cv-ppe-project

March 10, 2024

[3]:

```
%%time

! pip install --upgrade ultralytics -qq
```

```
CPU times: user 30.7 ms, sys: 4.56 ms, total: 35.2 ms
Wall time: 5.92 s
```

[4]:

```
import ultralytics
print(ultralytics.__version__)
```

```
8.1.10
```

[5]:

```
import warnings
warnings.filterwarnings("ignore")

import os
import re
import glob
import random
import yaml

import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
from matplotlib.patches import Rectangle
import seaborn as sns

import IPython.display as display
from PIL import Image
import cv2

from ultralytics import YOLO
```

[6]:

```
from google.colab import drive
drive.mount('/content/drive')
```

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

[7]:

```
class CFG:
    DEBUG = False
    FRACTION = 0.05 if DEBUG else 1.0
    SEED = 88

    # classes
    CLASSES = ['Hardhat', 'Mask', 'NO-Hardhat', 'NO-Mask',
               'NO-Safety Vest', 'Person', 'Safety Cone',
               'Safety Vest', 'machinery', 'vehicle']
    NUM_CLASSES_TO_TRAIN = len(CLASSES)

    # training
    EPOCHS = 3 if DEBUG else 50
    BATCH_SIZE = 16

    BASE_MODEL = 'yolov8x'
    BASE_MODEL_WEIGHTS = f'{BASE_MODEL}.pt'
    EXP_NAME = f'ppe_css_{EPOCHS}_epochs'

    OPTIMIZER = 'auto'
    LR = 1e-3
    LR_FACTOR = 0.01
    WEIGHT_DECAY = 5e-4
    DROPOUT = 0.0
    PATIENCE = 20
    PROFILE = False
    LABEL_SMOOTHING = 0.0

    # paths
    CUSTOM_DATASET_DIR = '/content/drive/MyDrive/archive/css-data/'
    OUTPUT_DIR = './'
```

[8]:

```
import os
```

[9]:

```
dict_file = {
    'train': os.path.join(CFG.CUSTOM_DATASET_DIR, 'train'),
    'val': os.path.join(CFG.CUSTOM_DATASET_DIR, 'valid'),
    'test': os.path.join(CFG.CUSTOM_DATASET_DIR, 'test'),
    'nc': CFG.NUM_CLASSES_TO_TRAIN,
    'names': CFG.CLASSES
    }

with open(os.path.join(CFG.OUTPUT_DIR, 'data.yaml'), 'w+') as file:
    yaml.dump(dict_file, file)
```

[10]:

```
### read yaml file created
def read_yaml_file(file_path = CFG.CUSTOM_DATASET_DIR):
    with open(file_path, 'r') as file:
        try:
            data = yaml.safe_load(file)
            return data
        except yaml.YAMLError as e:
            print("Error reading YAML:", e)
            return None

### print it with newlines
def print_yaml_data(data):
    formatted_yaml = yaml.dump(data, default_style=False)
    print(formatted_yaml)

file_path = os.path.join(CFG.OUTPUT_DIR, 'data.yaml')
yaml_data = read_yaml_file(file_path)

if yaml_data:
    print_yaml_data(yaml_data)
```

```
names:
- Hardhat
- Mask
- NO-Hardhat
- NO-Mask
- NO-Safety Vest
- Person
- Safety Cone
- Safety Vest
- machinery
- vehicle
nc: 10
test: /content/drive/MyDrive/archive/css-data/test
train: /content/drive/MyDrive/archive/css-data/train
val: /content/drive/MyDrive/archive/css-data/valid
```

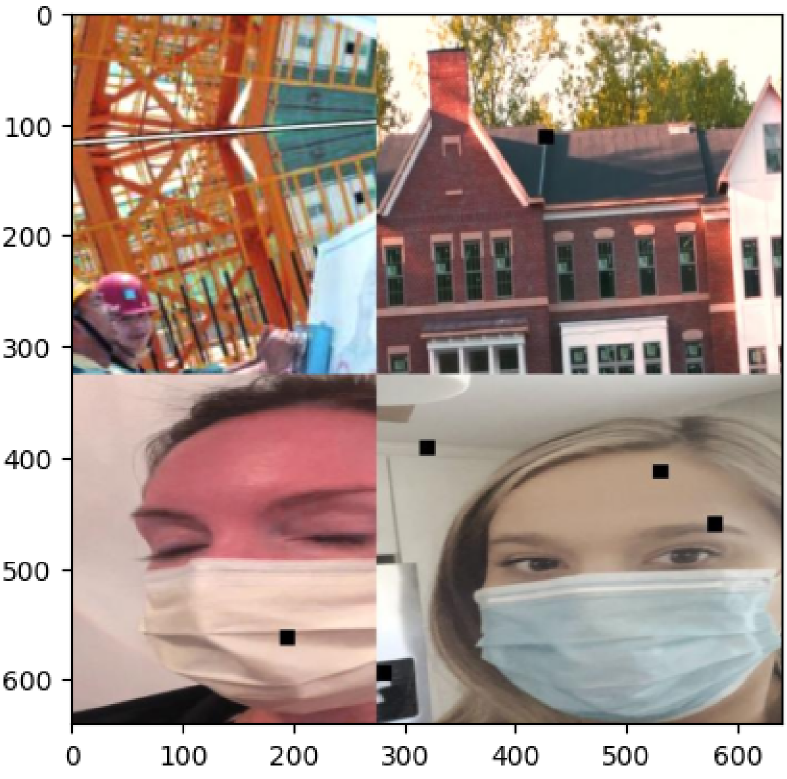
[37]:

```
def display_image(image, print_info = True, hide_axis = False):
    if isinstance(image, str):
        img = Image.open(image)
        plt.imshow(img)
    elif isinstance(image, np.ndarray):
        image = image[..., ::-1]  # BGR to RGB
        img = Image.fromarray(image)
        plt.imshow(img)
    else:
        raise ValueError("Unsupported image format")
    if print_info:
        print('Type: ', type(img), '\n')
        print('Shape: ', np.array(img).shape, '\n')

    if hide_axis:
        plt.axis('off')

    plt.show()
```

[12]:

```
example_image_path = '/content/drive/MyDrive/archive/css-data/train/images/
 ↪-1670-_png_jpg.rf.0463edb430019e01ec79eed27a6349d6.jpg'
display_image(example_image_path, print_info = True, hide_axis = False)
```

```
Type:  <class 'PIL.JpegImagePlugin.JpegImageFile'>

Shape:  (640, 640, 3)
```



