DOE-FIU Cooperate Agreement Annual Research Review – FIU Year 3

Nuclear Waste Identification and Classification using Deep Learning

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Nuclear Waste Identification and Classification using Deep learning

Overall Needs:

- Understand and identify the presence of nuclear waste within multiple, different environments in real time.
- Develop and use deep learning models to facilitate computer vision operations without needing experience with deep learning.

Objectives:

- Research and explore the development of different deep learning solutions.
  - ✓ There are many algorithms that aim to solve the same or similar problems, each with its own advantages and disadvantages.
- Develop models in such a way that they can be integrated with other code.
  - ✓ Once the models that identify and classify objects are developed, it might be of interest to forward the results to another system like a robot system.
- Deploy developed algorithms to enhance AAML functionality.
  - ✓ Algorithms developed for a dataset can be abstracted to function on similar datasets.

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Algorithm and Model Development to Identify and Classify Nuclear Waste

FIU Year 3 Highlights:

Implemented YOLOv7 model for Object Detection.

- ✓ For a given object, the model predicts the object's class, bounding box, and its confidence on the prediction.
- ✓ It reaches a high mAP on the test set.
- ✓ The model is designed to detect objects in real time using a CPU.
- ✓ It requires labeled data to learn how to detect objects.
- ✓ Since it learns from bounding box, it struggles to learn how to detect thin and/or long objects where the background is most of the box.

Example of the predictions results for a given image

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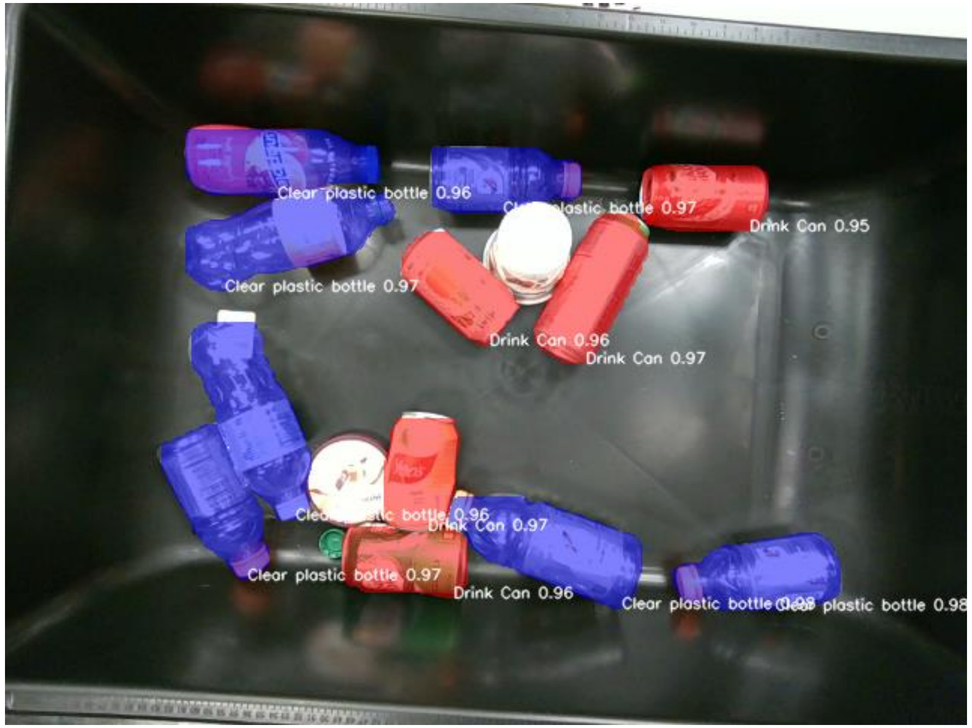
Algorithm and Model Development to Identify and Classify Nuclear Waste

FIU Year 3 Highlights:

Implemented YOLOv7 model for Instance Segmentation.

- ✓ For a given object, the model predicts the object’s class, segmentation mask, and its confidence on the prediction.
- ✓ It reaches a high mAP on the test set.
- ✓ The model is designed to detect objects in real time using a CPU, though it is slower than the Object Detection version.
- ✓ It requires labeled data to learn how to detect objects.
- ✓ It can detect thin and/or long objects better than the previous version



Example of the predictions results for a given image

Algorithm and Model Development to Identify and Classify Nuclear Waste

FIU Year 3 Highlights:

Implemented STEGO model for Unsupervised Semantic Segmentation.

