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Sandia National Laboratories

Using Object Detection to Train Better Image Classifiers

Unexpected Findings from Validation of a Large, Synthetic International Nuclear Safeguards Dataset

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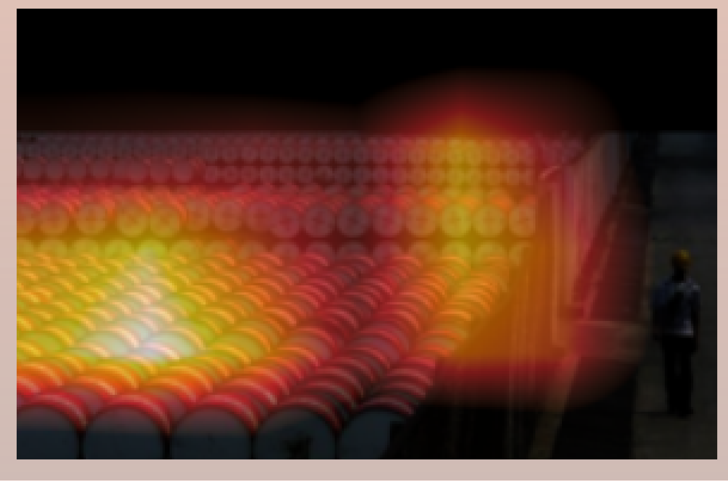
Background: In 2022, we published a dataset of **over 1 million images** featuring synthetic (computer-generated) and real UF6 containers:

- 30B and 48X, 48Y, and 48G container designs
- Real and synthetic backgrounds
- 0, 1, or multiple relevant containers per frame + distractors
- Diverse settings, lighting, perspectives

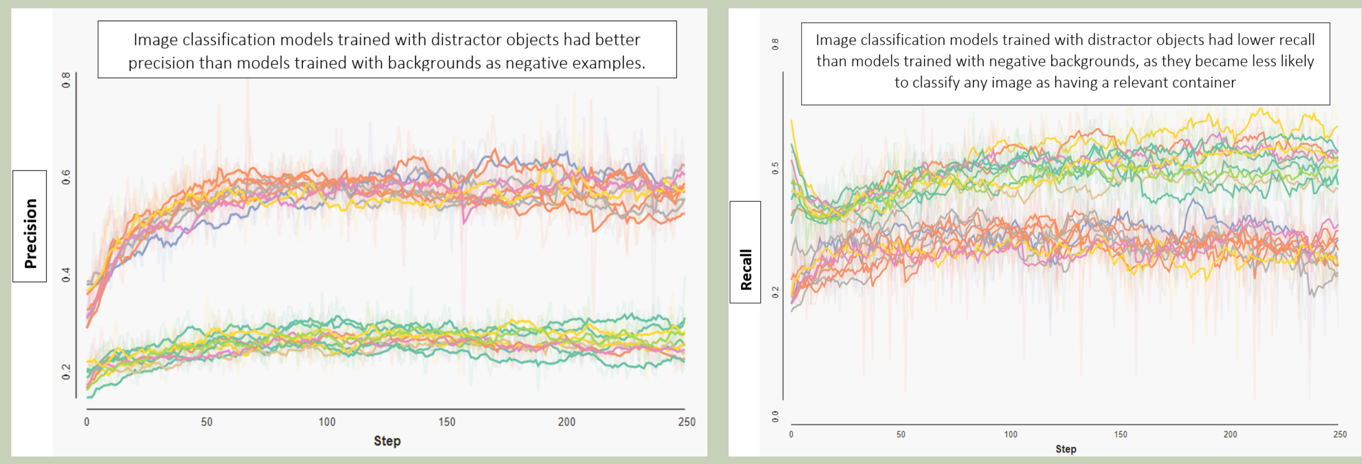
Novel, **iterative validation** methodology:

