DSI-33 CAPSTONE

Detecting Aircraft in Satellite Imagery

Looking at airplanes within satellite images may sound like a weird hobby but it has real-world use cases in areas such as:

- Defence intelligence
- Airport capability assessment
- Capacity planning/monitoring
- Search and Rescue

Singapore Changi Airport Added 8 New Airlines & 4 New Routes In 2022

The first 10 months of 2022 saw Changi Airport handle 23.6 million passenger movements.

BY **CHARLOTTE SEET** PUBLISHED 3 DAYS AGO

Global air travel forecast to bounce back by mid-2023 as China reopens

World's second-largest jet lessor expects revival despite shortage of new jets

Passport control at Xiaoshan international airport after China lifted quarantine requirements for international arrivals this month © Wei Zhiyang/Zhejiang Daily/VCG via Getty Images

Sylvia Pfeifer and **Philip Georgiadis** in London and **Jude Webber** in Dublin JANUARY 17 2023

4

China's air industry told to prepare for surge in travel after borders reopen

- An aviation industry body has predicted that passenger numbers will return to 70 per cent of the pre-pandemic total next year
- China has said it will start issuing passports and visas again, but it will take time for more flights to become available

Kawala Xie and **Mia Nulimaimaiti**
Published: 6:00am, 28 Dec, 2022

Why you can trust SCMP

Passenger Recovery Continues in November

Translations

La reprise du trafic de passagers se poursuit en novembre (pdf)
El tráfico aéreo de pasajeros continúo recuperándose en noviembre (pdf)
国际航协：11月客运量持续复苏 (pdf)
O transporte de passageiros por via aérea continua se recuperando em novembro (pdf)
حركة المسافرين تواصل تعافيها في شهر نوفمبر (pdf)

Geneva - The International Air Transport Association (IATA) announced that the air travel recovery continued through November 2022.

CONCERNS

01

SAFETY

Surge in airside workload and increased risk of incidents

02

EFFICIENCY

Bottlenecks may arise from inefficient processes developed during lull period

OPPORTUNITY

01 SAFETY

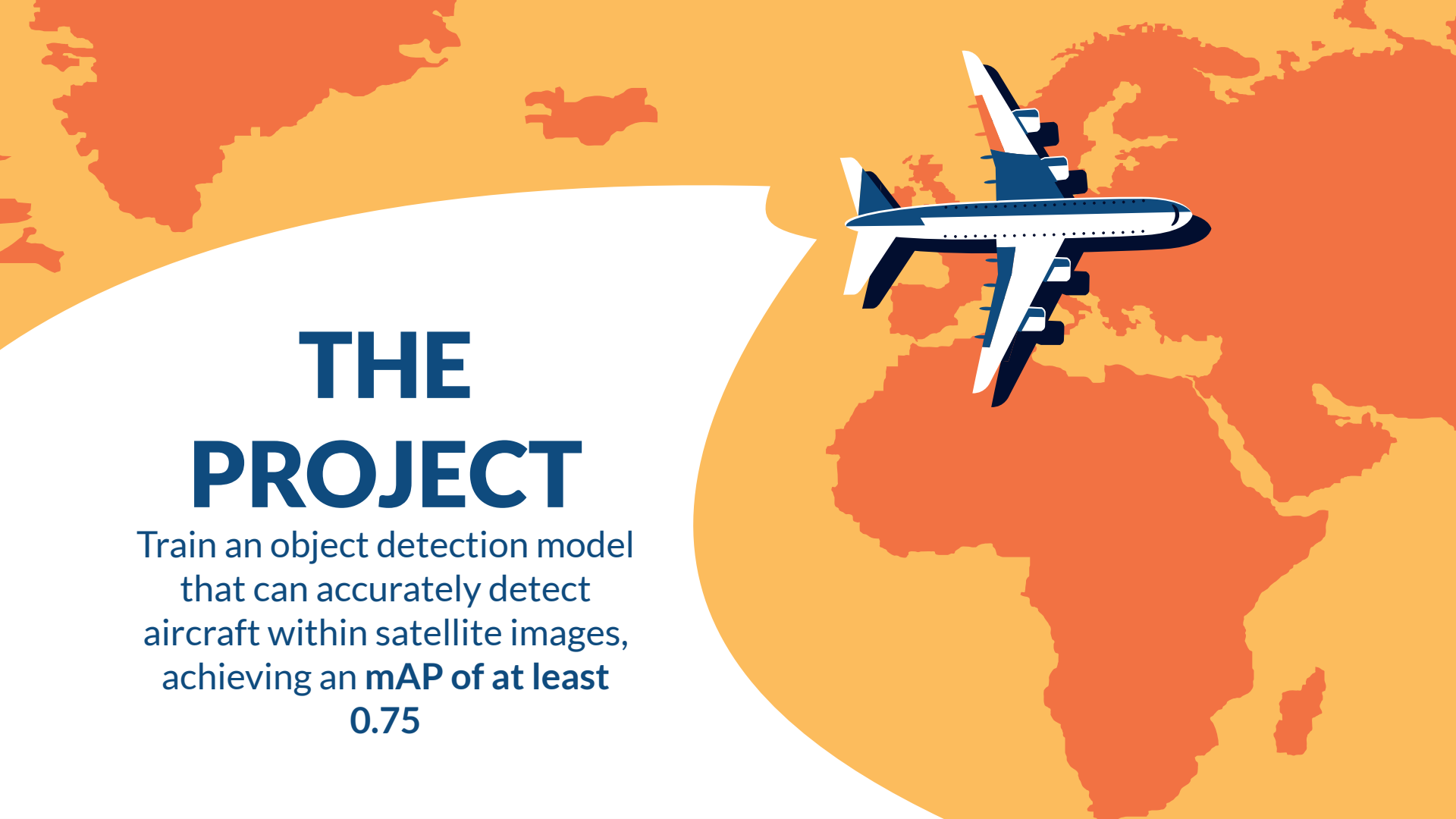
Monitor air traffic controllers' sector workloads and identify potential hazards