[13]:

```
def plot_random_images_from_folder(folder_path, num_images=20, seed=CFG.SEED):

    random.seed(seed)
    image_files = [f for f in os.listdir(folder_path) if f.endswith(('.jpg', '.
↪png', '.jpeg', '.gif'))]


    if len(image_files) < num_images:
        raise ValueError("Not enough images in the folder")


    selected_files = random.sample(image_files, num_images)


    num_cols = 5
    num_rows = (num_images + num_cols - 1) // num_cols
    fig, axes = plt.subplots(num_rows, num_cols, figsize=(12, 8))

    for i, file_name in enumerate(selected_files):

        img = Image.open(os.path.join(folder_path, file_name))

        if num_rows == 1:
            ax = axes[i % num_cols]
        else:
            ax = axes[i // num_cols, i % num_cols]

        ax.imshow(img)
        ax.axis('off')

    for i in range(num_images, num_rows * num_cols):
        if num_rows == 1:
            fig.delaxes(axes[i % num_cols])
        else:
            fig.delaxes(axes[i // num_cols, i % num_cols])

    plt.tight_layout()
    plt.show()
```

[14]:

```
folder_path = CFG.CUSTOM_DATASET_DIR + 'train/images/'
plot_random_images_from_folder(folder_path, num_images=20, seed=CFG.SEED)
```

[15]:

```
def get_image_properties(image_path):
    # Read the image file
    img = cv2.imread(image_path)


    if img is None:
        raise ValueError("Could not read image file")

    properties = {
        "width": img.shape[1],
        "height": img.shape[0],
        "channels": img.shape[2] if len(img.shape) == 3 else 1,
        "dtype": img.dtype,
    }

    return properties
```

[16]:

```
img_properties = get_image_properties(example_image_path)
img_properties
```

[16]:

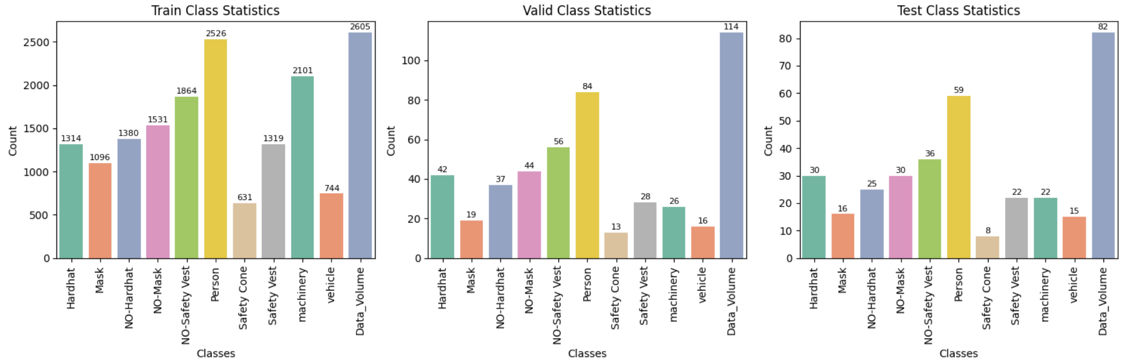
```
{'width': 640, 'height': 640, 'channels': 3, 'dtype': dtype('uint8')}
```

[17]:
```
%%time
class_idx = {str(i): CFG.CLASSES[i] for i in range(CFG.NUM_CLASSES_TO_TRAIN)}

class_stat = {}
data_len = {}
class_info = []

for mode in ['train', 'valid', 'test']:
    class_count = {CFG.CLASSES[i]: 0 for i in range(CFG.NUM_CLASSES_TO_TRAIN)}

    path = os.path.join(CFG.CUSTOM_DATASET_DIR, mode, 'labels')

    for file in os.listdir(path):
        with open(os.path.join(path, file)) as f:
            lines = f.readlines()

            for cls in set([line[0] for line in lines]):
                class_count[class_idx[cls]] += 1

    data_len[mode] = len(os.listdir(path))
    class_stat[mode] = class_count

    class_info.append({'Mode': mode, **class_count, 'Data_Volume':␣
 ↪data_len[mode]})

dataset_stats_df = pd.DataFrame(class_info)
dataset_stats_df
```

```
CPU times: user 507 ms, sys: 302 ms, total: 809 ms
Wall time: 40.2 s
```

[17]:
```
    Mode  Hardhat  Mask  NO-Hardhat  NO-Mask  NO-Safety Vest  Person  \
0  train     1314  1096        1380     1531            1864    2526
1  valid       42    19          37       44              56      84
2   test       30    16          25       30              36      59

   Safety Cone  Safety Vest  machinery  vehicle  Data_Volume
0          631         1319       2101      744         2605
1           13           28         26       16          114
2            8           22         22       15           82
```

[18]:
```
fig, axes = plt.subplots(1, 3, figsize=(15, 5))

# Plot vertical bar plots for each mode in subplots
for i, mode in enumerate(['train', 'valid', 'test']):
    sns.barplot(
        data=dataset_stats_df[dataset_stats_df['Mode'] == mode].
↪drop(columns='Mode'),
        orient='v',
        ax=axes[i],
        palette='Set2'
    )

    axes[i].set_title(f'{mode.capitalize()} Class Statistics')
    axes[i].set_xlabel('Classes')
    axes[i].set_ylabel('Count')
    axes[i].tick_params(axis='x', rotation=90)

    # Add annotations on top of each bar
    for p in axes[i].patches:
        axes[i].annotate(f"{int(p.get_height())}", (p.get_x() + p.get_width() /␣
↪2., p.get_height()),
                         ha='center', va='center', fontsize=8, color='black',␣
↪xytext=(0, 5),
                         textcoords='offset points')

plt.tight_layout()
plt.show()
```



[19]:
```
%%time

for mode in ['train', 'valid', 'test']:
    print(f'\nImage sizes in {mode} set:')

    img_size = 0
    for file in glob.glob(os.path.join(CFG.CUSTOM_DATASET_DIR, mode, 'images',␣
↪'*')):

        image = Image.open(file)
        if image.size != img_size:
            print(f'{image.size}')
            img_size = image.size
            print('\n')
```

```
Image sizes in train set:
(640, 640)



Image sizes in valid set:
(640, 640)



Image sizes in test set:
(640, 640)


CPU times: user 190 ms, sys: 101 ms, total: 291 ms
Wall time: 3.87 s
```

