Object Detection in an Urban Environment

Goal

To classify and localize the cars, pedestrians and cyclists in camera input feed. This is useful for self-driving cars and other road safety systems.

Setup

The code repository can be found at :

https://github.com/Vaibhav-ML/Udacity-Data-Scientist-Nanodegree

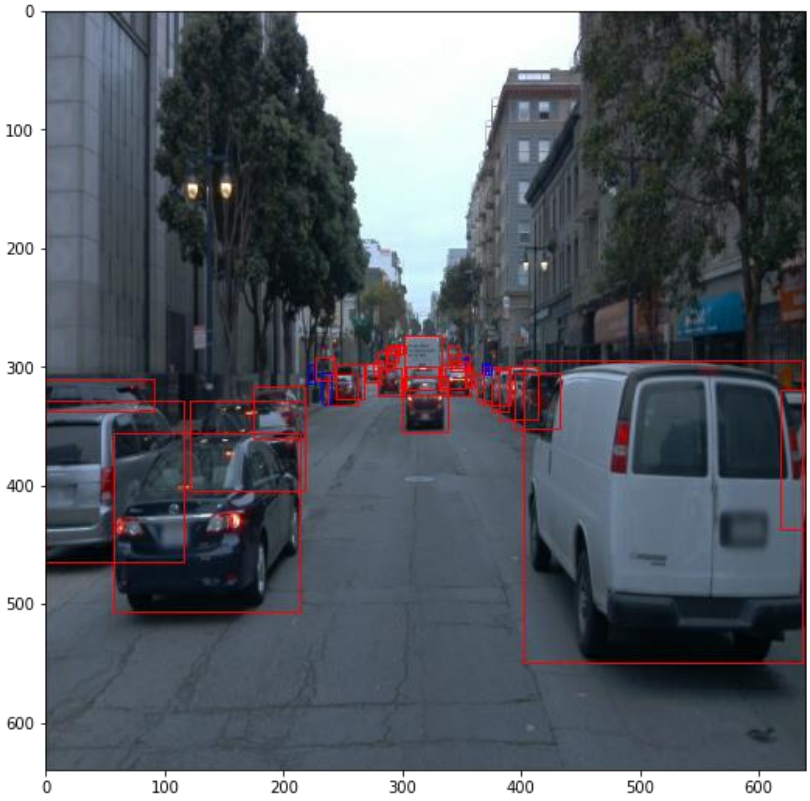
All the instruction to run the repository can be found in the README.md file present in the repository.

The config for Experiment 2 gives the best results.

Dataset

The dataset contains high resolution traffic images with three classes : vehicles, pedestrians and cyclists.

Below are some sample images from the dataset .



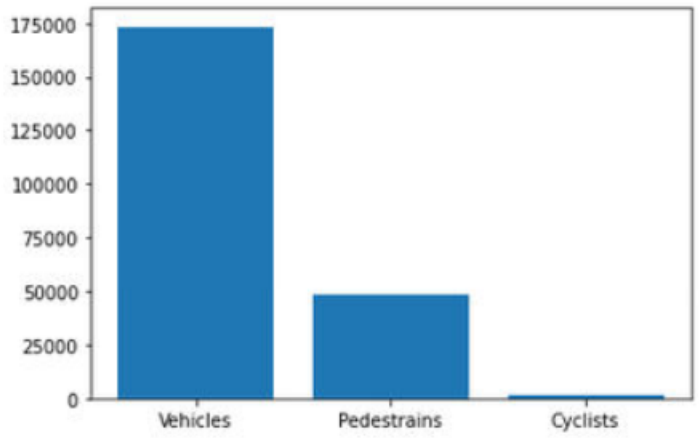
Dataset Analysis

The class distribution is roughly : 1730 : 488 : 12 (Vehicles : Pedestrians : Cyclists)

It is a heavily unbalanced class distribution.

Some images are taken at night and hence have low brightness.

Below is the class distribution graph.