02 EFFICIENCY

Reconsider utilization of aircraft maneuvering areas to refine existing procedures

PROBLEM STATEMENT

Airport operators need a way to improve airport capacity planning and workload monitoring capabilities beyond ground-based methods.



THE PROJECT

Train an object detection model that can accurately detect aircraft within satellite images, achieving an **mAP of at least 0.75**

WORKFLOW

DATA

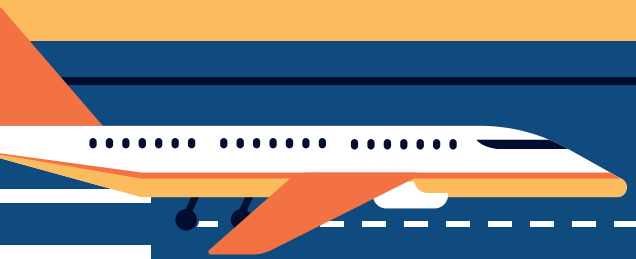
Import, explore, clean, and preprocess

MODEL

Train models and select best performing

EVALUATE

Run test detections and evaluate performance



01

DATA

Import, explore, clean, and preprocess

AIRBUS AIRCRAFT DATASET

EARTH OBSERVATION

Images taken by Airbus' Pleiades twin satellites

103 IMAGES

Of various airports worldwide, some appear multiple times at different acquisition dates

