CDAO

Automated Identification Of Military Aircraft From Images And Video

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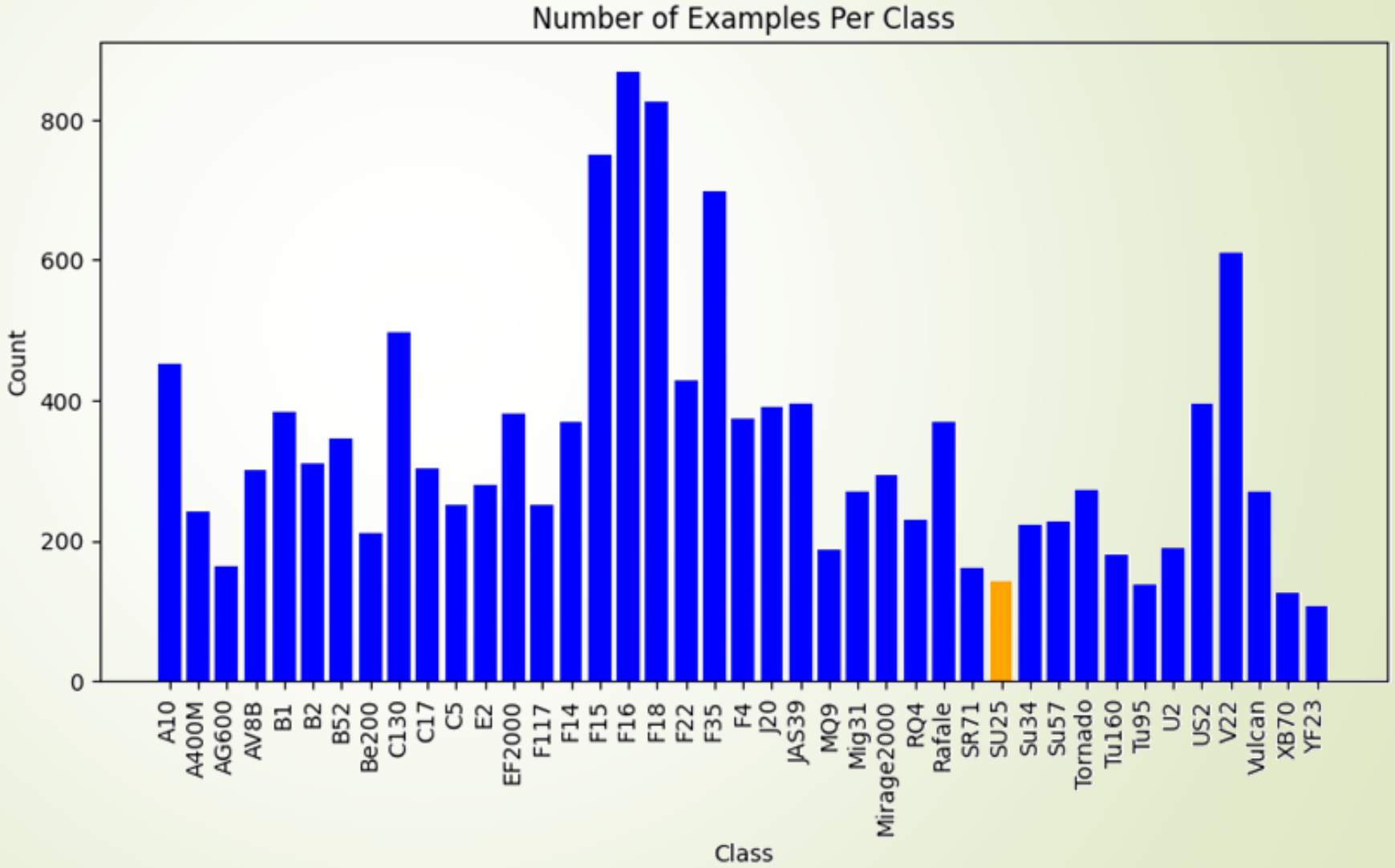
Purpose