Training

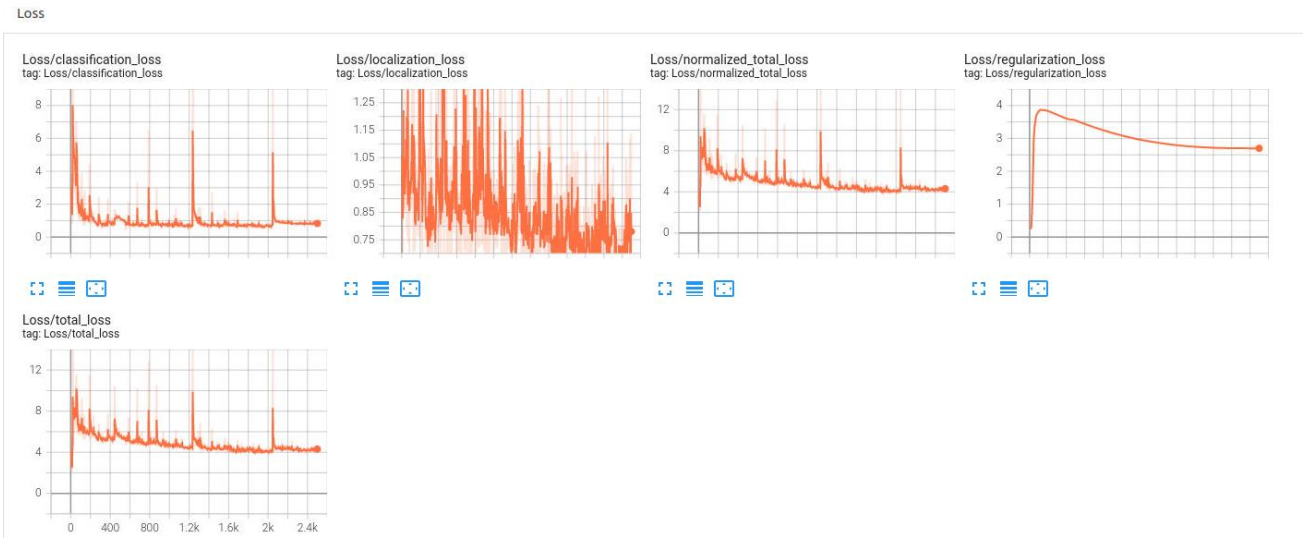
1. *Reference experiment*: The total training loss as well as the classification loss was really high for this experiment. Below are the AP and recall logs :

   Average Precision (AP) @[IoU=0.50:0.95 | area= all | maxDets=100] = 0.000
   Average Precision (AP) @[IoU=0.50 | area= all | maxDets=100] = 0.000
   Average Precision (AP) @[IoU=0.75 | area= all | maxDets=100] = 0.000
   Average Precision (AP) @[IoU=0.50:0.95 | area= small | maxDets=100] = 0.000
   Average Precision (AP) @[IoU=0.50:0.95 | area=medium | maxDets=100] = 0.007
   Average Precision (AP) @[IoU=0.50:0.95 | area= large | maxDets=100] = -1.000
   Average Recall (AR) @[IoU=0.50:0.95 | area= all | maxDets= 1] = 0.000
   Average Recall (AR) @[IoU=0.50:0.95 | area= all | maxDets= 10] = 0.000
   Average Recall (AR) @[IoU=0.50:0.95 | area= all | maxDets=100] = 0.005
   Average Recall (AR) @[IoU=0.50:0.95 | area= small | maxDets=100] = 0.000
   Average Recall (AR) @[IoU=0.50:0.95 | area=medium | maxDets=100] = 0.053
   Average Recall (AR) @[IoU=0.50:0.95 | area= large | maxDets=100] = -1.000