- ✓ For a given image, the model predicts a set of clusters and the segmentation mask for each cluster.
- ✓ The model is not designed to detect objects in real time using a CPU. However, by keeping a sufficiently small image size, it is possible to reach real-time inference speeds. There is a tradeoff with mAP.
- ✓ It does not require labeled data to learn how to detect the clusters.
- ✓ Sometimes it is unfeasible to convert the cluster masks into a polygon format because a cluster can contain one or more objects.

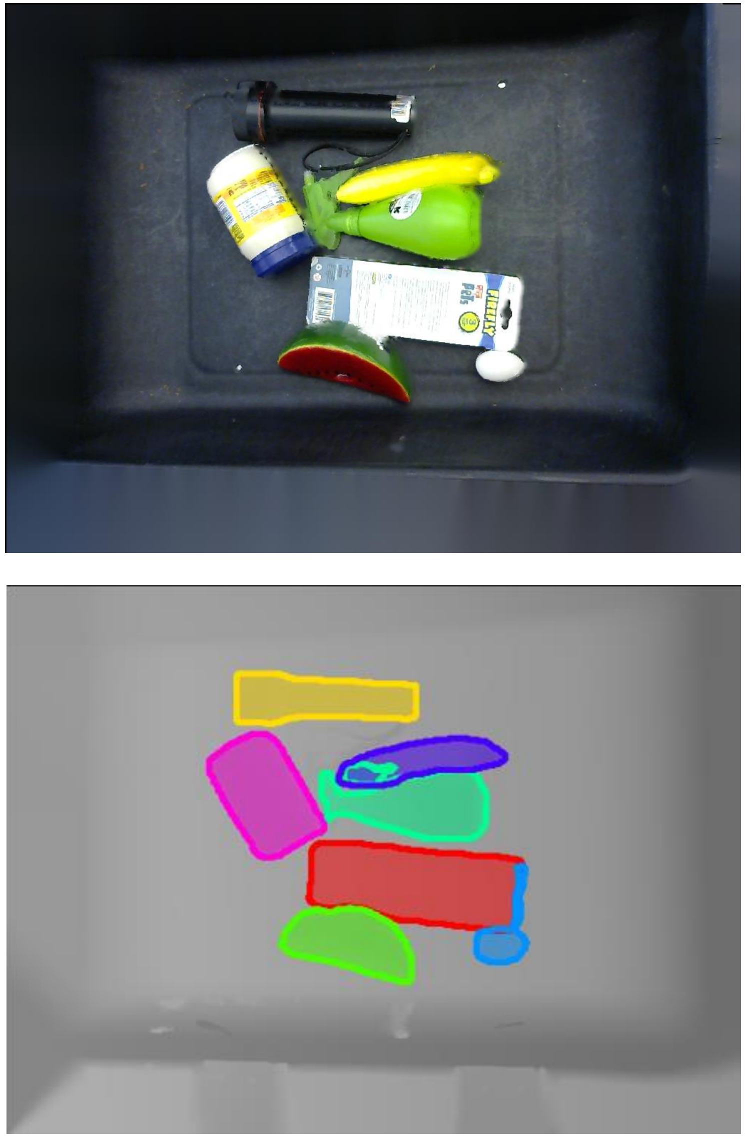
Example of the predictions results for a given image

Algorithm and Model Development to Identify and Classify Nuclear Waste

FIU Year 3 Highlights:

Implemented Mask R-CNN model for Disparity Image Segmentation.

- ✓ For a given disparity image, the model predicts an object's segmentation mask and its confidence that it is a foreground object.
- ✓ The model is not designed to detect objects in real time using a CPU. However, by keeping a sufficiently small image size, it is possible to reach real-time inference speeds. There is a tradeoff with mAP.
- ✓ It does require labeled data to learn how to detect the clusters. It can only detect foreground vs background objects.
- ✓ Struggles with nested objects.



Example of the predictions results for a given disparity image. The top image is used for comparison purposes only.

