Reducing Workplace Injuries in Singapore using Objection Detection Model

General Assembly Capstone Project

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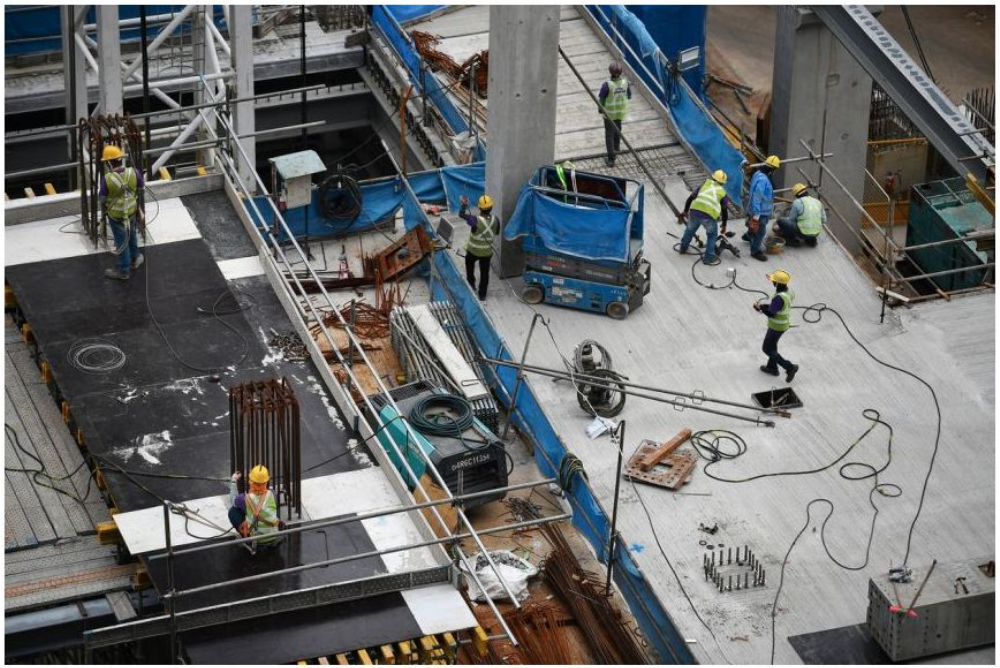
Introduction

Workplace injuries, fatalities can hinder business recovery from Covid-19 pandemic: Tan See Leng



The Manpower Ministry is reviewing the introduction of safety criteria to qualify for public-sector construction projects. PHOTO: ST FILE

Straits Times - July 29, 2021

- Employers and employees **need to step up their workplace safety and health efforts** as **injuries and fatalities can hinder business recovery from the Covid-19 pandemic**, said Manpower Minister Tan See Leng on Thursday (July 29).

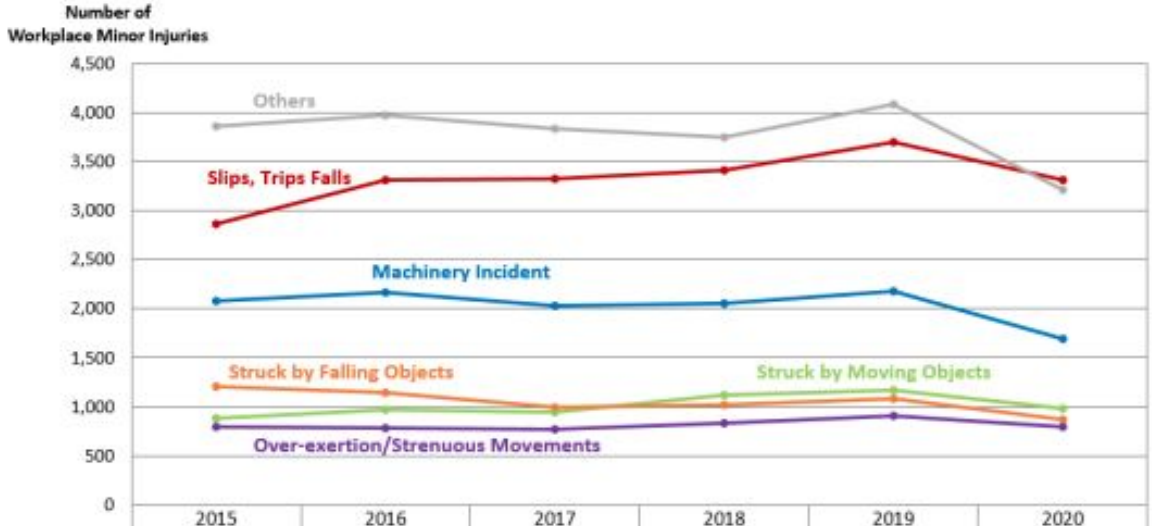
- He stressed that companies must **continue their workplace safety and health efforts** amid the pandemic, on top of the safe management measures to limit interactions at workplaces and prevent the spread of Covid-19 among workers.