   INFO:tensorflow:Eval metrics at step 2000
   I1215 21:40:06.577259 140628795279104 model_lib_v2.py:988] Eval metrics at step 2000
   INFO:tensorflow: + DetectionBoxes_Precision/mAP: 0.000042
   I1215 21:40:06.579910 140628795279104 model_lib_v2.py:991] + DetectionBoxes_Precision/mAP: 0.000042
   INFO:tensorflow: + DetectionBoxes_Precision/mAP@.50IOU: 0.000114
   I1215 21:40:06.581568 140628795279104 model_lib_v2.py:991] + DetectionBoxes_Precision/mAP@.50IOU: 0.000114
   INFO:tensorflow: + DetectionBoxes_Precision/mAP@.75IOU: 0.000000
   I1215 21:40:06.583297 140628795279104 model_lib_v2.py:991] + DetectionBoxes_Precision/mAP@.75IOU: 0.000000
   INFO:tensorflow: + DetectionBoxes_Precision/mAP (small): 0.000000

I1215 21:40:06.584882 140628795279104 model_lib_v2.py:991] + DetectionBoxes_Precision/mAP (small): 0.000000
INFO:tensorflow: + DetectionBoxes_Precision/mAP (medium): 0.006679
I1215 21:40:06.586670 140628795279104 model_lib_v2.py:991] + DetectionBoxes_Precision/mAP (medium): 0.006679
INFO:tensorflow: + DetectionBoxes_Precision/mAP (large): -1.000000
I1215 21:40:06.588349 140628795279104 model_lib_v2.py:991] + DetectionBoxes_Precision/mAP (large): -1.000000
INFO:tensorflow: + DetectionBoxes_Recall/AR@1: 0.000000
I1215 21:40:06.592261 140628795279104 model_lib_v2.py:991] + DetectionBoxes_Recall/AR@1: 0.000000
INFO:tensorflow: + DetectionBoxes_Recall/AR@10: 0.000000
I1215 21:40:06.593793 140628795279104 model_lib_v2.py:991] + DetectionBoxes_Recall/AR@10: 0.000000
INFO:tensorflow: + DetectionBoxes_Recall/AR@100: 0.004706
I1215 21:40:06.595592 140628795279104 model_lib_v2.py:991] + DetectionBoxes_Recall/AR@100: 0.004706
INFO:tensorflow: + DetectionBoxes_Recall/AR@100 (small): 0.000000
I1215 21:40:06.597191 140628795279104 model_lib_v2.py:991] + DetectionBoxes_Recall/AR@100 (small): 0.000000
INFO:tensorflow: + DetectionBoxes_Recall/AR@100 (medium): 0.053333
I1215 21:40:06.598931 140628795279104 model_lib_v2.py:991] + DetectionBoxes_Recall/AR@100 (medium): 0.053333
INFO:tensorflow: + DetectionBoxes_Recall/AR@100 (large): -1.000000
I1215 21:40:06.600528 140628795279104 model_lib_v2.py:991] + DetectionBoxes_Recall/AR@100 (large): -1.000000
INFO:tensorflow: + Loss/localization_loss: 0.757059
I1215 21:40:06.601971 140628795279104 model_lib_v2.py:991] + Loss/localization_loss: 0.757059
INFO:tensorflow: + Loss/classification_loss: 0.687994
I1215 21:40:06.603411 140628795279104 model_lib_v2.py:991] + Loss/classification_loss: 0.687994
INFO:tensorflow: + Loss/regularization_loss: 2.715815
I1215 21:40:06.604907 140628795279104 model_lib_v2.py:991] + Loss/regularization_loss: 2.715815
INFO:tensorflow: + Loss/total_loss: 4.160868
I1215 21:40:06.606426 140628795279104 model_lib_v2.py:991] + Loss/total_loss: 4.160868

The tensorboard logs depict the same story . The loss is on the higher side and this was expected as the dataset is complicated and would require augmentation strategies as well as hyperparameter tuning for obtaining better results.



2. *Improve on the reference*: I changed the optimizer to Adam and lowered the learning rate from 0.004 to 5e-4 . I also added some data augmentation methods like random horizontal flip, brightness adjustment (Ref. : https://github.com/tensorflow/models/blob/master/research/object_detection/protos/preprocessor.proto) etc. These were done as the dataset objects are present in mostly the centre or the periphery of the individual images. This all changes were made in Experiment 2.

   Here are the data augmentation examples :

I tried the base architecture as well as an SSD Resnet 101 V1 architecture as part of Experiment 1. Although it gave better results than the reference model but it was slower and less accurate than the model in Experiment 2.