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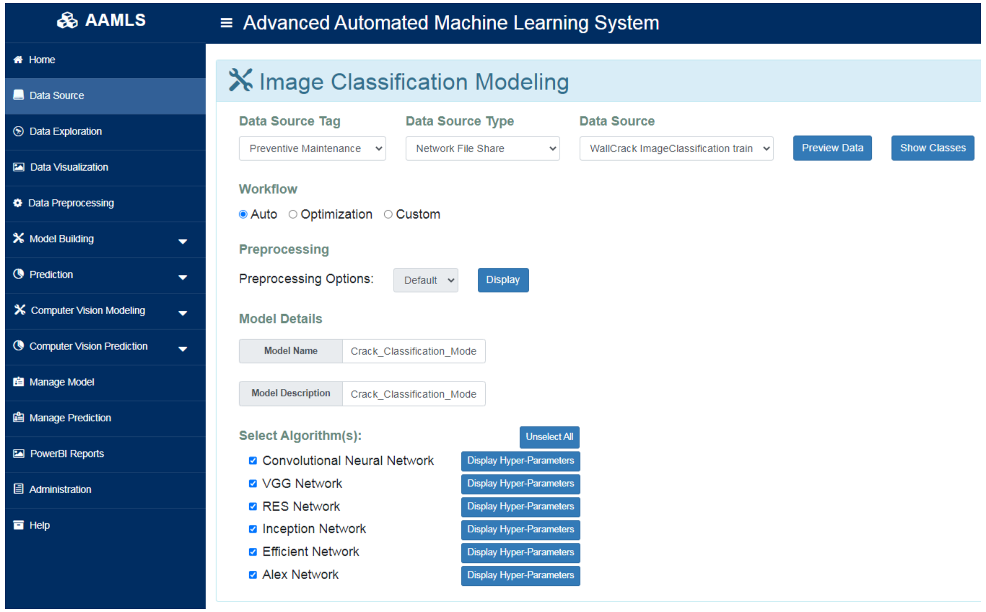
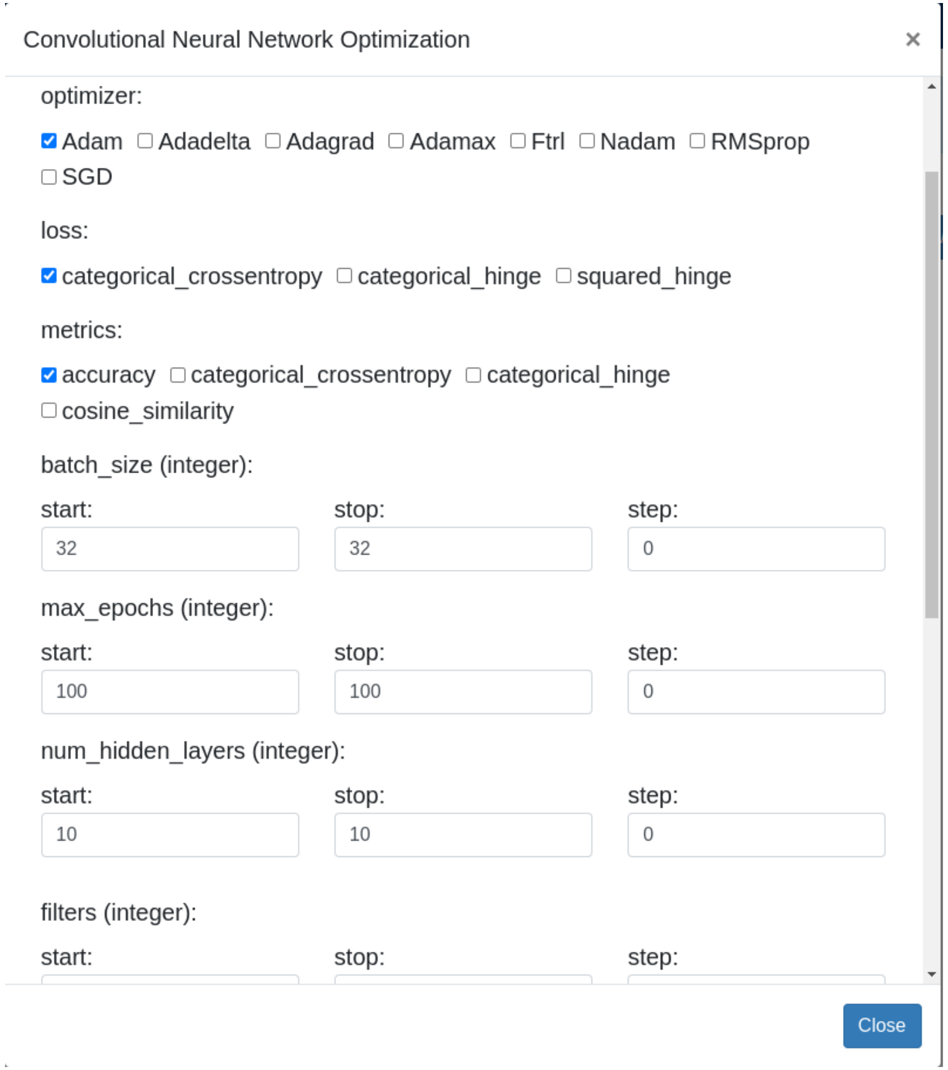
Transition Previously Trained Deep Learning Models to the Advance Automated Machine Learning (AAML) System

FIU Year 3 Highlights:

Implemented Image Classification Models.

