CrowdSenseAI

Avert Crowd Crushing with Deep Learning

By: Neo Wenxi, DSI37

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SEOUL HALLOWEEN **CROWD CRUSH 2022**

HOW THE TRAGEDY UNFOLDED

CELEBRATION

First virtually unrestricted Halloween festivities in three years that attracted 100,000 crowd on the street

CONTROL

Witnesses said police had trouble controlling the crowds.

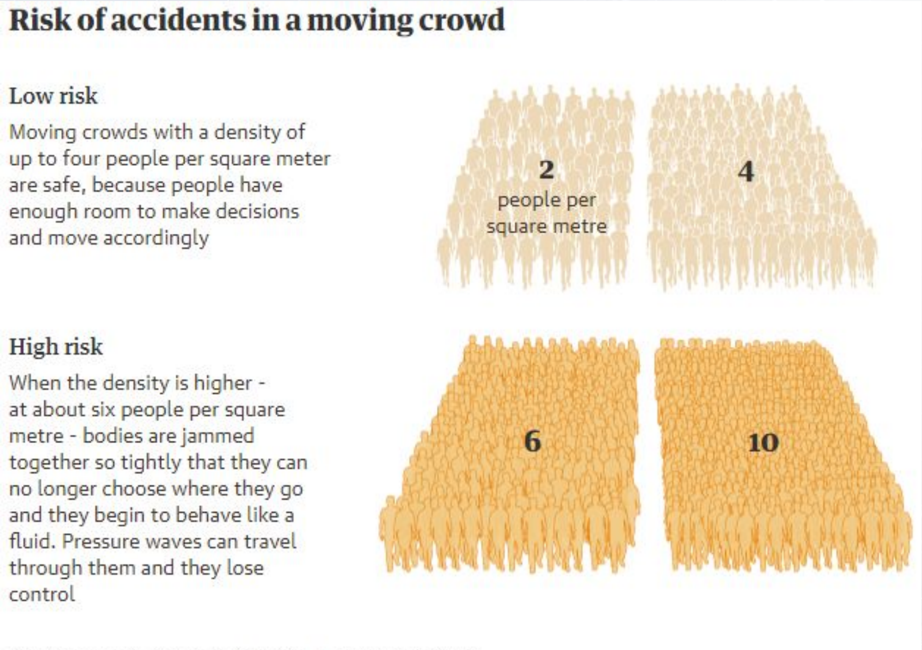
DENSITY

Bodies are jammed together so tightly that they can no longer choose where they go and they begin to behave like a fluid.

Source:
https://www.theguardian.com/world/2022/oct/31/how-did-the-seoul-itaewon-halloween-crowd-crush-happen-unfolded-a-visual-guide#:~:text=3-,A%20densely%20packed%20group%20exert%20pressure%20on%20each%20other%2C%20but,effect%20of%20similar%20holes%20elsewhere.

HOW THE TRAGEDY UNFOLDED

Crowd Crushing Risk increases when crowd density increases.

