

M2 - Chapter Assignment

OVERVIEW

In this activity, we are tasked to train YOLOv5 large-scale models using three different hyperparameter settings. The hyperparameter configurations are shown below:

Hyperparameter Settings	LR	Batch	Epochs	Image Size
Hyperparameter 1	0.01	64	50	640x640
Hyperparameter 2	0.02	32	75	640x640
Hyperparameter 3	0.03	16	100	640x640

After training, we are tasked to test the models and compare their results in terms of Precision, Recall, Mean Average Precisions @.5, Mean Average Precisions @.95, MSE, and RMSE. The dataset for this activity would be the same motorcycle dataset used in the previous activities.

I. DATASET

To view the image dataset used in this activity, go to:

<https://universe.roboflow.com/new-dataset-67/new-dataset-6-7/health>

This image dataset is created by merging the dataset of all groups (7, 8, 22, 9, 10, 23, 11, 12, and 24) under the 6-7 pm time scenario.

The image dataset originally consists of 2189 images, but was expanded via data augmentation to reach the required number of images and class labels. The augmented dataset consists of 6128 images, with 4.3k, 1.2k, and 612 images allotted for the training, validation, and testing sets, respectively.

6-7pm Augmented Dataset Computer Vision Project

SOURCE
YOLOv5 Small CCTV Chapter Project >

LAST UPDATED
a day ago

PROJECT TYPE
Object Detection

SUBJECT
motorcycle-helmet

CLASSES
Full-face, Half-face, Invalid, No-Helmet, Rider

VIEWS: 24

DOWNLOADS: 0

LICENSE
CC BY 4.0 >

IMAGES
5621 images

TRAIN / TEST SPLIT

- Training Set**: 82% (4.6k images)
- Validation Set**: 14% (804 images)
- Testing Set**: 4% (220 images)

PREPROCESSING
Auto-Orient: Applied

Below is a screenshot of the following augmentation techniques performed to create the expanded dataset.

AUGMENTATIONS

Outputs per training example: 3

Flip: Horizontal, Vertical

90° Rotate: Clockwise, Counter-Clockwise

Rotation: Between -15° and +15°

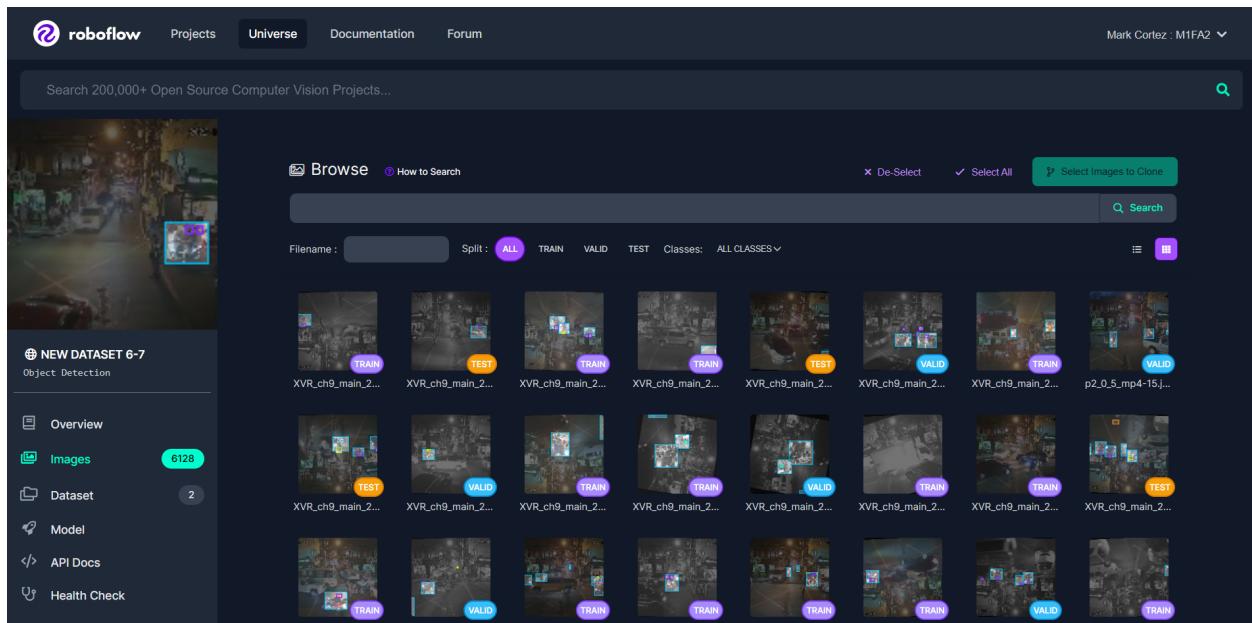
Saturation: Between -10% and +10%

Bounding Box: Flip: Horizontal, Vertical

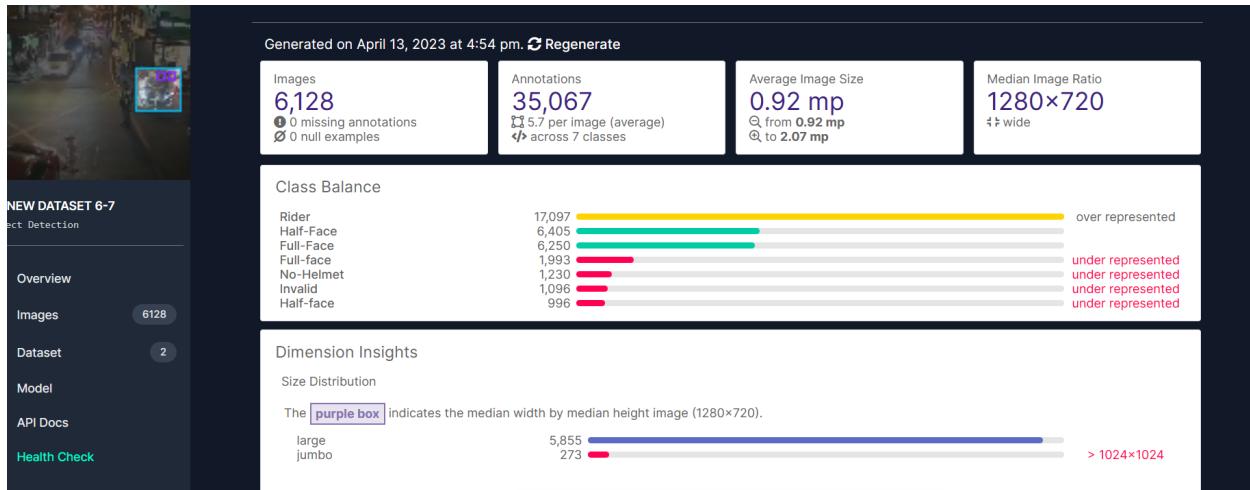
Bounding Box: 90° Rotate: Clockwise, Counter-Clockwise

Bounding Box: Brightness: Between 0% and +15%

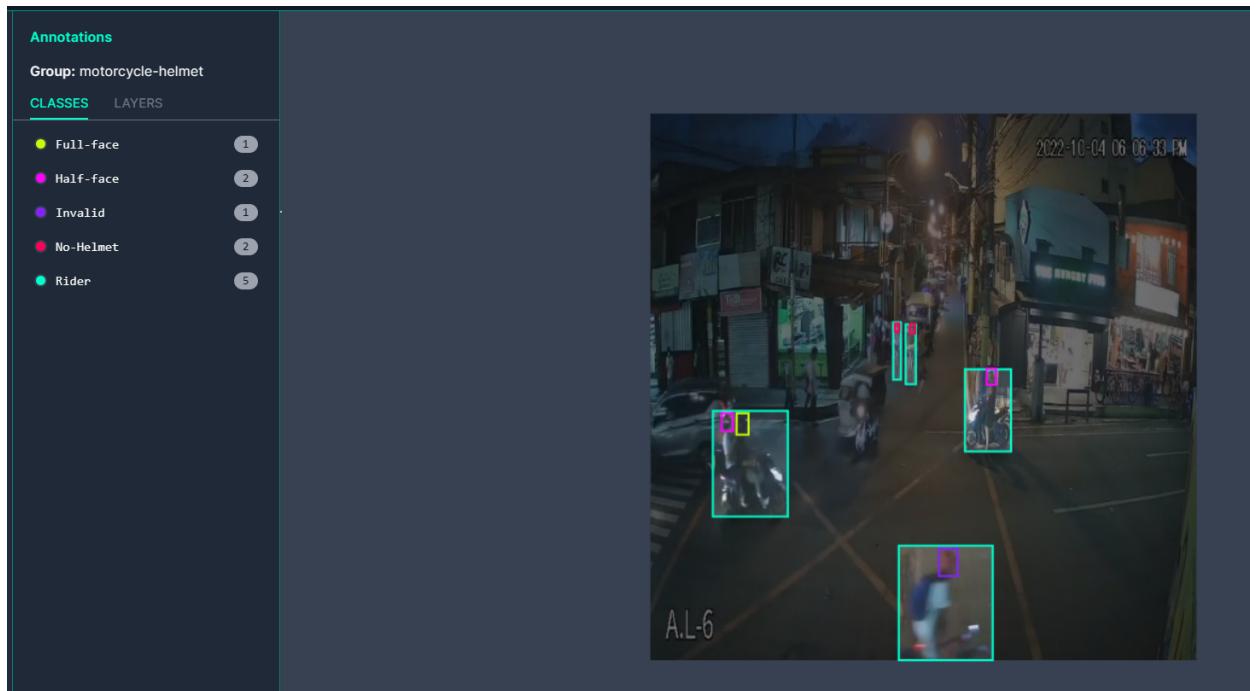
Below is a sample screenshot of the images in the RoboFlow project.



There are five classes that can be found on this image dataset: Full-Face, Half-face, Invalid, No-Helmet, and Rider. After augmentation, each of these classes reached over a thousand images. To see the specific detail of this dataset, below is a screenshot of the dataset health check.



Each class was labeled using RoboFlow's bounding box tool. Below is a sample image with annotations.

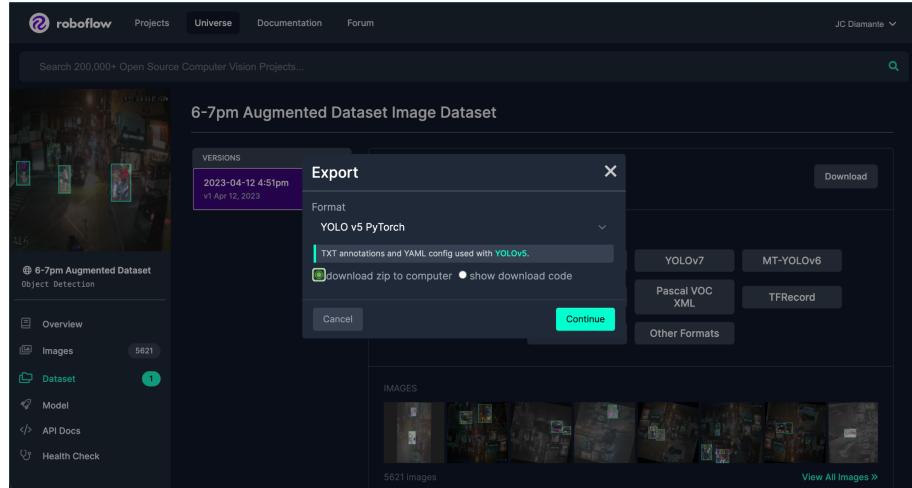


The liquid neon, magenta, red, bright turquoise, and purple bounding boxes represent the Full-face, Half-face, No-Helmet, Rider, and Invalid classes, respectively. Below are sample screenshots of images with annotations.

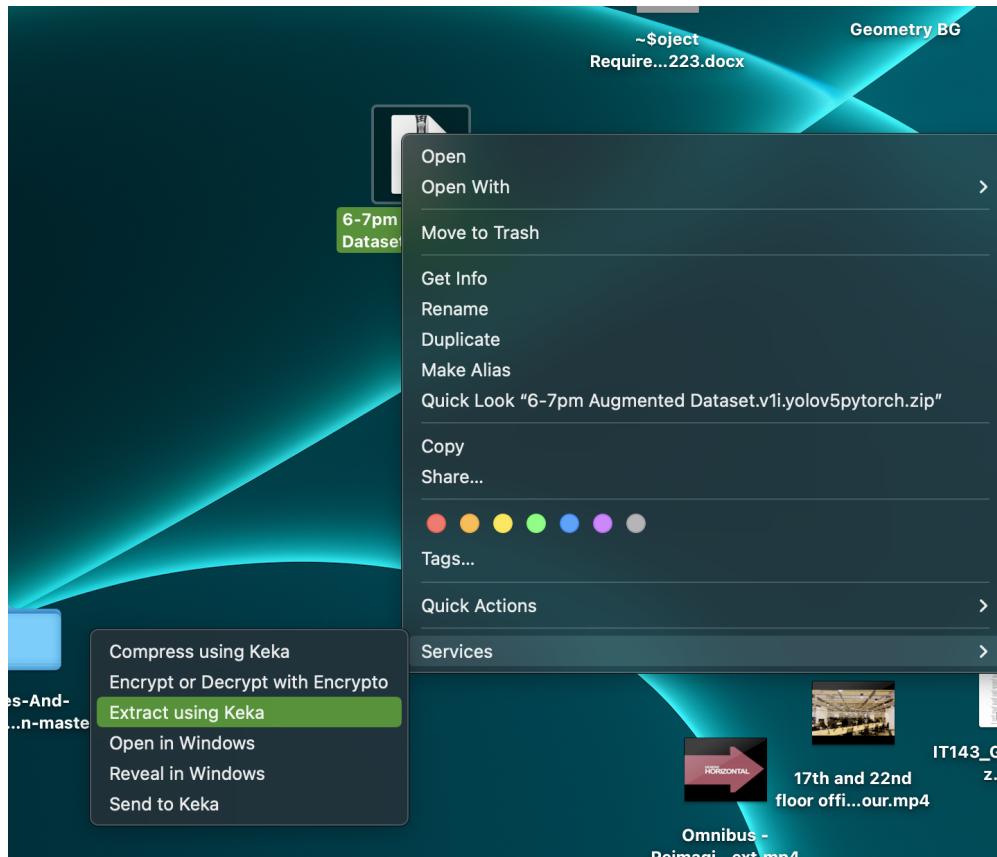


II. DATASET PREPARATION

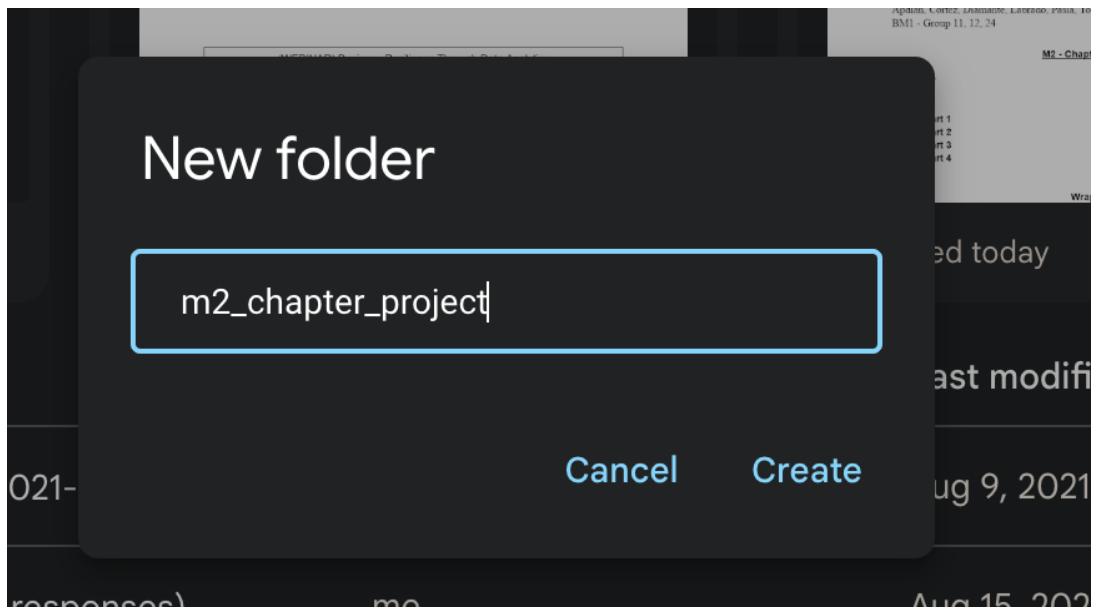
To use the dataset, click the download button. Then, select *download zip to computer* and choose *YOLO v5 PyTorch* as the format.