- There were 23 work-related deaths in the first half of this year, an **increase from the 16 workplace fatalities over the same period last year**. In the first half of 2019, there were 17 such deaths.

Introduction

CAUSES OF WORKPLACE MINOR INJURIES

The top three causes of workplace minor injuries were (i) Slips, Trips & Falls, (ii) Machinery Incidents, and (iii) Struck by Moving Objects. These collectively accounted for 55% (5,993 cases) of the total number of workplace minor injuries.



	2015	2016	2017	2018	2019	2020
Slips, Trips & Falls	2,863	3,315	3,323	3,407	3,694	3,318
Machinery Incidents	2,083	2,172	2,025	2,051	2,178	1,696
Struck by Moving Objects	882	971	939	1,114	1,173	979
Struck by Falling Objects	1,205	1,138	994	1,016	1,081	864
Over-exertion/Strenuous Movements	791	786	767	835	902	790
Others	3,864	3,972	3,834	3,750	4,083	3,210

Figure 18: Number of workplace minor injuries by cause of injury, 2015-2020

Workplace Safety and Health Report 2020 - National Statistics by Ministry of Manpower

A large number of workplace minor injuries **could have been prevented by using Personal Protective Equipment (PPE) including coverall uniforms**.

Problem Statement

- Overall End Goal -
  - To reduce the number of workplace injuries by using Object Detection Model to detect if any workers are not wearing PPE (Helmet and Safety Vest) properly inside a PPE zone
  - Sounding off an alarm to alert the workers on the infringement using real time monitoring by cameras
- Target Audience - Worksite Contractors / Companies, Ministry of Manpower

BCA

SMRT

MINISTRY OF MANPOWER

Dataset and Processing

- Images / Datasets -
  - Kaggle
  - Additional images downloaded from Google

- Processing - Using a graphical image annotation tool (LabelImg*) to draw bounding boxes for helmet, person and safety vest in all images

Source for LabelImg: https://github.com/tzutalin/labelImg

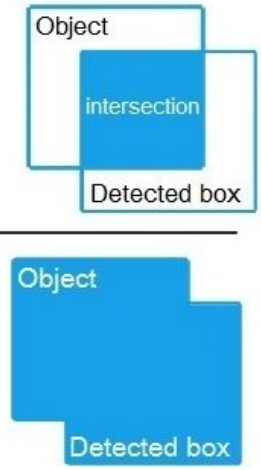
Building and Training the Final Object Detection Model

- Split into a ratio of 7:2:1 for Training:Validation:Test with a total of 1,213 images and annotations
- Utilizes Tensorflow Lite Model Maker library (TF API) to train a custom object detection model
- Leverages on transfer learning with EfficientDet-Lite0 model - Speeds up the process of training the model on a new task, achieve a more accurate and effective model
- Train using Training and Validation Images

Primary Evaluation Metric for the Model

- Mean Average Precision (mAP) - Popular metric in measuring the accuracy of object detection model
- Intersection over Union (IoU) - Determine TP, FP, FN