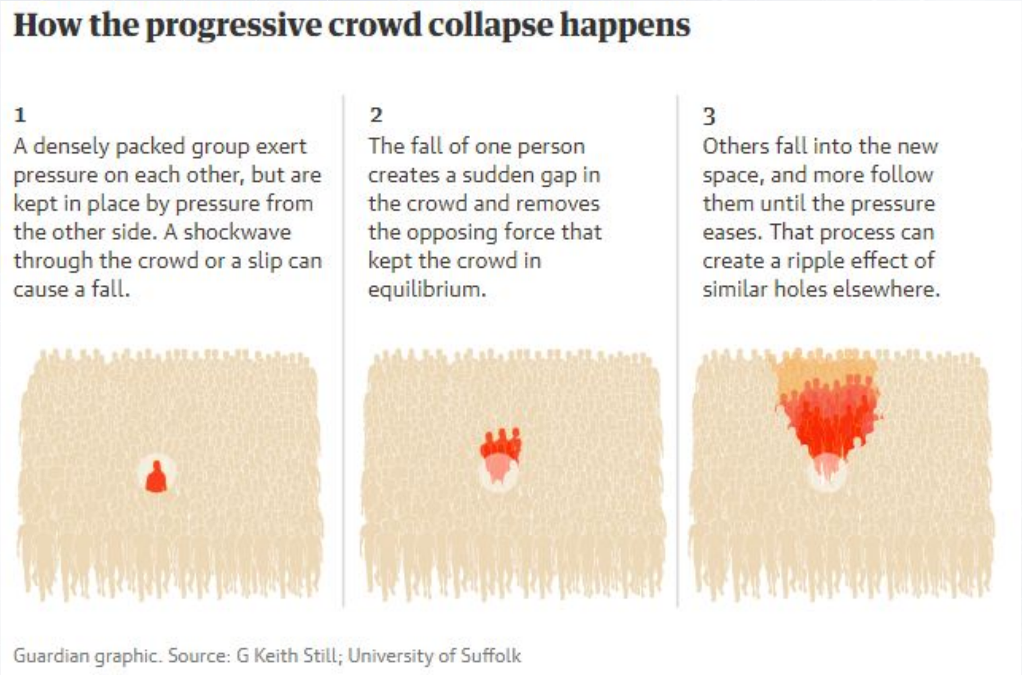


Guardian graphic. Source: G Keith Still; University of Suffolk

Source:
https://www.theguardian.com/world/2022/oct/31/how-did-the-seoul-itaewon-halloween-crowd-crush-happen-unfolded-a-visual-guide#:~:text=3-,A%20densely%20packed%20group%20exert%20pressure%20on%20each%20other%2C%20but,effect%20of%20similar%20holes%20elsewhere.

HOW THE TRAGEDY UNFOLDED

Densely packed crowd behaving like fluid.



Guardian graphic. Source: G Keith Still; University of Suffolk

Source: https://www.theguardian.com/world/2022/oct/31/how-did-the-seoul-itaewon-halloween-crowd-crush-happen-unfolded-a-visual-guide#:~:text=3-,A%20densely%20packed%20group%20exert%20pressure%20on%20each%20other%2C%20but,effect%20of%20similar%20holes%20elsewhere.

17,512

Total Deaths from **164** Crowd Crushing Incident

Source: https://en.wikipedia.org/wiki/List_of_fatal_crowd_crushes

01

PROBLEM STATEMENT

PROBLEM STATEMENT

SAFETY

Address the critical issue of crowd safety during public gatherings and events.

CONTROL

Prevention of crowd crushing disasters caused by overcrowding and mismanagement of crowded spaces.

DETECTION

Develop sophisticated deep learning model for real-time crowd presence detection

MITIGATION

Early warnings to authorities in hazardous conditions to protect lives

METHODOLOGY

01 PROBLEM

Identifying the problem statement

02 DATA

Source for the right data to solve the problem

03 EDA

Explore & Analysis the Data

04 MODELING

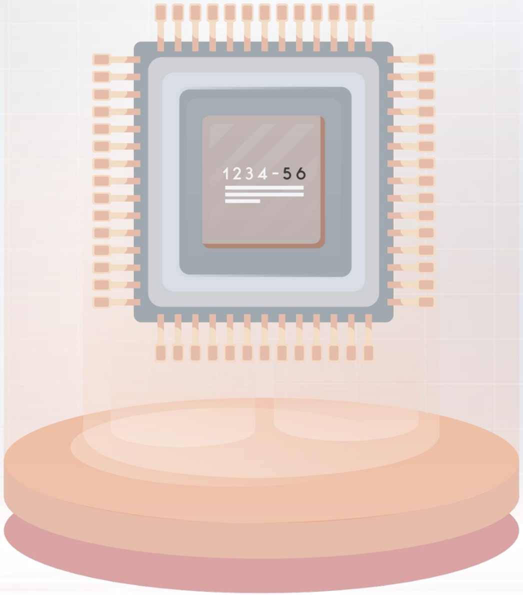
Develop Deep Learning Model for prediction