The training results were far better in Experiment 2 as compared to the reference model!

Below are the AP and Recall logs for Experiment 2:

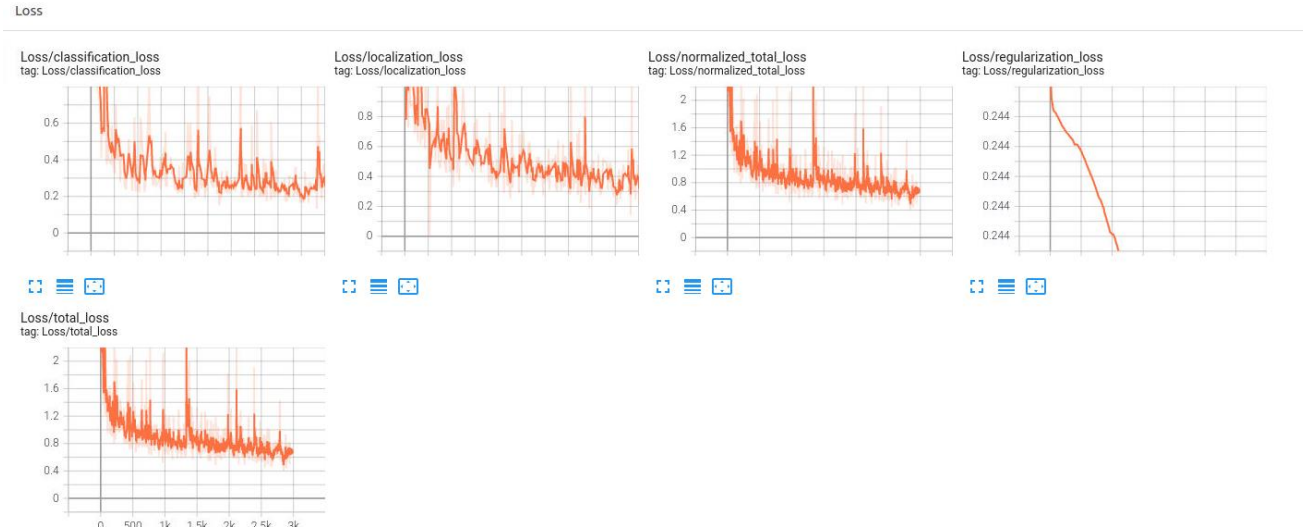
Average Precision (AP) @[IoU=0.50:0.95 | area= all | maxDets=100] = 0.107
Average Precision (AP) @[IoU=0.50 | area= all | maxDets=100] = 0.233
Average Precision (AP) @[IoU=0.75 | area= all | maxDets=100] = 0.089
Average Precision (AP) @[IoU=0.50:0.95 | area= small | maxDets=100] = 0.041
Average Precision (AP) @[IoU=0.50:0.95 | area=medium | maxDets=100] = 0.444
Average Precision (AP) @[IoU=0.50:0.95 | area= large | maxDets=100] = 0.428
Average Recall (AR) @[IoU=0.50:0.95 | area= all | maxDets= 1] = 0.027
Average Recall (AR) @[IoU=0.50:0.95 | area= all | maxDets= 10] = 0.113
Average Recall (AR) @[IoU=0.50:0.95 | area= all | maxDets=100] = 0.162
Average Recall (AR) @[IoU=0.50:0.95 | area= small | maxDets=100] = 0.097