$$IoU = \frac{\text{Area of Overlap}}{\text{Area of Union}}$$



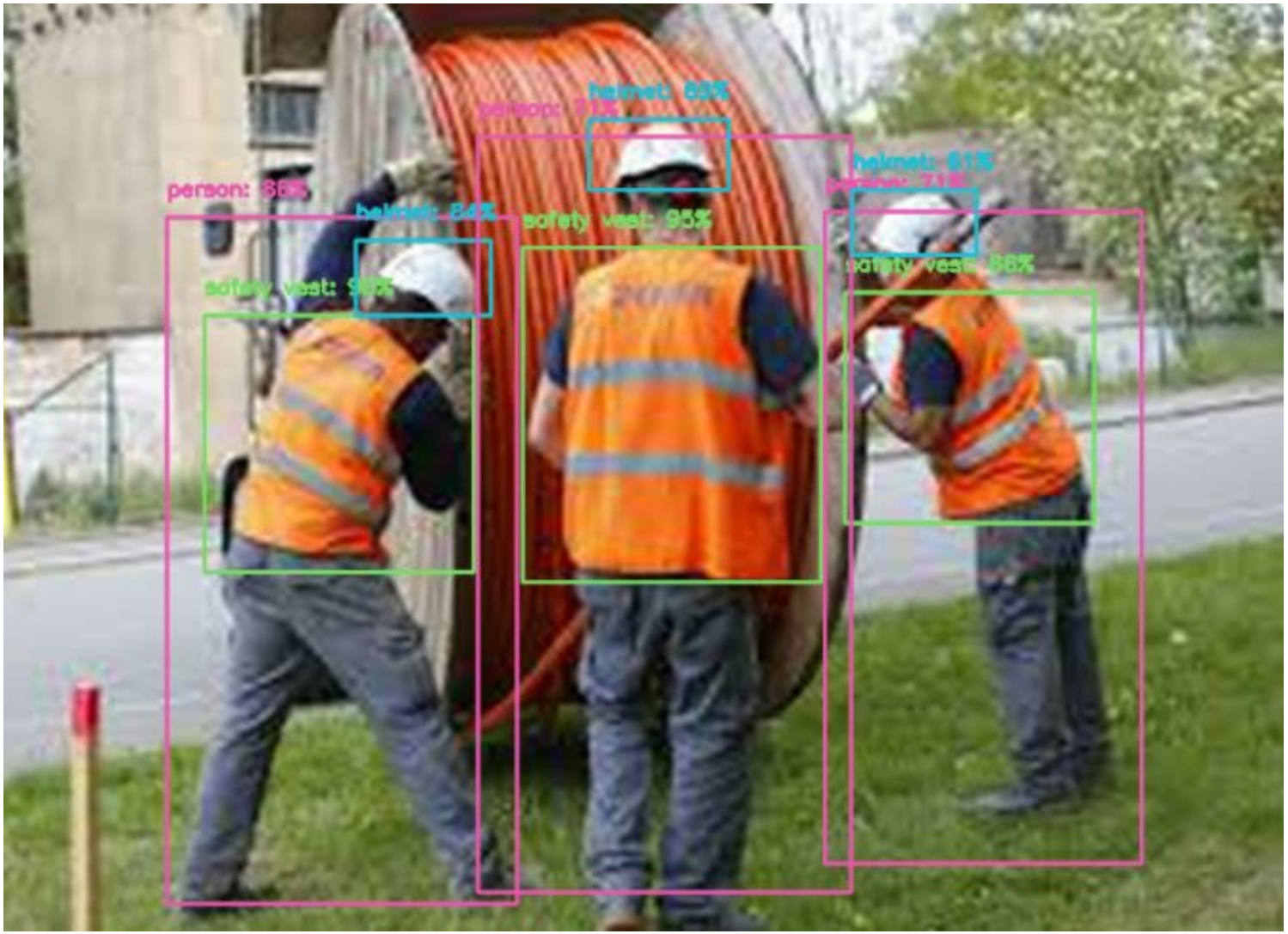
- Plot the Precision/Recall Curve and calculate the area under the PR curve for a specific class - AP
- Average of the AP calculated for all the classes

Evaluation Results

Results of Test Dataset (100 images) [Post Quantization]

- mAP (at IoU=.50:.05:.95) - Average of 10 IoU thresholds from 0.50 to 0.95 with step of 0.05 = **0.582** [More Stringent]
- mAP (at IoU=0.75) Consider the AP at IoU of 0.75 = **0.674**
- mAP (at IoU=0.50) - Consider the AP at IoU of 0.50 = **0.880** [Traditional Method]

Images from Test Dataset



Images from Test Dataset

Evaluating the Model (Manual)

- True Positive (TP) - IoU > 0.5
- False Positive (FP) - IoU < 0.5 or Duplicated Bounding Box
- False Negative (FN) - There is no detection (but supposed to detect) or Wrong classification predicted
- True Negative (TN) - Not evaluated

Results of Test Dataset of 100 images

	Predicted: No	**Predicted: Yes**
Actual: No	TN=N/A	FP = 10
Actual: Yes	FN = 102	TP = 366