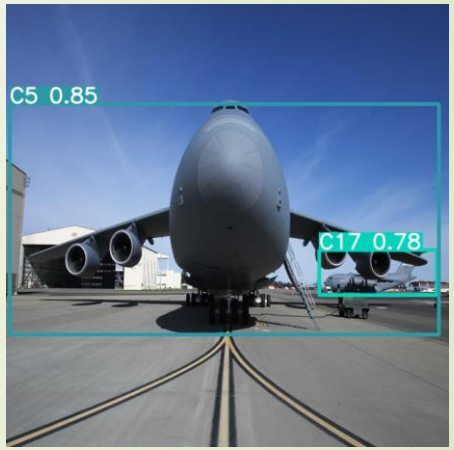
- Build an image classification model based on the Kaggle Military Aircraft dataset and assess how the model performs on a new batch of 140 images
- We elected to use the YOLO v5 model and derived our work from an existing Kaggle notebook
  - This notebook trained a YOLO v5 model to categorize and locate aircraft in an image which exceeded the requirements of the project
  - Because we used a model trained on this dataset, we felt that it was too derivative of that effort and identified an approach to expand the usefulness of the model
  - The SU-25 (widely being used in Ukraine right now) was absent from the original 40 aircraft in the dataset
  - We downloaded 115 unique SU-25 images for training and 25 for validation

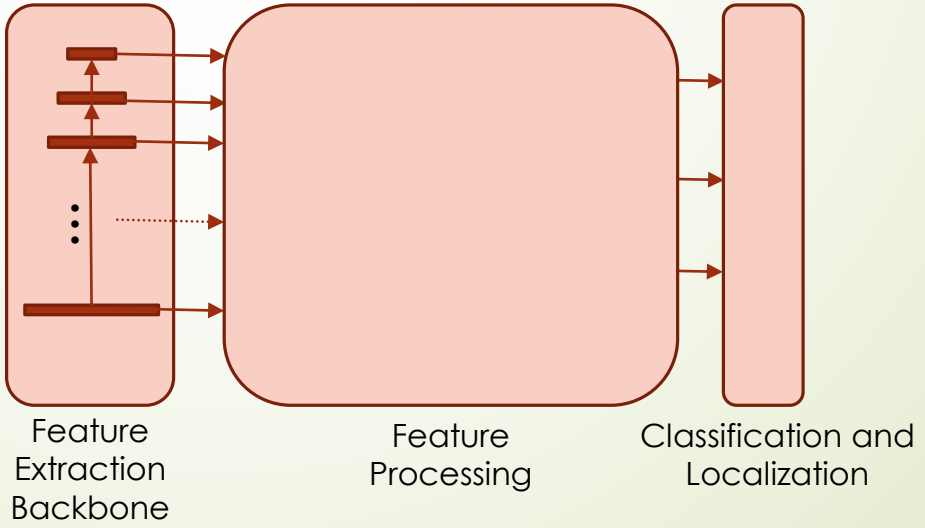
Military Aircraft Dataset



YOLO v5

- You Only Look Once (YOLO) v5 is a version of the YOLO model introduced by Joseph Redmon in 2016 that simultaneously classified object(s) in an image and also determined where they were
- YOLO v5 built upon this work and is an implementation completely in PyTorch
- Advantages:
  - Combined localization and classification
  - Fast
  - Multi-object





Baseline Results Discussion

- We leveraged the YOLO v5 model with pre-trained weights from the Kaggle notebook:
  - https://www.kaggle.com/code/blackadder97/militaryaircraftdetection-with-yolov5
- The baseline capability that was inherited from the above notebook is identified in the next slide
- Our goal was to add a new class of aircraft to the dataset without negatively impacting the performance of the model

