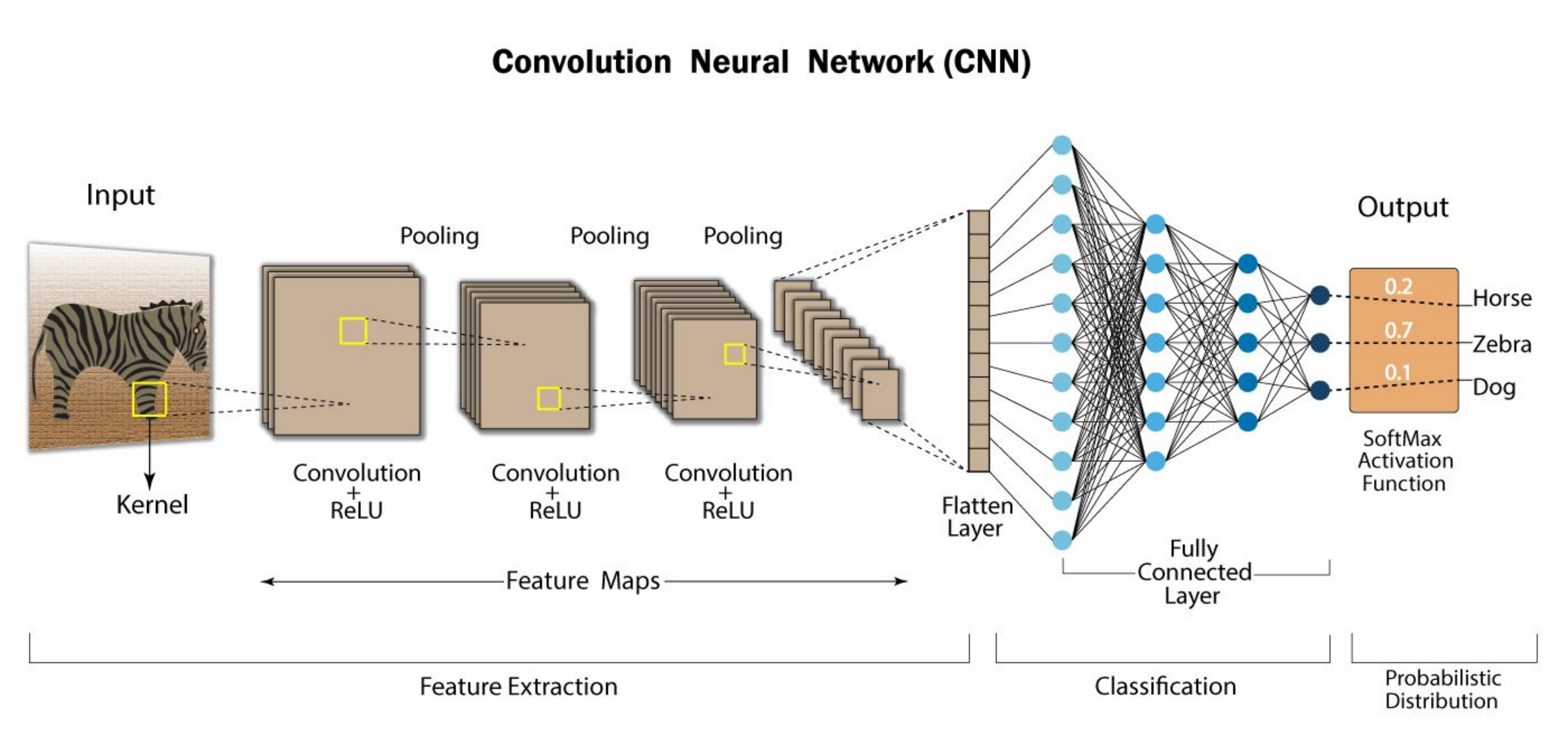
Computer Vision Basics



Multiple objects of several classes in our problem → Object Detection

https://www.kaggle.com/getting-started/169984

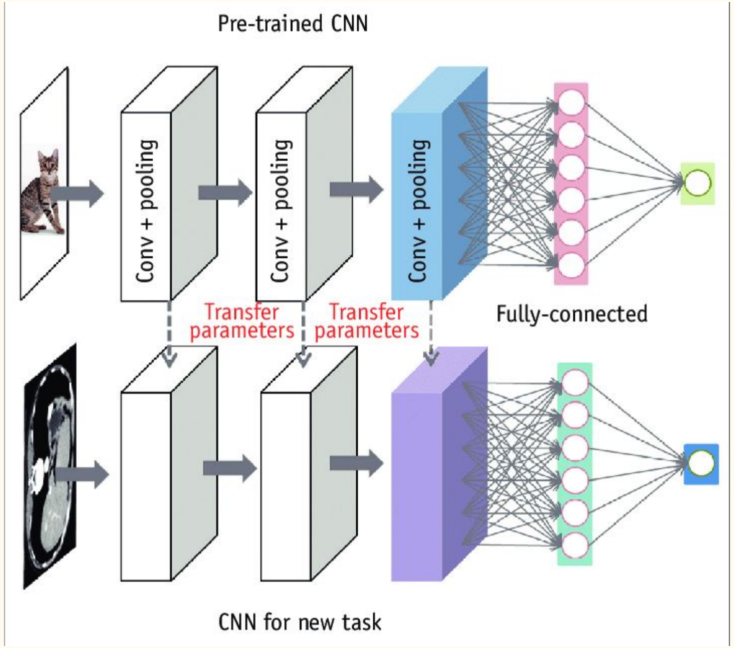
CV and Deep Learning:
Convolutional Neural Networks (CNN)



https://developersbreach.com/convolution-neural-network-deep-learning/ [accessed 30 Aug, 2021]