[20]:

```
CFG.BASE_MODEL_WEIGHTS
```

[20]:

```
'yolov8x.pt'
```

[21]:

```
import torch

# Define the device
device = torch.device('cuda' if torch.cuda.is_available() else 'cpu')
```

[22]:

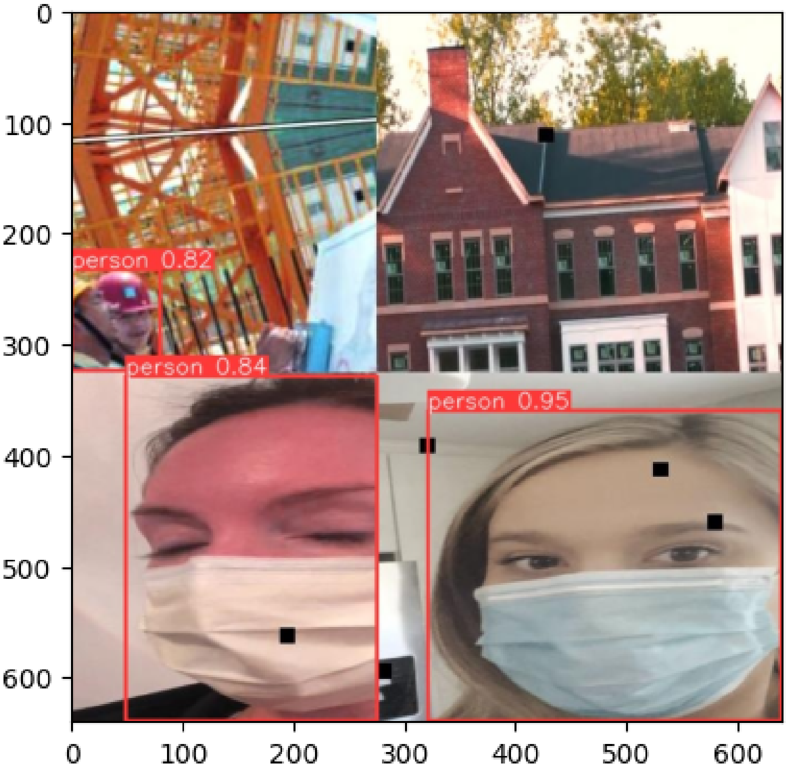
```
model = YOLO(CFG.BASE_MODEL_WEIGHTS)

results = model.predict(
    source = example_image_path,

    classes = [0],
    conf = 0.30,
    device = device, # inference with dual GPU
    imgsz = (img_properties['height'], img_properties['width']),

    save = True,
    save_txt = True,
    save_conf = True,
    exist_ok = True,
)
```

```
image 1/1 /content/drive/MyDrive/archive/css-
data/train/images/-1670-_png_jpg.rf.0463edb430019e01ec79eed27a6349d6.jpg:
640x640 3 persons, 97.5ms
Speed: 4.8ms preprocess, 97.5ms inference, 870.8ms postprocess per image at
shape (1, 3, 640, 640)
Results saved to runs/detect/predict
1 label saved to runs/detect/predict/labels
```

[23]:

```
### check predictions with base model
example_image_inference_output = example_image_path.split('/')[-1]
display_image(f'/content/runs/detect/predict/-1670-_png_jpg.rf.
↪0463edb430019e01ec79eed27a6349d6.jpg')
```

```
Type:  <class 'PIL.JpegImagePlugin.JpegImageFile'>

Shape:  (640, 640, 3)
```



[24]:

```python
print('Model: ', CFG.BASE_MODEL_WEIGHTS)
print('Epochs: ', CFG.EPOCHS)
print('Batch: ', CFG.BATCH_SIZE)
```

```
Model:  yolov8x.pt
Epochs:  50
Batch:  16
```

[25]:

```python
### Load pre-trained YOLO model
model = YOLO(CFG.BASE_MODEL_WEIGHTS)
```