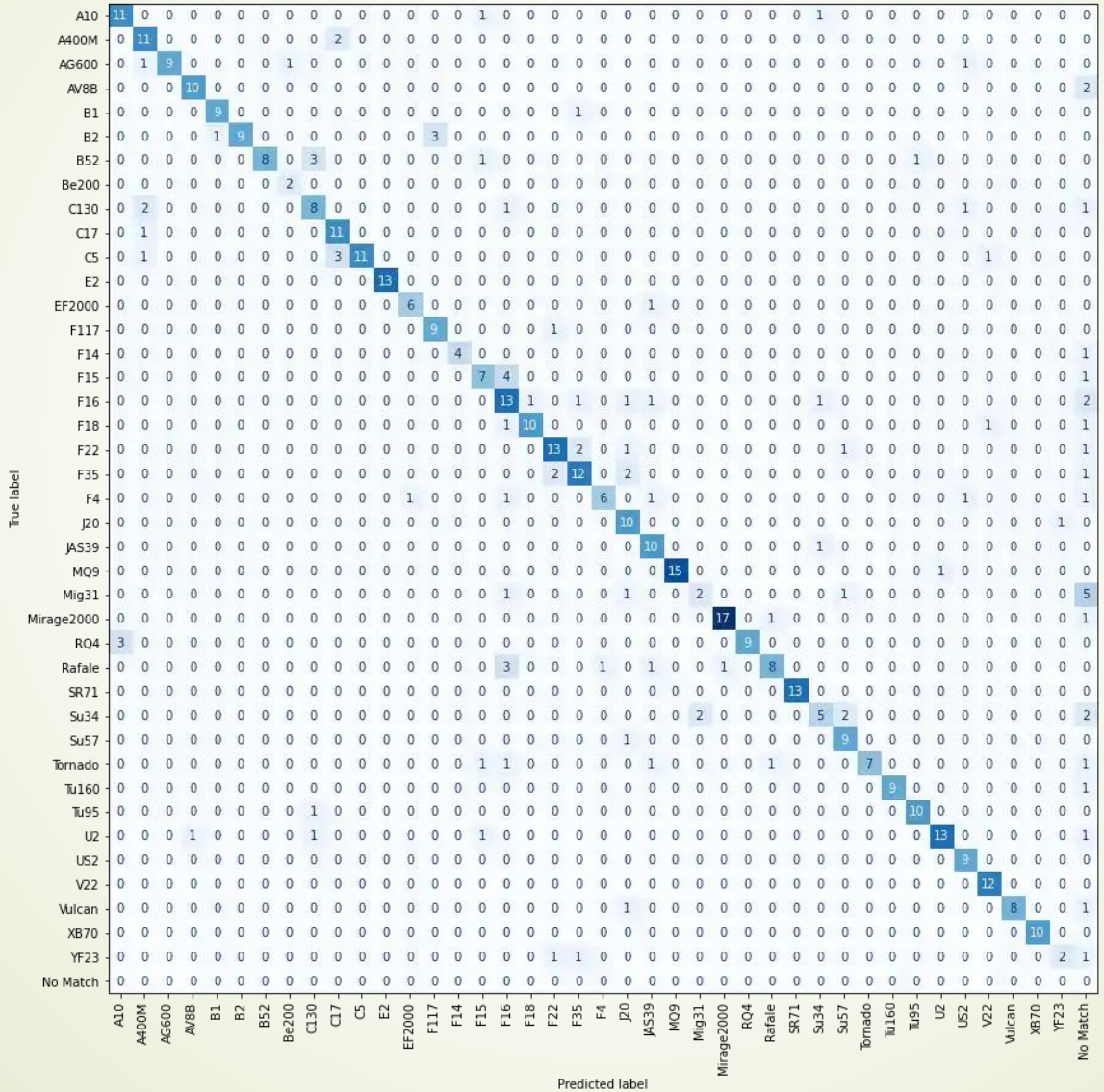
Baseline Results

- The model was tested on 478 aircraft images provided
- Average accuracy on the test dataset was 0.77

	precision	recall	f1-score	support
A10	0.79	0.85	0.81	13
A400M	0.69	0.85	0.76	13
AG600	1.00	0.75	0.86	12
AV8B	0.91	0.83	0.87	12
B1	0.90	0.90	0.90	10
B2	1.00	0.69	0.82	13
B52	1.00	0.62	0.76	13
Be200	0.67	1.00	0.80	2
C130	0.62	0.62	0.62	13
C17	0.69	0.92	0.79	12
C5	1.00	0.69	0.81	16
E2	1.00	1.00	1.00	13
EF2000	0.86	0.86	0.86	7
F117	0.75	0.90	0.82	10
F14	1.00	0.80	0.89	5
F15	0.64	0.58	0.61	12
F16	0.52	0.65	0.58	20
F18	0.91	0.77	0.83	13
F22	0.76	0.72	0.74	18
F35	0.71	0.71	0.71	17

	precision	recall	f1-score	support
F4	0.86	0.55	0.67	11
J20	0.59	0.91	0.71	11
JAS39	0.67	0.91	0.77	11
MQ9	1.00	0.94	0.97	16
Mig31	0.50	0.20	0.29	10
Mirage2000	0.94	0.89	0.92	19
RQ4	1.00	0.75	0.86	12
Rafale	0.80	0.57	0.67	14
SR71	1.00	1.00	1.00	13
Su34	0.63	0.45	0.53	11
Su57	0.69	0.90	0.78	10
Tornado	1.00	0.58	0.74	12
Tu160	1.00	0.90	0.95	10
Tu95	0.91	0.91	0.91	11
U2	0.93	0.76	0.84	17
US2	0.75	1.00	0.86	9
V22	0.86	1.00	0.92	12
Vulcan	1.00	0.80	0.89	10
XB70	1.00	1.00	1.00	10
YF23	0.67	0.40	0.50	5