- Added models like VGG,ResNet, InceptionNet, EfficientNet, AlexNet, and a custom model.
- Implemented the ability to customize the models with different number of layers, activation functions, etc.



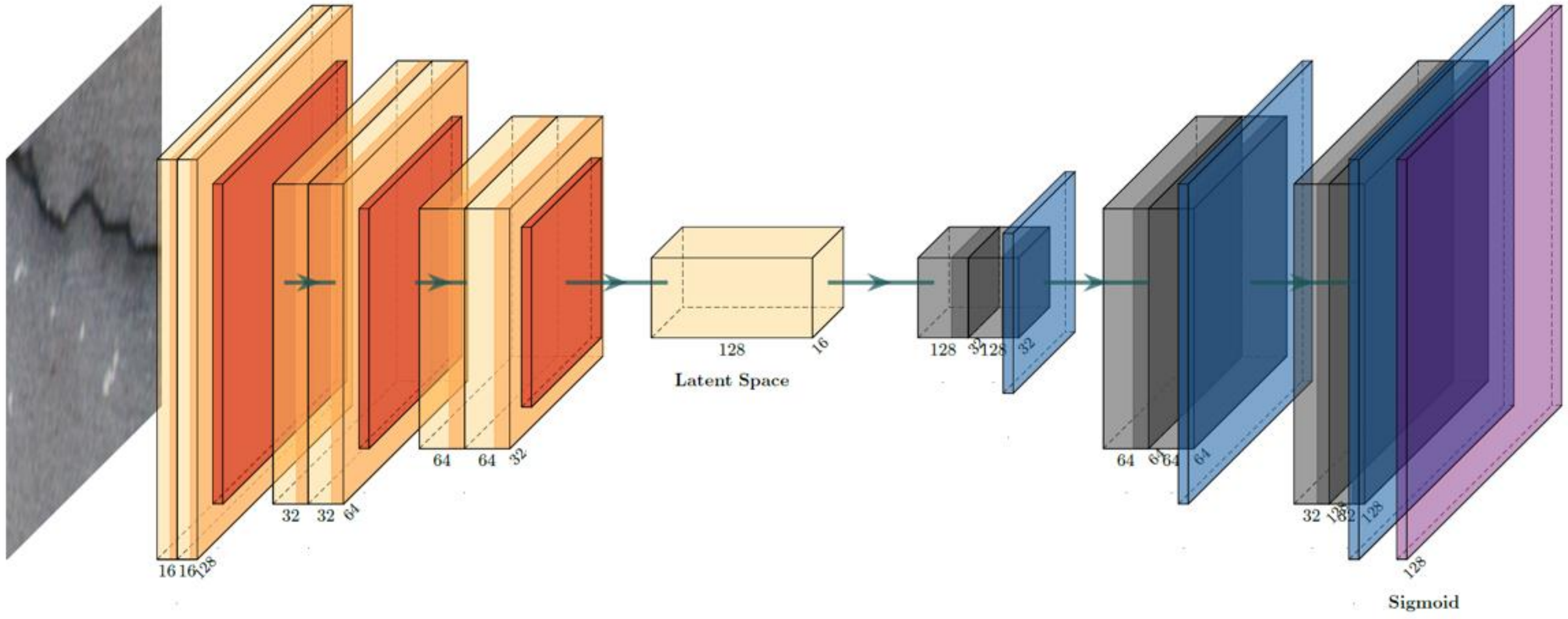


Transition Previously Trained Deep Learning Models to the Advance Automated Machine Learning (AAML) System

FIU Year 3 Highlights:

Implemented Anomaly Detection Models.

- Added an Autoencoder model that learns how to compress and decompress normal data. When given anomalous data, it fails, and the degree of failure corresponds to how different the anomalous data is from the normal data.
- Implemented the ability to customize the models with different number of layers, activation functions, etc. to enhance the performance of the model on new data.