Average Recall (AR) @[IoU=0.50:0.95 | area=medium | maxDets=100] = 0.540
Average Recall (AR) @[IoU=0.50:0.95 | area= large | maxDets=100] = 0.670
INFO:tensorflow:Eval metrics at step 2500
I1215 19:02:29.361037 140411958515456 model_lib_v2.py:988] Eval metrics at step 2500
INFO:tensorflow: + DetectionBoxes_Precision/mAP: 0.106636
I1215 19:02:29.369823 140411958515456 model_lib_v2.py:991] + DetectionBoxes_Precision/mAP: 0.106636
INFO:tensorflow: + DetectionBoxes_Precision/mAP@.50IOU: 0.233006
I1215 19:02:29.371702 140411958515456 model_lib_v2.py:991] + DetectionBoxes_Precision/mAP@.50IOU: 0.233006
INFO:tensorflow: + DetectionBoxes_Precision/mAP@.75IOU: 0.088867
I1215 19:02:29.373291 140411958515456 model_lib_v2.py:991] + DetectionBoxes_Precision/mAP@.75IOU: 0.088867
INFO:tensorflow: + DetectionBoxes_Precision/mAP (small): 0.041406
I1215 19:02:29.374817 140411958515456 model_lib_v2.py:991] + DetectionBoxes_Precision/mAP (small): 0.041406
INFO:tensorflow: + DetectionBoxes_Precision/mAP (medium): 0.443651
I1215 19:02:29.376449 140411958515456 model_lib_v2.py:991] + DetectionBoxes_Precision/mAP (medium): 0.443651
INFO:tensorflow: + DetectionBoxes_Precision/mAP (large): 0.428136
I1215 19:02:29.378222 140411958515456 model_lib_v2.py:991] + DetectionBoxes_Precision/mAP (large): 0.428136
INFO:tensorflow: + DetectionBoxes_Recall/AR@1: 0.027315
I1215 19:02:29.379950 140411958515456 model_lib_v2.py:991] + DetectionBoxes_Recall/AR@1: 0.027315
INFO:tensorflow: + DetectionBoxes_Recall/AR@10: 0.113490
I1215 19:02:29.382022 140411958515456 model_lib_v2.py:991] + DetectionBoxes_Recall/AR@10: 0.113490
INFO:tensorflow: + DetectionBoxes_Recall/AR@100: 0.161706
I1215 19:02:29.383764 140411958515456 model_lib_v2.py:991] + DetectionBoxes_Recall/AR@100: 0.161706
INFO:tensorflow: + DetectionBoxes_Recall/AR@100 (small): 0.097009
I1215 19:02:29.385457 140411958515456 model_lib_v2.py:991] + DetectionBoxes_Recall/AR@100 (small): 0.097009
INFO:tensorflow: + DetectionBoxes_Recall/AR@100 (medium): 0.540135
I1215 19:02:29.387208 140411958515456 model_lib_v2.py:991] + DetectionBoxes_Recall/AR@100 (medium): 0.540135
INFO:tensorflow: + DetectionBoxes_Recall/AR@100 (large): 0.670400
I1215 19:02:29.389199 140411958515456 model_lib_v2.py:991] + DetectionBoxes_Recall/AR@100 (large): 0.670400
INFO:tensorflow: + Loss/localization_loss: 0.449796
I1215 19:02:29.390682 140411958515456 model_lib_v2.py:991] + Loss/localization_loss: 0.449796
INFO:tensorflow: + Loss/classification_loss: 0.244869
I1215 19:02:29.392213 140411958515456 model_lib_v2.py:991] + Loss/classification_loss: 0.244869
INFO:tensorflow: + Loss/regularization_loss: 0.242850