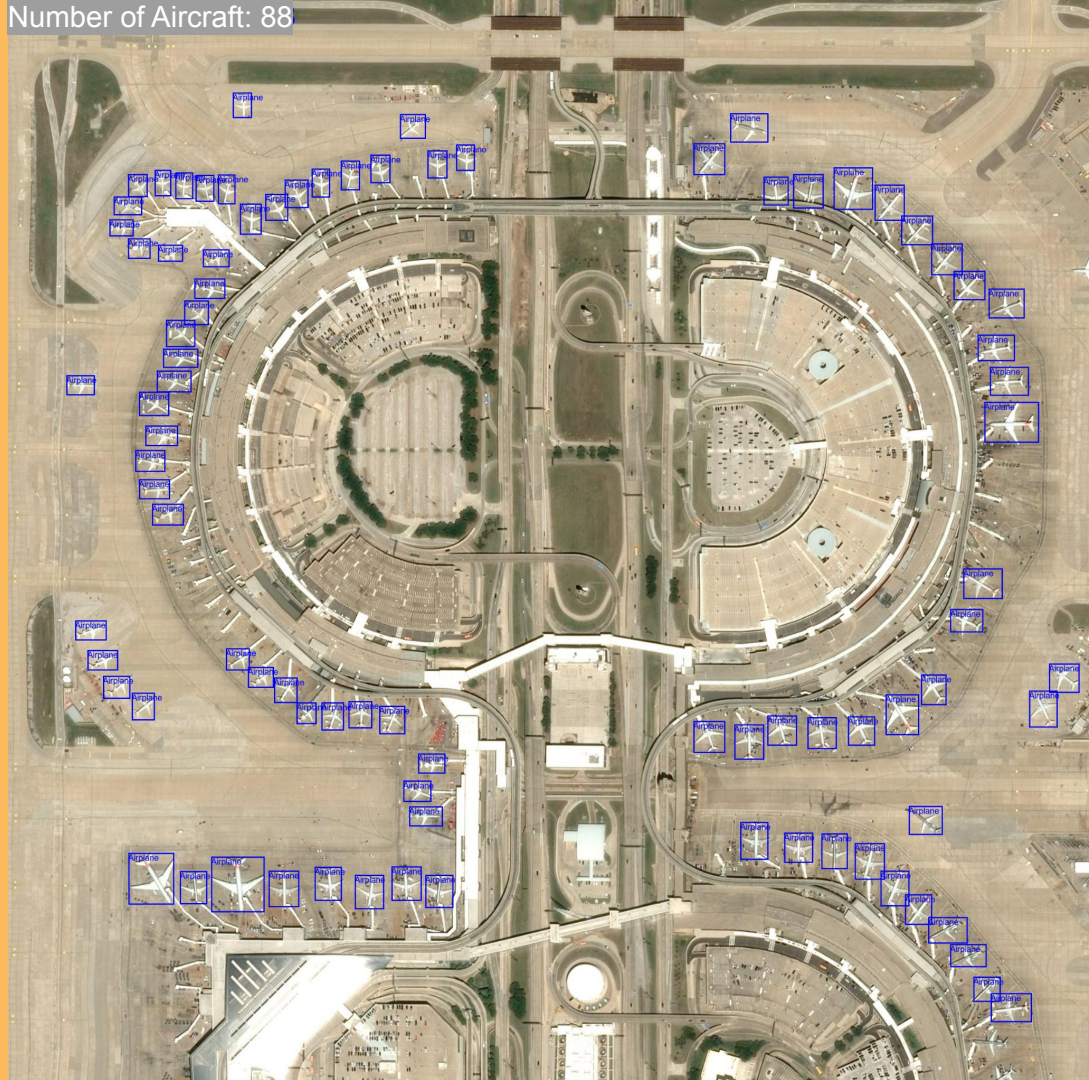
ANNOTATIONS

CSV file containing bounding box coordinates

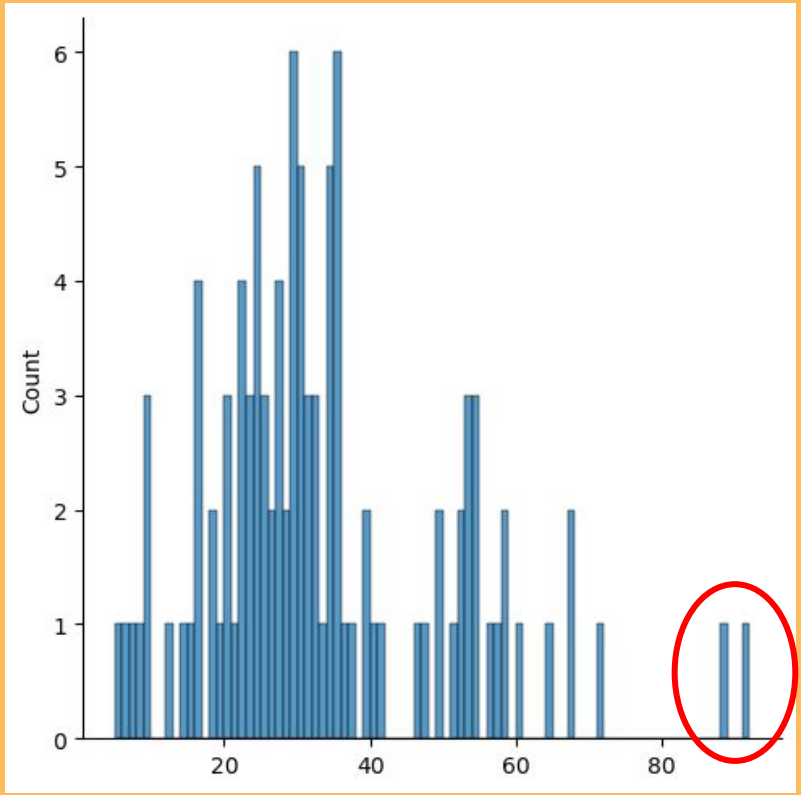
Obtained from Kaggle: https://www.kaggle.com/datasets/airbusgeo/airbus-aircrafts-sample-dataset

Raw image from dataset

What the images look like with annotations



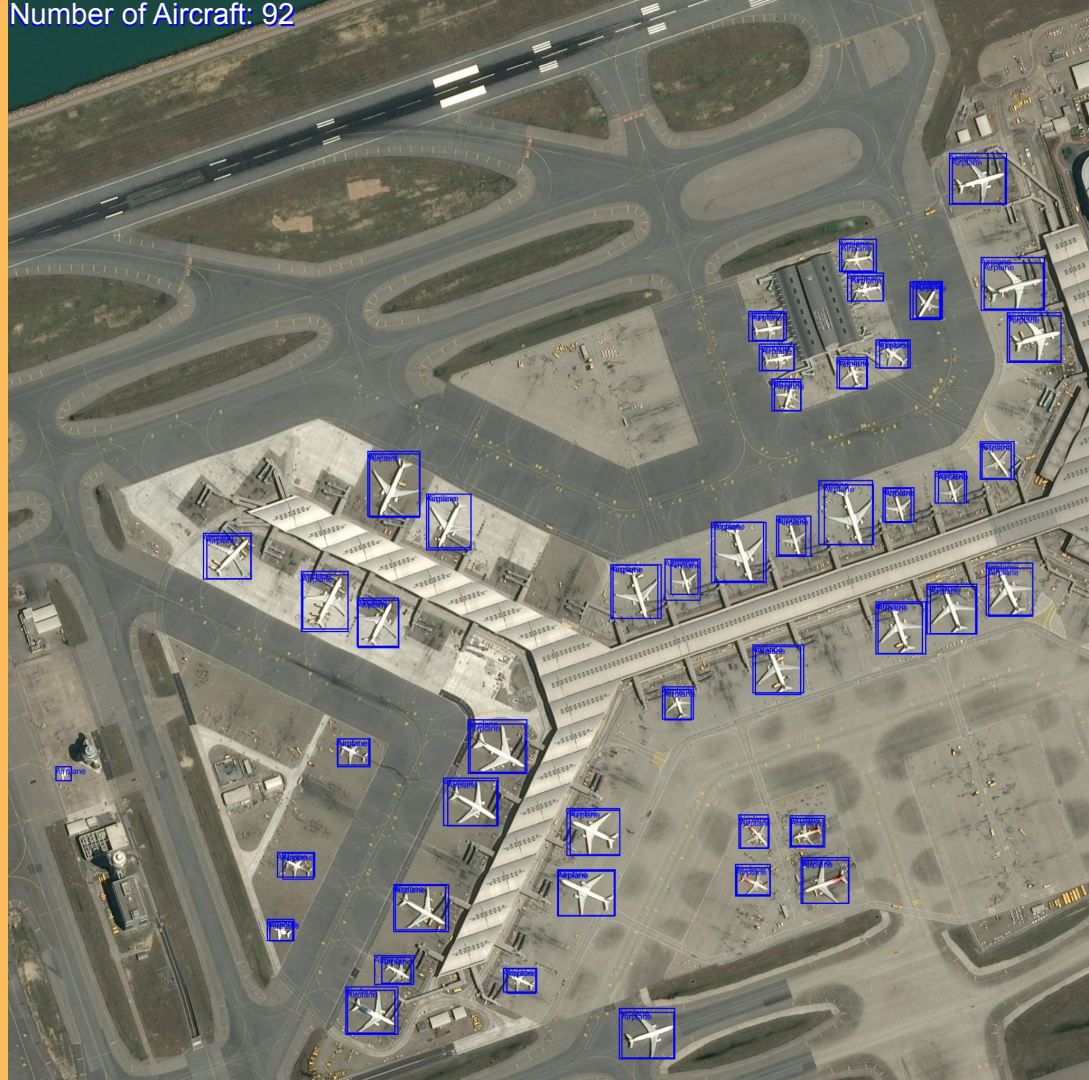
Distribution of Aircraft Counts per Image