Extract the downloaded dataset using any software extraction tool.



Create a folder in google drive for the project..



Upload the files in the newly created google drive folder.

My Drive > m2_chapter_project

Name	Owner	Last modified
valid	me	12:23AM
train	me	12:41AM
test	me	12:23AM
data.yaml	me	12:35AM

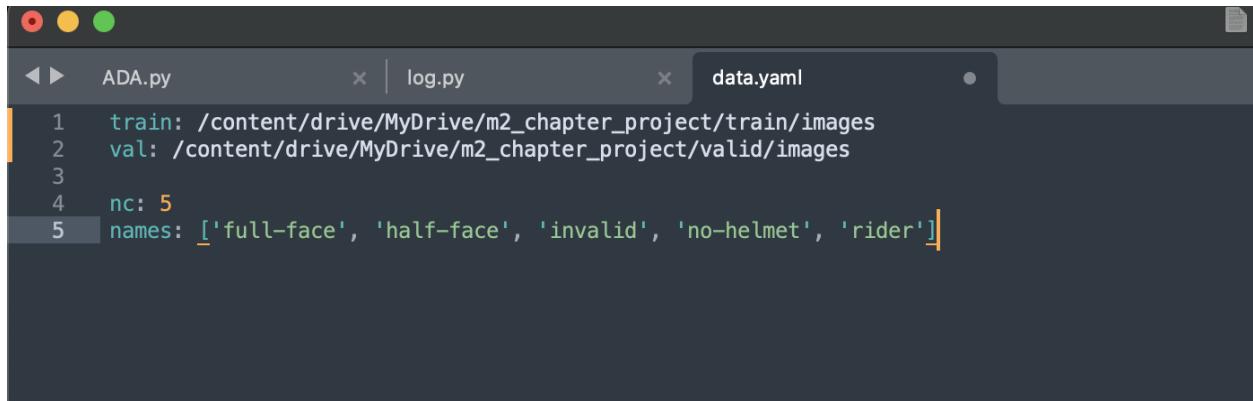
Who has access

Uploading 1 item

File	Status
train	250 of 9197
data.yaml	100%
test	443 of 443
valid	1611 of 1611

III. DATA.YAML

Inside the data.yaml, write the path location of the training and validation image dataset.



```
train: /content/drive/MyDrive/m2_chapter_project/train/images
val: /content/drive/MyDrive/m2_chapter_project/valid/images
nc: 5
names: ['full-face', 'half-face', 'invalid', 'no-helmet', 'rider']
```

IV. GOOGLE COLLAB LINK

To view the whole code for this activity, go to:

Hyperparameter 1-2:

https://colab.research.google.com/drive/1E9wo0SPBjz1JGRr_XWNYFFD-it_bLI9W#scrollTo=MPFT20HYedsx

Hyperparameter 3:

https://colab.research.google.com/drive/1xHGfYreh9Ba4Of8CN9DeELiJZ7_eJcHr?authuser=2#scrollTo=i0fXtPq358_U

V. INSTALL AND IMPORT REQUIRED LIBRARIES

Install the required libraries and packages using the command `!pip install <package>`.

Then, clone the GitHub repository and install the needed requirements. As for the dataset, copy the code provided in the Roboflow project. This section of the document would apply to all large-scale YOLO v5 models.

```
[ ] # !pip install -U PyYAML
# !pip install wandb
# !pip install seaborn
# !pip install pandas
# !pip install matplotlib
# !pip install numpy
# !pip install opencv-python

[ ] !git clone https://github.com/ultralytics/yolov5.git
!cd yolov5

!pip install -qr requirements.txt

Cloning into 'yolov5'...
remote: Enumerating objects: 15393, done.
remote: Counting objects: 100% (24/24), done.
remote: Compressing objects: 100% (18/18), done.
remote: Total 15393 (delta 9), reused 17 (delta 6), pack-reused 15369
Receiving objects: 100% (15393/15393), 14.37 MiB | 16.97 MiB/s, done.
Resolving deltas: 100% (10522/10522), done.
/content/yolov5
----- 184.3/184.3 kB 16.1 MB/s eta 0:00:00
----- 62.7/62.7 kB 9.4 MB/s eta 0:00:00

[ ] !cd /content/yolov5

!pip install roboflow

from roboflow import Roboflow
rf = Roboflow(api_key="Bb250fCeyOna857GP88e")
project = rf.workspace("yolov5-small-cctv-chapter-project").project("6-7pm-augmented-dataset-22dci")
dataset = project.version(1).download("yolov5")
```

Wait for all libraries and packages to be installed and the dataset to be successfully extracted.

```
DOWNGLOADING python-dotenv-1.0.0-py3-none-any.whl (42 kB)
[ ] Requirement already satisfied: PyYAML>=5.3.1 in /usr/local/lib/python3.9/dist-packages (from roboflow) (6.0)
Requirement already satisfied: python-dateutil in /usr/local/lib/python3.9/dist-packages (from roboflow) (2.8.2)
Collecting requests-toolbelt
  Downloading requests_toolbelt-0.10.1-py2.py3-none-any.whl (54 kB)
----- 54.5/54.5 kB 9.1 MB/s eta 0:00:00
Requirement already satisfied: chardet==4.0.0 in /usr/local/lib/python3.9/dist-packages (from roboflow) (4.0.0)
Requirement already satisfied: fonttools>=4.22.0 in /usr/local/lib/python3.9/dist-packages (from matplotlib->roboflow) (4.39.3)
Requirement already satisfied: packaging>=20.0 in /usr/local/lib/python3.9/dist-packages (from matplotlib->roboflow) (23.0)
Requirement already satisfied: importlib-resources>=3.2.0 in /usr/local/lib/python3.9/dist-packages (from matplotlib->roboflow) (5.12.0)
Requirement already satisfied: contourpy>=1.0.1 in /usr/local/lib/python3.9/dist-packages (from matplotlib->roboflow) (1.0.7)
Requirement already satisfied: charset-normalizer>=2.0.0 in /usr/local/lib/python3.9/dist-packages (from requests->roboflow) (2.0.12)
Requirement already satisfied: zipp>=3.1.0 in /usr/local/lib/python3.9/dist-packages (from importlib-resources>=3.2.0->matplotlib->roboflow) (3.15.0)
Building wheels for collected packages: wget
  Building wheel for wget (setup.py ... done
  Created wheel for wget: filename=wget-3.2-py3-none-any.whl size=9676 sha256=6fa6d51e0147df2bab842dd8527be282d49098bd151c2c1757bda38c5908f4da
  Stored in directory: /root/.cache/pip/wheels/04/5f/3e/46cc37c5d698415694d83f607f833f03f0149e49b3af9d0f38
Successfully built wget
Installing collected packages: wget, python-dotenv, pyparsing, idna, cycler, requests-toolbelt, roboflow
  Attempting uninstall: pyparsing
    Found existing installation: pyparsing 3.0.9
    Uninstalling pyparsing-3.0.9:
      Successfully uninstalled pyparsing-3.0.9
  Attempting uninstall: idna
    Found existing installation: idna 3.4
    Uninstalling idna-3.4:
      Successfully uninstalled idna-3.4
  Attempting uninstall: cycler
    Found existing installation: cycler 0.11.0
    Uninstalling cycler-0.11.0:
      Successfully uninstalled cycler-0.11.0
Successfully installed cycler-0.10.0 idna-2.10 pyparsing-2.4.7 python-dotenv-1.0.0 requests-toolbelt-0.10.1 roboflow-1.0.3 wget-3.2
loading Roboflow workspace...
Loading Roboflow project...
Downloading Dataset Version Zip in 6-7pm-Augmented-Dataset-1 to yolov5pytorch: 100% [308534313 / 308534313] bytes
Extracting Dataset Version Zip to 6-7pm-Augmented-Dataset-1 in yolov5pytorch:: 100% [██████████] 11254/11254 [00:01<00:00, 7201.12it/s]
```

Mount the google drive link of the created folder in the previous section.

+ Code + Text | ⌂ Copy to Drive

```
Successfully uninstalled cycler-0.11.0
[ ] Successfully installed cycler-0.10.0 idna-2.10 pyParsing-2.4.7 python-dotenv-1.0.0 requests-toolbelt-0.10.1 roboflow-1.0.3 wget-3.2
loading Roboflow workspace...
loading Roboflow project...
Downloading Dataset Version Zip in 6-7pm-Augmented-Dataset-1 to yolov5pytorch: 100% [308534313 / 308534313] bytes
Extracting Dataset Version Zip to 6-7pm-Augmented-Dataset-1 in yolov5pytorch:: 100%|██████████| 11254/11254 [00:01<00:00, 7201.12it/s]
```

```
[ ] # Importing the required libraries
from google.colab import drive
# import shutil

# Mounting the Google Drive to the Colab Notebook
drive.mount('/content/drive')

# # Specifying the path of the Google Drive folder to download
# folder_path = '/content/drive/MyDrive/m2_chapter_project'

# # Specifying the path of the destination folder in the Colab Notebook
# destination_path = '/content/yolov5/dataset/'

# # Copying the folder from Google Drive to Colab Notebook
# shutil.copytree(folder_path, destination_path)

Drive already mounted at /content/drive; to attempt to forcibly remount, call drive.mount("/content/drive", force_remount=True).

Double-click (or enter) to edit

[ ] hyperparameter_1_dataset = '/content/datasets/scenario-1-3'
hyperparameter_2_dataset = '/content/datasets/scenario-2-1'
hyperparameter_2_dataset = '/content/datasets/scenario-3-1'
```

VI. MODEL 1 - HYPERPARAMETER 1: TRAINING AND TESTING

Training the model with a learning rate of 0.01, batch size of 64, 50 epochs, and an image size of 640 x 640.

```
+ Code + Text | Copy to Drive Connect

Hyperparameter 1

ipython train.py --img 640 --batch 64 --epochs 50 --data (dataset.location)/data.yaml --hyp /content/drive/MyDrive/m2_chapter_project/hyp1.scratch.yaml --weights yolov5l.pt --name hyperparam_1 --cache

train: weights=yolov5l.pt, cfgs: data/content/yolov5/NEW-DATASET-6-7-2/data.yaml, hyp:/content/drive/MyDrive/m2_chapter_project/hyp1.scratch.yaml, epochs=50, batch_size=64, imgsz=640, rect=False, resume: github: up to date with https://github.com/Ultralytics/yolov5
requirements: /content/requirements.txt not found, check failed.
YOLOv5 v7.0-144-ga66fa83 Python-3.9.16 torch-2.0.0+cu118 CUDA-0 (NVIDIA A100-SXM4-40GB, 40514MiB)

hyperparameters: lr=0.001, lrf=0.01, momentum=0.937, weight_decay=0.0005, warmup_epochs=3.0, warmup_momentum=0.8, warmup_bias_lr=0.1, box=0.05,cls_pw=0.5, obj=1.0, obj_pw=1.0, iou_t=0.2, anchor ClearML run 'pip install clearml' to automatically track, visualize and remotely train YOLOv5 in ClearML
Comet: https://comet.ml/docs/comet_ml/ to automatically track and visualize YOLOv5 runs in Comet
TensorBoard: Start with 'tensorboard --logdir runs/train', view at http://localhost:6006/
Downloading https://ultralytics.com/assets/Arial.ttf to /root/.config/Ultralytics/Arial.ttf...
Downloading https://ultralytics.com/assets/yolov5/releases/download/v7.0/yolov5l.pt to yolov5l.pt...
100% 755k/755k [00:00<00:00, 24.6MB/s]
100% 89.3M/89.3M [00:01<00:00, 77.0MB/s]

Overriding model.yaml nc=80 with ncs5

      from    n      params   module           arguments
0       -1    1        7040  models.common.Conv      [3, 64, 6, 2, 2]
1       -1    1     73984  models.common.Conv      [64, 128, 3, 2]
2       -1    3     102408  models.common.C3      [128, 256, 3]
3       -1    1     295424  models.common.Conv      [128, 256, 3, 2]
4       -1    6     111208  models.common.C3      [256, 256, 6]
5       -1    1     1180672  models.common.Conv     [256, 512, 3, 2]
6       -1    9     6433792  models.common.C3      [512, 512, 9]
7       -1    1     4720640  models.common.Conv     [512, 1024, 3, 2]
8       -1    3     9971712  models.common.C3      [1024, 1024, 3]
9       -1    1     2624512  models.common.SPPF     [1024, 1024, 5]
10      -1    1     525312  models.common.Conv     [1024, 512, 1, 1]
11      -1    1          0  torch.nn.modules.upsampling.Upsample  [None, 2, 'nearest']
12      [-1, 6]    6          0  models.common.Concat  [1]
13      -1    3     2757632  models.common.C3      [1024, 512, 3, False]
14      -1    1     131584  models.common.Conv     [512, 256, 1, 1]
15      -1    1          0  torch.nn.modules.upsampling.Upsample  [None, 2, 'nearest']
```

```

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Epoch GPU_mem box_loss obj_loss cls_loss Instances Size
45/49 34.3G 0.0298 0.02502 0.003631 304 640: 100% 65/65 [00:30<00:00, 2.17it/s]
Class Images Instances P R mAP50 mAP50-95: 100% 10/10 [00:08<00:00, 1.18it/s]
all 1173 6936 0.723 0.604 0.638 0.332

Epoch GPU_mem box_loss obj_loss cls_loss Instances Size
46/49 34.3G 0.02943 0.0246 0.003576 377 640: 100% 65/65 [00:30<00:00, 2.16it/s]
Class Images Instances P R mAP50 mAP50-95: 100% 10/10 [00:08<00:00, 1.19it/s]
all 1173 6936 0.72 0.626 0.651 0.344

Epoch GPU_mem box_loss obj_loss cls_loss Instances Size
47/49 34.3G 0.02916 0.02446 0.003475 257 640: 100% 65/65 [00:29<00:00, 2.17it/s]
Class Images Instances P R mAP50 mAP50-95: 100% 10/10 [00:08<00:00, 1.19it/s]
all 1173 6936 0.729 0.616 0.646 0.342

Epoch GPU_mem box_loss obj_loss cls_loss Instances Size
48/49 34.3G 0.02867 0.02417 0.003376 383 640: 100% 65/65 [00:29<00:00, 2.17it/s]
Class Images Instances P R mAP50 mAP50-95: 100% 10/10 [00:08<00:00, 1.18it/s]
all 1173 6936 0.737 0.609 0.651 0.35

Epoch GPU_mem box_loss obj_loss cls_loss Instances Size
49/49 34.3G 0.02864 0.02412 0.003524 420 640: 100% 65/65 [00:29<00:00, 2.17it/s]
Class Images Instances P R mAP50 mAP50-95: 100% 10/10 [00:08<00:00, 1.18it/s]
all 1173 6936 0.756 0.598 0.649 0.349

50 epochs completed in 0.562 hours.
Optimizer stripped from runs/train/hyperparam_1/weights/last.pt, 92.9MB
Optimizer stripped from runs/train/hyperparam_1/weights/best.pt, 92.9MB

Validating runs/train/hyperparam_1/weights/best.pt...
Fusing layers...
Model summary: 267 layers, 46129818 parameters, 0 gradients, 107.7 GFLOPs
      Class   Images  Instances     P     R   mAP50   mAP50-95: 100% 10/10 [00:16<00:00, 1.61s/it]
      all    1173    6936    0.738    0.609    0.651    0.35
      Full-Face 1173    1674    0.758    0.673    0.717    0.339
      Half-Face 1173    1466    0.782    0.651    0.713    0.323
      Invalid  1173     217    0.587    0.433    0.444    0.255
      No-Helmet 1173     227    0.668    0.449    0.49    0.197
      Kidn...  1173    3552    0.892    0.836    0.892    0.635
Results saved to runs/train/hyperparam_1