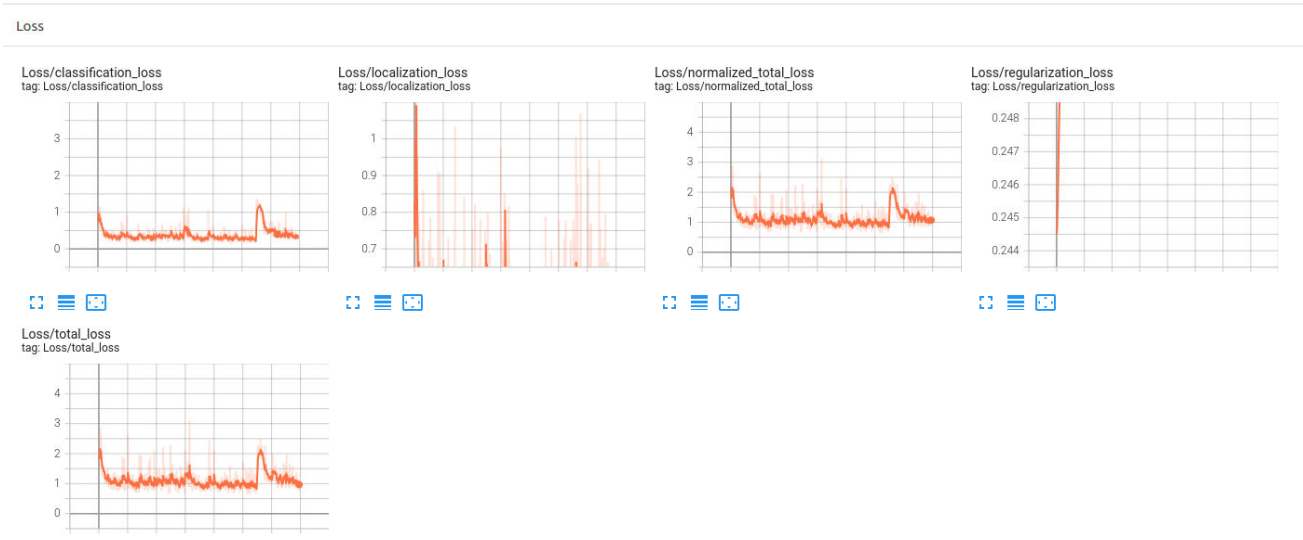
I1215 19:02:29.393750 140411958515456 model_lib_v2.py:991] + Loss/regularization_loss: 0.242850
INFO:tensorflow: + Loss/total_loss: 0.937514
I1215 19:02:29.395201 140411958515456 model_lib_v2.py:991] + Loss/total_loss: 0.937514

The total loss is down from 4.16 in the reference experiment ot 0.9375 in Experiment 2.

Below are the tensorboard logs for Experiment 2.