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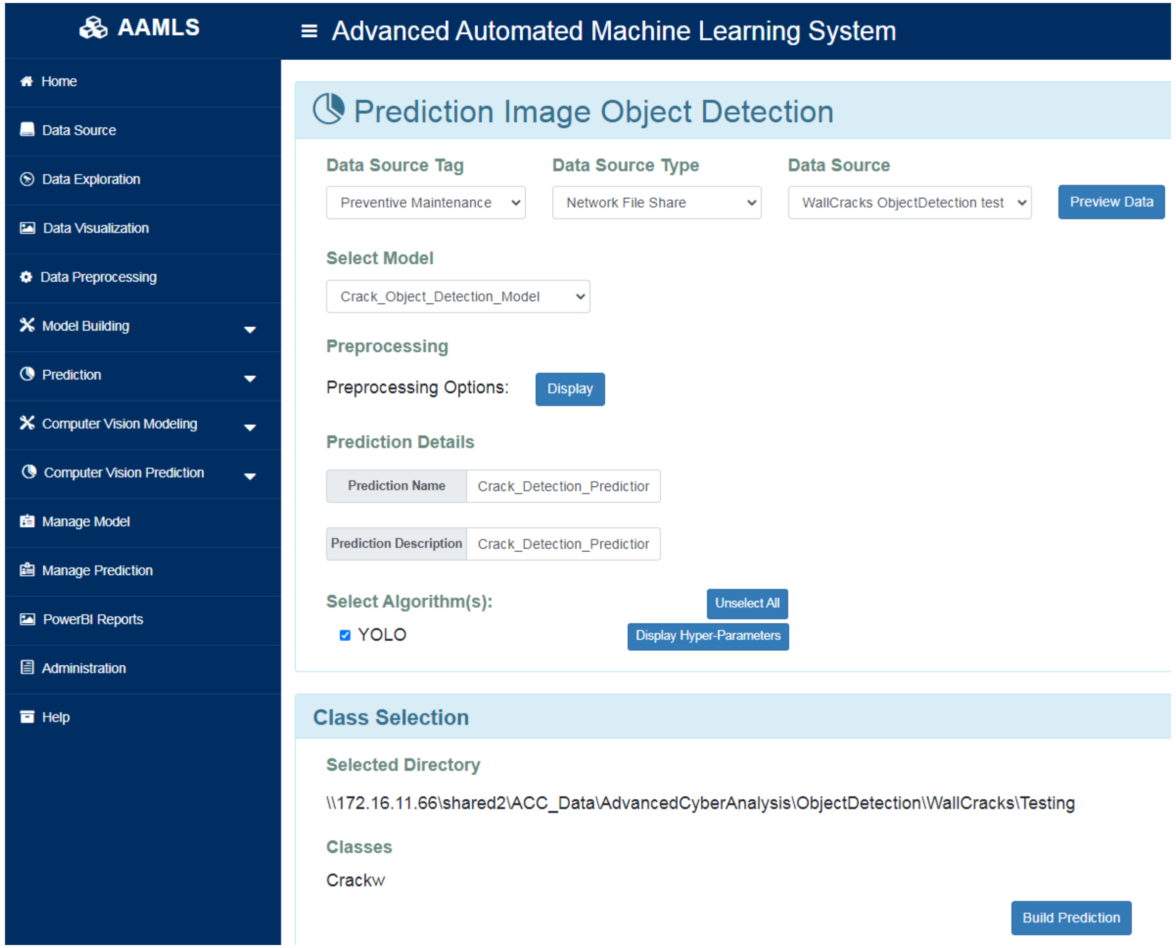
Transition Previously Trained Deep Learning Models to the Advance Automated Machine Learning (AAML) System

FIU Year 3 Highlights:

Implemented Object Detection Models.

- Added YOLOv3 model that has high performance and low latency when predicting.
- Implemented the ability to customize the model's confidence and IoU thresholds. Also implemented transfer learning to reduce training time while maintaining a high performance.



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Projected Scope

Future work

- Research and implement an object detection algorithm that has these properties:
  - Does not require labeled data to learn to detect a new object.
  - Has the ability to choose which objects to detect, not just every foreground object.
  - Has real-time or close to real-time inference speeds.

  Those properties make up for all the shortcomings of the current solutions. The team plans to research computer vision and natural language processing models to do text-prompted zero-shot object detection. However, the real-time inference speeds will be a challenge.
- Continue to deploy the implemented models on the AAML System.
  - Models on the AAML System can be used for the same tasks, but on different data. This flexibility provides solid solutions to people working on similar problem sets that do not have the time or experience to develop the deep learning solutions themselves.

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Thank You. Questions?