Basics Of Our Approach:

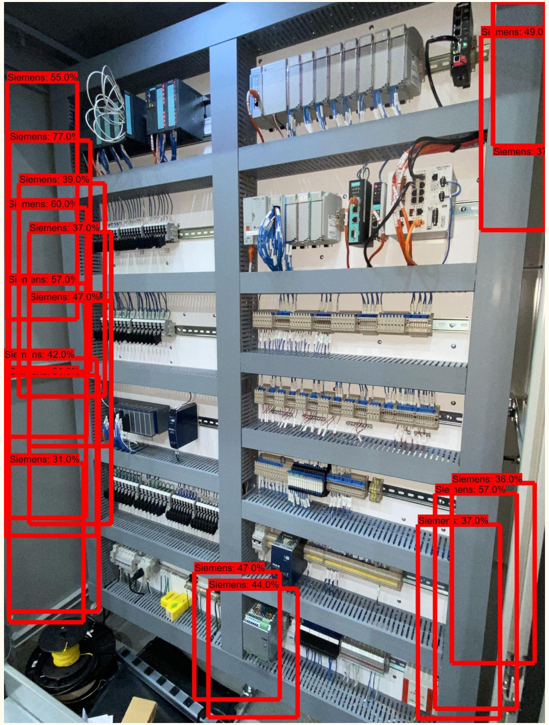
- No time to train the model from scratch → choose a pre-trained CNN model and use **transfer learning**:
  - Keep the structure
  - Start from pre-trained weights/parameters
  - Additional classes of objects can be added



https://www.researchgate.net/figure/Transfer-learning-Transfer-learning-is-process-of-taking-pretrained-model-usually_fig1_338540456 [accessed 27 Aug, 2021]

A First Model

Out of the box performance:



Oh.
That is clearly quite bad.

-

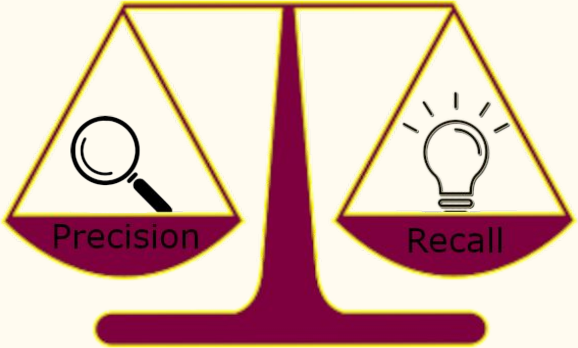
But **how** bad?

Recall vs. Precision

Perfect Precision:

Do we make mistakes?

Do we miss things?

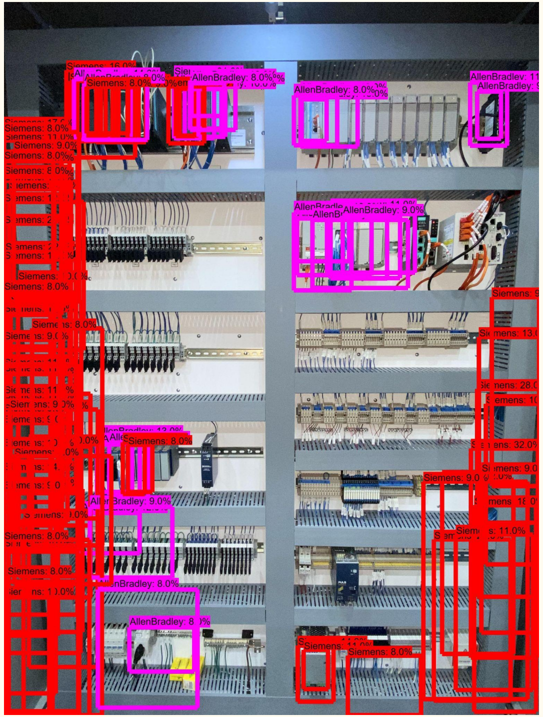


0 1

← Detection Score Threshold →

0 1

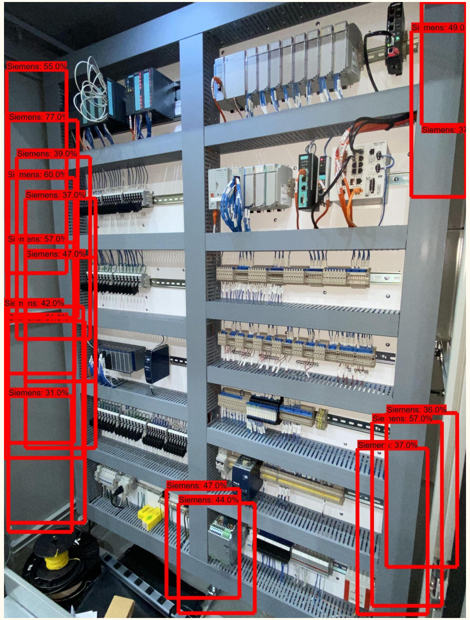
Total Recall:



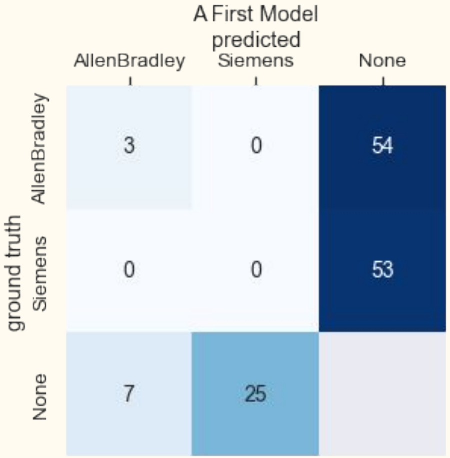
0 1

A First Model - Evaluated

Visually:

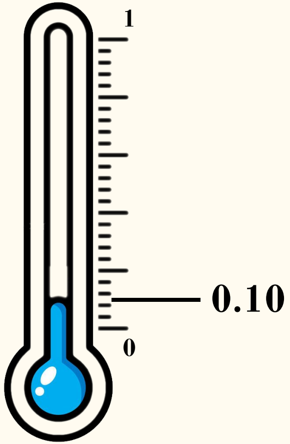


Confusion Matrix:



Precision: 0.125
Recall: 0.035

mAP Score:

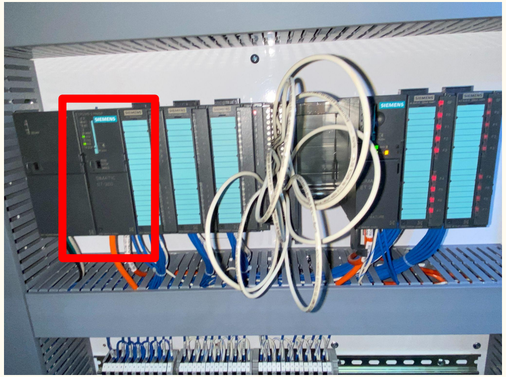


Available Data

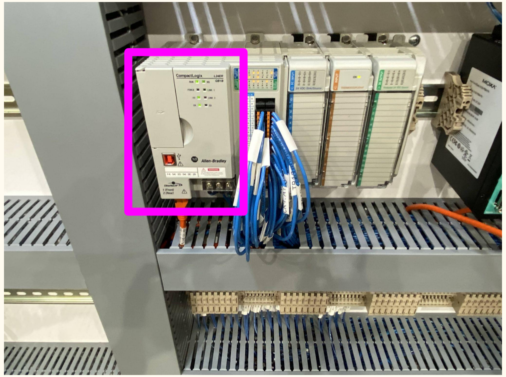
Original EPRI images were photographs of the same cabinet as training and test data

(if used for training, leads to data leakage)

TRAINING DATA



Siemens S7-300



Allen Bradley CompactLogix 5370

TEST DATA

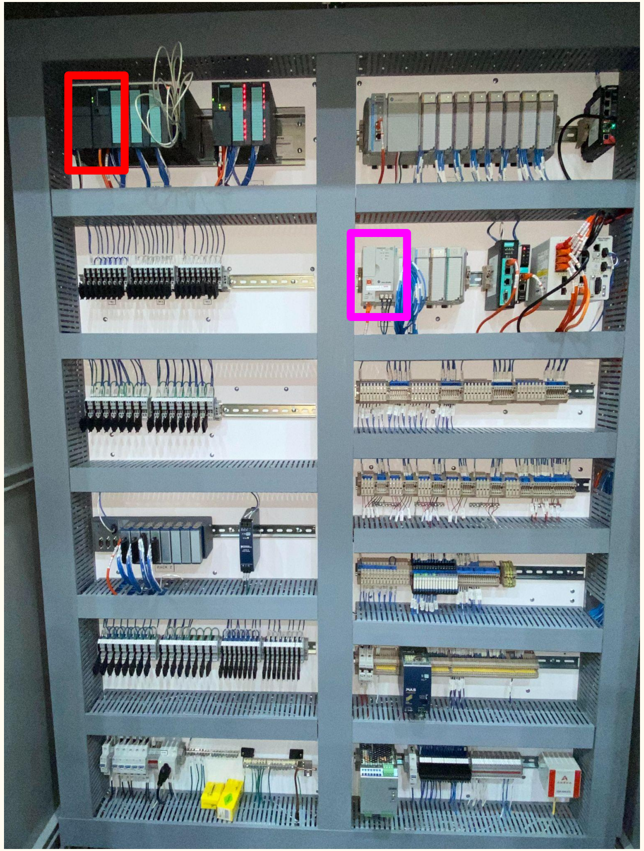


Image Synthesis

Scraping and labeling controller images from using Google search

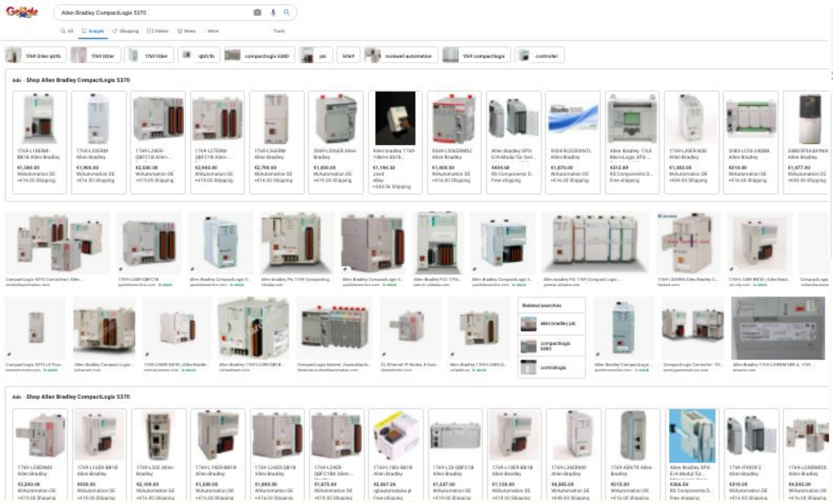
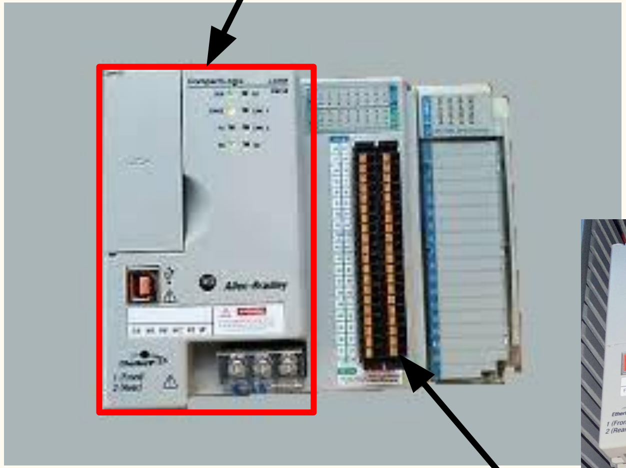


Image Synthesis

Which part of the object to include?