Baseline Confusion Matrix



Addition of Aircraft Class

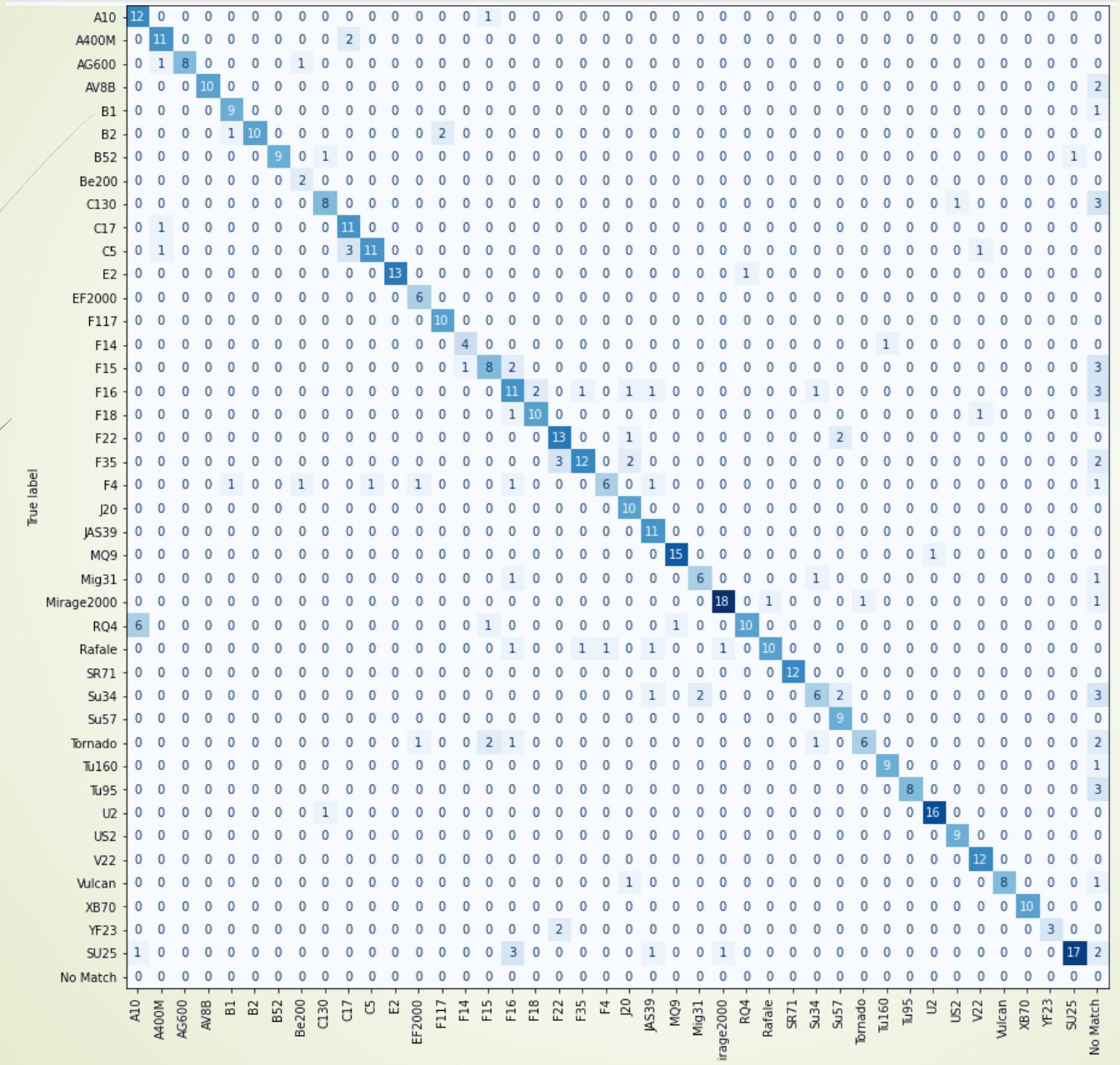
- With the prevalence of the SU-25 in the skies over Ukraine and its absence from the data set, we thought it would be useful to improve the existing model by updating the training to include SU-25s
- We identified 140 SU-25 images and added 115 to the training set and reserved 25 for validation
- We used Roboflow to create label data compatible with YOLO v5
- Initially, we attempted to only freeze the last layer in the YOLO v5 model but it performed poorly on the SU-25 class
- Ultimately, we froze the bottom 16 layers of the network and allowed the top 8 to be trained
- We retrained the system starting with the baseline weights for 30 epochs