05 EVALUATION

Evaluate the performance of the models

06 DEPLOYMENT

Test & deploy the final product

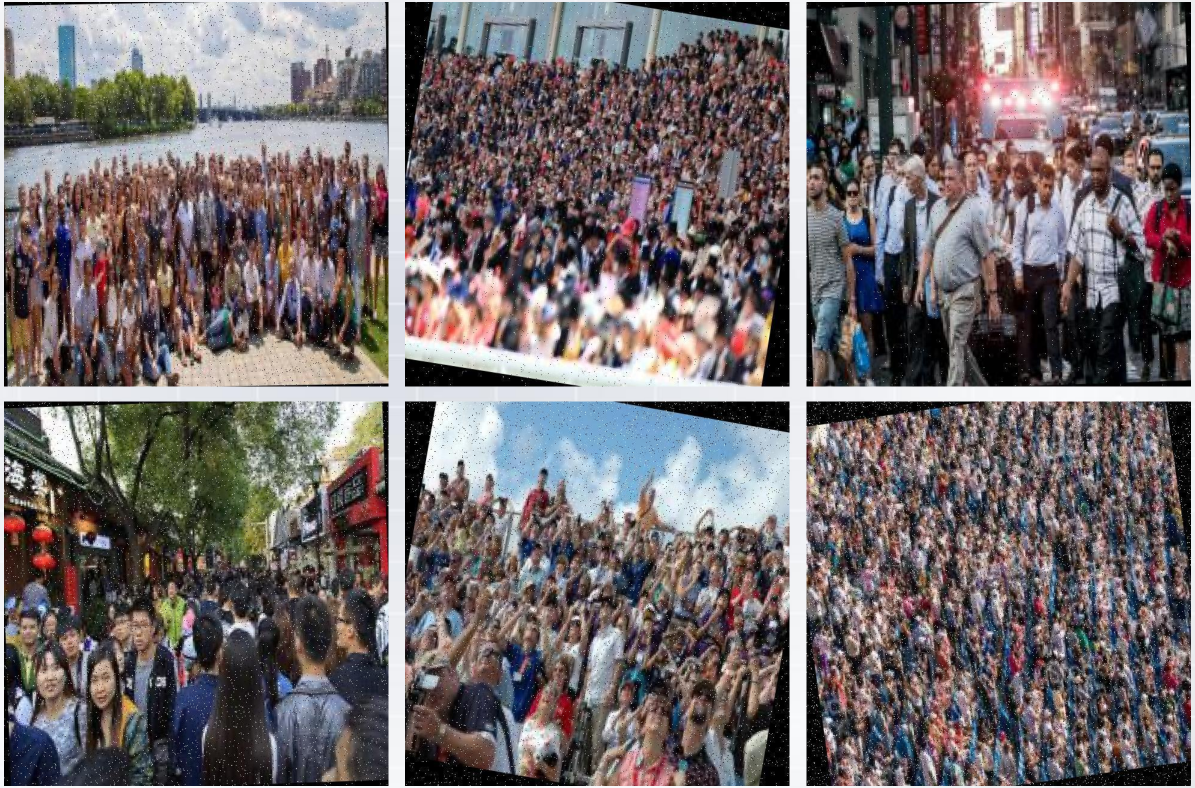


02

EXPLORATORY DATA ANALYSIS

DATASET

Crowd dataset
with **4k images**
for model training.



Source: https://universe.roboflow.com/embien-7xos5/peoplecounter-xqtwr

GROUND-TRUTH LABELS

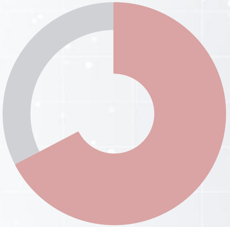
Ground-Truth Labels for training the model in the format:

(c, x, y, w, h)