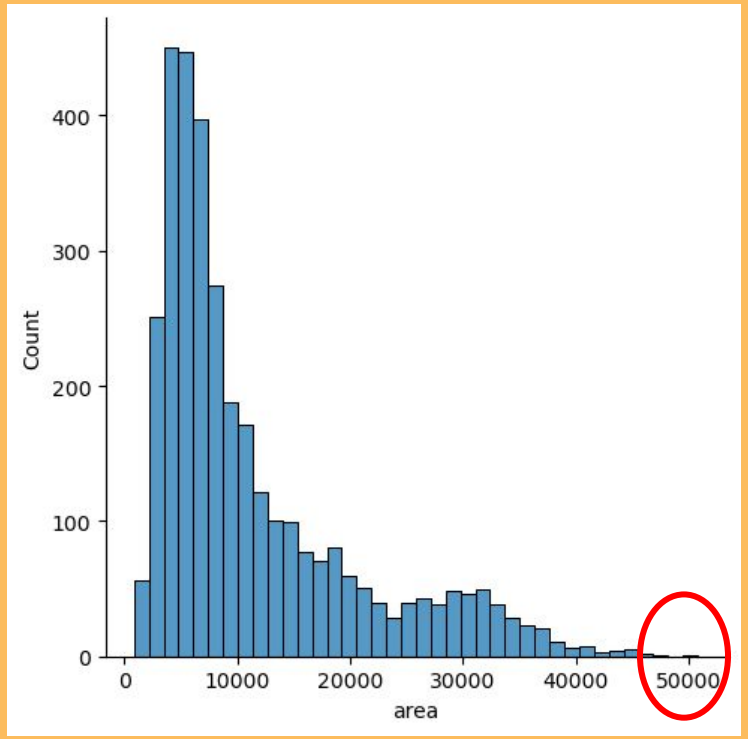
Bulk of the images have between 10-40 aircraft