SU-25 Augmentation Results

- The model was tested on 478 test set plus 25 SU-25 images
- Average accuracy was 0.78, slightly improved over the baseline

	precision	recall	f1-score	support
A10	0.632	0.923	0.75	13
A400M	0.786	0.846	0.815	13
AG600	1	0.8	0.889	10
AV8B	1	0.833	0.909	12
B1	0.818	0.9	0.857	10
B2	1	0.769	0.87	13
B52	1	0.818	0.9	11
Be200	0.5	1	0.667	2
C130	0.8	0.667	0.727	12
C17	0.688	0.917	0.786	12
C5	0.917	0.688	0.786	16
E2	1	0.929	0.963	14
EF2000	0.75	1	0.857	6
F117	0.833	1	0.909	10
F14	0.8	0.8	0.8	5
F15	0.667	0.571	0.615	14
F16	0.524	0.55	0.537	20
F18	0.833	0.769	0.8	13
F22	0.722	0.813	0.765	16
F35	0.857	0.632	0.727	19
F4	0.857	0.462	0.6	13
J20	0.667	1	0.8	10
JAS39	0.688	1	0.815	11
MQ9	0.938	0.938	0.938	16
Mig31	0.75	0.667	0.706	9
Mirage2000	0.9	0.857	0.878	21
RQ4	0.909	0.556	0.69	18
Rafale	0.909	0.667	0.769	15
SR71	1	1	1	12
Su34	0.667	0.429	0.522	14
Su57	0.692	1	0.818	9
Tornado	0.857	0.462	0.6	13
Tu160	0.9	0.9	0.9	10
Tu95	1	0.727	0.842	11
U2	0.941	0.941	0.941	17
US2	0.9	1	0.947	9
V22	0.857	1	0.923	12
Vulcan	1	0.8	0.889	10
XB70	1	1	1	10
YF23	1	0.6	0.75	5
SU25	0.944	0.68	0.791	25

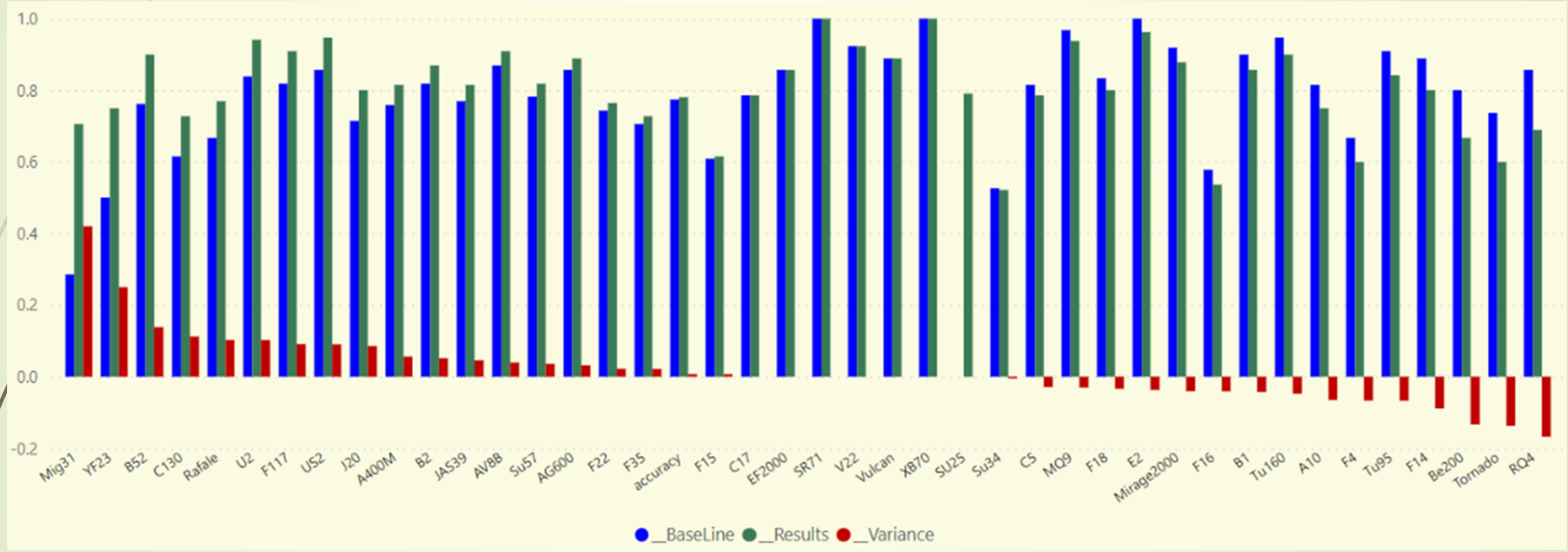
Confusion Matrix (with SU-25)