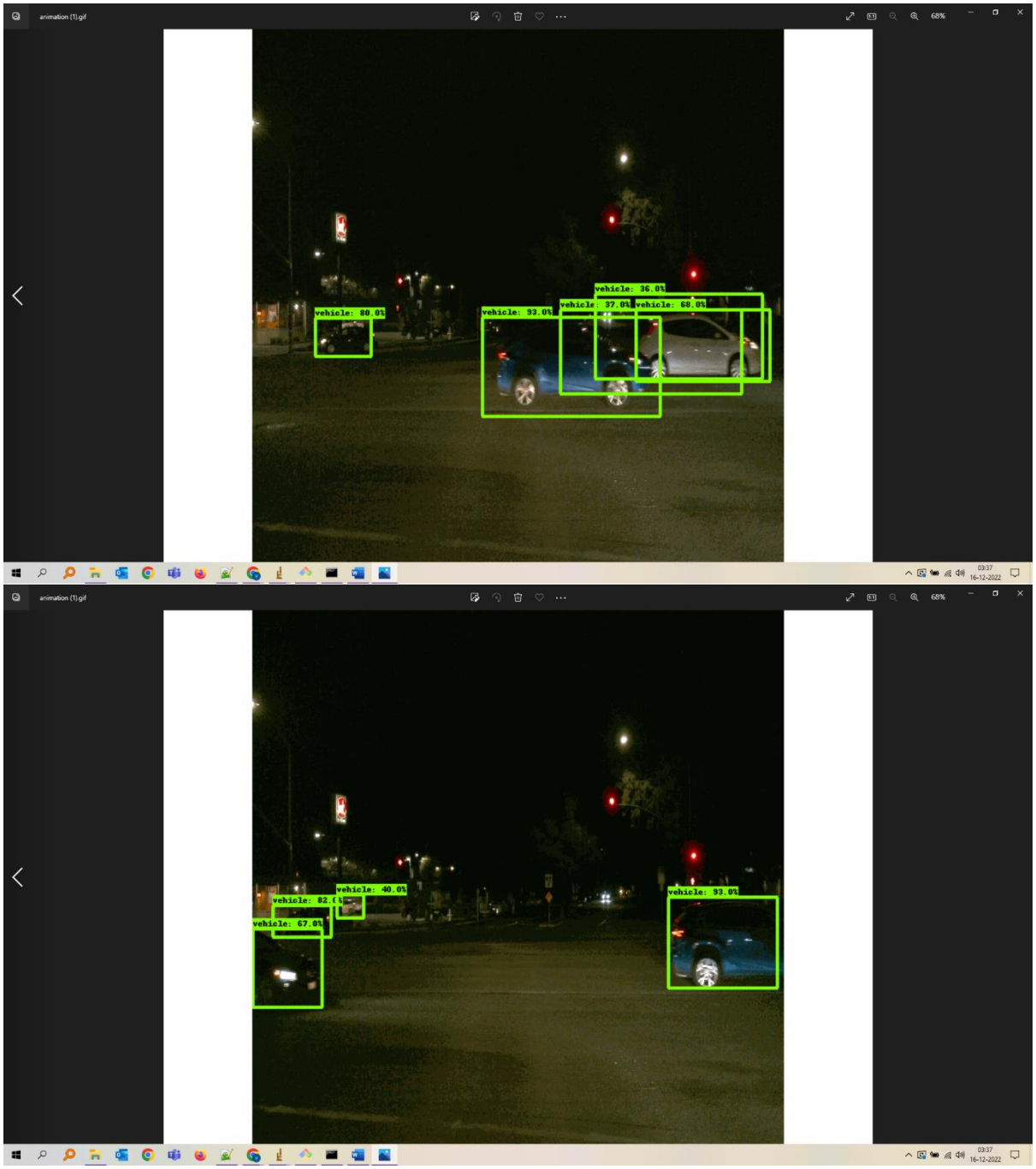


Below are the tensorboard logs for Experiment 1.