Precision: 0.973
Recall: 0.782

Example of False Negative

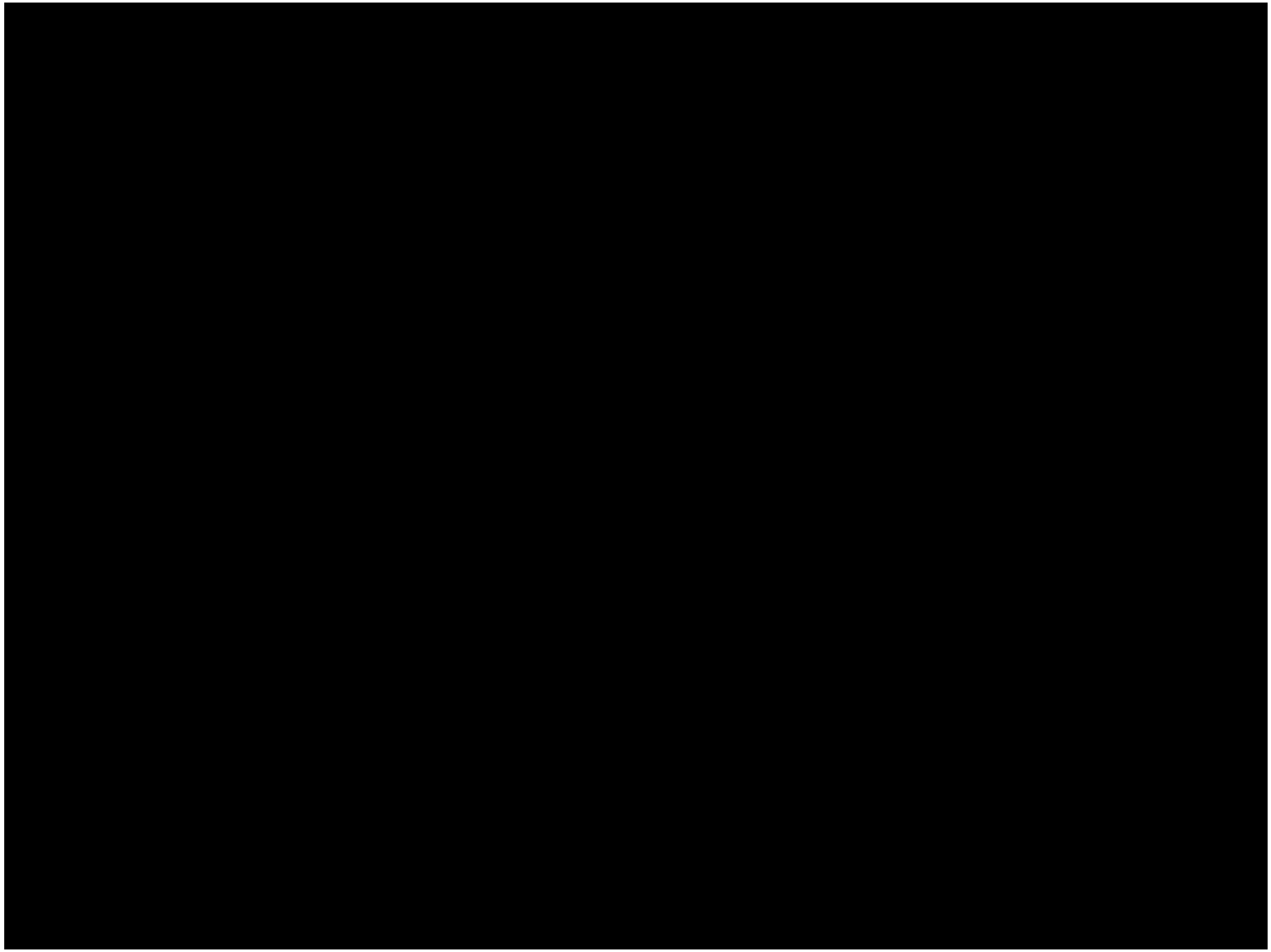
Example of False Negative

Example of False Positive

Summary of Error Analysis

- Resolution of images are quite bad in general
- False Negative Analysis - Fails to detect the following objects:
  - Helmet - 40%; Person - 35%; Safety Vest - 25%
  - Possible Reasons - Insufficient images for various angles, positions of the objects; blockage of some parts of the objects
- False Positive Analysis - 1 BB tend to group 2 identical objects together
  - Possible Reasons - For some images, the BB was drawn to overlap several objects