```

Testing Hyperparameter 1 model.

```
[ ] detecting and predicting using the test dataset
[python detect.py --weights runs/train/hyperparam_1/weights/best.pt --img 640 --conf 0.1 --source /content/yolov5/NEW-DATASET-6-7-2/test/images --name hyperparam_1

detect: weights=['runs/train/hyperparam_1/weights/best.pt'], source=/content/yolov5/NEW-DATASET-6-7-2/test/images, data=data/coco128.yaml, imgsz=[640, 640], conf_thres=0.1, iou_thres=0.45
requirements: /content/requirements.txt not found, check failed.
YOLOv5 v7.0+14-a66fa8 Python 3.9.16 torch-2.0.0+cu118 CUDA:0 (NVIDIA A100-SXM4-40GB, 40514MiB)

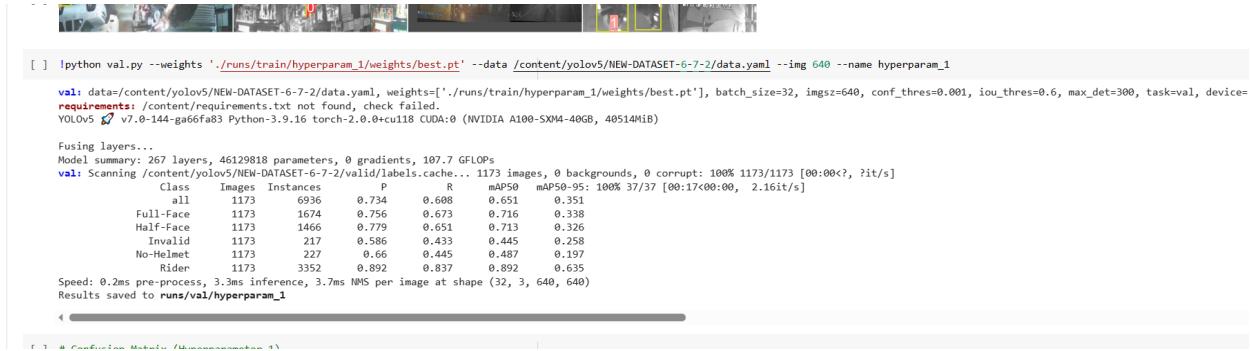
Fusing layers...
[ 1/1] fusing 267 layers, 48129015 parameters, 0 gradients, 100% 7 GFLOPs
image 1/597 [content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp_104_jpg_rf_3f46908f7fd01815e265763e8212.jpg]: 640x640 5 Full-Faces, 4 Riders, 9.1ms
image 2/597 [content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp_104_jpg_rf_3f4595107e44d099-200c210c7b1d14.jpg]: 640x640 2 Half-Faces, 5 Riders, 9.0ms
image 3/597 [content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp_124_jpg_rf_122333c3ca69d317b25ea80ff5.jpg]: 640x640 2 Half-Faces, 2 Invalids, 4 Riders, 9.0ms
image 4/597 [content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp_124_jpg_rf_2d872422731c07d012ca15b1b8e6.jpg]: 640x640 2 Half-Faces, 1 No-Helmet, 4 Riders, 9.1ms
image 5/597 [content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp_124_jpg_rf_d420c289526d563bd192973c9fe20e3.jpg]: 640x640 1 Half-Face, 1 No-Helmet, 3 Riders, 9.0ms
image 6/597 [content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp_133_jpg_rf_l9cf14ee03419573d3855899842b.jpg]: 640x640 2 Invalids, 1 No-Helmets, 2 Riders, 9.1ms
image 7/597 [content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp_151_jpg_rf_rfr_2f31cabd303b744972c29b8d8.jpg]: 640x640 5 Half-Faces, 2 Riders, 8.9ms
image 8/597 [content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp_180_jpg_rf_rfr_2f31cabd303b744972c29b8d8.jpg]: 640x640 7 Half-Faces, 6 Riders, 9.0ms
image 9/597 [content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp_197_jpg_rf_rfr_4ca4643bc81d14901e587d45cd29c.jpg]: 640x640 5 Half-Faces, 4 Riders, 9.2ms
image 10/597 [content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp_202_jpg_rf_d772ef693d7967877f01a85e0db.jpg]: 640x640 8 Half-Faces, 4 Riders, 9.4ms
image 11/597 [content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp_211_jpg_rf_d772ef693d7967877f01a85e0db.jpg]: 640x640 4 Half-Faces, 3 Riders, 9.3ms
image 12/597 [content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp_233_jpg_rf_rfr_2f31cabd303b744972c29b8d8.jpg]: 640x640 1 Full-Face, 1 Half-Face, 4 Riders, 9.0ms
image 13/597 [content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp_234_jpg_rf_rfr_2f31cabd303b744972c29b8d8.jpg]: 640x640 1 Full-Face, 4 Half-Faces, 5 Riders, 9.0ms
image 14/597 [content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp_234_jpg_rf_rfr_096f69d7943c1009773da08f81c14c.jpg]: 640x640 2 Full-Faces, 8 Half-Faces, 6 Riders, 9.4ms
image 15/597 [content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp_235_jpg_rf_rfr_6fd7f3fe2f089824275a8ff660093.jpg]: 640x640 2 Full-Faces, 2 Riders, 9.0ms
image 16/597 [content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp_257_jpg_rf_rfr_19fb7208237445826767613f13f.jpg]: 640x640 2 Full-Faces, 6 Half-Faces, 7 Riders, 9.1ms
image 17/597 [content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp_261_jpg_rf_rfr_051ab15d8243d7e93bbf1418249f.jpg]: 640x640 2 Full-Faces, 6 Half-Faces, 5 Riders, 9.3ms
image 18/597 [content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp_261_jpg_rf_rfr_0ee07d2b3c69e48bd175673c87a.jpg]: 640x640 1 Rider, 9.0ms
image 19/597 [content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp_311_jpg_rf_cbf2837794c41bd362894b3d1bc30880fje.jpg]: 640x640 1 Full-Face, 1 Half-Face, 1 Rider, 8.9ms
image 20/597 [content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp_344_jpg_rf_rfr_16f7ed4818908470008a0a56e441793.jpg]: 640x640 2 Full-Faces, 1 Half-Face, 3 Riders, 9.0ms
image 21/597 [content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp_345_jpg_rf_rfr_c894c942018739947add5f94d.jpg]: 640x640 3 Riders, 9.0ms
image 22/597 [content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp_348_jpg_rf_rfr_ae44836342fa3b11223df30re0eba5.jpg]: 640x640 1 Full-Face, 2 Riders, 9.4ms
image 23/597 [content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp_354_jpg_rf_rfr_69462762d56356740513855.jpg]: 640x640 1 Half-Face, 2 Riders, 8.9ms
image 24/597 [content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp_355_jpg_rf_rfr_77290d494093614764bae49f.jpg]: 640x640 1 Full-Face, 1 Half-Face, 1 Rider, 8.9ms
image 25/597 [content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp_379_jpg_rf_rfr_77290d494093614764bae49f.jpg]: 640x640 (no detection), 9.0ms
image 26/597 [content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp_409_jpg_rf_rfr_77290d494093614764bae49f.jpg]: 640x640 (no detection), 8.8ms
image 27/597 [content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp_410_jpg_rf_rfr_cf630a225c55fbfa88b29b9b19z.jpg]: 640x640 1 Rider, 8.8ms
image 28/597 [content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp_439_jpg_rf_rfr_28315592567f2d4331c3942b3e0.jpg]: 640x640 3 Full-Faces, 4 Half-Faces, 6 Riders, 8.7ms
image 29/597 [content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp_440_jpg_rf_rfr_cfdf4009039876593e9edf3edc6.jpg]: 640x640 1 Full-Face, 3 Half-Faces, 1 Invalid, 6 Riders, 8.7ms
image 30/597 [content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp_449_jpg_rf_rfr_4fc262dd516152748fb057fa27525e.jpg]: 640x640 1 Half-Face, 3 Riders, 8.8ms
```

Display sample ground truth data for model 1.

```
# Ground Truth Data 1
print("GROUND TRUTH TRAINING DATA:")
Image(filename='/content/yolov5/runs/train/hyperparam_1/train_batch0.jpg', width=900)
```



Display the performance results of model 1.

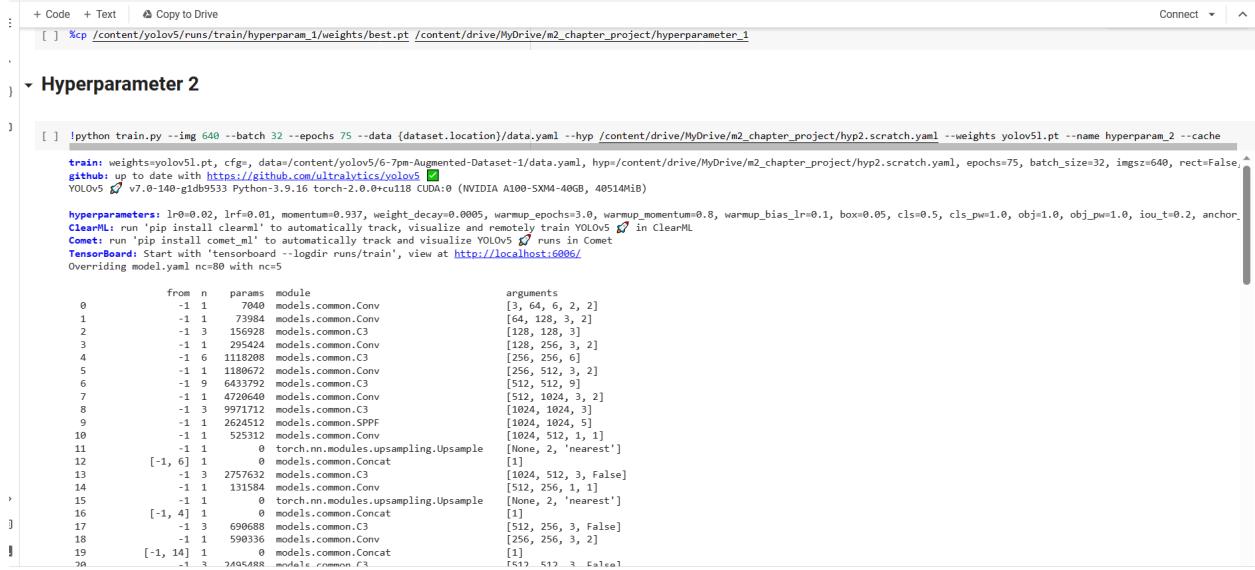


```
[ ] [python val.py --weights './runs/train/hyperparam_1/weights/best.pt' --data /content/yolov5/NEW-DATASET-6-7-2/data.yaml --img 640 --name hyperparam_1
val: data=/content/yolov5/NEW-DATASET-6-7-2/data.yaml, weights='./runs/train/hyperparam_1/weights/best.pt', batch_size=32, imgsz=640, conf_thres=0.001, iou_thres=0.6, max_det=300, task=val, device='cpu', requirements=/content/requirements.txt not found, check failed.
YOLOv5 v7.0-144-ga66fa83 Python-3.9.16 torch-2.0.0+cu118 CUDA:0 (NVIDIA A100-SXM4-40GB, 40514MiB)

Fusing layers...
Model summary: 267 layers, 46129818 parameters, 0 gradients, 107.7 GFLOPs
val: Scanning /content/yolov5/NEW-DATASET-6-7-2/valid/labels.cache... 1173 images, 0 backgrounds, 0 corrupt: 100% 1173/1173 [00:00<?, ?it/s]
      Class   Images Instances   P     R   mAP50   mAP50-95: 100% 37/37 [00:17<00:00,  2.16it/s]
      all    1173     6936   0.734   0.608   0.651   0.351
      Full-Face 1173    1674   0.756   0.673   0.716   0.338
      Half-Face 1173    1466   0.779   0.651   0.713   0.326
      Invalid  1173     217   0.586   0.433   0.445   0.258
      No-Helmet 1173     227   0.66    0.445   0.487   0.197
      Rider   1173    3352   0.892   0.837   0.892   0.635
Speed: 0.2ms pre-process, 3.3ms inference, 3.7ms NMS per image at shape (32, 3, 640, 640)
Results saved to runs/val/hyperparam_1
```

VII. MODEL 2 - HYPERPARAMETER 2: TRAINING AND TESTING

Training the model with a learning rate of 0.02, batch size of 32, epochs of 75, and image size of 640 x 640.



```
+ Code + Text ⌂ Copy to Drive Connect ▾
[ ] %cp /content/yolov5/runs/train/hyperparam_1/weights/best.pt /content/drive/MyDrive/m2_chapter_project/hyperparameter_1
```