2 images with particularly high number of aircraft

Extra set of annotations



Distribution of Bounding Box Sizes



Investigate bounding boxes with area >50,000 pixels

Only one bounding box of size

Just a jumbo A380

IMAGES & ANNOTATIONS

After Cleaning

103

IMAGES

W:2560xH:2560

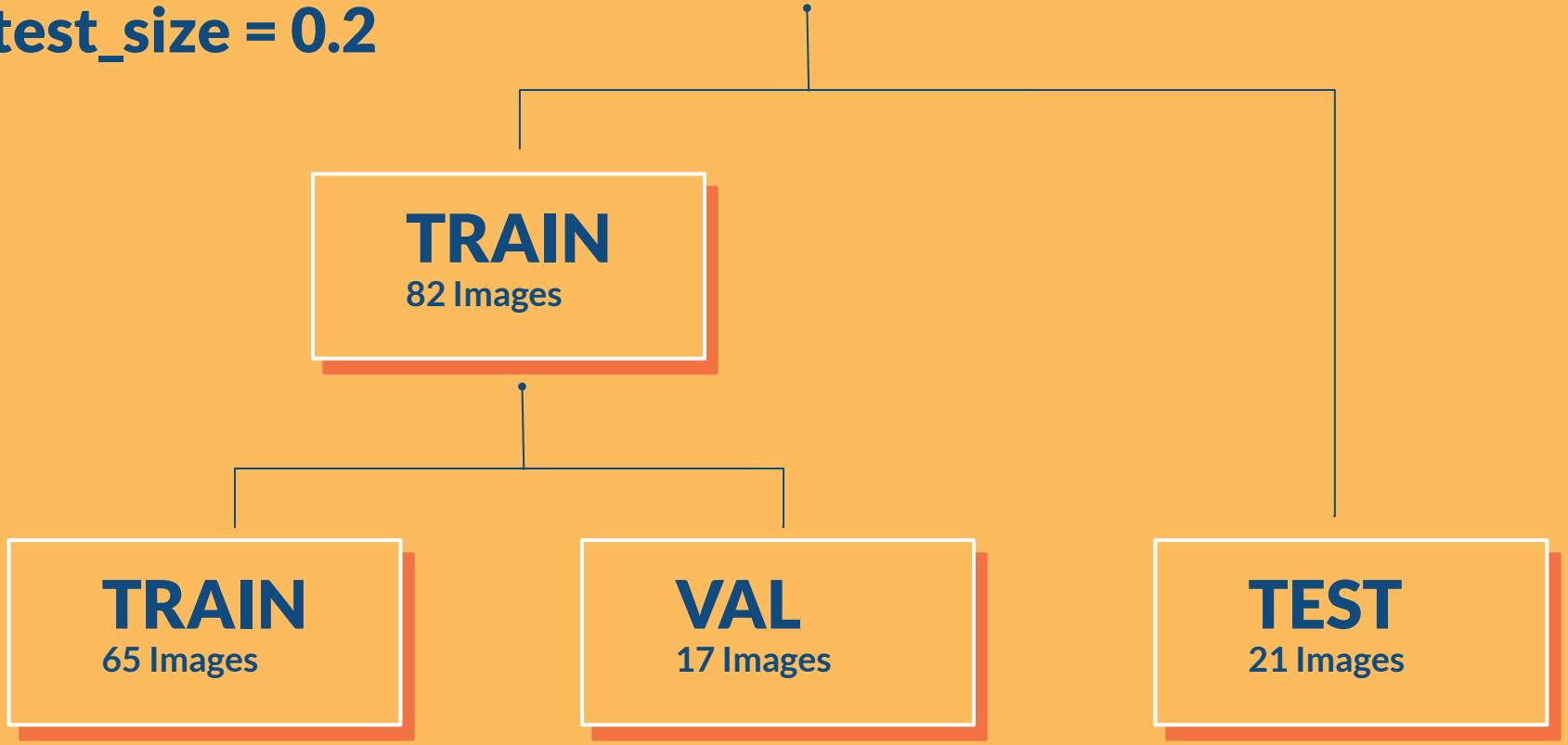
3379

AIRCRAFT

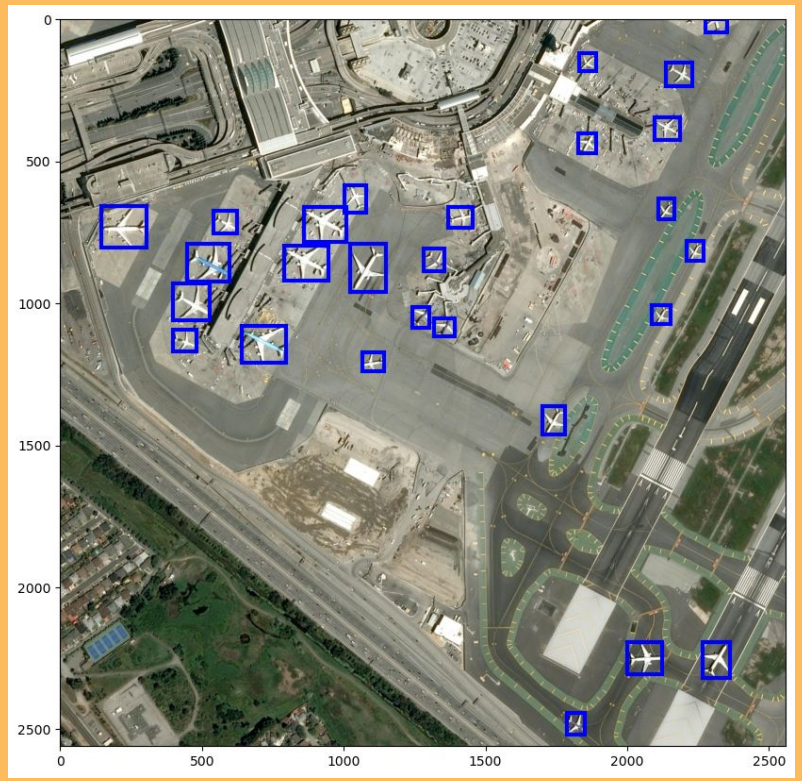
Annotated targets

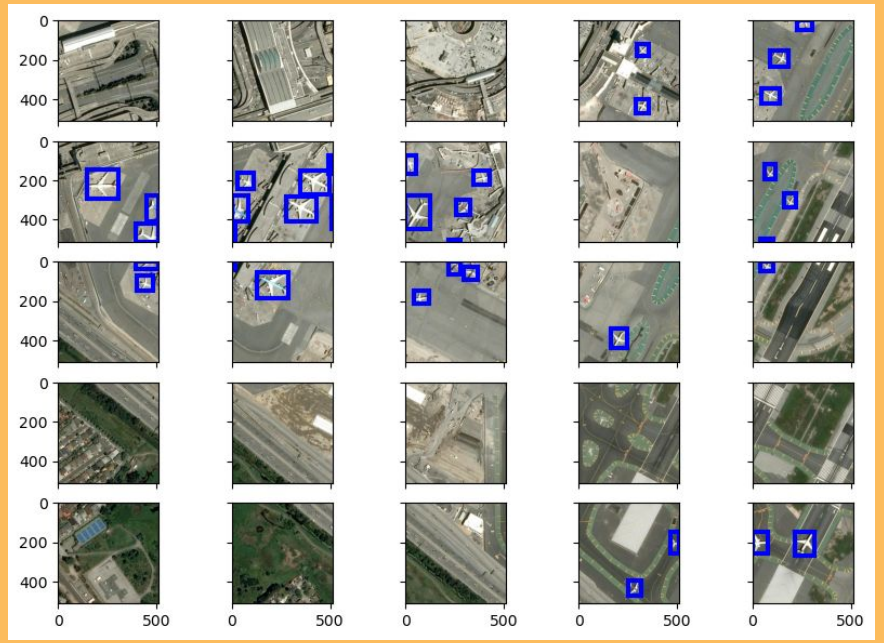
TRAIN-VAL-TEST SPLIT

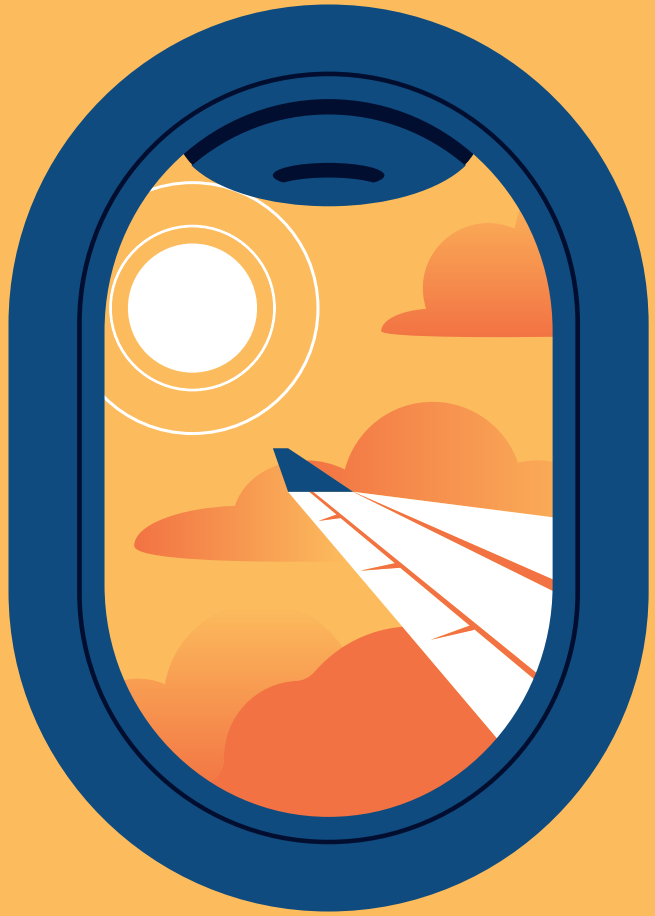
test_size = 0.2



TILING


0
500
1000
1500
2000
2500
0
500
1000
1500
2000
2500


0
200
400
0
500



WHY TILE?

LARGE IMAGE SIZE

Training on 2560x2560 is taxing on GPU resources. Also, YOLO is trained on lower resolution images.

SMALL TARGETS

Down-sampling the image is not ideal since it'll reduce the resolution and turn targets into blobs

BOUNDING BOX FORMAT

Pascal voc

Xmin, Ymin, Xmax, Ymax

Yolo

Xcentre, Ycentre, Width, Height

FINAL DATASET

SET	IMAGE TILES	ANNOTATIONS
TRAIN	1625	2125
VAL	425	492

02

MODEL

YOLOv7
YOLOv8

AIM

Train an object detection model that can accurately detect aircraft within satellite images, achieving an **mAP** of at least **0.75**