Observations

- The RQ4 is often misclassified as an A10
- The BE-200 is recognized less than 50% of the time
- The aircraft most commonly not yielding any classification include the C-130, F-15, F-16, SU-35, TU-95, and the new SU-25

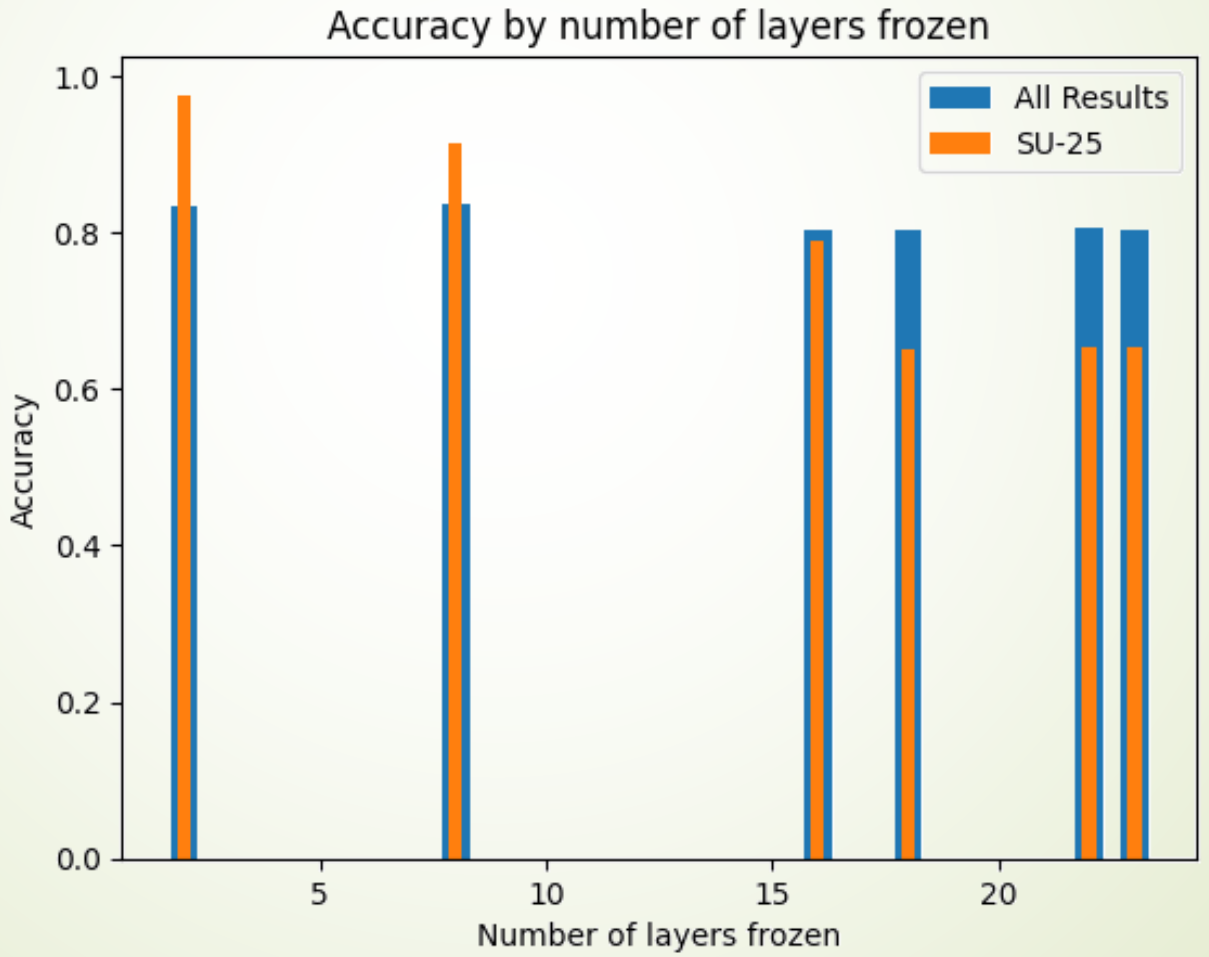
Classification Report Metrics (F1-score)