Object Detection on Video



Moving Forward

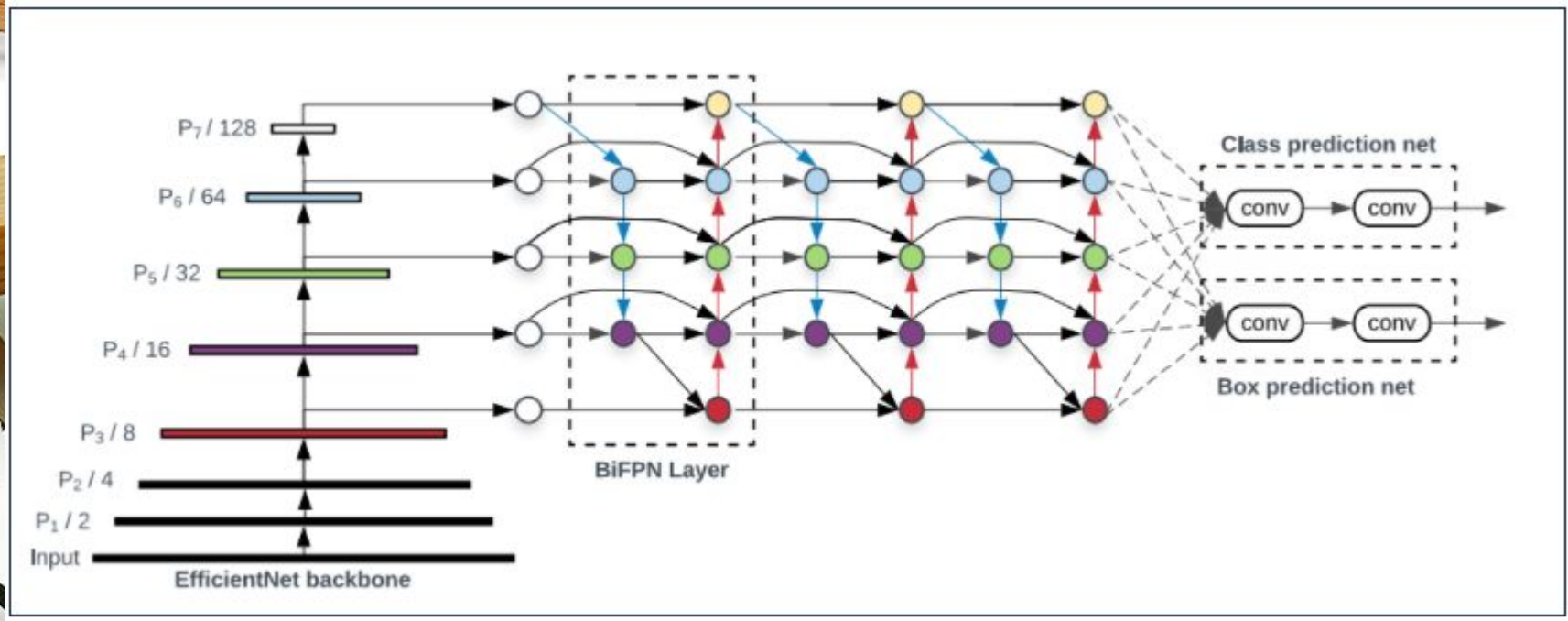
- Improving the performance of the Object Detection Model
  - Train with more images and images of the similar resolution/quality of the camera feed
  - Consideration of user's specific requirement
  - Leverage on Image Augmentation

- Integration of the Object Detection Model with Camera and Alarm system and Controller to trigger an alarm when required
- Deployment of the overall system - Viewing of the Camera feed with the Object Detection Model