Hyperparameter 2

```
[ ] [python train.py --img 640 --batch 32 --epochs 75 --data (dataset.location)/data.yaml --hyp /content/drive/MyDrive/m2_chapter_project/hyp2.scratch.yaml --weights yolov5l.pt --name hyperparam_2 --cache
train: weights=yolov5l.pt, cfgs, data=/content/yolov5/6-7pm-Augmented-Dataset-1/data.yaml, hyps=/content/drive/MyDrive/m2_chapter_project/hyp2.scratch.yaml, epochs=75, batch_size=32, imgsz=640, rect=False,
github: up to date with https://github.com/ultralytics/yolov5 v7.0-140-g1db9533 Python-3.9.16 torch-2.0.0+cu118 CUDA:0 (NVIDIA A100-SXM4-40GB, 40514MiB)

hyperparameters: lr=0.02, lr_f=0.01, momentum=0.937, weight_decay=0.0005, warmup_epochs=3.0, warmup_momentum=0.8, warmup_bias_lr=0.1, box=0.05, cls=0.5, cls_pw=1.0, obj=1.0, obj_pw=1.0, iou_t=0.2, anchor_
ClearML: run 'pip install clearml' to automatically track, visualize and remotely train YOLOv5 v7.0-140-g1db9533 in ClearML
Comet: run 'pip install comet_ml' to automatically track and visualize YOLOv5 v7.0-140-g1db9533 in Comet
TensorBoard: Start with 'tensorboard --logdir runs/train', view at http://localhost:6006/
Overriding model.yaml nc=8 with ncs=5

          frame   n   params   module           arguments
          0       -1    1     7848   models.common.Conv   [3, 64, 6, 2, 2]
          1       -1    1    73984   models.common.Conv   [64, 128, 3, 2]
          2       -1    3    156928   models.common.C3   [128, 128, 3]
          3       -1    1    295424   models.common.Conv   [128, 256, 3, 2]
          4       -1    6    1118280   models.common.C3   [256, 256, 6]
          5       -1    1    1180672   models.common.Conv   [256, 512, 3, 2]
          6       -1    9    6433792   models.common.C3   [512, 512, 9]
          7       -1    1    4728640   models.common.Conv   [512, 1024, 3, 2]
          8       -1    3    9971712   models.common.C3   [1024, 1024, 3]
          9       -1    1    2624512   models.common.SPPF  [1024, 1024, 5]
          10      -1    1    525312   models.common.Conv   [1024, 512, 1, 1]
          11      -1    1      0   torch.nn.modules.upsampling.Upsample  [None, 2, 'nearest']
          12      [-1, 6]    1      0   models.common.Concat  []
          13      -1    3    2757632   models.common.C3   [1024, 512, 3, False]
          14      -1    1    131584   models.common.Conv   [512, 256, 1, 1]
          15      -1    1      0   torch.nn.modules.upsampling.Upsample  [None, 2, 'nearest']
          16      [-1, 4]    1      0   models.common.Concat  []
          17      -1    3    690688   models.common.C3   [512, 256, 3, False]
          18      -1    1    590336   models.common.Conv   [256, 256, 3, 2]
          19      [-1, 14]   1      0   models.common.Concat  []
          20      -1    3    240448   models.common.C3   [512, 512, 3, False]
```

```

File Edit View Insert Runtime Tools Help Changes will not be saved
+ Code + Text ⌘ Copy to Drive Cor
[ ]
Epoch 71/74 GPU.mem box_loss obj_loss cls_loss Instances Size
21.1G 0.02697 0.0228 0.002937 146 640: 100% 130/130 [00:31<00:00, 4.12it/s]
Class Images Instances P R mAP50 mAP50-95: 100% 19/19 [00:08<00:00, 2.14it/s]
all 1173 6936 0.739 0.655 0.681 0.384

Epoch 72/74 GPU.mem box_loss obj_loss cls_loss Instances Size
21.1G 0.02678 0.02252 0.002801 135 640: 100% 130/130 [00:31<00:00, 4.12it/s]
Class Images Instances P R mAP50 mAP50-95: 100% 19/19 [00:08<00:00, 2.14it/s]
all 1173 6936 0.776 0.644 0.686 0.386

Epoch 73/74 GPU.mem box_loss obj_loss cls_loss Instances Size
21.1G 0.02653 0.02251 0.002934 114 640: 100% 130/130 [00:31<00:00, 4.10it/s]
Class Images Instances P R mAP50 mAP50-95: 100% 19/19 [00:08<00:00, 2.17it/s]
all 1173 6936 0.76 0.65 0.685 0.387

Epoch 74/74 GPU.mem box_loss obj_loss cls_loss Instances Size
21.1G 0.02669 0.02233 0.002816 91 640: 100% 130/130 [00:31<00:00, 4.12it/s]
Class Images Instances P R mAP50 mAP50-95: 100% 19/19 [00:08<00:00, 2.17it/s]
all 1173 6936 0.767 0.642 0.686 0.39

75 epochs completed in 0.882 hours.
Optimizer stripped from runs/train/hyperparam_2/weights/last.pt, 92.9MB
Optimizer stripped from runs/train/hyperparam_2/weights/best.pt, 92.9MB

Validating runs/train/hyperparam_2/weights/best.pt...
Fusing layers...
Model summary: 267 layers, 46129818 parameters, 0 gradients, 107.7 GFLOPs
Class Images Instances P R mAP50 mAP50-95: 100% 19/19 [00:16<00:00, 1.16it/s]
all 1173 6936 0.765 0.641 0.686 0.39
Full-Face 1173 1674 0.784 0.696 0.748 0.388
Half-Face 1173 1466 0.802 0.707 0.755 0.362
Invalid 1173 217 0.596 0.465 0.482 0.285
No-Helmet 1173 227 0.731 0.493 0.547 0.249
Rider 1173 3352 0.913 0.844 0.897 0.664

Results saved to runs/train/hyperparam_2

```

Testing hyperparameter 2 model.

```

File Edit View Insert Runtime Tools Help Connect ▾
+ Code + Text ⌘ Copy to Drive
[ ]
#detecting and predicting using the test dataset
!python detect.py --weights runs/train/hyperparam_2/weights/best.pt --img 640 --conf 0.1 --source /content/yolov5/NEW-DATASET-6-7-2/test/images --name hyperparam_2
detect: weights='runs/train/hyperparam_2/weights/best.pt', source=/content/yolov5/NEW-DATASET-6-7-2/test/images, data=data/coco128.yaml, imgsz=[640, 640], conf_thres=0.1, iou_thres=0.45, max_det=1000, c
requirements: /content/requirements.txt not found, check failed.
YOLOv5 v7.0-144-ga6f6a83 Python-3.9.16-torch-2.0.0+cu118 CUDA:0 (NVIDIA A100-SXM4-40GB, 40514MiB)

Fusing layers...
Model summary: 267 layers, 46129818 parameters, 0 gradients, 107.7 GFLOPs
image 1/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp4-101.jpg_rf_3f4609bf715a5fb0c1815e265763eb2.jpg: 640x640 5 Full-Faces, 4 Riders, 9.9ms
image 2/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp4-104.jpg_rf_349e07e40a099230ec281c807bd14.jpg: 640x640 1 Full-Face, 2 Half-Faces, 5 Riders, 9.9ms
image 3/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp4-122.jpg_rf_r_122333c36a98cd317bd2b5eae80f5.jpg: 640x640 2 Half-Faces, 2 Invalids, 4 Riders, 9.7ms
image 4/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp4-124.jpg_rf_rf_2d872422731c9c7d70712dcae15b1be8.jpg: 640x640 1 Half-Face, 1 No-Helmet, 3 Riders, 9.9ms
image 5/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp4-124.jpg_rf_rf_d426e2829c9656d1b293739cf23e07c0.jpg: 640x640 2 Half-Faces, 3 No-Helmets, 3 Riders, 9.8ms
image 6/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp4-133.jpg_rf_rf_1c9f14ee030441957de338559988f42b.jpg: 640x640 2 Invalids, 2 No-Helmets, 3 Riders, 9.9ms
image 7/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp4-154.jpg_rf_rf_ed81843a548ef29a45d26fbaf87e38e.jpg: 640x640 4 Half-Faces, 2 Riders, 9.9ms
image 8/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp4-186.jpg_rf_rf_3f2c1bae0e303b0e044972cd29b9a4d.jpg: 640x640 7 Half-Faces, 6 Riders, 10.0ms
image 9/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp4-197.jpg_rf_rf_4cae44638e611e4901e5470d2c89d.jpg: 640x640 6 Half-Faces, 3 Riders, 9.9ms
image 10/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp4-202.jpg_rf_rf_3f2c1bae0e303b0e044972cd29b9a4d.jpg: 640x640 8 Half-Faces, 4 Riders, 10.0ms
image 11/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp4-203.jpg_rf_rf_3f2c1bae0e303b0e044972cd29b9a4d.jpg: 640x640 1 Full-Face, 2 Half-Faces, 5 Riders, 9.9ms
image 12/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp4-221.jpg_rf_rf_9ff9ab5b7b47aae15a1b5733a14510.jpg: 640x640 1 Full-Face, 5 Half-Faces, 4 Riders, 10.0ms
image 13/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp4-223.jpg_rf_rf_3f2c1bae0e303b0e044972cd29b9a4d.jpg: 640x640 1 Full-Face, 7 Half-Faces, 5 Riders, 9.9ms
image 14/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp4-234.jpg_rf_rf_09696a6394c3b2009f73adbe8f1c4.jpg: 640x640 1 Full-Face, 9 Half-Faces, 6 Riders, 9.8ms
image 15/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp4-233.jpg_rf_rf_6df3c7fe2f09924275a8ffff66e0e3.jpg: 640x640 2 Full-Faces, 2 Riders, 10.1ms
image 16/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp4-257.jpg_rf_rf_19h72082374458bf06e0f03276131f.jpg: 640x640 1 Full-Face, 7 Half-Faces, 8 Riders, 9.9ms
image 17/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp4-261.jpg_rf_rf_f051a1b1d76862d43d7e93bbf8181482b.jpg: 640x640 3 Full-Faces, 2 Half-Faces, 5 Riders, 10.2ms
image 18/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp4-26_1.jpg_rf_rf_0e0e07d7db136c9048db197567387.jpg: 640x640 1 Rider, 9.9ms
image 19/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp4-31.jpg_rf_rf_c2837796c4b1d36462bd399390f0e.jpg: 640x640 1 Full-Face, 1 Rider, 9.7ms
image 20/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp4-34.jpg_rf_rf_167e4d41988e4d700808a1546e1973.jpg: 640x640 2 Full-Faces, 4 Riders, 11.6ms
image 21/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp4-345.jpg_rf_rf_c8b44209dc94c2018730299a7add5d9f9a.jpg: 640x640 1 Full-Face, 4 Riders, 11.6ms
image 22/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp4-354.jpg_rf_rf_65a67762d36e07350f9a89f1c153b55f.jpg: 640x640 1 Half-Face, 3 Riders, 9.8ms
image 23/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp4-374.jpg_rf_rf_61d56f3693a274a139f9280ca0e085.jpg: 640x640 1 Full-Face, 1 Half-Face, 2 Riders, 10.4ms
image 24/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp4-379.jpg_rf_rf_798c f364b942346e0919e142c2d4abe7.jpg: 640x640 2 Riders, 9.9ms
image 25/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp4-379.jpg_rf_rf_798c f364b942346e0919e142c2d4abe7.jpg: 640x640 (no detections), 9.8ms
image 26/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp4-409.jpg_rf_rf_779d0f55ff28bc816caa2e2d518c87.jpg: 640x640 1 Rider, 9.8ms
image 27/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp4-410.jpg_rf_rf_cf630a225cfab15f5ab8ccbb29b0e19.jpg: 640x640 1 Rider, 9.8ms
image 28/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/2_mp4-439.jpg_rf_rf_283185592567fb2df34317c94b32e95.jpg: 640x640 3 Full-Faces, 3 Half-Faces, 6 Riders, 9.9ms

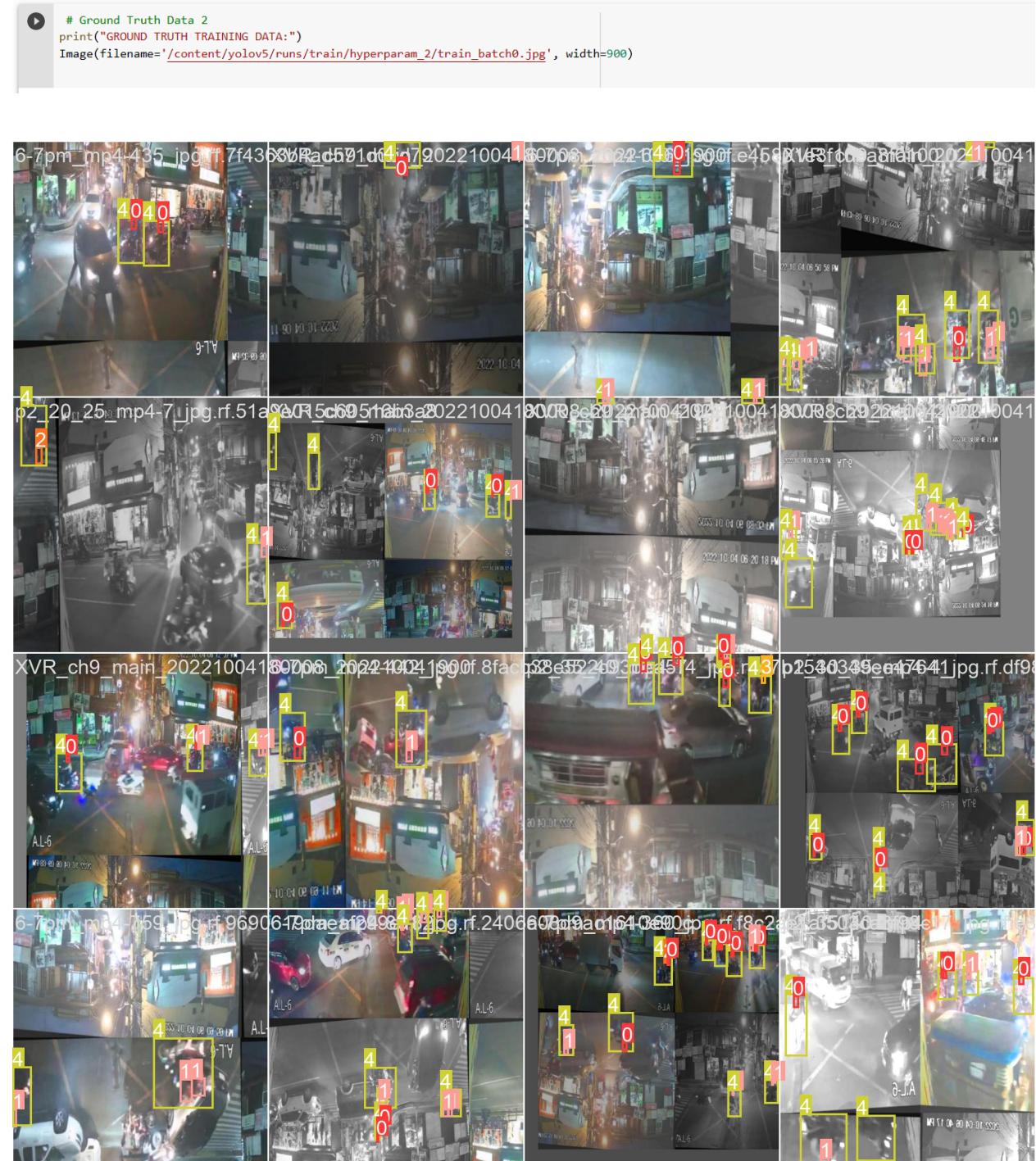
```