[26]:

```python
%%time

### train
model.train(
    data=os.path.join(CFG.OUTPUT_DIR, 'data.yaml'),
    task='detect',
    imgsz=(img_properties['height'], img_properties['width']),
    epochs=CFG.EPOCHS,
    batch=CFG.BATCH_SIZE,
    optimizer=CFG.OPTIMIZER,
    lr0=CFG.LR,
    lrf=CFG.LR_FACTOR,
    weight_decay=CFG.WEIGHT_DECAY,
    dropout=CFG.DROPOUT,
    fraction=CFG.FRACTION,
    patience=CFG.PATIENCE,
    profile=CFG.PROFILE,
    label_smoothing=CFG.LABEL_SMOOTHING,
    name=f'{CFG.BASE_MODEL}_{CFG.EXP_NAME}',
    seed=CFG.SEED,
    val=True,
    amp=True,
    exist_ok=True,
    resume=False,
    device=0,  # Specify CPU as the device
    verbose=False,
)
```

```
Ultralytics YOLOv8.1.10  Python-3.10.12 torch-2.1.0+cu121 CUDA:0 (Tesla T4,
15102MiB)
engine/trainer: task=detect, mode=train, model=yolov8x.pt,
data=./data.yaml, epochs=50, time=None, patience=20, batch=16, imgsz=(640, 640),
save=True, save_period=-1, cache=False, device=0, workers=8, project=None,
name=yolov8x_ppe_css_50_epochs, exist_ok=True, pretrained=True, optimizer=auto,
verbose=False, seed=88, deterministic=True, single_cls=False, rect=False,
cos_lr=False, close_mosaic=10, resume=False, amp=True, fraction=1.0,
profile=False, freeze=None, multi_scale=False, overlap_mask=True, mask_ratio=4,
dropout=0.0, val=True, split=val, save_json=False, save_hybrid=False, conf=None,
iou=0.7, max_det=300, half=False, dnn=False, plots=True, source=None,
vid_stride=1, stream_buffer=False, visualize=False, augment=False,
agnostic_nms=False, classes=None, retina_masks=False, embed=None, show=False,
save_frames=False, save_txt=False, save_conf=False, save_crop=False,
show_labels=True, show_conf=True, show_boxes=True, line_width=None,
format=torchscript, keras=False, optimize=False, int8=False, dynamic=False,
simplify=False, opset=None, workspace=4, nms=False, lr0=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=7.5, cls=0.5, dfl=1.5, pose=12.0, kobj=1.0,
label_smoothing=0.0, nbs=64, hsv_h=0.015, hsv_s=0.7, hsv_v=0.4, degrees=0.0,
translate=0.1, scale=0.5, shear=0.0, perspective=0.0, flipud=0.0, fliplr=0.5,
mosaic=1.0, mixup=0.0, copy_paste=0.0, auto_augment=randaugment, erasing=0.4,
crop_fraction=1.0, cfg=None, tracker=botsort.yaml,
save_dir=runs/detect/yolov8x_ppe_css_50_epochs
Overriding model.yaml nc=80 with nc=10

                   from  n    params  module
arguments
  0                  -1  1      2320  ultralytics.nn.modules.conv.Conv
[3, 80, 3, 2]
  1                  -1  1    115520  ultralytics.nn.modules.conv.Conv
[80, 160, 3, 2]
  2                  -1  3    436800  ultralytics.nn.modules.block.C2f
[160, 160, 3, True]
  3                  -1  1    461440  ultralytics.nn.modules.conv.Conv
[160, 320, 3, 2]
  4                  -1  6   3281920  ultralytics.nn.modules.block.C2f
[320, 320, 6, True]
  5                  -1  1   1844480  ultralytics.nn.modules.conv.Conv
[320, 640, 3, 2]
  6                  -1  6  13117440  ultralytics.nn.modules.block.C2f
[640, 640, 6, True]
  7                  -1  1   3687680  ultralytics.nn.modules.conv.Conv
[640, 640, 3, 2]
  8                  -1  3   6969600  ultralytics.nn.modules.block.C2f
[640, 640, 3, True]
  9                  -1  1   1025920  ultralytics.nn.modules.block.SPPF
[640, 640, 5]
 10                  -1  1         0  torch.nn.modules.upsampling.Upsample
[None, 2, 'nearest']
 11             [-1, 6]  1         0  ultralytics.nn.modules.conv.Concat
[1]
 12                  -1  3   7379200  ultralytics.nn.modules.block.C2f
[1280, 640, 3]
 13                  -1  1         0  torch.nn.modules.upsampling.Upsample
[None, 2, 'nearest']
 14             [-1, 4]  1         0  ultralytics.nn.modules.conv.Concat
```

```
[1]
 15                  -1  3   1948800  ultralytics.nn.modules.block.C2f
[960, 320, 3]
 16                  -1  1    922240  ultralytics.nn.modules.conv.Conv
[320, 320, 3, 2]
 17            [-1, 12]  1         0  ultralytics.nn.modules.conv.Concat
[1]
 18                  -1  3   7174400  ultralytics.nn.modules.block.C2f
[960, 640, 3]
 19                  -1  1   3687680  ultralytics.nn.modules.conv.Conv
[640, 640, 3, 2]
 20             [-1, 9]  1         0  ultralytics.nn.modules.conv.Concat
[1]
 21                  -1  3   7379200  ultralytics.nn.modules.block.C2f
[1280, 640, 3]
 22        [15, 18, 21]  1   8727598  ultralytics.nn.modules.head.Detect
[10, [320, 640, 640]]
Model summary: 365 layers, 68162238 parameters, 68162222 gradients, 258.2 GFLOPs

Transferred 589/595 items from pretrained weights
TensorBoard: Start with 'tensorboard --logdir
runs/detect/yolov8x_ppe_css_50_epochs', view at http://localhost:6006/
Freezing layer 'model.22.dfl.conv.weight'
AMP: running Automatic Mixed Precision (AMP) checks with YOLOv8n…
Downloading
https://github.com/ultralytics/assets/releases/download/v8.1.0/yolov8n.pt to
'yolov8n.pt'…

100%|     | 6.23M/6.23M [00:00<00:00, 95.1MB/s]

AMP: checks passed
WARNING  updating to 'imgsz=640'. 'train' and 'val' imgsz must be an integer,
while 'predict' and 'export' imgsz may be a [h, w] list or an integer, i.e.
'yolo export imgsz=640,480' or 'yolo export imgsz=640'

train: Scanning /content/drive/MyDrive/archive/css-
data/train/labels.cache… 550 images, 1 backgrounds, 0 corrupt:
100%|     | 550/550 [00:00<?, ?it/s]

train: WARNING  /content/drive/MyDrive/archive/css-
data/train/images/004720_jpg.rf.afc486560a4004c7cfd67910af31a29c.jpg: 1
duplicate labels removed


albumentations: Blur(p=0.01, blur_limit=(3, 7)), MedianBlur(p=0.01,
blur_limit=(3, 7)), ToGray(p=0.01), CLAHE(p=0.01, clip_limit=(1, 4.0),
tile_grid_size=(8, 8))

val: Scanning /content/drive/MyDrive/archive/css-
data/valid/labels.cache… 114 images, 10 backgrounds, 0 corrupt:
```

```
100%|     | 114/114 [00:00<?, ?it/s]

Plotting labels to runs/detect/yolov8x_ppe_css_50_epochs/labels.jpg…
optimizer: 'optimizer=auto' found, ignoring 'lr0=0.001' and
'momentum=0.937' and determining best 'optimizer', 'lr0' and 'momentum'
automatically…
optimizer: AdamW(lr=0.000714, momentum=0.9) with parameter groups
97 weight(decay=0.0), 104 weight(decay=0.0005), 103 bias(decay=0.0)
TensorBoard: model graph visualization added
Image sizes 640 train, 640 val
Using 2 dataloader workers
Logging results to runs/detect/yolov8x_ppe_css_50_epochs
Starting training for 50 epochs…

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

       1/50      13.5G      1.424      2.344      1.582        190        640:
100%|     | 35/35 [00:50<00:00,  1.43s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|     | 4/4 [00:05<00:00,  1.44s/it]

                   all        114        697      0.343      0.384      0.277
0.111



      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

       2/50      14.1G      1.365       1.82      1.524        156        640:
100%|     | 35/35 [00:48<00:00,  1.38s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.11s/it]

                   all        114        697       0.21       0.32      0.164
0.0658



      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

       3/50      14.1G       1.41      1.813      1.548         93        640:
100%|     | 35/35 [00:46<00:00,  1.32s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.14s/it]

                   all        114        697      0.288      0.268      0.202
0.089



      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
```

```
       4/50      14.1G      1.381      1.771      1.555        134        640:
100%|     | 35/35 [00:46<00:00,  1.34s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.16s/it]

                   all        114        697      0.347      0.279      0.227
0.0867



      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

       5/50        14G      1.352      1.738      1.539        106        640:
100%|     | 35/35 [00:46<00:00,  1.33s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.13s/it]

                   all        114        697      0.464      0.342      0.318
0.129



      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

       6/50        14G      1.334       1.68       1.53        100        640:
100%|     | 35/35 [00:47<00:00,  1.36s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.24s/it]

                   all        114        697      0.366      0.345      0.279
0.12



      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

       7/50      14.1G      1.321      1.624      1.483         83        640:
100%|     | 35/35 [00:46<00:00,  1.34s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.08s/it]

                   all        114        697      0.451       0.35      0.322
0.13



      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

       8/50        14G      1.259      1.516      1.472        136        640:
100%|     | 35/35 [00:48<00:00,  1.38s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.05s/it]
```

```
                   all        114        697        0.5      0.422      0.417
0.168


      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

       9/50      14.1G      1.265      1.474      1.465        148        640:
100%|     | 35/35 [00:46<00:00,  1.33s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.15s/it]

                   all        114        697      0.489      0.437      0.372
0.16


      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

      10/50        14G      1.232      1.442       1.44        131        640:
100%|     | 35/35 [00:47<00:00,  1.37s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.16s/it]

                   all        114        697      0.595      0.484      0.486
0.192


      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

      11/50        14G      1.238      1.426      1.432        155        640:
100%|     | 35/35 [00:48<00:00,  1.38s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.05s/it]

                   all        114        697      0.644      0.442      0.496
0.216


      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

      12/50      14.1G      1.173      1.366      1.421         99        640:
100%|     | 35/35 [00:48<00:00,  1.38s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.09s/it]

                   all        114        697      0.638      0.449       0.46
0.202
```

```
      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

      13/50      14.1G      1.157      1.275      1.389        153        640: 
100%|     | 35/35 [00:46<00:00,  1.33s/it]
                 Class     Images  Instances      Box(P          R      mAP50 
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.07s/it]

                   all        114        697      0.712       0.43      0.478 
0.194



      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

      14/50      14.1G      1.165      1.271      1.378        178        640: 
100%|     | 35/35 [00:47<00:00,  1.35s/it]
                 Class     Images  Instances      Box(P          R      mAP50 
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.05s/it]

                   all        114        697      0.683        0.5      0.542 
0.24



      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

      15/50        14G      1.123      1.217      1.354        143        640: 
100%|     | 35/35 [00:47<00:00,  1.35s/it]
                 Class     Images  Instances      Box(P          R      mAP50 
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.09s/it]

                   all        114        697      0.678       0.51      0.531 
0.237



      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

      16/50        14G      1.107      1.216      1.354        191        640: 
100%|     | 35/35 [00:46<00:00,  1.33s/it]
                 Class     Images  Instances      Box(P          R      mAP50 
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.04s/it]

                   all        114        697      0.666      0.475      0.511 
0.222



      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
      17/50        14G      1.102      1.172      1.347        110        640:
100%|     | 35/35 [00:46<00:00,  1.34s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.03s/it]

                   all        114        697      0.673      0.523      0.553
0.235


      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

      18/50      14.1G        1.1      1.137      1.323        171        640:
100%|     | 35/35 [00:47<00:00,  1.35s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.10s/it]

                   all        114        697      0.728      0.536      0.586
0.24


      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

      19/50        14G       1.06      1.085      1.309        203        640:
100%|     | 35/35 [00:47<00:00,  1.36s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.10s/it]

                   all        114        697      0.727      0.541      0.596
0.251


      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

      20/50        14G      1.041      1.043      1.293        188        640:
100%|     | 35/35 [00:48<00:00,  1.37s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.11s/it]

                   all        114        697      0.699       0.55      0.583
0.283


      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

      21/50        14G      1.033      1.001      1.275        163        640:
100%|     | 35/35 [00:46<00:00,  1.32s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.07s/it]
```

```
                   all        114        697      0.753       0.55      0.622
0.281



      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

      22/50      14.1G      1.045      1.054      1.303        146        640:
100%|     | 35/35 [00:47<00:00,  1.37s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.05s/it]

                   all        114        697       0.72      0.542      0.587
0.279



      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

      23/50        14G      1.017      1.003      1.279        100        640:
100%|     | 35/35 [00:46<00:00,  1.32s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.03s/it]

                   all        114        697      0.761      0.557      0.609
0.287



      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

      24/50        14G      0.979     0.9582      1.256        129        640:
100%|     | 35/35 [00:48<00:00,  1.37s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.09s/it]

                   all        114        697      0.794      0.534       0.62
0.292



      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

      25/50        14G     0.9684     0.9333      1.251        143        640:
100%|     | 35/35 [00:46<00:00,  1.34s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.04s/it]

                   all        114        697      0.809      0.573      0.655
0.296
```

```
      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

      26/50        14G     0.9663     0.9004       1.23        211        640:
100%|      | 35/35 [00:46<00:00,  1.34s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|      | 4/4 [00:04<00:00,  1.08s/it]

                   all        114        697      0.767      0.607      0.649
0.299



      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

      27/50      14.1G      0.946     0.9181      1.231        158        640:
100%|      | 35/35 [00:47<00:00,  1.37s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|      | 4/4 [00:04<00:00,  1.05s/it]

                   all        114        697      0.795      0.589      0.647
0.322



      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

      28/50      14.1G     0.9381      0.854      1.207        202        640:
100%|      | 35/35 [00:47<00:00,  1.36s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|      | 4/4 [00:04<00:00,  1.12s/it]

                   all        114        697      0.815      0.594      0.666
0.303



      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

      29/50        14G     0.9132     0.8375      1.201         90        640:
100%|      | 35/35 [00:46<00:00,  1.32s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|      | 4/4 [00:04<00:00,  1.07s/it]