YOLO ADVANTAGES

Speed

YOLO is faster than other state-of-the-art object detectors

Performance

High detection performance, few background errors

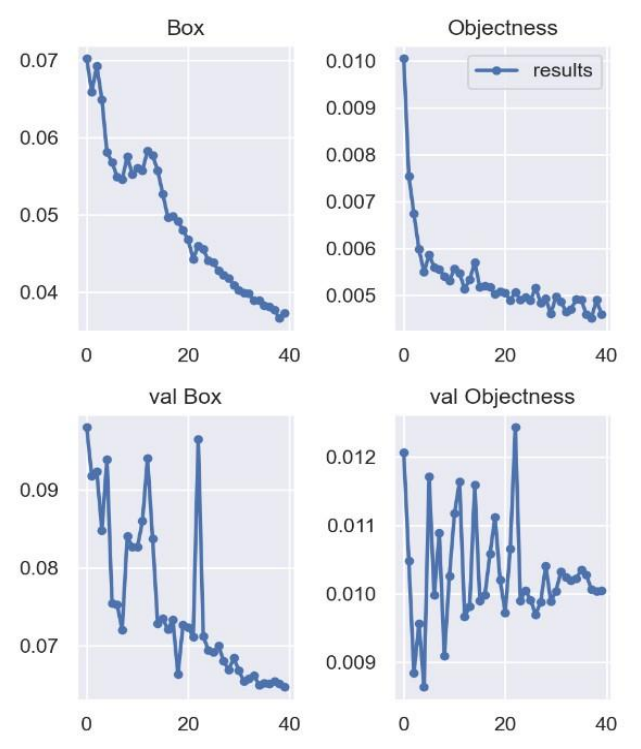
Generalization

Able to generalize from natural images to domains like art

Open Source

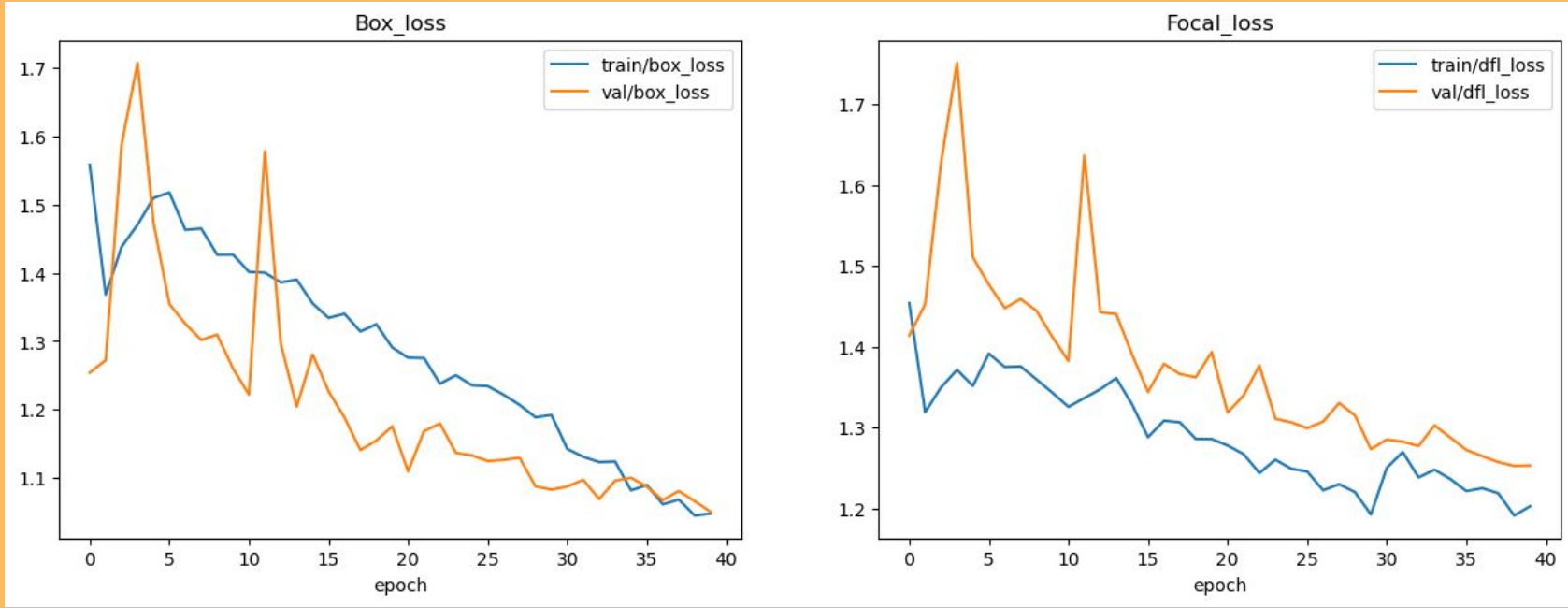
Community driven development has led to major improvements

YOLOv7 TRAIN LOSS



- Train and validation loss functions generally decrease across the 40 epochs, except for validation obj_loss.

YOLOv8 TRAIN LOSS

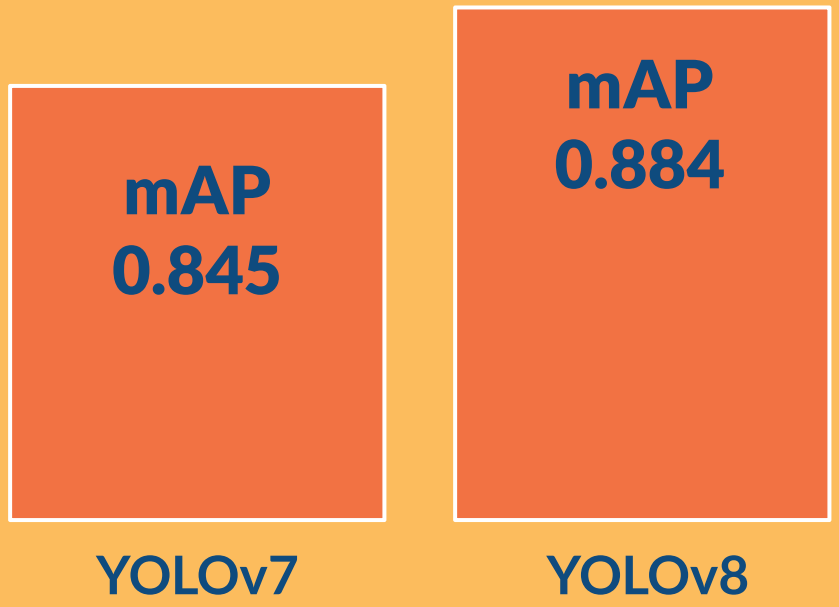


Losses are both pretty turbulent in the initial epochs but gradually tapers off in a downward trend.
Train and validation losses (for both box and focal loss) reduces as the number of epoch increases, implying good fit up till epoch 40.

OBJECT DETECTION METRICS

Precision	True Positive / (True Positive + False Negative)
Recall	True Positive / (True Positive + False Positive)
Intersection over Union	Area of Overlap / Area of Union
Mean Average Precision	Metric that takes into account all 3 above