C: Class
X & Y: Center of Bounding Box
W & H: Width & Height of Bounding Box

```
0 0.121875 0.27421875 0.0328125 0.05625
0 0.40703125 0.28046875 0.01875 0.0421875
0 0.221875 0.28203125 0.0234375 0.0421875
0 0.32109375 0.28359375 0.0234375 0.0421875
0 0.51328125 0.2890625 0.0234375 0.0375
0 0.2703125 0.2875 0.0203125 0.046875
0 0.859375 0.309375 0.0234375 0.028125
0 0.90625 0.33125 0.0234375 0.0421875
0 0.73203125 0.34453125 0.01875 0.0328125
0 0.98359375 0.3515625 0.0203125 0.0515625
0 0.74296875 0.3671875 0.01875 0.0328125
0 0.13671875 0.35703125 0.0203125 0.0515625
0 0.62265625 0.37265625 0.025 0.046875
0 0.30078125 0.37421875 0.0203125 0.0609375
0 0.70390625 0.38125 0.01875 0.0421875
0 0.3796875 0.38203125 0.01875 0.0234375
0 0.96171875 0.046875 0.0140625 0.0421875
0 0.090625 0.38203125 0.025 0.05625
0 0.328125 0.38828125 0.0296875 0.05625
```

TRAIN, VALIDATION & TEST

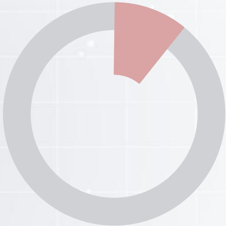


70%

Train Dataset
2.9k images

20%

Validation Dataset
836 images



10%

Test Dataset
415 images

PROPERTIES

SIZE

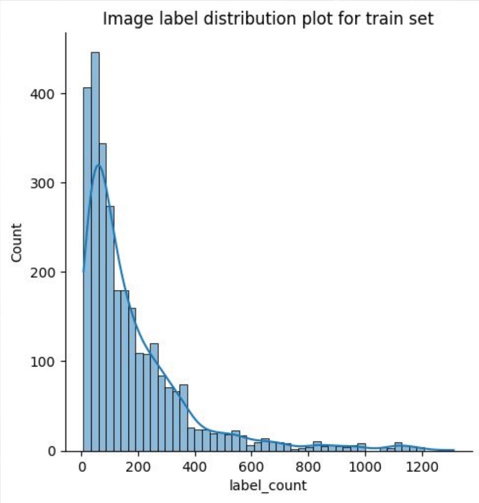
Image Size:
640 x 640

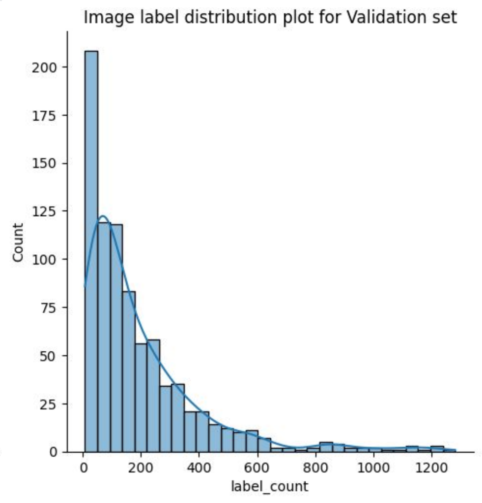
LABELS

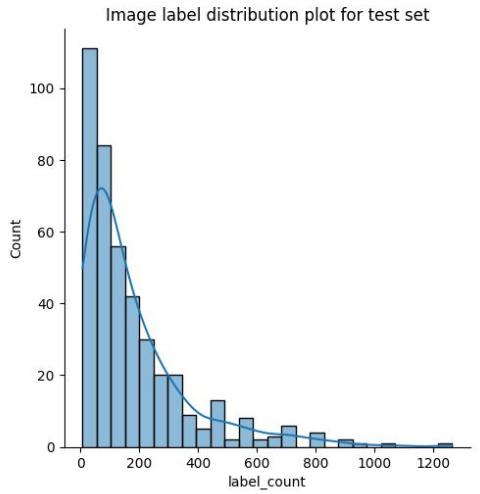
Ground-Truth Labels majority below 200 per image