Code + Text ⌘ Copy to Drive

```
image 414/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/XVR_ch9_main_20221004180008_20221004190008-spliced_mp4-171.jpg.rf.366fa22820e96cb5f99a9b4bb6c50fb.jpg: 640x640 5 Half-Faces, 3 Riders, 9.2ms
image 415/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/XVR_ch9_main_20221004180008_rf.c1d7ed1af6115aa30112684af6c88b0.jpg: 640x640 1 Half-Face, 2 Riders, 9.2ms
image 416/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/XVR_ch9_main_20221004180008_spliced_mp4-172.jpg.rf.rf.69d86b61de5950727676df5f2f6de1.jpg: 640x640 2 Half-Faces, 1 Rider, 9.1ms
image 417/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/XVR_ch9_main_20221004180008_spliced_mp4-173.jpg.rf.rf.fcf8e90e9a1c76f276f14d995d3e15.jpg: 640x640 1 Half-Face, 1 Rider, 9.2ms
image 418/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/XVR_ch9_main_20221004180008_20221004190008-spliced_mp4-174.jpg.rf.rf.4653fe82d4e0d16fec0c1a4cb92dd4.jpg: 640x640 2 Half-Faces, 2 Riders, 9.1ms
image 419/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/XVR_ch9_main_20221004180008_20221004190008-spliced_mp4-188.jpg.rf.rf.5e2c19d10ff0eae9ee8a4ebc088d8d.jpg: 640x640 1 Full-Face, 3 Half-Faces, 2 Riders, 9.1ms
image 420/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/XVR_ch9_main_20221004180008_20221004190008-spliced_mp4-181.jpg.rf.rf.rf.7e9bc1af820274d92c4e5a9c9b8d80.jpg: 640x640 3 Half-Faces, 2 Riders, 9.3ms
image 421/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/XVR_ch9_main_20221004180008_20221004190008-spliced_mp4-182.jpg.rf.rf.e9d5f6f32765d1d9ab04ec2b951489f7.jpg: 640x640 2 Half-Faces, 1 Rider, 10.5ms
image 422/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/XVR_ch9_main_20221004180008_20221004190008-spliced_mp4-183.jpg.rf.rf.1039814a949a0415db9ab0c0820d385d0d.jpg: 640x640 2 Half-Faces, 1 Rider, 9.8ms
image 423/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/XVR_ch9_main_20221004180008_20221004190008-spliced_mp4-187.jpg.rf.rf.0b7e1f4c7574af6c6f9c9b75e8c28e.jpg: 640x640 1 Full-Face, 2 Half-Faces, 2 R:
image 424/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/XVR_ch9_main_20221004180008_20221004190008-spliced_mp4-208.jpg.rf.rf.9a67c67ab07d3170715923c9212447.jpg: 640x640 9 Half-Faces, 3 Riders, 9.4ms
image 425/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/XVR_ch9_main_20221004180008_20221004190008-spliced_mp4-205.jpg.rf.rf.17a7a5f483b62471fb746a6247f3d4.jpg: 640x640 3 Half-Faces, 1 Rider, 9.3ms
image 426/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/XVR_ch9_main_20221004180008_20221004190008-spliced_mp4-285.jpg.rf.rf.2a84d8484dd5d3384baeef66bf393a0.jpg: 640x640 4 Half-Faces, 1 Rider, 9.2ms
image 427/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/XVR_ch9_main_20221004180008_20221004190008-spliced_mp4-289.jpg.rf.rf.f278962606180aa1477e509b9377e7.jpg: 640x640 3 Half-Faces, 9.3ms
image 428/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/XVR_ch9_main_20221004180008_20221004190008-spliced_mp4-290.jpg.rf.rf.67172d0d7355c87e3c157d28f6f78.jpg: 640x640 4 Half-Faces, 1 Rider, 9.2ms
image 429/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/XVR_ch9_main_20221004180008_20221004190008-spliced_mp4-212.jpg.rf.rf.28703756a2a6ed30fa32d4f2d197.jpg: 640x640 1 Full-Face, 3 Half-Faces, 2 Riders, 9.2ms
image 430/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/XVR_ch9_main_20221004180008_20221004190008-spliced_mp4-227.jpg.rf.rf.46f2671931638704da1f09c58e3c3ebdb.jpg: 640x640 5 Half-Faces, 3 Riders, 9.1ms
image 431/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/XVR_ch9_main_20221004180008_20221004190008-spliced_mp4-222.jpg.rf.rf.5182b6602805593e2c30ff67b3b859b.jpg: 640x640 4 Half-Faces, 4 Riders, 9.2ms
image 432/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/XVR_ch9_main_20221004180008_20221004190008-spliced_mp4-232.jpg.rf.rf.0f542e8bc34bd183a4ad5f120702.jpg: 640x640 1 No-Helmet, 1 Rider, 9.2ms
image 433/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/XVR_ch9_main_20221004180008_20221004190008-spliced_mp4-232.jpg.rf.rf.5182b6602805593e2c30ff67b3b859b.jpg: 640x640 2 Half-Faces, 1 No-Helmet, 2 R:
image 434/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/XVR_ch9_main_20221004180008_20221004190008-spliced_mp4-233.jpg.rf.rf.4492e124cc2d109e429d.jpg: 640x640 2 Half-Faces, 1 No-Helmet, 2 R:
image 435/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/XVR_ch9_main_20221004180008_20221004190008-spliced_mp4-233.jpg.rf.rf.5182b6602805593e2c30ff67b3b859b.jpg: 640x640 2 Half-Faces, 1 No-Helmet, 2 R:
image 436/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/XVR_ch9_main_20221004180008_20221004190008-spliced_mp4-235.jpg.rf.rf.5182b6602805593e2c30ff67b3b859b.jpg: 640x640 2 Half-Faces, 2 Half-Faces, 2 Riders, 9.1ms
image 437/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/XVR_ch9_main_20221004180008_20221004190008-spliced_mp4-240.jpg.rf.rf.b013e3ab7aade6d9896a7118d462c.jpg: 640x640 4 Full-Faces, 2 Half-Faces, 2 Riders, 9.1ms
image 438/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/XVR_ch9_main_20221004180008_20221004190008-spliced_mp4-240.jpg.rf.rf.6d3a007f5901749acce94fd0709flace.jpg: 640x640 1 Full-Face, 2 Half-Faces, 2 R:
image 439/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/XVR_ch9_main_20221004180008_20221004190008-spliced_mp4-222.jpg.rf.rf.064944584469d9a9e8a13b7a562ff2b.jpg: 640x640 4 Full-Faces, 1 Rider, 9.2ms
image 440/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/XVR_ch9_main_20221004180008_20221004190008-spliced_mp4-250.jpg.rf.rf.53385f404bd9a79181bcbad0ff62e3d75.jpg: 640x640 2 Full-Faces, 3 Riders, 9.3ms
image 441/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/XVR_ch9_main_20221004180008_20221004190008-spliced_mp4-257.jpg.rf.rf.66aa92171c720593724f93846321195.jpg: 640x640 1 Full-Face, 1 Invalid, 1 Rider
image 442/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/XVR_ch9_main_20221004180008_20221004190008-spliced_mp4-257.jpg.rf.rf.66aa92171c720593724f93846321195.jpg: 640x640 1 Full-Face, 4 Half-Faces, 4 R:
image 443/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/XVR_ch9_main_20221004180008_20221004190008-spliced_mp4-257.jpg.rf.rf.5204e1f6c2ff6d3e13f276059641t710.jpg: 640x640 1 Full-Face, 2 Half-Faces, 3 R:
image 444/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/XVR_ch9_main_20221004180008_20221004190008-spliced_mp4-257.jpg.rf.rf.887797d1dfc13a9e90a4e5756302272b.jpg: 640x640 2 Half-Faces, 1 Rider, 9.2ms
image 445/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/XVR_ch9_main_20221004180008_20221004190008-spliced_mp4-263.jpg.rf.rf.c07eaef7c93d972d036152fcdefb766.jpg: 640x640 2 Half-Faces, 2 Riders, 9.3ms
image 446/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/XVR_ch9_main_20221004180008_20221004190008-spliced_mp4-263.jpg.rf.rf.d9517da321f63895fd72aca6aa4260.jpg: 640x640 1 Full-Face, 2 Riders, 9.2ms
```

```
FILE EDIT VIEW INSERT RUNTIME TOOLS HELP SEARCH WITHIN THIS LINE SELECT
+ Code + Text ⌘ Copy to Drive
[ ] image 561/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/p_0_40_45_mp4-8.jpg.rf.36fc1ddff227c2b4dd21ad8d52d96.jpg: 640x640 7 Full-Faces, 1 No-Helmet, 6 Riders, 9.2ms
image 562/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/p_0_40_45_mp4-9.jpg.rf.b2b08a3144d3f2085aa347685f52166.jpg: 640x640 1 Full-Face, 2 Invalids, 3 Riders, 9.2ms
image 563/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/p_0_40_45_mp4-19.jpg.rf.b393dcd232e0b8a5f1d56fe8c775d584.jpg: 640x640 3 Full-Faces, 2 Half-Faces, 3 Riders, 9.5ms
image 564/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/p_0_40_45_mp4-21.jpg.rf.rf.a2061a9c6168a428c1e477d280bf91f3e.jpg: 640x640 1 Full-Face, 6 Half-Faces, 4 Riders, 9.3ms
image 565/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/p_0_40_45_mp4-29.jpg.rf.rf.841ca9e74793f4159b7e5624ab5d9b7c.jpg: 640x640 3 Full-Faces, 2 Half-Face, 1 No-Helmet, 6 Riders, 8.9ms
image 566/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/p_0_40_45_mp4-32.jpg.rf.rf.8885d3f44098c76d278e51b108d444.jpg: 640x640 1 Full-Face, 1 Rider, 8.9ms
image 567/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/p_0_40_45_mp4-32.jpg.rf.rf.8885d3f44098c76d278e51b108d444.jpg: 640x640 1 Full-Face, 1 Rider, 8.9ms
image 568/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/p_0_40_45_mp4-36.jpg.rf.rf.69246c250810043606552d35210ddad.jpg: 640x640 1 Full-Face, 4 Riders, 8.8ms
image 569/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/XVR_ch9_main_20221004180008_20221004190008-spliced_mp4-233.jpg.rf.rf.2d7950c6bfffedbc33a7f0e5d24f.jpg: 640x640 1 Full-Face, 1 Half-Face, 2 R:
image 570/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/p_0_50_55_mp4-19.jpg.rf.rf.58726275e628eefc1b5136e8ebc025b2a.jpg: 640x640 2 Full-Faces, 2 Half-Faces, 6 Riders, 9.9ms
image 571/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/p_0_50_55_mp4-21.jpg.rf.rf.58726275e628eefc1b5136e8ebc025b2a.jpg: 640x640 5 Full-Faces, 1 Half-Face, 5 Riders, 9.6ms
image 572/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/p_0_50_55_mp4-21.jpg.rf.rf.9aa2a9f593f919166a7cafa8f8223c3b38b.jpg: 640x640 1 No-Helmet, 2 Riders, 9.4ms
image 573/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/p_0_50_55_mp4-9.jpg.rf.rf.942094625f42bdf9caaa3be34ab336.jpg: 640x640 1 Rider, 9.9ms
image 574/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/p_0_55_60_mp4-10.jpg.rf.rf.bb00c0a484e9649102dff3a3f4149f.jpg: 640x640 1 Full-Faces, 2 Half-Faces, 7 Riders, 9.5ms
image 575/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/p_0_55_60_mp4-12.jpg.rf.rf.bb00c0a484e9649102dff3a3f4149f.jpg: 640x640 4 Full-Faces, 2 Half-Faces, 4 Riders, 9.4ms
image 576/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/p_0_55_60_mp4-13.jpg.rf.rf.41933993711b6921545e9af9fb1f80fc.jpg: 640x640 8 Full-Faces, 2 Half-Faces, 9 Riders, 9.4ms
image 577/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/p_0_55_60_mp4-24.jpg.rf.rf.a1f0d13522a0eac95d9c1907f0c206.jpg: 640x640 1 Full-Face, 1 Invalid, 3 Riders, 9.7ms
image 578/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/p_0_55_60_mp4-4.jpg.rf.rf.0818221556dfb3f0b3d065a6e77a29.jpg: 640x640 1 No-Helmet, 1 Rider, 10.2ms
image 579/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/p_0_50_55_mp4-10.jpg.rf.rf.06da80931967df5f4f8bea7838862.jpg: 640x640 1 No-Helmet, 3 Riders, 9.6ms
image 580/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/p_0_50_55_mp4-12.jpg.rf.rf.d8a7f1a2479401a438aaeab1.jpg: 640x640 4 Rider, 9.7ms
image 581/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/p_0_50_55_mp4-13.jpg.rf.rf.58726275e628eefc1b5136e8ebc025b2a.jpg: 640x640 1 Full-Face, 2 Rides, 9.4ms
image 582/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/p_0_50_55_mp4-13.jpg.rf.rf.dfffb01f38480692315aa03f46c02765.jpg: 640x640 1 Full-Face, 1 Half-Face, 2 Riders, 9.2ms
image 583/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/p_0_50_55_mp4-15.jpg.rf.rf.833aa8b25e5d9a0544e89199.jpg: 640x640 2 Full-Faces, 1 Half-Face, 2 Riders, 9.3ms
image 584/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/p_0_50_55_mp4-20.jpg.rf.rf.34a51e89d4cf2b21d116f5c0e6440.jpg: 640x640 1 Full-Face, 2 Half-Faces, 2 Riders, 9.3ms
image 585/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/p_0_50_55_mp4-21.jpg.rf.rf.ae1489eb5079340979bdabf71656770.jpg: 640x640 7 Full-Faces, 2 Invalids, 2 No-Helmets, 11 Riders, 9.3ms
image 586/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/p_0_50_55_mp4-25.jpg.rf.rf.5ccfd4c05e5d5b389c5662a5e52210.jpg: 640x640 3 Full-Faces, 1 Half-Face, 4 Riders, 9.6ms
image 587/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/p_0_50_55_mp4-26.jpg.rf.rf.bbd6d66052a5492c9cff8e2fa85b5d.jpg: 640x640 2 Full-Faces, 3 Half-Faces, 1 No-Helmet, 9 Riders, 9.3ms
image 588/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/p_0_50_55_mp4-1013.jpg.rf.rf.7875ca708f531d58e5f8e0c695662cafa.jpg: 640x640 5 Full-Faces, 4 Half-Faces, 7 Riders, 9.2ms
image 589/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/p_0_50_55_mp4-1370.jpg.rf.rf.454a454d4ff875f534bc7b75c3a71887d.jpg: 640x640 3 Full-Faces, 7 Half-Faces, 1 No-Helmet, 7 Riders, 9.6ms
image 590/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/p_0_50_55_mp4-1370.jpg.rf.rf.9668087ab7ba29a7d2ba3fa841378.jpg: 640x640 2 Full-Faces, 7 Half-Faces, 1 No-Helmet, 8 Riders, 9.3ms
image 591/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/p_0_50_55_mp4-1372.jpg.rf.rf.a47529c46ee7a7f75377e8f97702b2.jpg: 640x640 2 Full-Faces, 6 Half-Faces, 2 Invalids, 9 Riders, 9.2ms
image 592/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/p_0_50_55_mp4-1374.jpg.rf.rf.4e31f07ab0e2ceaa6252a7c0e4677d.jpg: 640x640 3 Full-Faces, 7 Half-Faces, 7 Riders, 9.2ms
image 593/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/p_0_50_55_mp4-1374.jpg.rf.rf.8231a661f4da25d2a242129998485.jpg: 640x640 3 Full-Faces, 6 Half-Faces, 8 Riders, 9.3ms
image 594/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/p_0_50_55_mp4-1377.jpg.rf.rf.ba0a102a0e7f2917f8a10b1d63a08.jpg: 640x640 3 Full-Faces, 4 Half-Faces, 1 Invalid, 7 Riders, 9.6ms
image 595/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/p_0_50_55_mp4-1379.jpg.rf.rf.29495a384f4dc472875e1508561d5.jpg: 640x640 2 Full-Faces, 7 Half-Faces, 10 Riders, 9.2ms
image 596/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/p_0_50_55_mp4-1379.jpg.rf.rf.9fc66149d3a1e3a8f94873e5eb761.jpg: 640x640 2 Full-Faces, 7 Half-Faces, 7 Riders, 9.3ms
image 597/597 /content/yolov5/NEW-DATASET-6-7-2/test/images/p_0_50_55_mp4-999.jpg.rf.rf.8f63a70aaeae2a18912ebd4ea01.jpg: 640x640 4 Rider, 9.2ms
Speed: 0.5ms pre-process, 9.5ms inference, 1.0ms NMS per image at shape (1, 3, 640, 640)
Results saved to runs/detect/hyperparam_2
```

Display ground truth data for model 2.