                   all        114        697      0.821      0.613      0.677
0.326



      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
      30/50        14G     0.8989     0.7995      1.194        188        640:
100%|     | 35/35 [00:48<00:00,  1.37s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.11s/it]

                   all        114        697      0.749      0.551      0.608
0.3



      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

      31/50        14G     0.8777     0.8079      1.179        110        640:
100%|     | 35/35 [00:46<00:00,  1.33s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.04s/it]

                   all        114        697      0.788      0.596      0.647
0.319



      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

      32/50      13.8G     0.8616     0.7846      1.164         86        640:
100%|     | 35/35 [00:46<00:00,  1.34s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.02s/it]

                   all        114        697       0.82      0.591      0.663
0.311



      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

      33/50      14.1G     0.8427      0.747      1.153        104        640:
100%|     | 35/35 [00:46<00:00,  1.33s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.03s/it]

                   all        114        697      0.819      0.637      0.704
0.328



      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

      34/50      14.1G     0.8427     0.7387      1.158        132        640:
100%|     | 35/35 [00:47<00:00,  1.35s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.08s/it]
```

```
                   all        114        697      0.835      0.633      0.708
0.337


      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

      35/50        14G     0.8299     0.7322      1.152        161        640:
100%|     | 35/35 [00:47<00:00,  1.36s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.08s/it]

                   all        114        697      0.835      0.615      0.695
0.339


      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

      36/50      14.1G      0.801     0.7144      1.128        162        640:
100%|     | 35/35 [00:46<00:00,  1.33s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.03s/it]

                   all        114        697      0.799      0.636       0.69
0.337


      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

      37/50        14G     0.7979     0.6967      1.132        149        640:
100%|     | 35/35 [00:48<00:00,  1.37s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.02s/it]

                   all        114        697      0.829      0.634      0.695
0.334


      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

      38/50      14.1G     0.7841     0.6739      1.124        109        640:
100%|     | 35/35 [00:46<00:00,  1.33s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.03s/it]

                   all        114        697      0.862      0.636      0.715
0.335
```

```
      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

      39/50      14.1G     0.7733     0.6561      1.108        208        640:
100%|     | 35/35 [00:47<00:00,  1.35s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.04s/it]

                   all        114        697      0.838      0.624      0.691
0.337



      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

      40/50      14.1G     0.7543     0.6369       1.09         88        640:
100%|     | 35/35 [00:46<00:00,  1.33s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.04s/it]

                   all        114        697      0.828      0.643      0.695
0.351


Closing dataloader mosaic
albumentations: Blur(p=0.01, blur_limit=(3, 7)), MedianBlur(p=0.01,
blur_limit=(3, 7)), ToGray(p=0.01), CLAHE(p=0.01, clip_limit=(1, 4.0),
tile_grid_size=(8, 8))

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

      41/50        14G     0.7784     0.6011      1.112         64        640:
100%|     | 35/35 [00:51<00:00,  1.47s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.06s/it]

                   all        114        697      0.871      0.602      0.687
0.333



      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

      42/50        14G     0.7627     0.5754      1.104         66        640:
100%|     | 35/35 [00:45<00:00,  1.31s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.04s/it]

                   all        114        697      0.825      0.628      0.705
0.351
```

```
      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

      43/50        14G     0.7311     0.5336      1.074         88        640:
100%|     | 35/35 [00:46<00:00,  1.34s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.09s/it]

                   all        114        697      0.867      0.623      0.712
0.365



      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

      44/50        14G     0.7036     0.5212      1.068         96        640:
100%|     | 35/35 [00:46<00:00,  1.33s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.09s/it]

                   all        114        697      0.879      0.625       0.71
0.379



      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

      45/50      13.9G     0.6852     0.5022      1.053         66        640:
100%|     | 35/35 [00:46<00:00,  1.33s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.04s/it]

                   all        114        697      0.855      0.651       0.72
0.36



      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

      46/50        14G     0.6757      0.479      1.044         95        640:
100%|     | 35/35 [00:46<00:00,  1.32s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.04s/it]

                   all        114        697      0.864      0.643      0.717
0.374



      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
      47/50        14G      0.663     0.4701      1.041        105        640:
100%|     | 35/35 [00:47<00:00,  1.35s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.03s/it]

                   all        114        697      0.826      0.648      0.708
0.364



      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

      48/50        14G     0.6383     0.4542      1.025         71        640:
100%|     | 35/35 [00:46<00:00,  1.32s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.03s/it]

                   all        114        697      0.816      0.658      0.711
0.374



      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

      49/50        14G     0.6243     0.4396      1.008         83        640:
100%|     | 35/35 [00:46<00:00,  1.33s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.04s/it]

                   all        114        697      0.843      0.646      0.718
0.377



      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size

      50/50        14G     0.6281     0.4385      1.003         74        640:
100%|     | 35/35 [00:46<00:00,  1.32s/it]
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|     | 4/4 [00:04<00:00,  1.05s/it]

                   all        114        697       0.86      0.654      0.722
0.375



50 epochs completed in 0.852 hours.
Optimizer stripped from runs/detect/yolov8x_ppe_css_50_epochs/weights/last.pt,
136.7MB
Optimizer stripped from runs/detect/yolov8x_ppe_css_50_epochs/weights/best.pt,
136.7MB
```

```
Validating runs/detect/yolov8x_ppe_css_50_epochs/weights/best.pt…
Ultralytics YOLOv8.1.10  Python-3.10.12 torch-2.1.0+cu121 CUDA:0 (Tesla T4,
15102MiB)
Model summary (fused): 268 layers, 68133198 parameters, 0 gradients, 257.4
GFLOPs
                 Class     Images  Instances      Box(P          R      mAP50
mAP50-95): 100%|      | 4/4 [00:07<00:00,  1.81s/it]
                   all        114        697      0.878      0.625       0.71
0.379
Speed: 0.5ms preprocess, 31.1ms inference, 0.0ms loss, 5.1ms postprocess per
image
Results saved to runs/detect/yolov8x_ppe_css_50_epochs
CPU times: user 33min 21s, sys: 8min 17s, total: 41min 39s
Wall time: 51min 53s
```