Potential Applications

- Increase aircraft scope
- Continuously monitor overhead and identify drones
- Perform object detection and localization in video

Model Performance vs. Frozen Layers



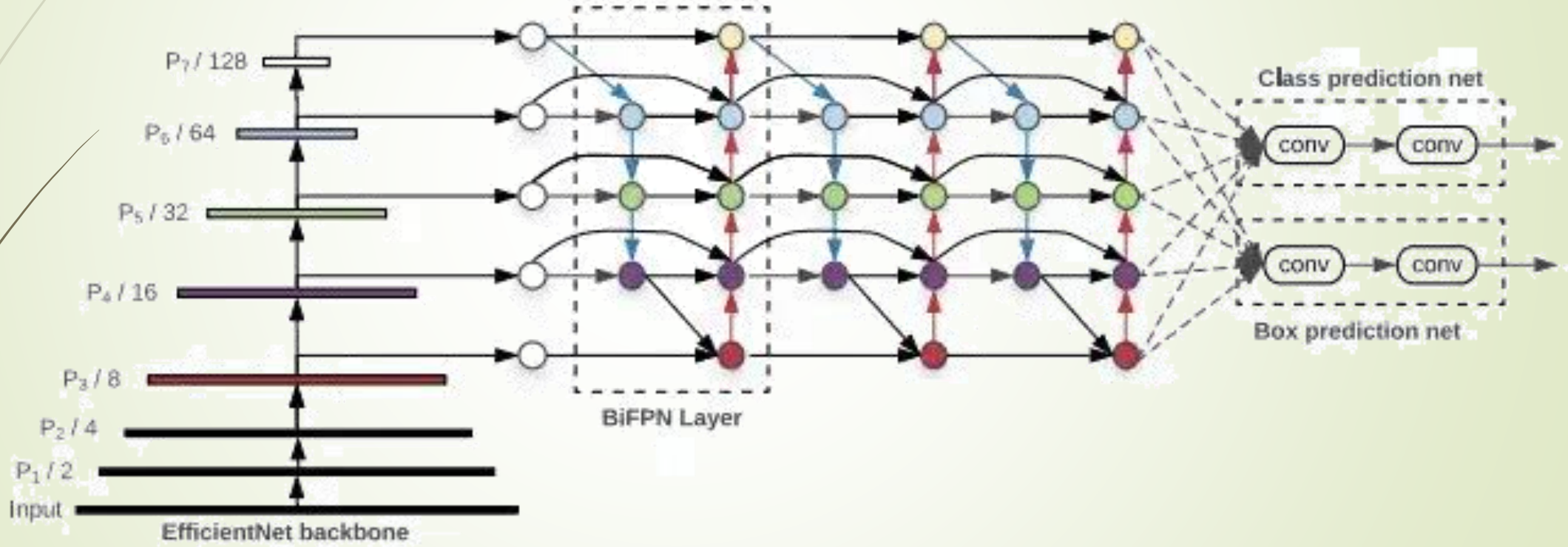
Conclusion

- YOLO v5 performed well classifying and locating aircraft images in images
- The model is relatively easy to use and customize for novel purposes
- A new aircraft class was successfully added to a trained model
- Interestingly, the model needed to be more deeply trained
  - Initially, it was expected that the lower layers would learn how to classify general aircraft and only the final layer would need to be retrained
  - Instead, the top 8 layers of the 24-layer model were retrained which yielded successful results
  - A simple experiment was conducted on frozen layer depth but further research will be useful
- YOLO v5 is capable of very fast classification and localization so this model could also be used on a video of an aircraft