AUGMENTATION

Images were randomly tilted with mixture of colored & gray-scaled images





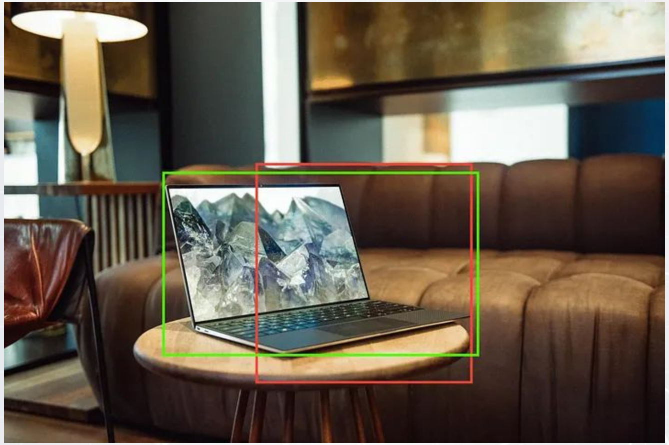


03

MODELING

Model selection

- Project utilized two models: YOLOv5 and YOLOv8.
- YOLO stands for "You Only Look Once."
- YOLO's algorithm is real-time object detection, identifies and locates multiple elements in an image.
- Uses convolutional neural networks (CNN) for instant recognition.
- YOLO performs predictions for the entire image simultaneously.
- Offers fast and accurate object detection for various applications.



roboflow

Source: https://towardsdatascience.com/on-object-detection-metrics-with-worked-example-216f173ed31e

THE PREPARATION

MODELS

YOLOv5 & YOLOv8

MACHINE

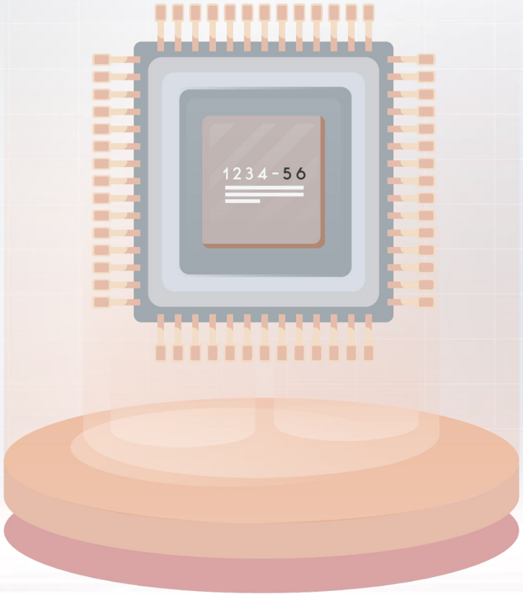
Modeling performed on Google Collab
GPU: NVIDIA A100-SXM4-40GB

PARAMETERS

Epoch: 100 & 200
Batch: 8 & 16

Modeling

MODEL	EPOCH	BATCH	REMARKS
YOLOv5	100	16	Training: train dataset Validation: All 3 dataset (train, valid, test).
YOLOv8	100	8	Training: train dataset Validation: All 3 dataset (train, valid, test). Batch: 8 due GPU out of memory error
YOLOv8	200	8	Training: train dataset Validation: All 3 dataset (train, valid, test). Batch: 8 due GPU out of memory error