Bounding box -
the part that the model is trained to “pick out”

Mask



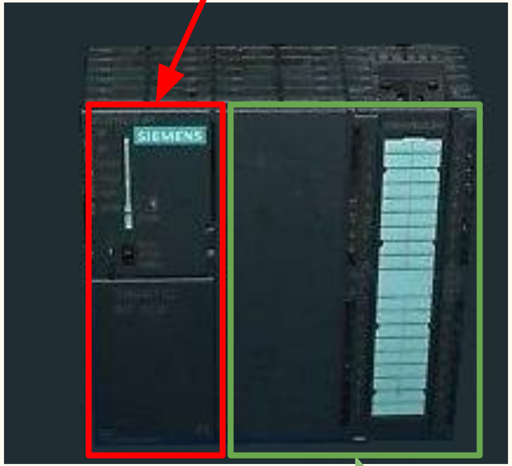
Cables usually plugged in here

Image Synthesis

Which part of the object to include?

Mask

Bounding box -
the part that the model is
trained to “pick out”



Does not always appear with the controller

Image Synthesis

Pasting controller images onto random electrical cabinet backgrounds

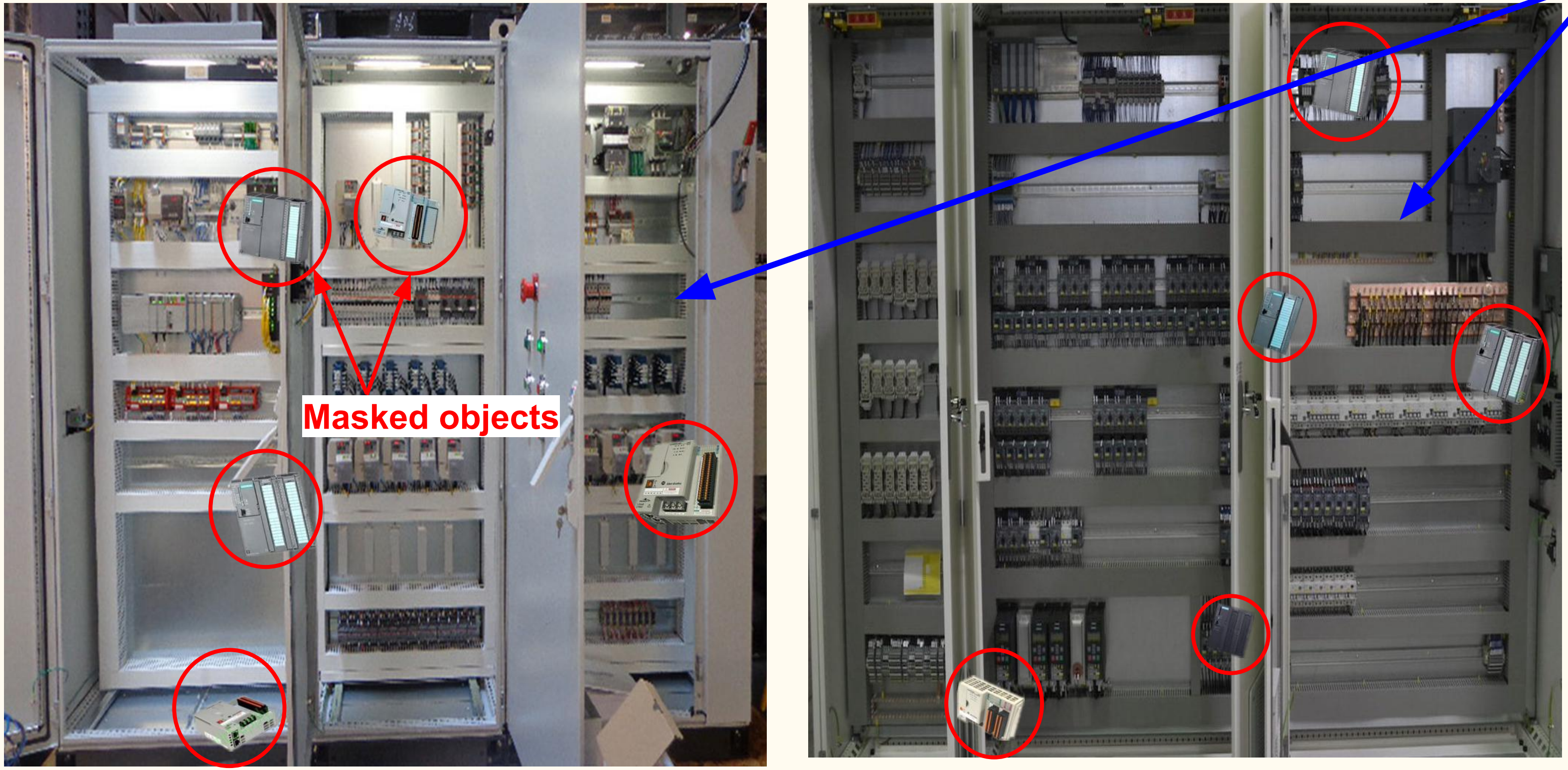
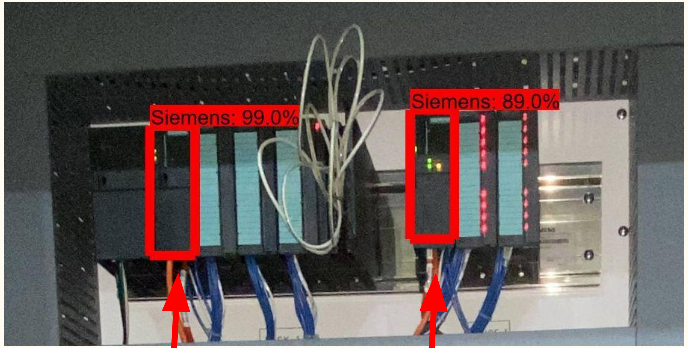