COMPARE MODELS - mAP



YOLOv8 edges its predecessor out by a small margin in terms of validation mAP

03

EVALUATE

Run test detections and evaluate performance

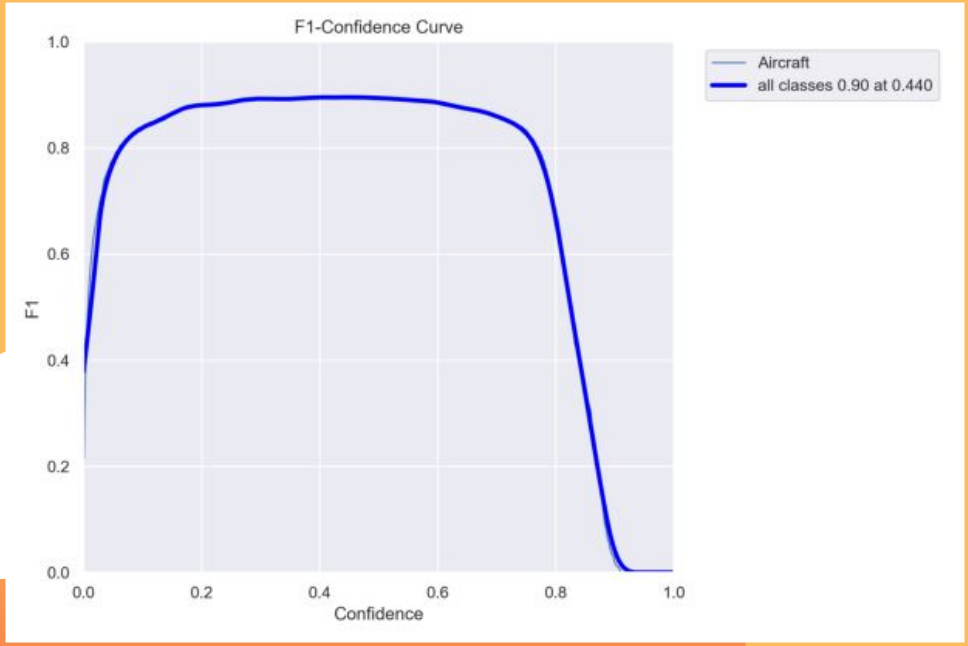
YOLOv8 Test Scores

PRECISION	RECALL	MEAN AVERAGE PRECISION
0.969	0.923	0.922

VISUALIZE TEST DETECTION

- Confidence threshold set at 0.001 as per YOLO test parameters.
- Model has a lot of **erroneous detections**, although most if not all of these have **very low confidence scores**

SETTING AN APPROPRIATE CONFIDENCE THRESHOLD



- Use **F1 score** to inform choice of confidence threshold for detection using the final model, since the F1 score strikes a **balance between both precision and recall**.
- Selected **confidence threshold will be 0.440 or 44%** for the maximum F1 of 0.90.

DETECTION ON UNSEEN IMAGE

- Model is able to **detect all visible aircraft** in the picture with **no false positives**


Aircraft 0.75
Aircraft 0.77
Aircraft 0.84
Aircraft 0.78
Aircraft 0.80
Singapore Changi Airport
Aircraft 0.83
Aircraft 0.83
Aircraft 0.80
Aircraft 0.79
Aircraft 0.82
Aircraft 0.81
Aircraft 0.80
Aircraft 0.84
Aircraft 0.83
Aircraft 0.84
Aircraft 0.80
Google Earth
Image © 2023 Maxar Technologies

04

CONCLUSIONS

Key takeaways, limitations, and future directions

CONCLUSIONS

- The final YOLOv8 custom model is capable of detecting airplanes from satellite images with little to no noise using the right confidence threshold.
- The selected model has also met the target mAP stipulated the start of the project.

RECOMMENDATIONS

- Although lacking in features, the model may be applied on the following tasks:

    a. **Identify potential hazards** particularly during periods of high workload
    b. Look out for **traffic hotspots** and better plan aircraft pushback and taxi procedures
    c. Ensure parking bays are **efficiently assigned**

- Civil Aviation Authorities may also use this to monitor air traffic movement in smaller or more rural airports

FUTURE DIRECTIONS

- Collect train images across a greater variety of backgrounds, e.g. over water, to train and test on.
- Expand dataset to include aircraft that are not commercial jets. Classification of aircraft into finer grained subcategories should prove to be useful to a wider range of stakeholders.
- Experiment with the use of synthetic training data.
- Deploy the model on a platform such as UP42 that is able to provide "real-time" satellite feeds.

QnA

MODELS

2 versions of the YOLO object detection model were fine-tuned with the processed Airbus Aircraft Dataset for the aircraft detection task.

Similarly to yolov7, image augmentations are by default included in the training. There is no need for autoanchor (anchor evolution tuning) due to it being an 'anchor-free' model This means it predicts directly the center of an object instead of the offset from a known anchor box.

Image augmentation is in-built into the training of the model, and these can be enabled or disabled. E.g. flipud - flip up or down, fliplr - flip left or right. fliplr and mosaic are 2 that are enabled by default.

2. Autoanchor enabled by default, Autoanchor will analyse your anchors against your dataset and training settings (like --img-size), and will adjust anchors as necessary. This is a form of hyperparameter tuning. See this [medium
article](https://towardsdatascience.com/training-yolo-select-anchor-boxes-like-this-3226cb8d7f0b) for explanation on anchors.

Mean Average Precision (mAP)

- Metric used to evaluate object detection models
- Based on the following sub metrics:
  - Confusion Matrix
  - Intersection over Union
  - Recall
  - Precision
- The mAP incorporates the trade-off between precision and recall and considers both false positives (FP) and false negatives (FN). An aircraft detection system would need to balance recall with precision to ensure that capacity is correctly monitored. The presence of too many false detections (whether positive or negative) would be highly detrimental to efficiency and the effectiveness of the model.
- Used in COCO, many benchmarks, widely accepted as the de facto metric for object detection models