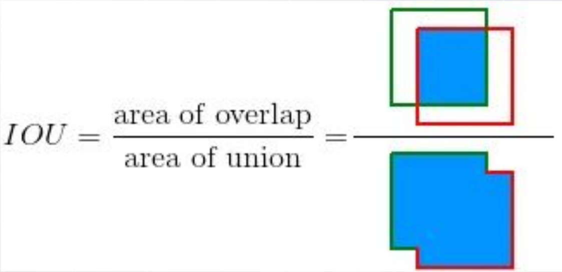


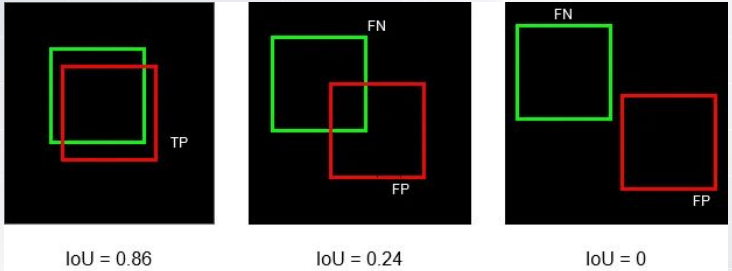
04

MODEL EVALUATION

Intersection over Union

- Intersection over Union (IoU) measures the extent of overlap between the ground truth (gt) and the prediction (pd) bounding boxes.
- IoU is used with a threshold (α) to determine correct detections.
- Example on the right shows the output when α is set to 0.5 (TP: IoU ≥ α, FP & FN: IoU < α)





Definition of terms:

- True Positive (TP) — Correct detection
- False Positive (FP) — Incorrect detection
- False Negative (FN) — A Ground-truth missed (not detected)
- True Negative (TN) — Not used in object detection as it pertains to background regions that are correctly not detected by the model.

Source: https://towardsdatascience.com/on-object-detection-metrics-with-worked-example-216f173ed31e

METRICS

mAP

mean Average Precision (mAP) assess the model's overall detection accuracy across all classes.

PRECISION

Measures the model's accuracy in identifying relevant objects by calculating the ratio of True Positives (TPs) to all detections

RECALL

Evaluates the model's ability to detect all ground truth objects, indicating the proportion of True Positives (TPs) among all actual ground truth instances.

$$P = \frac{\mathrm{TP}}{\mathrm{TP} + \mathrm{FP}} = \frac{TP}{\text{all detections}}$$

$$R = \frac{\mathrm{TP}}{\mathrm{TP} + \mathrm{FN}} = \frac{TP}{\text{all ground-truths}}$$

Source: https://towardsdatascience.com/on-object-detection-metrics-with-worked-example-216f173ed31e