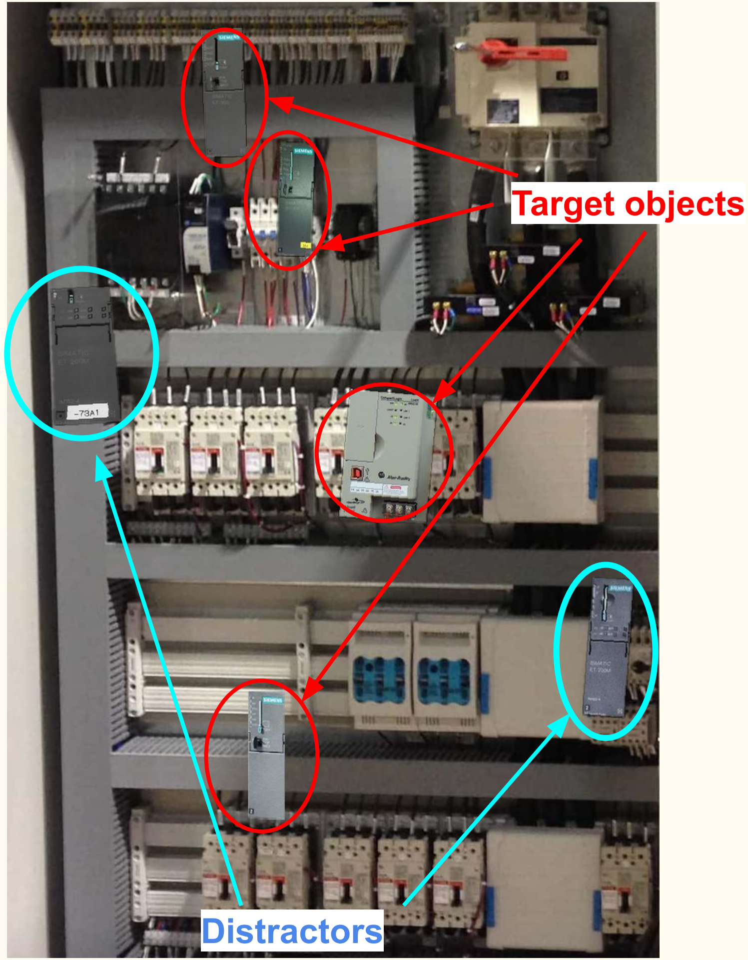
Image Synthesis

Adding distractors - Helping model better identify the correct targets



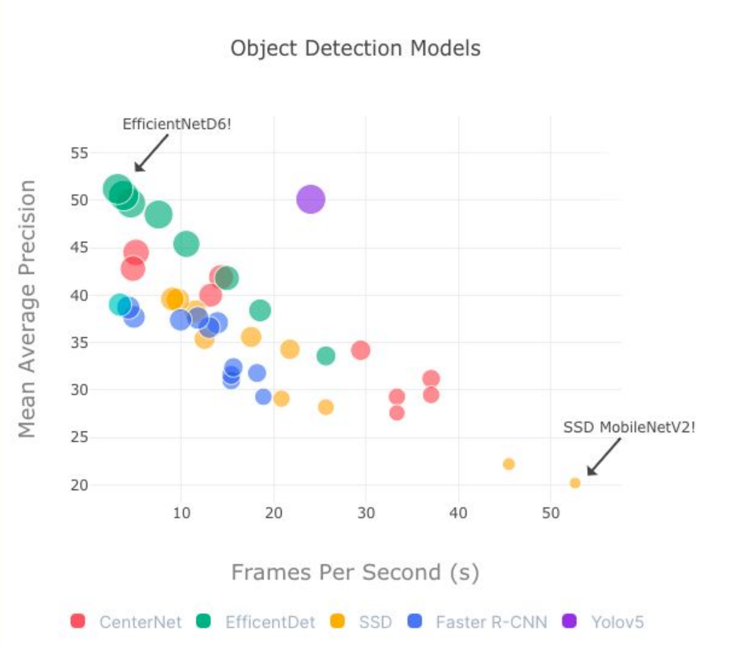
Correct detection

Incorrect detection



Comparison Between Various Models

Tradeoff between computing power and performance

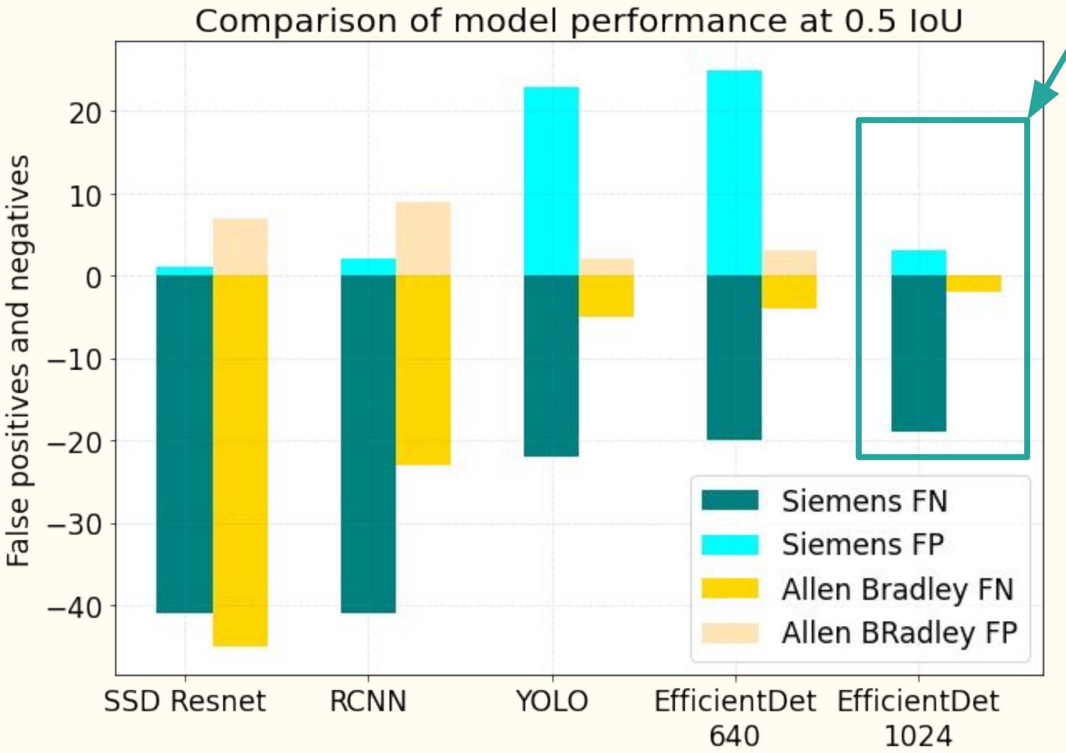


Models that we trained and tested included:

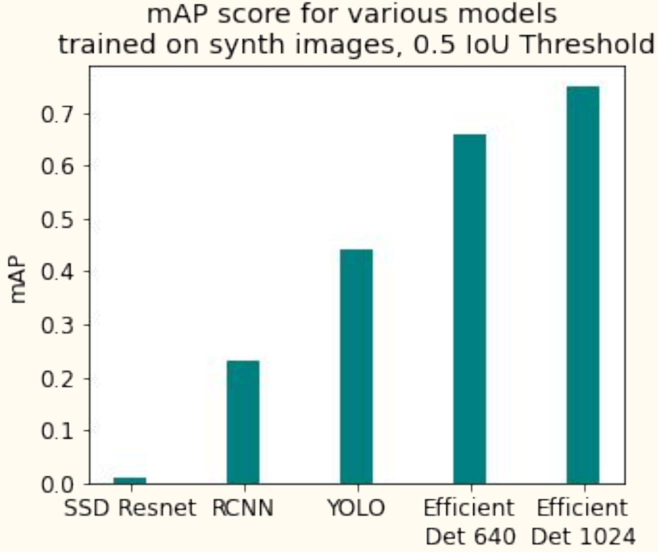
- YOLO4
- SSD ResNet152 V1 FPN 640x640
- Faster R-CNN ResNet50 V1 640x640
- EfficientDet D1 640x640
- EfficientDet D4 1024x1024

https://victordibia.com/blog/state-of-object-detection/

Models trained on synthetic images and evaluated on test images from EPRI

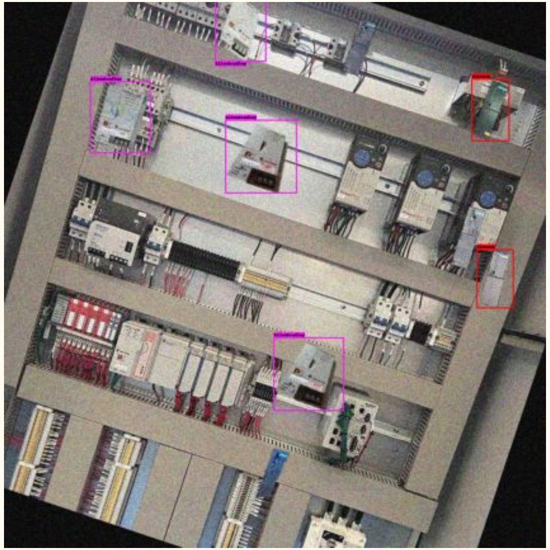


EfficientDet at 1024 resolution has overall least FP and FN for both modules, and relatively good mAP