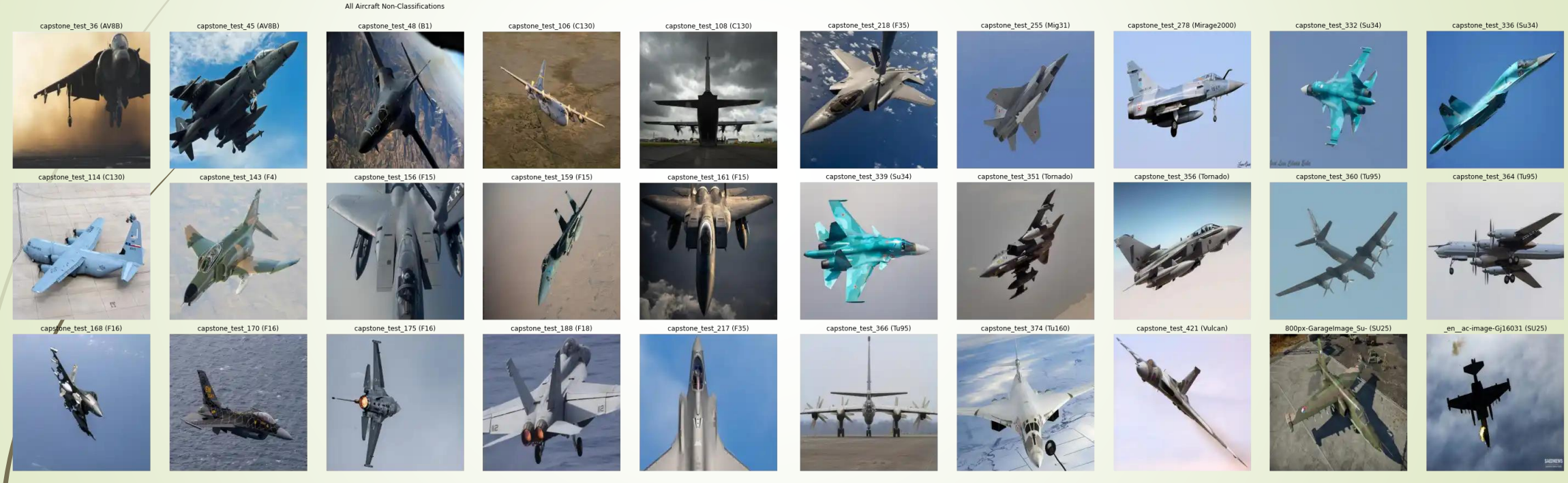
Questions

Backup

Detailed YOLO v5 Architecture



Images Below Confidence Threshold



Select Misclassifications

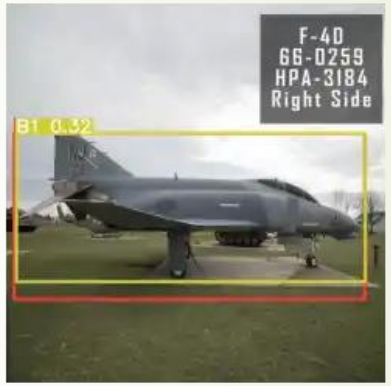
Sample Incorrect Aircraft Classifications

capstone_test_297 (Rafale)

capstone_test_91 (C5)

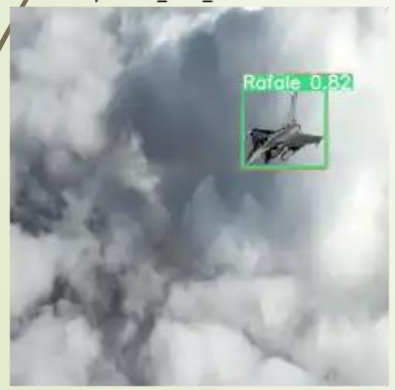
capstone_test_140 (F4)

capstone_test_137 (F4)



9ecb4bb870be2795bdd1d (SU25)

capstone_test_300 (Rafale)



capstone_test_148 (F14)

capstone_test_128 (E2)

capstone_test_88 (C5)

capstone_test_21 (A400M)