Display the performance results of model 2.

```
[ ] python val.py --weights './runs/train/hyperparam_2/weights/best.pt' --data /content/yolov5/NEW-DATASET-6-7-2/data.yaml --img 640 --name hyperparam_2
val: data=/content/yolov5/NEW-DATASET-6-7-2/data.yaml, weights=['./runs/train/hyperparam_2/weights/best.pt'], batch_size=32, imgsz=640, conf_thres=0.001, iou_thres=0.6, max_det=300, task=val, device=, w
requirements: /content/requirements.txt not found, check failed.
YOLOv5 v7.0-144-ga6fa83 Python-3.9.16 torch-2.0.0+cu18 CUDA:0 (NVIDIA A100-SXM4-40GB, 40514MiB)

Fusing layers...
Model summary: 267 layers, 46129818 parameters, 0 gradients, 107.7 GFLOPs
val: Scanning /content/yolov5/NEW-DATASET-6-7-2/valid/labels.cache... 1173 images, 0 backgrounds, 0 corrupt: 100% 1173/1173 [00:00<?, ?it/s]
Class Images Instances P R mAP@.5%
all 1173 6936 0.768 0.643 0.687 0.39
Full-Face 1173 1674 0.786 0.697 0.75 0.388
Half-Face 1173 1466 0.805 0.798 0.757 0.363
Invalid 1173 217 0.597 0.465 0.482 0.287
No-Helmet 1173 227 0.74 0.498 0.551 0.249
Rider 1173 3352 0.914 0.845 0.897 0.665
Speed: 0.2ms pre-process, 3.3ms inference, 2.9ms NMS per image at shape (32, 3, 640, 640)
Results saved to runs/val/hyperparam_2
```

[] # Confusion Matrix (Hyperparameter 2)

VIII. MODEL 3 - HYPERPARAMETER 3: TRAINING AND TESTING

Training the model with a learning rate of 0.03, batch size of 16, epochs of 100, and image size of 640 x 640.

```
[ ] !python train.py --img 640 --batch 16 --epochs 100 --data {dataset.location}/data.yaml --hyp /content/drive/MyDrive/m2_chapter_project/hyp3.scratch.yaml --weights yolov5l.pt --name hyperparam_3 --cache
train: weights=yolov5l.pt, cfg=, data=/content/yolov5/NEW-DATASET-6-7-2/data.yaml, hyp=/content/drive/MyDrive/m2_chapter_project/hyp3.scratch.yaml, epochs=100, batch_size=16, imgsz=640, rect=False, resume
github: ▲ YOLOv5 is out of date by 1 commit. Use 'git pull' or 'git clone https://github.com/ultralytics/yolov5' to update.
requirements: /content/requirements.txt not found, check failed.
YOLOv5 v7.0-144-ga6fa83 Python-3.9.16 torch-2.0.0+cu18 CUDA:0 (NVIDIA A100-SXM4-40GB, 40514MiB)

hyperparameters: lr=0.03, lrf=0.01, momentum=0.937, weight_decay=0.0005, warmup_epochs=3.0, warmup_momentum=0.8, warmup_bias_lr=0.1, box=0.05, cls=0.5, cls_pw=1.0, obj=1.0, obj_pw=1.0, iou_t=0.2, anchor
ClearML: run 'pip install clearml' to automatically track, visualize and remotely train YOLOv5 in ClearML
Comet: run 'pip install comet_ml' to automatically track and visualize YOLOv5 runs in Comet
TensorBoard: Start with 'tensorboard --logdir runs/train', view at http://localhost:6006
Overriding model.yaml ncs=80 with ncs=5

from n params module arguments
0 -1 1 7040 models.common.Conv [3, 64, 6, 2, 2]
1 -1 1 73984 models.common.Conv [64, 128, 3, 2]
2 -1 3 156328 models.common.C3 [128, 128, 3]
3 -1 1 295424 models.common.Conv [128, 256, 3, 2]
4 -1 6 1118208 models.common.C3 [256, 256, 6]
5 -1 1 1180672 models.common.Conv [256, 512, 3, 2]
6 -1 9 6433792 models.common.C3 [512, 512, 9]
7 -1 1 4720640 models.common.Conv [512, 1024, 3, 2]
8 -1 3 9971712 models.common.C3 [1024, 1024, 3]
9 -1 1 2624512 models.common.SPPF [1024, 1024, 5]
10 -1 1 525312 models.common.Conv [1024, 512, 1, 1]
11 -1 1 0 torch.nn.modules.upsampling.Upsample [None, 2, 'nearest']
12 [-1, 6] 1 0 models.common.Concat [1]
13 -1 3 2757632 models.common.C3 [1024, 512, 3, False]
14 -1 1 1315920 models.common.Conv [512, 256, 1, 1]
15 -1 1 0 torch.nn.modules.upsampling.Upsample [None, 2, 'nearest']
16 [-1, 4] 1 0 models.common.Concat [1]
17 -1 3 690688 models.common.C3 [512, 256, 3, False]
18 -1 1 590336 models.common.Conv [256, 256, 3, 2]
19 [-1, 14] 1 0 models.common.Concat [1]
20 -1 3 2495488 models.common.C3 [512, 512, 3, False]
```

[5] Epoch GPU_mem box_loss obj_loss cls_loss Instances Size									
im_3	92/99	11.16	0.0263	0.02213	0.002698	60	640: 100% 259/259 [00:34<00:00, 7.55it/s]	mAP50	mAP50-95: 100% 37/37 [00:09<00:00, 4.09it/s]
		Class	Images	Instances	P	R			
		all	1173	6936	0.739	0.65	0.677	0.39	
im_3	93/99	11.16	0.02609	0.0222	0.002729	71	640: 100% 259/259 [00:34<00:00, 7.55it/s]	mAP50	mAP50-95: 100% 37/37 [00:09<00:00, 4.09it/s]
		Class	Images	Instances	P	R			
		all	1173	6936	0.74	0.661	0.678	0.392	
im_3	94/99	11.16	0.02601	0.02164	0.002772	89	640: 100% 259/259 [00:34<00:00, 7.55it/s]	mAP50	mAP50-95: 100% 37/37 [00:09<00:00, 4.00it/s]
		Class	Images	Instances	P	R			
		all	1173	6936	0.746	0.657	0.676	0.392	
rve.png	95/99	11.16	0.02549	0.02166	0.002686	106	640: 100% 259/259 [00:34<00:00, 7.56it/s]	mAP50	mAP50-95: 100% 37/37 [00:09<00:00, 4.00it/s]
		Class	Images	Instances	P	R			
		all	1173	6936	0.736	0.66	0.677	0.392	
.ion_matrix.p...	96/99	11.16	0.02533	0.0212	0.002576	76	640: 100% 259/259 [00:34<00:00, 7.48it/s]	mAP50	mAP50-95: 100% 37/37 [00:09<00:00, 4.07it/s]
		Class	Images	Instances	P	R			
		all	1173	6936	0.748	0.651	0.678	0.394	
,correlogram...	97/99	11.16	0.02514	0.02189	0.002606	117	640: 100% 259/259 [00:34<00:00, 7.57it/s]	mAP50	mAP50-95: 100% 37/37 [00:09<00:00, 4.08it/s]
		Class	Images	Instances	P	R			
		all	1173	6936	0.744	0.652	0.678	0.393	
atch0.jpg	98/99	11.16	0.02522	0.02149	0.002595	108	640: 100% 259/259 [00:34<00:00, 7.57it/s]	mAP50	mAP50-95: 100% 37/37 [00:09<00:00, 4.07it/s]
		Class	Images	Instances	P	R			
		all	1173	6936	0.756	0.653	0.679	0.395	
tch0_labels.j...	99/99	11.16	0.02479	0.02124	0.002559	90	640: 100% 259/259 [00:34<00:00, 7.48it/s]	mAP50	mAP50-95: 100% 37/37 [00:09<00:00, 4.08it/s]
		Class	Images	Instances	P	R			
		all	1173	6936	0.753	0.658	0.682	0.398	
tch2_labels.j...									
tch2_pred.jpg									
100 epochs completed in 1.258 hours.									
Optimizer stripped from runs/train/hyperparam_3/weights/last.pt, 92.9MB									
Optimizer stripped from runs/train/hyperparam_3/weights/best.pt, 92.9MB									
Validating runs/train/hyperparam_3/weights/best.pt...									
Fusing layers...									
Model summary: 267 layers, 46129818 parameters, 0 gradients, 107.7 GFLOPs									
.md		Class	Images	Instances	P	R	mAP50	mAP50-95: 100% 37/37 [00:16<00:00, 2.28it/s]	
		all	1173	6936	0.753	0.658	0.682	0.398	
		Full-Face	1173	1674	0.803	0.709	0.75	0.413	
		Half-Face	1173	1466	0.789	0.718	0.751	0.374	
		Invalid	1173	217	0.551	0.499	0.479	0.293	
md		No-Helmet	1173	227	0.713	0.52	0.531	0.239	
		Rider	1173	3352	0.908	0.847	0.899	0.673	
□ 143.08 GB available									

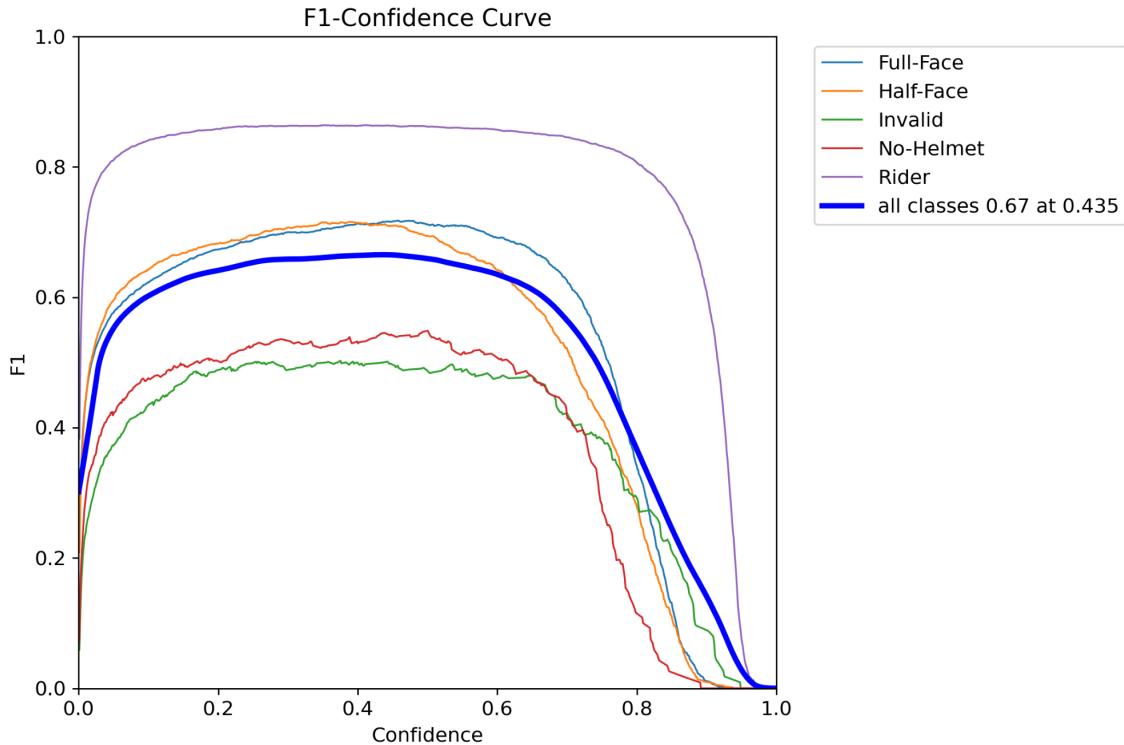
```
!python val.py --weights './runs/train/hyperparam_3/weights/best.pt' --data /content/yolov5/NEW-DATASET-6-7-2/data.yaml --img 640 --name hyperparam_3
val: data=/content/yolov5/NEW-DATASET-6-7-2/data.yaml, weights=['./runs/train/hyperparam_3/weights/best.pt'], batch_size=32, imgsz=640, conf_thres=0.001, iou_thres=0.6, max_
requirements: /content/requirements.txt not found, check failed.
YOLOv5 v7.0-145-g94714fe Python-3.9.16-torch-2.0.0+cu118 CUDA-0 (NVIDIA A100-SXM4-40GB, 40514MiB)

Fusing layers...
Model summary: 267 layers, 46129818 parameters, 0 gradients, 107.7 GFLOPs
val: Scanning /content/yolov5/NEW-DATASET-6-7-2/valid/labels.cache... 1173 images, 0 backgrounds, 0 corrupt: 100% 1173/1173 [00:00<?, ?it/s]
    Class   Images Instances P R mAP50 mAP50-95: 100% 37/37 [00:16<00:00, 2.18it/s]
    all     1173   6936  0.756 0.656 0.683 0.4
    Full-Face 1173   1674  0.804 0.707 0.751 0.411
    Half-Face 1173   1466  0.795 0.715 0.752 0.377
    Invalid   1173   217   0.558 0.498 0.479 0.296
    No-Helmet 1173   227   0.714 0.515 0.532 0.241
    Rider     1173   3352  0.909 0.846 0.899 0.673
Speed: 0.2ms pre-process, 3.2ms inference, 3.5ms NMS per image at shape (32, 3, 640, 640)
Results saved to runs/val/hyperparam_3
```