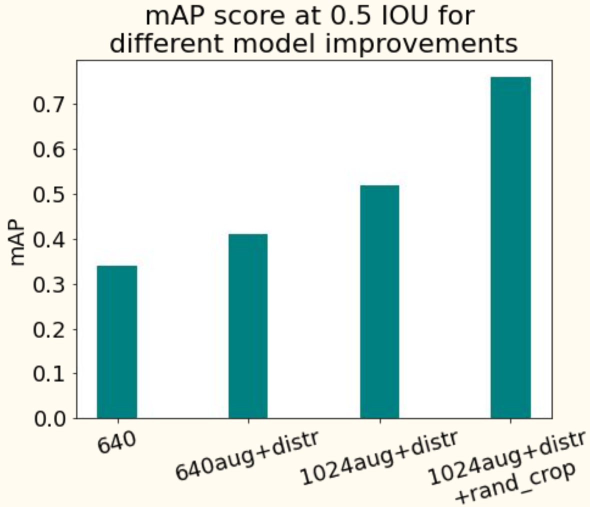


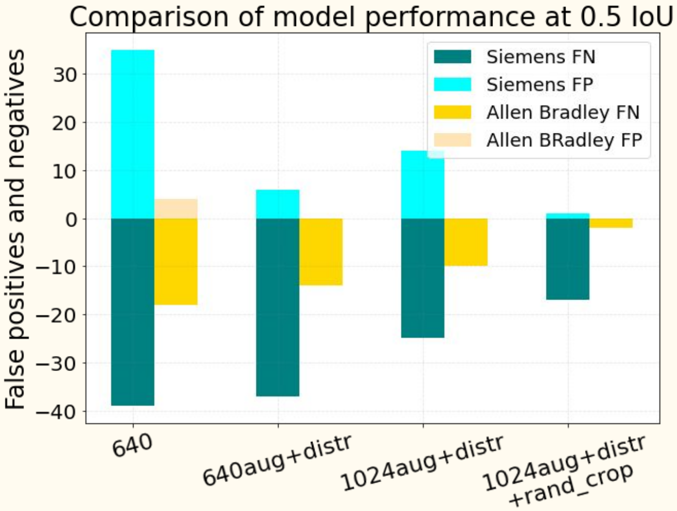
EfficientDet: Modeling

- Higher input image resolution
- Image augmentation
- Distractor objects
- Model-specific parameters:
  learning rate, anchor boxes, ...