Q&A

Supplementary Slides

EfficientDet Architecture

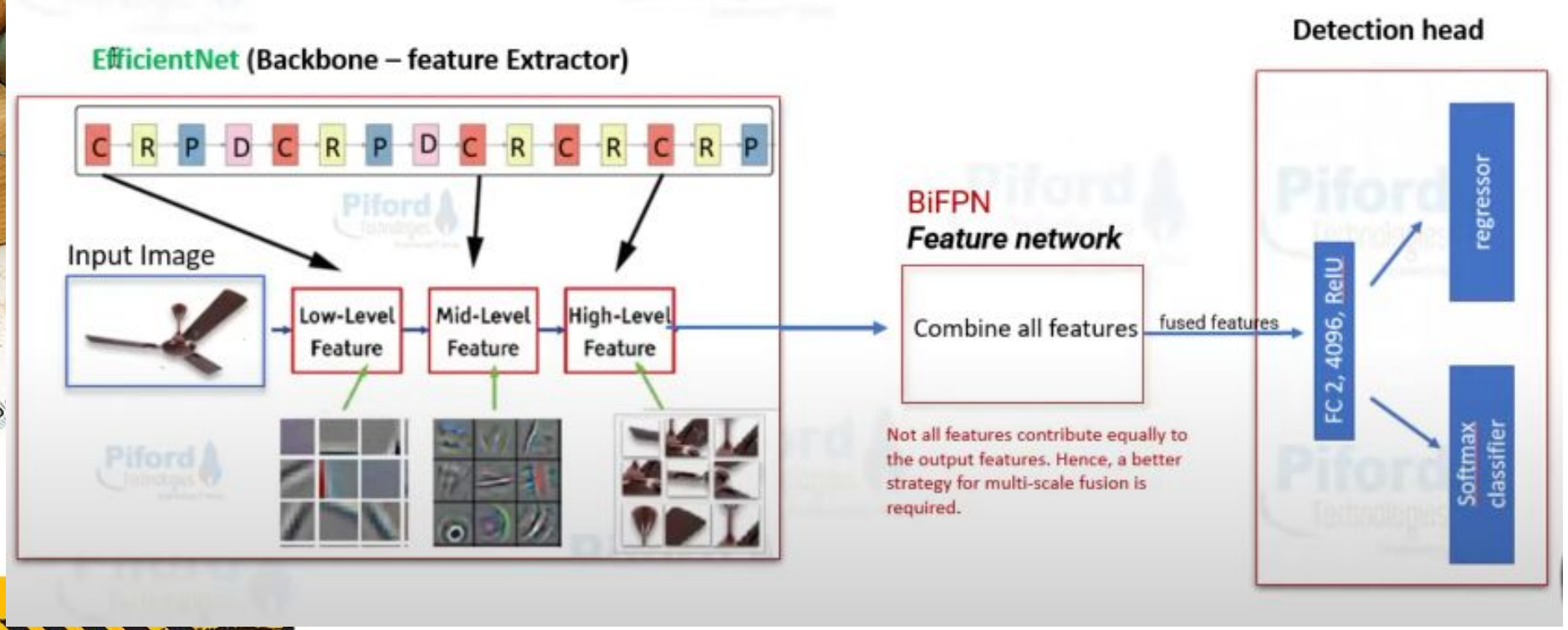


- Two key aspects -
  - **Compound Scaling** - Scaling up all dimensions (depth, width, image size) while maintaining a balance between all dimensions of the network
  - **BiFPN** (Bi-directional Feature Pyramid Network) - A type of feature pyramid network which allows easy and fast multi-scale feature fusion.

EfficientDet

- Multi-Scale Feature Fusion - Combination of low-resolution, semantically strong features in the later layers with high-resolution, semantically weak features in the earlier layers via a top-down pathway and lateral connections.
- Concept of not all features contributes equally to output features.
- Repeated Blocks of BiFPN layer to enable more highl-level feature fusion
- Useful Links -
  - https://amaarora.github.io/2020/08/13/efficientnet.html
  - https://amaarora.github.io/2021/01/11/efficientdet.html#efficientdet-architecture
  - https://www.youtube.com/watch?v=qZobxWXlJ0g

EfficientDet

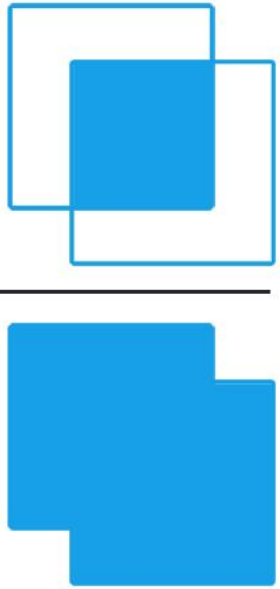


Source: https://www.youtube.com/watch?v=OsA3zH5NKYc&t=612s

mAP

- To do the calculation of AP for object detection, we would first need to understand IoU. The IoU is given by the ratio of the area of intersection and area of union of the predicted bounding box and ground truth bounding box.