[26]:

```
ultralytics.utils.metrics.DetMetrics object with attributes:

ap_class_index: array([0, 1, 2, 3, 4, 5, 6, 7, 8, 9])
box: ultralytics.utils.metrics.Metric object
confusion_matrix: <ultralytics.utils.metrics.ConfusionMatrix object at
0x7c484fc99570>
curves: ['Precision-Recall(B)', 'F1-Confidence(B)', 'Precision-Confidence(B)',
'Recall-Confidence(B)']
curves_results: [[array([         0,    0.001001,    0.002002,    0.003003,
0.004004,    0.005005,    0.006006,    0.007007,    0.008008,    0.009009,
0.01001,    0.011011,    0.012012,    0.013013,    0.014014,    0.015015,
0.016016,    0.017017,    0.018018,    0.019019,     0.02002,    0.021021,
0.022022,    0.023023,
          0.024024,    0.025025,    0.026026,    0.027027,    0.028028,
0.029029,     0.03003,    0.031031,    0.032032,    0.033033,    0.034034,
0.035035,    0.036036,    0.037037,    0.038038,    0.039039,     0.04004,
0.041041,    0.042042,    0.043043,    0.044044,    0.045045,    0.046046,
0.047047,
          0.048048,    0.049049,     0.05005,    0.051051,    0.052052,
0.053053,    0.054054,    0.055055,    0.056056,    0.057057,    0.058058,
0.059059,     0.06006,    0.061061,    0.062062,    0.063063,    0.064064,
0.065065,    0.066066,    0.067067,    0.068068,    0.069069,     0.07007,
0.071071,
          0.072072,    0.073073,    0.074074,    0.075075,    0.076076,
0.077077,    0.078078,    0.079079,     0.08008,    0.081081,    0.082082,
0.083083,    0.084084,    0.085085,    0.086086,    0.087087,    0.088088,
0.089089,     0.09009,    0.091091,    0.092092,    0.093093,    0.094094,
0.095095,
          0.096096,    0.097097,    0.098098,    0.099099,      0.1001,
0.1011,      0.1021,      0.1031,      0.1041,     0.10511,     0.10611,
0.10711,     0.10811,     0.10911,     0.11011,     0.11111,     0.11211,
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0.11912,
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0.83984,
           0.84084,     0.84184,     0.84284,     0.84384,     0.84484,
0.84585,     0.84685,     0.84785,     0.84885,     0.84985,     0.85085,
0.85185,     0.85285,     0.85385,     0.85485,     0.85586,     0.85686,
0.85786,     0.85886,     0.85986,     0.86086,     0.86186,     0.86286,
0.86386,
           0.86486,     0.86587,     0.86687,     0.86787,     0.86887,
0.86987,     0.87087,     0.87187,     0.87287,     0.87387,     0.87487,
0.87588,     0.87688,     0.87788,     0.87888,     0.87988,     0.88088,
0.88188,     0.88288,     0.88388,     0.88488,     0.88589,     0.88689,
0.88789,
           0.88889,     0.88989,     0.89089,     0.89189,     0.89289,
0.89389,     0.89489,      0.8959,      0.8969,      0.8979,      0.8989,
0.8999,      0.9009,      0.9019,      0.9029,      0.9039,      0.9049,
0.90591,     0.90691,     0.90791,     0.90891,     0.90991,     0.91091,
0.91191,
           0.91291,     0.91391,     0.91491,     0.91592,     0.91692,
0.91792,     0.91892,     0.91992,     0.92092,     0.92192,     0.92292,
0.92392,     0.92492,     0.92593,     0.92693,     0.92793,     0.92893,
0.92993,     0.93093,     0.93193,     0.93293,     0.93393,     0.93493,
0.93594,
           0.93694,     0.93794,     0.93894,     0.93994,     0.94094,
0.94194,     0.94294,     0.94394,     0.94494,     0.94595,     0.94695,
0.94795,     0.94895,     0.94995,     0.95095,     0.95195,     0.95295,
0.95395,     0.95495,     0.95596,     0.95696,     0.95796,     0.95896,
0.95996,
           0.96096,     0.96196,     0.96296,     0.96396,     0.96496,
0.96597,     0.96697,     0.96797,     0.96897,     0.96997,     0.97097,
0.97197,     0.97297,     0.97397,     0.97497,     0.97598,     0.97698,
0.97798,     0.97898,     0.97998,     0.98098,     0.98198,     0.98298,
0.98398,
           0.98498,     0.98599,     0.98699,     0.98799,     0.98899,
0.98999,     0.99099,     0.99199,     0.99299,     0.99399,     0.99499,
0.996,       0.997,       0.998,       0.999,           1]), array([[
0.86076,     0.86076,     0.86076, …,          0,          0,          0],
       [    0.90476,     0.90476,     0.85714, …,          0,          0,
0],
       [    0.71014,     0.71014,     0.71014, …,           0,           0,
0],
       …,
       [    0.90244,     0.90244,     0.90244, …,           0,           0,
0],
       [    0.96364,     0.96364,     0.94545, …,           0,           0,
0],
       [    0.66667,     0.66667,     0.66667, …,           0,           0,
0]]), 'Confidence', 'Recall']]
fitness: 0.41218191984872277
keys: ['metrics/precision(B)', 'metrics/recall(B)', 'metrics/mAP50(B)',
'metrics/mAP50-95(B)']
maps: array([    0.47072,     0.53125,     0.29947,     0.27766,     0.31274,
0.3923,     0.34982,      0.3935,     0.48893,     0.27398])
names: {0: 'Hardhat', 1: 'Mask', 2: 'NO-Hardhat', 3: 'NO-Mask', 4: 'NO-Safety
Vest', 5: 'Person', 6: 'Safety Cone', 7: 'Safety Vest', 8: 'machinery', 9:
'vehicle'}
plot: True
results_dict: {'metrics/precision(B)': 0.878353021072615, 'metrics/recall(B)':
0.6251615993148584, 'metrics/mAP50(B)': 0.710474628943105,
'metrics/mAP50-95(B)': 0.3790382855049025, 'fitness': 0.41218191984872277}
save_dir: PosixPath('runs/detect/yolov8x_ppe_css_50_epochs')
speed: {'preprocess': 0.5319662261427495, 'inference': 31.13748316179242,
'loss': 0.0007570835581996985, 'postprocess': 5.107450903507702}
task: 'detect'
```