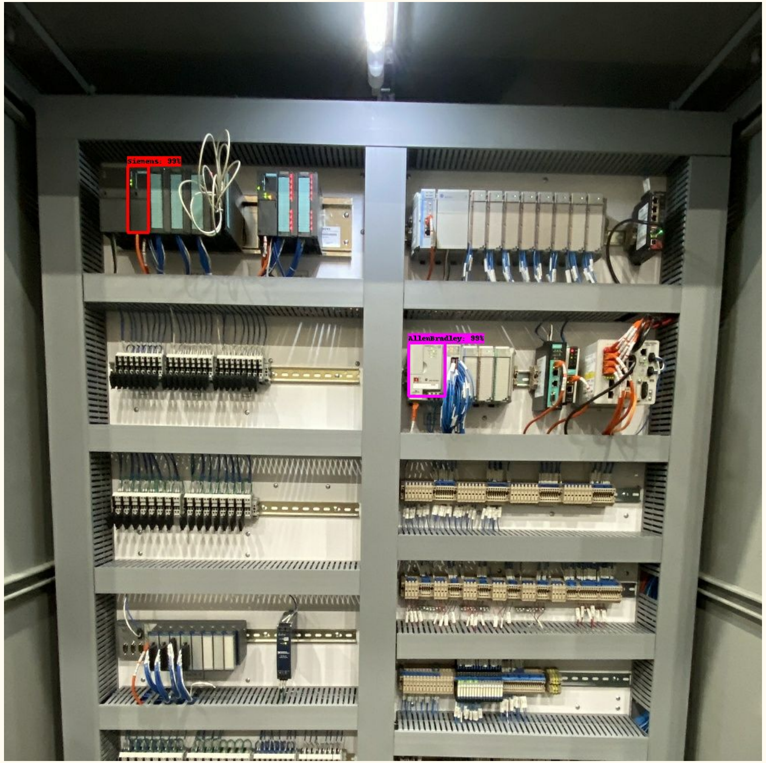


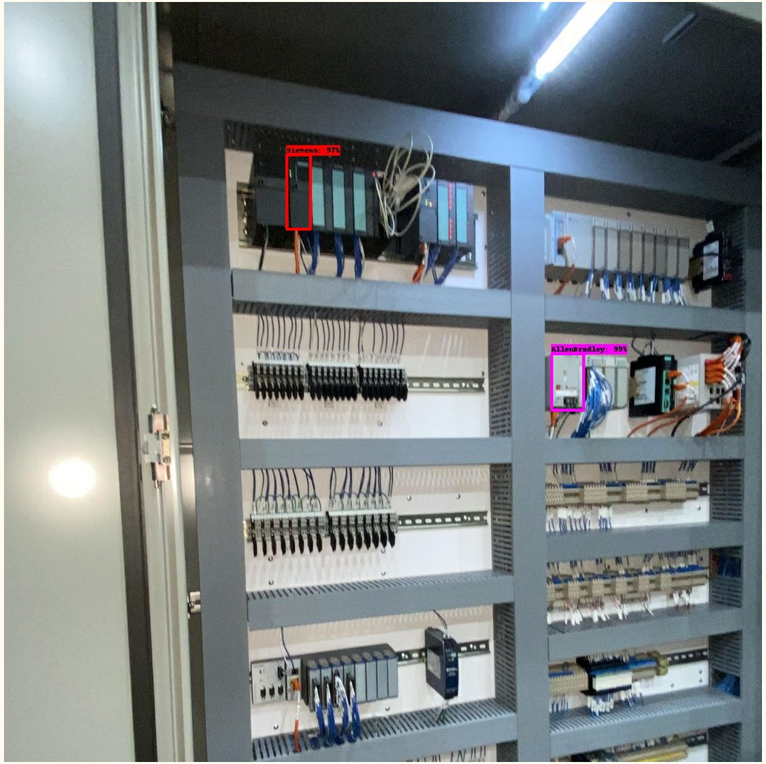
example of an augmented training image



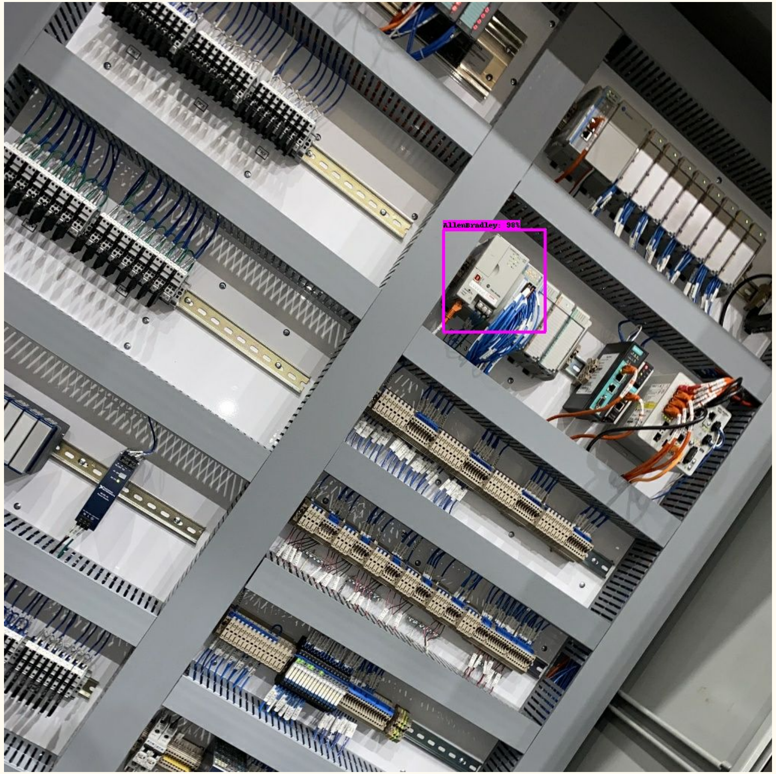


EfficientDet: Results





EfficientDet: Results



EfficientDet: Results

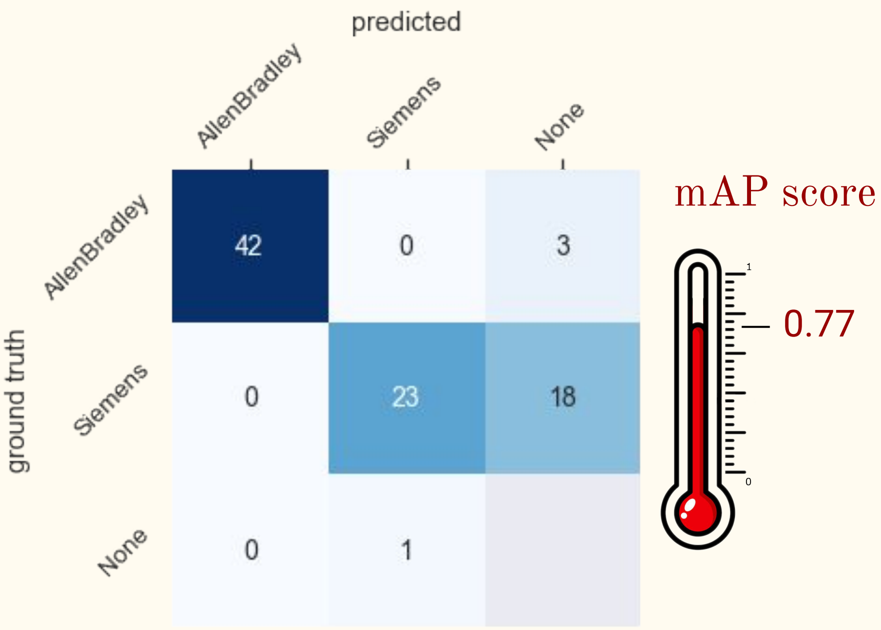
obscuration by cables

EfficientDet: Results

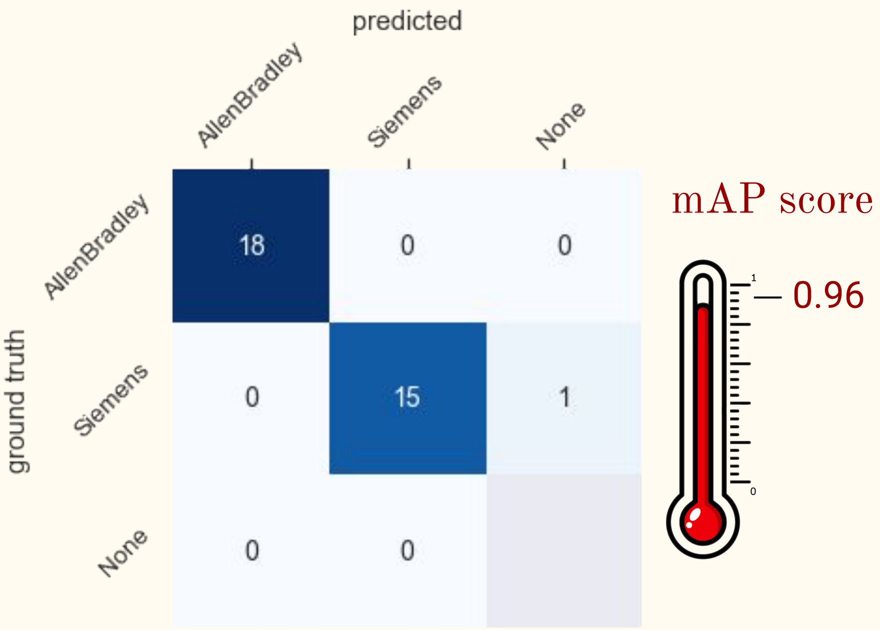
a single false detection + non-detections due to obliqueness

EfficientDet: Results

all images



only face-on images



How The Model Could Be Improved

- More diverse training and testing data; data from real control cabinets would be ideal
- Include more controllers as new classes
- Tweaking model hyperparameters - a more exhaustive search

Conclusion

Fake it till you make it!

Proof-of-concept completed successfully - demonstrable feasibility of using computer vision as an inventory tool