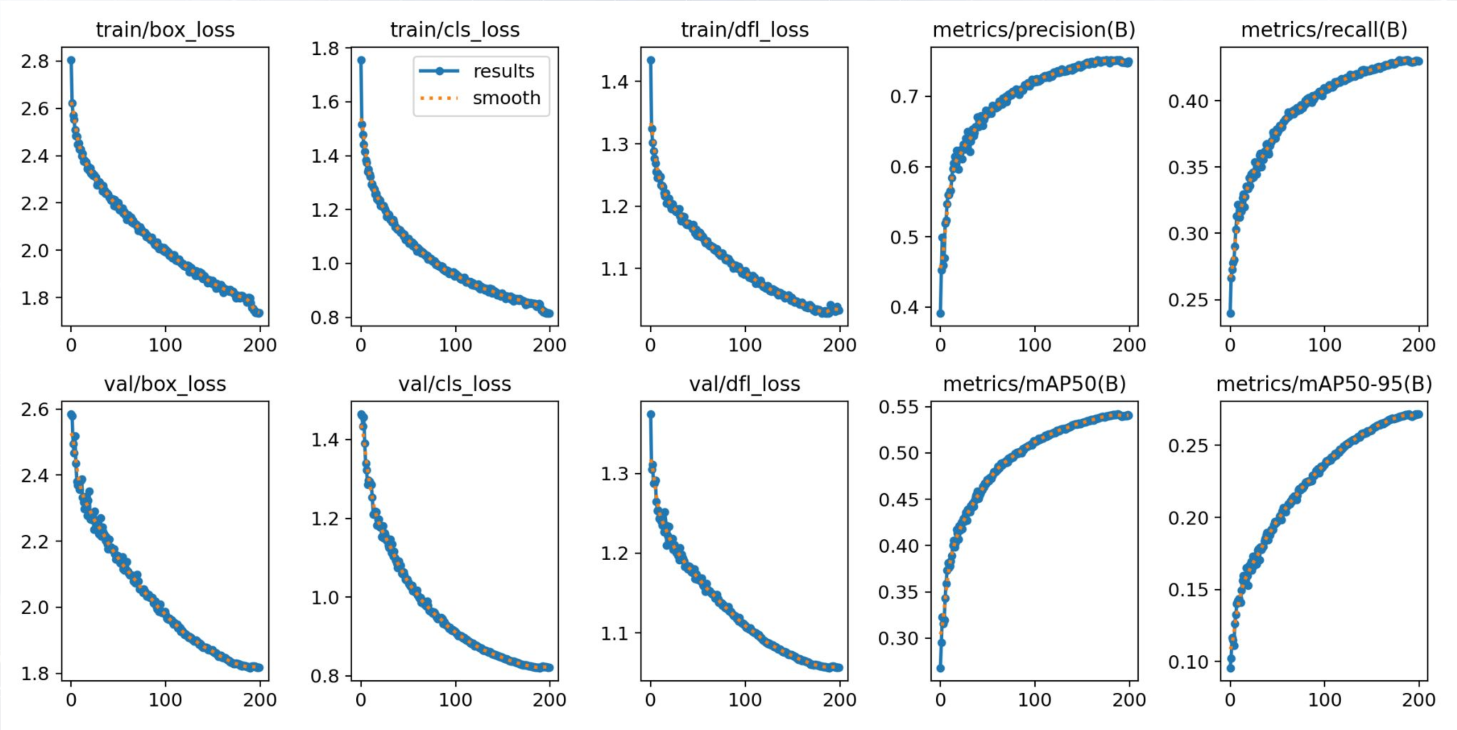
Model Performances

	mAP50[1]			Precision			Recall		
	Train	Val[2]	Test	Train	Val[2]	Test	Train	Val[2]	Test
YOLOv5 (Baseline)	46.7%	45.6%	45.8%	70.7%	69.6%	69.0%	37.3%	36.5%	36.9%
YOLOv8 (100 Epoch)	55.1% (+8.4%)	52.9% (+7.3%)	54.6% (+8.8%)	75.6% (+4.9%)	73.8% (+4.2%)	73.7% (+4.7%)	44.4% (+7.1%)	42.3% (+5.8%)	44.6% (+7.7%)
YOLOv8 (200 Epoch)	**56.6% (+9.9%)**	**54.1% (+8.5%)**	**55.7% (+9.9%)**	**77.6% (+6.9%)**	**74.8% (+5.2%)**	**74.9% (+5.9%)**	**45.3% (+8.0%)**	**43.0% (+6.5%)**	**45.3% (+8.4%)**

1: Mean Average Precision @ IoU 0.5   2: Validation Score

Model Results

- Metrics performance rate of increase diminishes as epoch approaches the end.
- Validation losses (box, class, distribution focal loss) approaches zero towards the end.



MODEL INFERENCE

Predictions on the test set made by the best model.

Source: https://universe.roboflow.com/embien-7xos5/peoplecounter-xqtwr

PRODUCT DEMONSTRATION

05

LIMITATIONS & FUTURE WORKS

LIMITATIONS & FUTURE WORKS

HARDWARE

High processing power is required for deep learning models. Higher processing GPU required.

DATA

Model is as good as the data gets. More data required to improve model accuracy.

TIME

Besides processing power, more time is required to run models for further improvement.

AREA

Future work: Automated calculation / retrieval from mapping database for the triggering limits

WARNING

Future work: Automated messaging / email system to alert authorities.

06

CONCLUSIONS

CONCLUSIONS

PREEMPTIVE

Closing off high-risk areas during public gatherings and events before they become overcrowded

PROACTIVE

Deployment of security personnel, regulation of crowd control at congregation areas and potential chokepoints

PREDICTIVE

CCTVs and drones with deep learning detection model to monitor the crowd capacity & provide early warning.

3 Key Factors to Prevent Overcrowding...

THANKS!

https://www.linkedin.com/in/neo-wenxi/

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