$$IoU = \frac{\text{Area of Overlap}}{\text{Area of Union}}$$

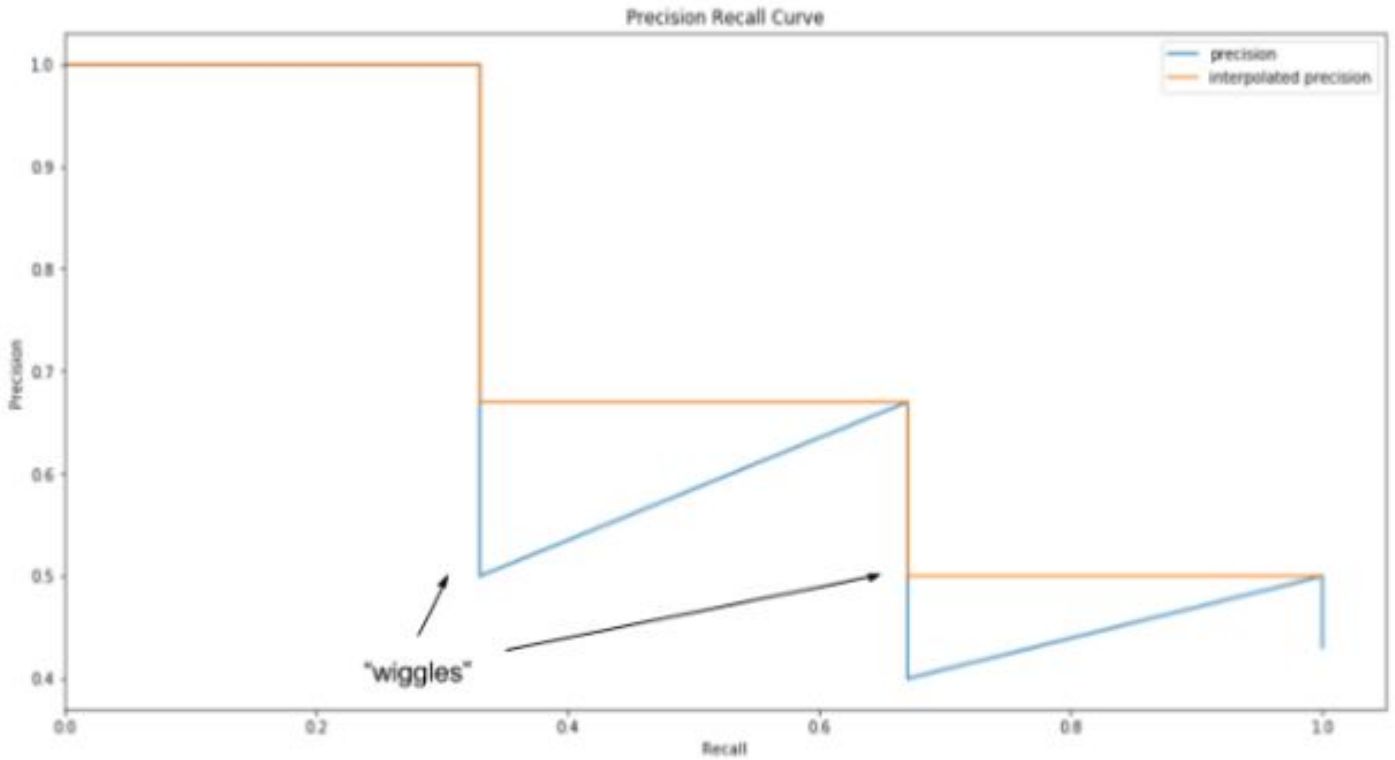


mAP

- With the TP, FP and FN formally defined, we can now calculate the precision and recall of our detection for a given class across the test set.
- Each BB would have its confidence level, usually given by its softmax layer, and would be used to rank the outp
- Before we plot the PR curve, we need first need to know the interpolated precision.
- The interpolated precision, p_interp, is calculated at each recall level, r, by taking the maximum precision measured for that r.

mAP

- Their intention of interpolating the PR curve was to reduce the impact of “wiggles” caused by small variations in the ranking of detections.



mAP

- The AP is then calculated by taking the area under the PR curve.
- The mAP for object detection is the average of the AP calculated for all the classes. It is also important to note that for some papers, they use AP and mAP interchangeably.

Source -

https://towardsdatascience.com/breaking-down-mean-average-precision-map-ae462f623a52

Additional resource -

https://jonathan-hui.medium.com/map-mean-average-precision-for-object-detection-45c121a31173