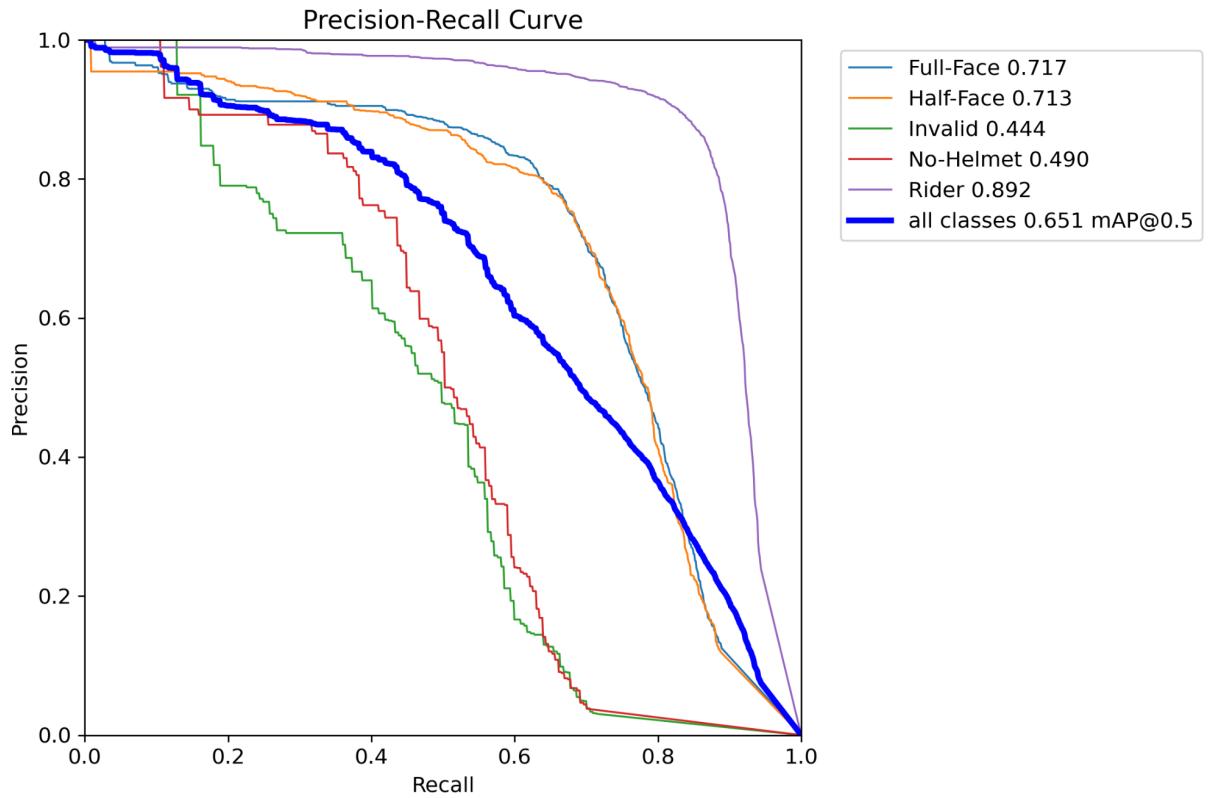
Ground truth data



IX. MODEL 1 - HYPERPARAMETER 1: TENSORBOARD RESULTS

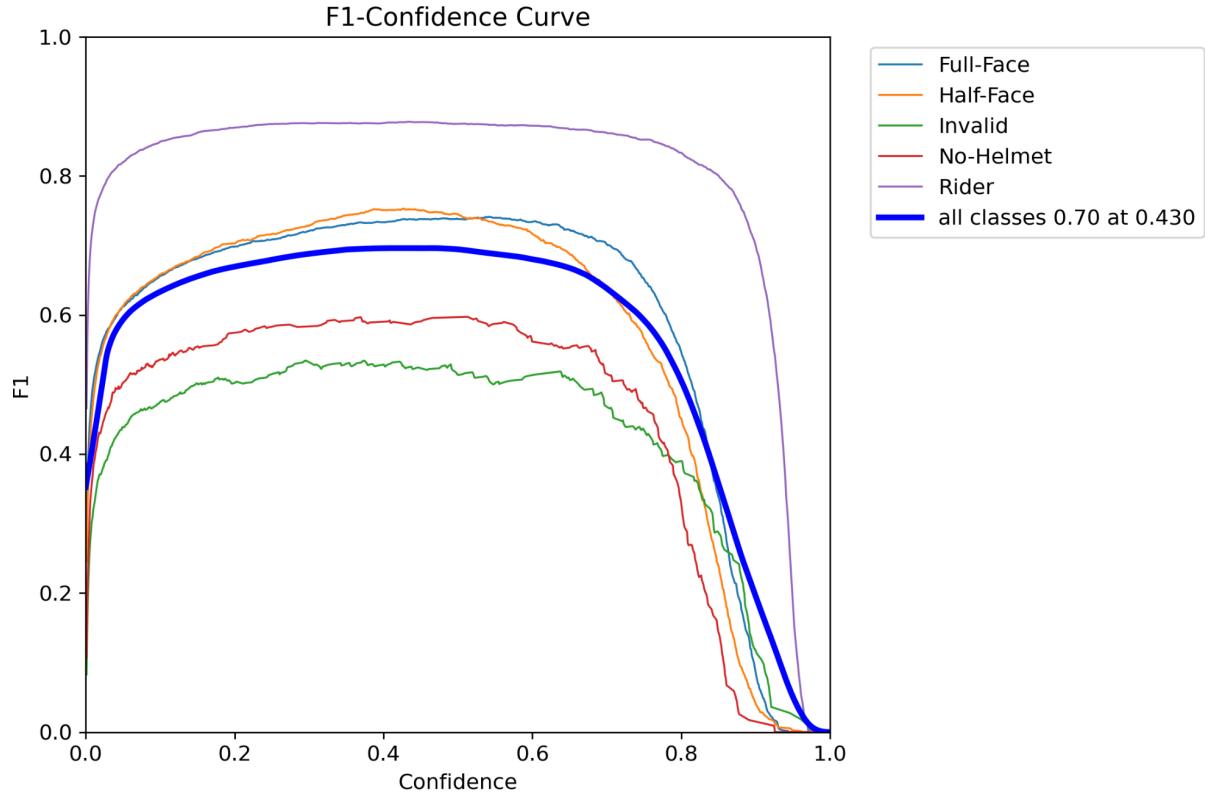


The following TensorBoard result for model 1 illustrates the curve estimation of the statistical data acquired based on machine learning evaluation metrics F1 score and confidence curve. The model shows the confidence curve based on the result on the F1 score of the helmet identification. As illustrated by the curve graph, class ‘Rider’ has the highest F1-score at 1.0 confidence rate. All classes then range on a confidence rate of 0.67 at 0.435.



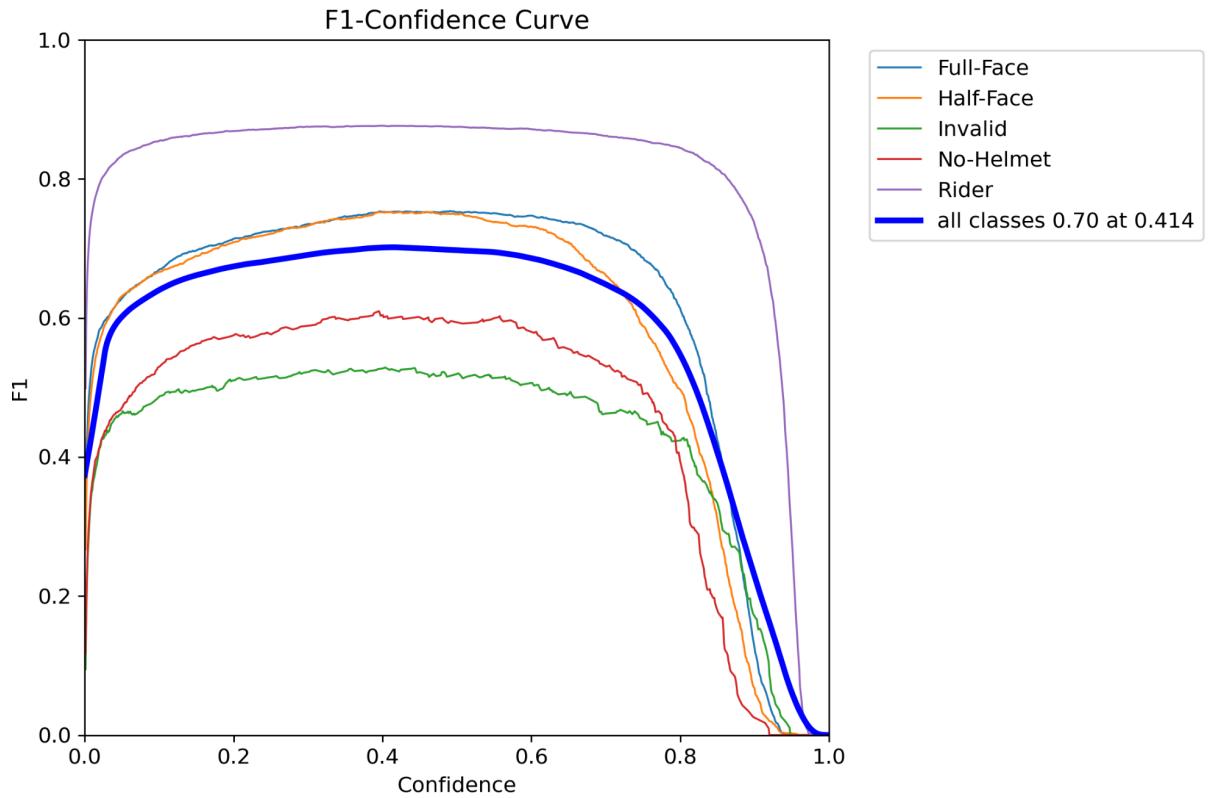
Based on the Precision-Recall curve estimation for model 1, initially, all the detection classes resulted in a high positive prediction yielding at a 1.0 rate. It then continues to regress as we consider their trade-off with the recall metric or the completeness of positive prediction. At 1.0 recall rate, the precision of ‘Rider’ class yielded the best result of 0.892. The classes for the detection of the helmet type ‘Full-face’ and ‘Half-face’ at a similar recall comes next with 0.717 and 0.713. Classes ‘Invalid’ and ‘No-Helmet’ are estimated to reach more than 0.4 just shy of the 0.5 mark. Overall, all classes resulted in a mAP@0.5 estimation of 65.1%.

X. MODEL 2 - HYPERPARAMETER 2: TENSORBOARD RESULTS

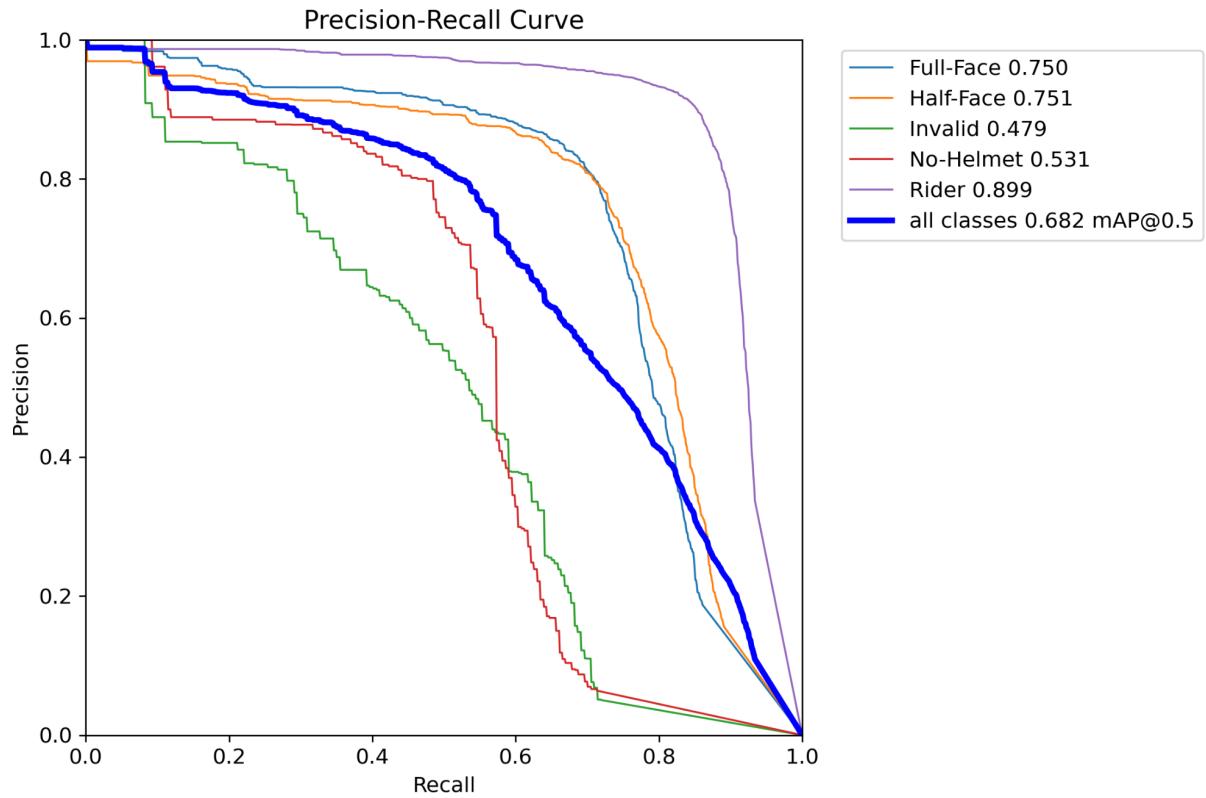


The following TensorBoard result for model 2 illustrates the curve estimation of the statistical data acquired based on machine learning evaluation metrics F1 score and confidence curve. The model shows the confidence curve based on the result of the F1 score of the helmet identification. All classes range on a confidence rate of 0.70 to 0.430. We can see that the confidence rate of hyperparameter 2 is higher compared to the confidence rate of all classes from hyperparameter 1.

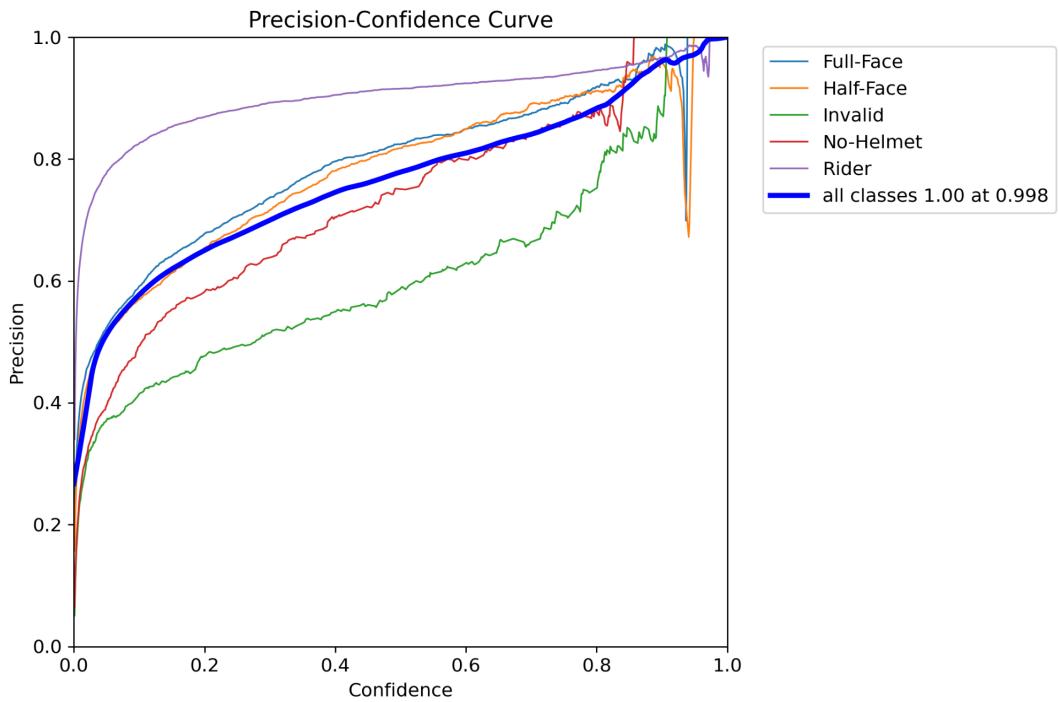
XI. MODEL 3 - HYPERPARAMETER 3: TENSORBOARD RESULTS



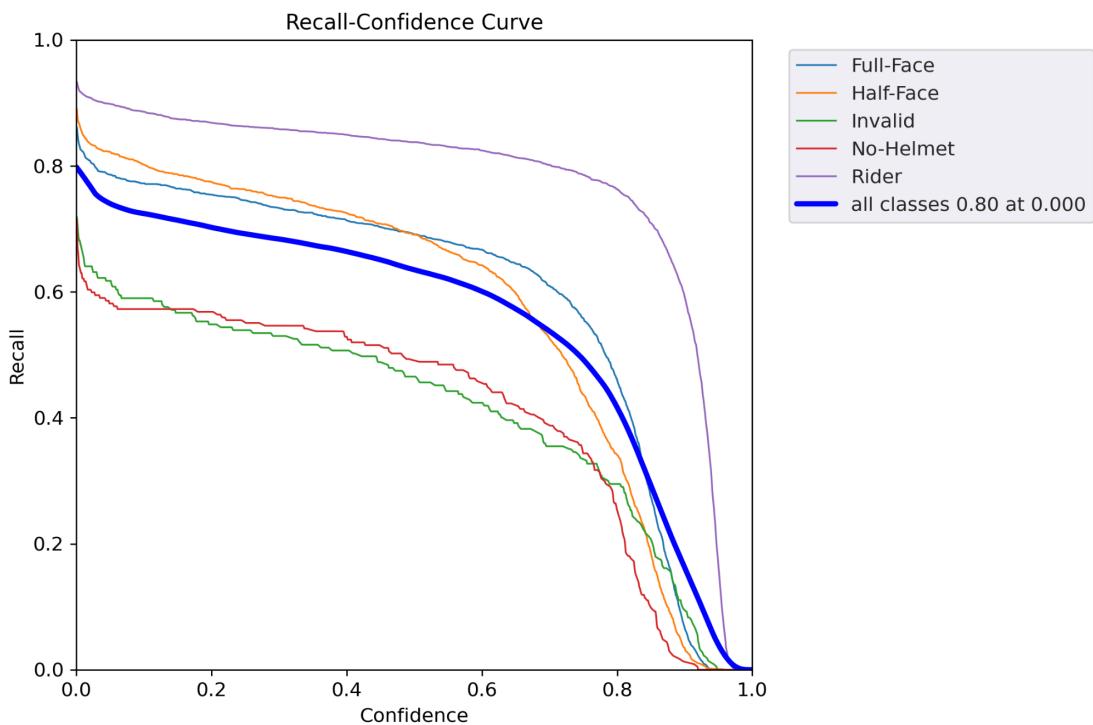
The following TensorBoard result for model 3 illustrates the curve estimation of the statistical data acquired based on machine learning evaluation metrics F1 score and confidence curve. The model shows the confidence curve based on the result on the F1 score of the helmet identification. As illustrated by the curve graph, class ‘Rider’ has the highest F1-score at 1.0 confidence rate. All classes then range on a confidence rate of 0.70 to 0.414.