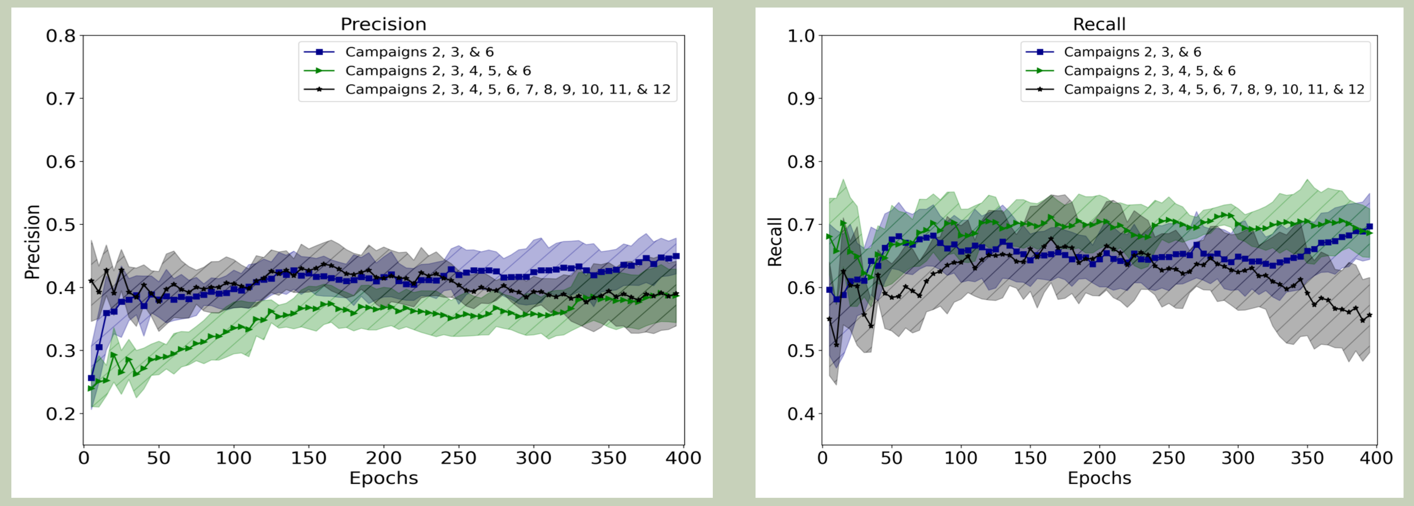
- Interpret what model is learning
- Render synthetic images
- Train model on synthetic data
- Test model on real data

Results **interpretation**:

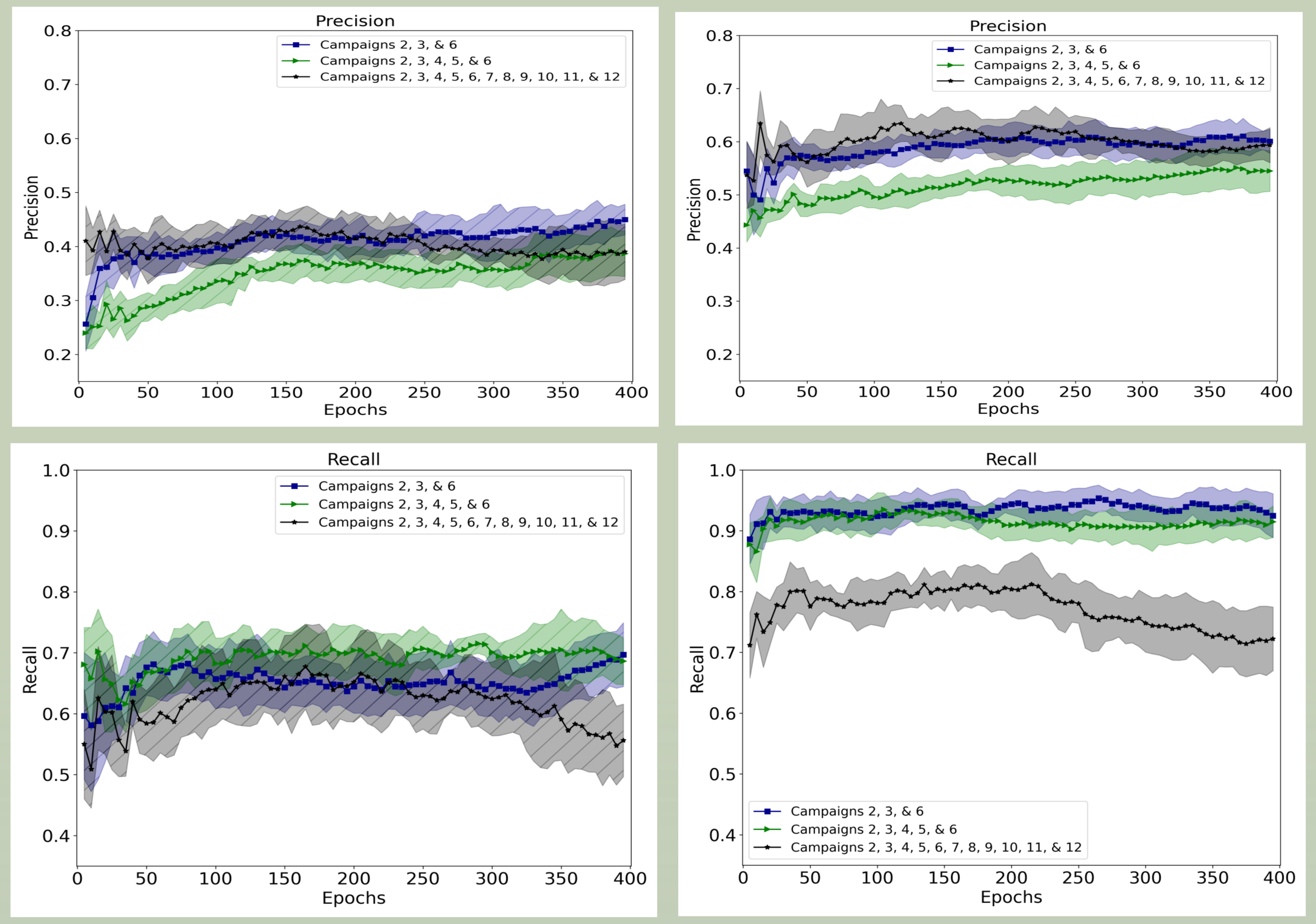


Finding 1
Object detection models perform well as image classifiers

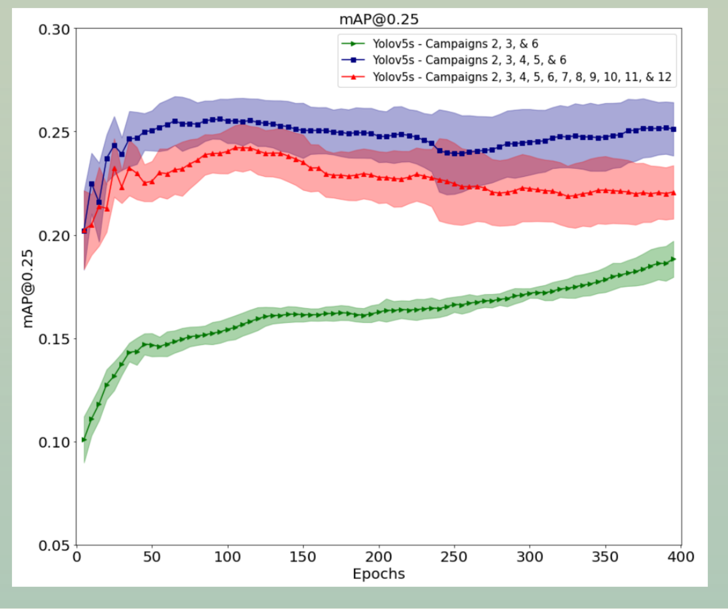




Finding 2
Models perform differently on 30B and 48 style containers



Finding 3
Confirmed greater image complexity yields better models



Conclusions
- Computer vision models are learning the wrong features.
- Computer vision models trained on synthetic data still perform worse than they should.

Current Research
1) Characterize synthetic and real image features.
- Determine which features of the data are causing disparate model performance
- Process the data to bring real and synthetic images closer in relevant feature space

2) Masked receptive fields to limit irrelevant learning.
- Train on most relevant pixels as defined by SME
- Reduce or eliminate learning from background

Use our data
- Unclassified and open source
- Labelled
- Permissions suitable for publication
- Custom API for dataset navigation

https://limbo-ml.readthedocs.io

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Abstract: International nuclear safeguards are measures put in place through state's sovereign bilateral or multilateral agreements with the International Atomic Energy Agency (IAEA) – under the auspices of the United Nations – to ensure that commercial nuclear materials and facilities remain in peaceful use. The plethora of potentially relevant material that requires review as part of international nuclear safeguards monitoring has led to interest in potential applications of computer vision technologies. However, relevant datasets for international safeguards tend to be rare and small, neither of which is ideal for computer vision research. To address this need, our team at Sandia National Laboratories has developed a large, open-source dataset which contains synthetic and real images that are relevant for international safeguards. The images include two models of containers that are used to transport and store uranium hexafluoride throughout the nuclear fuel cycle, with relevance for uranium conversion, enrichment, and fuel fabrication. The images also include a host of distractor objects such as 55-gallon drums, propane tanks, and beer kegs. In the development of these images, our team implemented a unique data validation method of iteratively testing images with multiple computer vision techniques, observing results (including with machine learning explainability methods), and developing new images to counter biases, inconsistencies, or unrealistic traits in the data. As part of this validation process, we trained image classifiers (which return a list of classes present in an image) and object detection models (which return the location and class of objects present in an image) with the synthetic data, tested their performance on the real images, and reviewed the models' performance. To compare between image classification and object detection models, we assessed object detectors as if they were image classifiers. If the object detection models found any instance of an object within the image regardless of its location, it was counted as a correct detection. This allowed us to compare our classifiers and object detectors in terms of a binary confusion matrix of true positives, true negatives, false positives, and false negatives. In doing so, we found that the object detectors that had moderate performance using typical object detection performance metrics like mean average precision (mAP) performed better than our classifiers when assessed using the confusion matrix. In the poster, we share our methods, results, discussion, and future research directions.

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