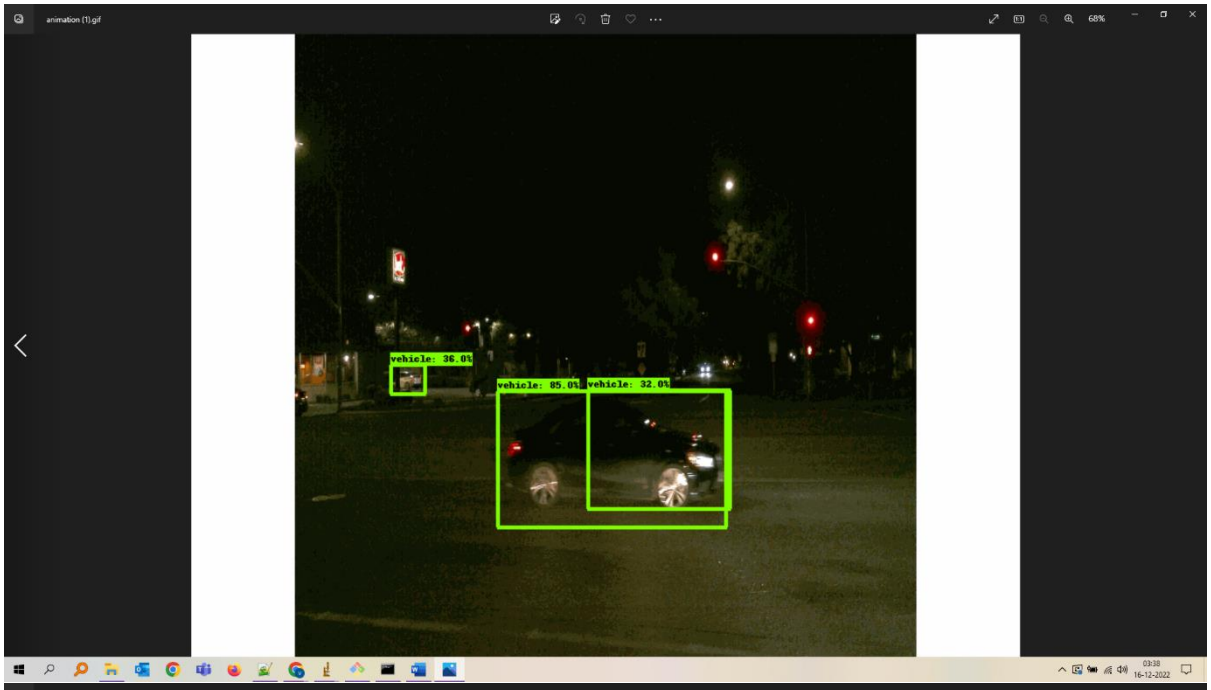


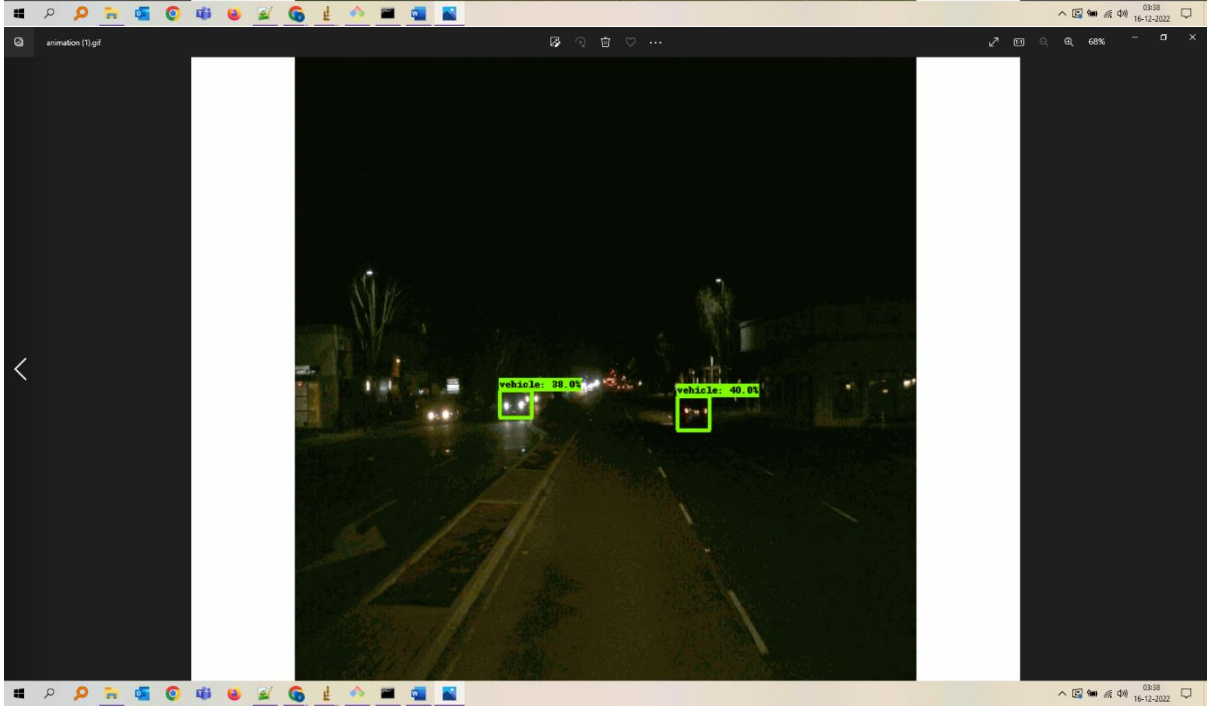
It is evident that the Experiment 2 model works the best!

Below you can find some snippets from the animation generated by the model of Experiment 2 :


animation (1).gif
68%
vehicle: 80.0%
vehicle: 93.0%
vehicle: 37.0%
vehicle: 36.0%
vehicle: 68.0%
03:37
16-12-2022

animation (1).gif
68%
vehicle: 40.0%
vehicle: 67.0%
vehicle: 93.0%
03:37
16-12-2022


animation (1).gif
68%
vehicle: 36.0%
vehicle: 85.0%
vehicle: 32.0%
03:38
16-12-2022


animation (1).gif
68%
vehicle: 38.0%
vehicle: 40.0%
03:38
16-12-2022