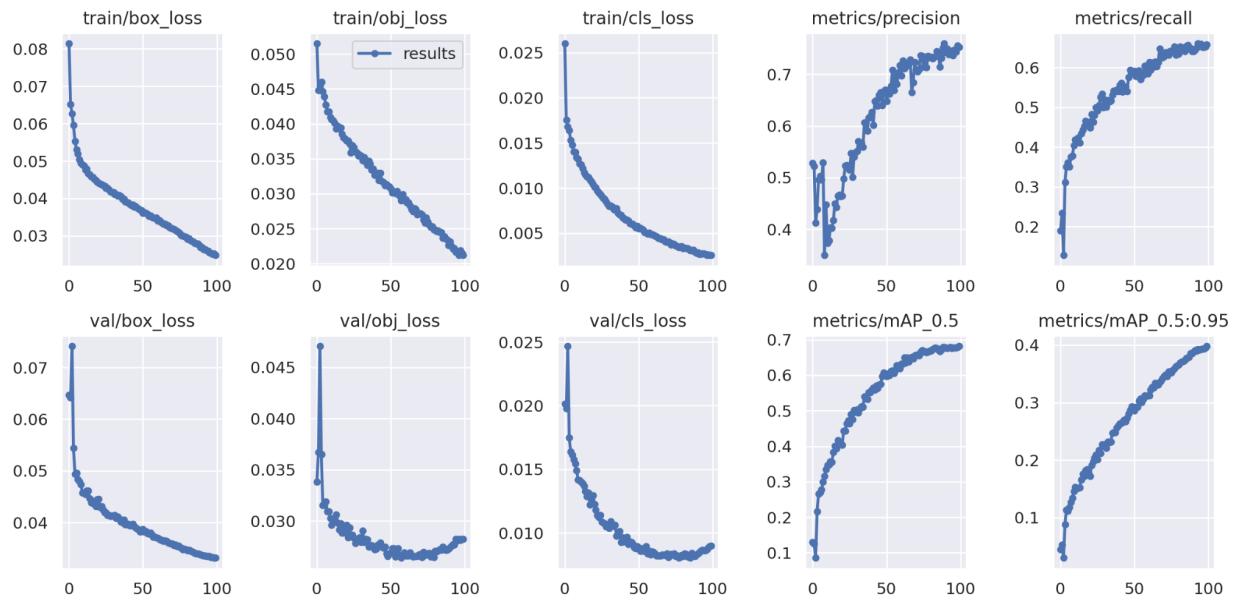
Based on the Precision-Recall curve estimation for model 3, initially, all the detection classes resulted in a high positive prediction yielding at a 1.0 rate. It then continues to regress as we consider their trade-off with the recall metric or the completeness of positive prediction. At 1.0 recall rate, the precision of ‘Rider’ class yielded the best result of 0.899. The classes for the detection of the helmet type ‘Full-face’ and ‘Half-face’ at a similar recall comes next with 0.750 and 0.751. Classes ‘Invalid’ and ‘No-Helmet’ are estimated to reach more than 0.531 just shy of the 0.5 mark.



Based on the Precision-Confidence curve estimation for model 3, initially, all the detection classes resulted in a high positive prediction yielding at a 1.0 rate. We can see that the classifications from the graph increase. And overall, all classes has a Precision-Confidence rate of 1.00 at 0.998



Based on the Recall-Confidence curve estimation for model 3, initially, all the detection classes resulted in a high positive prediction yielding at a 0.80 to 0.00 rate. The graph shows the confidence vs recall of the helmet classifications.



These following graphs show the train loss, metrics precision, metrics recall, val loss, and metrics maP. The graph shows the following summary of the parameters of the model. It shows the following graph results to fully display the train results.

XII. CONFUSION MATRICES

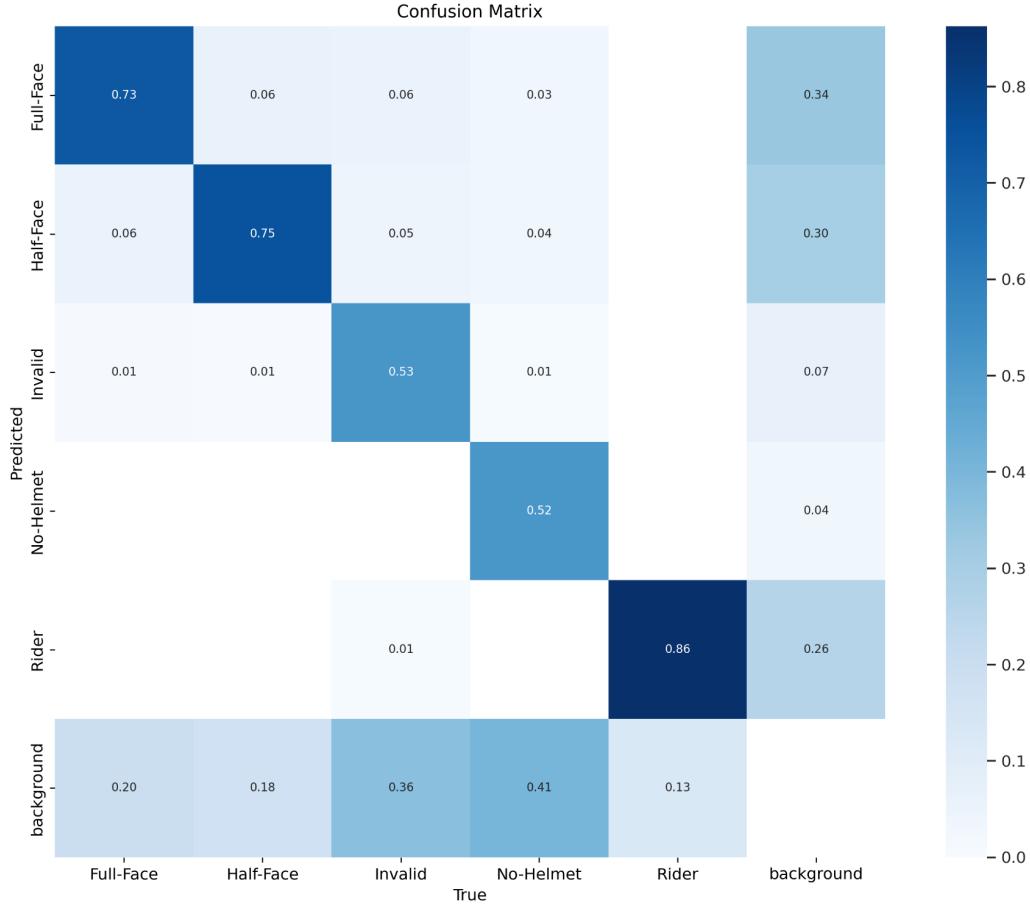
A. MODEL 1 - HYPERPARAMETER 1



The screenshot above is the confusion matrix for model 1. Based on the graph, the model performed best in detecting the Rider class as it obtained the highest true positive value of 0.86, followed by the Full-Face and Half-Face classes with a true positive value of 0.72. Although the Half-Face class is underrepresented, it obtained a true value equivalent to that of the Full-Face

class, implying a good model performance despite a huge gap in instances. The model performed least on the invalid class as it obtained a value of 0.48 only.

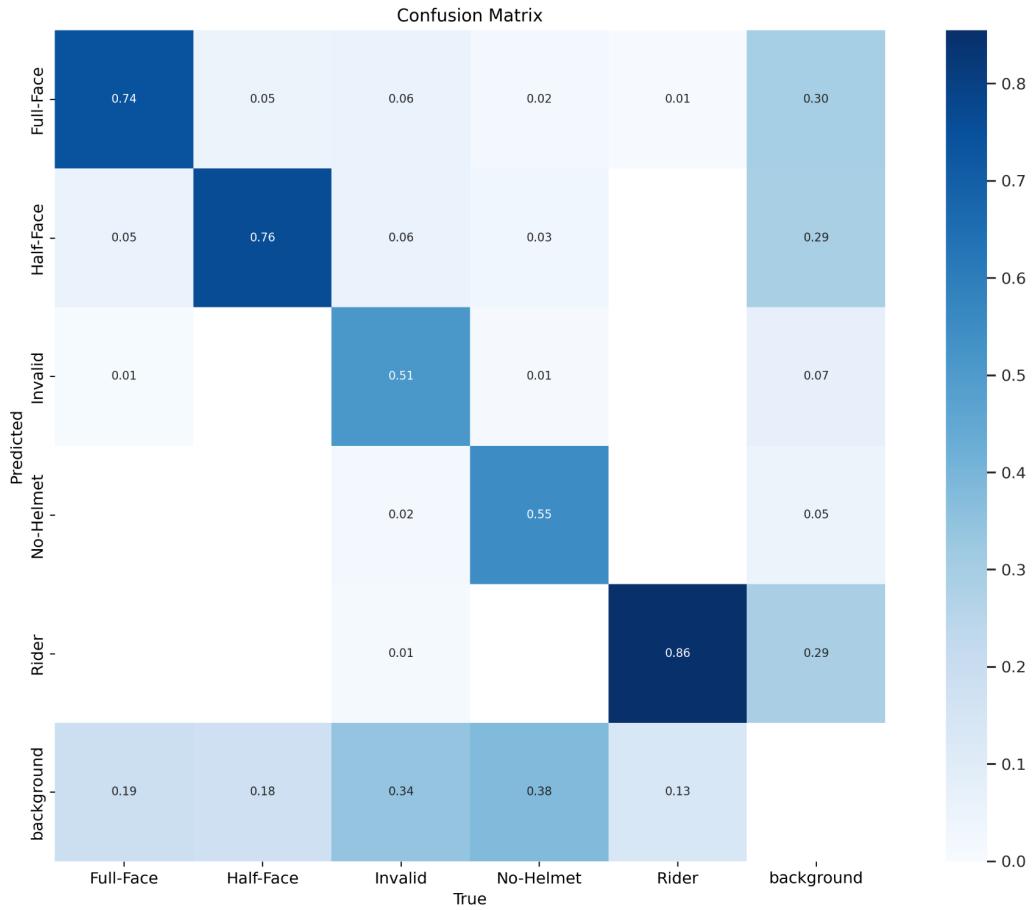
B. MODEL 2 - HYPERPARAMETER 2



The screenshot above is the confusion matrix for model 2. Based on the graph, the model performed best on the Rider class as it obtained a true positive value of 0.86. From this, we can infer that the performance of the model in detecting such a class did not change when compared to the previous model's performance. The model then performed satisfactorily in detecting the Half-Face and Full-Face classes, as it obtained a true positive value of 0.75 and 0.73,

respectively. Comparing the true positive values of models 1 and 2, the biggest increase is observed in the Invalid class, as it changed from 0.48 to 0.53.

C. MODEL 3 - HYPERPARAMETER 3



The presented illustration above defines the confusion matrix of model 3 using hyperparameters setting 3. The matrix shows that the third model was able to perform at par with the two previous models. Classes ‘Full-face’ and ‘Half-face’ yielded a true positive value of 0.74 and 0.76, which is very similar to the previous model 2. While for the classes ‘Invalid’ and ‘No-helmet’, true positive values are 0.51 and 0.55. There is a noticeable slight increase for the

class ‘No helmet’ when compared to model 2. Similarly, ‘Rider’ class retains its original estimated value.

XIII. VIDEO OUTPUT LINK

To view the video output of each model, open the video folder found in this link:
<https://drive.google.com/drive/folders/1xx4aL5mvUc5aWdGJQYHjdp1ebiFjOCyo?usp=sharing>

XIV. RESULTS AND DISCUSSION

Training Metric Results

	Precision	Recall	mAP @.5	mAP @.95
Model 1	0.738	0.609	0.651	0.35
Model 2	0.765	0.641	0.686	0.39
Model 3	0.753	0.658	0.682	0.398

The table above shows the metric results of training the three large-scale YOLOv5 models. Based on the results, recall and mean Average Precision increase as the learning rate and the number of epochs increases and the batch size decreases. It can be observed that there is a slight decrease of 0.012 in precision, 0.004 in mAP @.5, and 0.008 in mAP @.95 for model 3 when compared to model 2.

Testing Metric Results

	Precision	Recall	mAP @.5	mAP @.95
Model 1	0.734	0.608	0.651	0.351
Model 2	0.768	0.643	0.687	0.39
Model 3	0.756	0.656	0.683	0.4

The table above shows the metric results of testing the three large-scale YOLOv5 models. Based on the results, the performance of the model increases as we decrease the batch size and increase both the learning rate and the number of epochs. Model 3 performed the best as it obtained precision, recall, mAP @.5, and mAP @.95 of 0.756, 0.656, 0.683, and 0.4, respectively.

In addition, we can see that all three models performed satisfactorily in detecting target objects as the precision and recall exhibited a good trade-off. The difference in precision and recall is only 0.126, 0.125, and 0.1 for models 1, 2, and 3, respectively.

It can also be seen that the mean Average Precision for threshold .95 is significantly lower than the mean Average Precision for threshold .5 since this measures the intersection over union of the model. With a 95% expected IoU, it implies that the model should almost perfectly detect objects in all categories. Hence, it will yield a lower value as it requires the predicted bounding box to be 95% close to the actual annotated box as seen on the ground truth of data.

Comparing the training and testing results, it can be inferred that all three models performed generally well without any signs of overfitting or underfitting, as the training and testing metric values are close to each other. There is also a noticeable trend when it comes to the Precision and Recall values of the models. Recall rates tend to increase when there is a decrease in Precision and vice-versa. This is mainly due to the Precision/Recall trade-off that is inherent by nature in the model's performance.

Conclusion/Recommendations:

In summary, three hyperparameters were used in this project with varying specifications related to Learning Rate, Batch Size, Epochs, and Image size. From here, iterations of different models were trained to obtain the best possible result. Training and testing metric results of the three models infer that hyperparameter 2 settings provide the most accurate result in terms of mAP@0.5 and Precision while hyperparameter 3 resulted in the highest Recall value. For the mAP@0.95, both models 2 and 3 yielded the same value.

Possible recommendations to further increase the performance of the models is to include larger scale datasets that may include more augmentation techniques. This could provide the necessary solution, especially in low light scenario images data.

To view all files and other documents:

https://drive.google.com/drive/folders/1Fy9R9nICE9pJAsknH-cdhD67tdjYtLjV?usp=share_link

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