[27]:

```
img_properties
```

[27]:

```
{'width': 640, 'height': 640, 'channels': 3, 'dtype': dtype('uint8')}
```

[28]:

```
model.export(
    format = 'openvino',
    imgsz = (img_properties['height'], img_properties['width']),
    half = False,
    int8 = False,
    simplify = False,
    nms = False,
)
```

```
Ultralytics YOLOv8.1.10  Python-3.10.12 torch-2.1.0+cu121 CUDA:0 (Tesla T4,
15102MiB)
Model summary (fused): 268 layers, 68133198 parameters, 0 gradients, 257.4
GFLOPs

PyTorch: starting from
'runs/detect/yolov8x_ppe_css_50_epochs/weights/best.pt' with input shape (1, 3,
640, 640) BCHW and output shape(s) (1, 14, 8400) (130.4 MB)
```

```
requirements: Ultralytics requirement ['onnx>=1.12.0'] not found,
attempting AutoUpdate…
Collecting onnx>=1.12.0
  Downloading
onnx-1.15.0-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (15.7 MB)
                           15.7/15.7 MB 71.8 MB/s eta 0:00:00
Requirement already satisfied: numpy in /usr/local/lib/python3.10/dist-packages
(from onnx>=1.12.0) (1.23.5)
Requirement already satisfied: protobuf>=3.20.2 in
/usr/local/lib/python3.10/dist-packages (from onnx>=1.12.0) (3.20.3)
Installing collected packages: onnx
Successfully installed onnx-1.15.0

requirements: AutoUpdate success  9.9s, installed 1 package:
['onnx>=1.12.0']
requirements:  Restart runtime or rerun command for updates

to take effect



ONNX: starting export with onnx 1.15.0 opset 17…
ONNX: export success  15.6s, saved as
'runs/detect/yolov8x_ppe_css_50_epochs/weights/best.onnx' (260.1 MB)
requirements: Ultralytics requirement ['openvino-dev>=2023.0'] not
found, attempting AutoUpdate…
Collecting openvino-dev>=2023.0
  Downloading openvino_dev-2023.3.0-13775-py3-none-any.whl (5.9 MB)
                           5.9/5.9 MB 25.3 MB/s eta 0:00:00
Collecting addict>=2.4.0 (from openvino-dev>=2023.0)
  Downloading addict-2.4.0-py3-none-any.whl (3.8 kB)
Requirement already satisfied: defusedxml>=0.7.1 in
/usr/local/lib/python3.10/dist-packages (from openvino-dev>=2023.0) (0.7.1)
Collecting jstyleson>=0.0.2 (from openvino-dev>=2023.0)
  Downloading jstyleson-0.0.2.tar.gz (2.0 kB)
  Preparing metadata (setup.py): started
  Preparing metadata (setup.py): finished with status 'done'
Collecting networkx<=3.1.0 (from openvino-dev>=2023.0)
  Downloading networkx-3.1-py3-none-any.whl (2.1 MB)
                           2.1/2.1 MB 64.0 MB/s eta 0:00:00
Requirement already satisfied: numpy>=1.16.6 in /usr/local/lib/python3.10/dist-
packages (from openvino-dev>=2023.0) (1.23.5)
Requirement already satisfied: opencv-python in /usr/local/lib/python3.10/dist-
packages (from openvino-dev>=2023.0) (4.8.0.76)
Collecting openvino-telemetry>=2022.1.0 (from openvino-dev>=2023.0)
  Downloading openvino_telemetry-2023.2.1-py3-none-any.whl (23 kB)
Requirement already satisfied: pillow>=8.1.2 in /usr/local/lib/python3.10/dist-
packages (from openvino-dev>=2023.0) (9.4.0)
Requirement already satisfied: pyyaml>=5.4.1 in /usr/local/lib/python3.10/dist-
```

```
packages (from openvino-dev>=2023.0) (6.0.1)
Requirement already satisfied: requests>=2.25.1 in
/usr/local/lib/python3.10/dist-packages (from openvino-dev>=2023.0) (2.31.0)
Requirement already satisfied: scipy>=1.8 in /usr/local/lib/python3.10/dist-
packages (from openvino-dev>=2023.0) (1.11.4)
Collecting texttable>=1.6.3 (from openvino-dev>=2023.0)
  Downloading texttable-1.7.0-py2.py3-none-any.whl (10 kB)
Requirement already satisfied: tqdm>=4.54.1 in /usr/local/lib/python3.10/dist-
packages (from openvino-dev>=2023.0) (4.66.1)
Collecting openvino==2023.3.0 (from openvino-dev>=2023.0)
  Downloading openvino-2023.3.0-13775-cp310-cp310-manylinux2014_x86_64.whl (38.3
MB)
                           38.3/38.3 MB 187.8 MB/s eta
0:00:00
Requirement already satisfied: charset-normalizer<4,>=2 in
/usr/local/lib/python3.10/dist-packages (from requests>=2.25.1->openvino-
dev>=2023.0) (3.3.2)
Requirement already satisfied: idna<4,>=2.5 in /usr/local/lib/python3.10/dist-
packages (from requests>=2.25.1->openvino-dev>=2023.0) (3.6)
Requirement already satisfied: urllib3<3,>=1.21.1 in
/usr/local/lib/python3.10/dist-packages (from requests>=2.25.1->openvino-
dev>=2023.0) (2.0.7)
Requirement already satisfied: certifi>=2017.4.17 in
/usr/local/lib/python3.10/dist-packages (from requests>=2.25.1->openvino-
dev>=2023.0) (2024.2.2)
Building wheels for collected packages: jstyleson
  Building wheel for jstyleson (setup.py): started
  Building wheel for jstyleson (setup.py): finished with status 'done'
  Created wheel for jstyleson: filename=jstyleson-0.0.2-py3-none-any.whl
size=2385
sha256=4e03762859430a6cd617895ab1bb08a0b60fbdd4ac750a4ac8319fa44cbda335
  Stored in directory: /tmp/pip-ephem-wheel-cache-v84x3x33/wheels/12/51/c6/a1e75
1db88203e11c6d9ffe4683ca3d8c14b1479639bec1006
Successfully built jstyleson
Installing collected packages: texttable, openvino-telemetry, jstyleson, addict,
openvino, networkx, openvino-dev
  Attempting uninstall: networkx
    Found existing installation: networkx 3.2.1
    Uninstalling networkx-3.2.1:
      Successfully uninstalled networkx-3.2.1
Successfully installed addict-2.4.0 jstyleson-0.0.2 networkx-3.1
openvino-2023.3.0 openvino-dev-2023.3.0 openvino-telemetry-2023.2.1
texttable-1.7.0

requirements: AutoUpdate success  17.8s, installed 1 package:
['openvino-dev>=2023.0']
```

```
requirements:  Restart runtime or rerun command for updates

to take effect


OpenVINO: starting export with openvino
2023.3.0-13775-ceeafaf64f3-releases/2023/3…
OpenVINO: export success  20.1s, saved as
'runs/detect/yolov8x_ppe_css_50_epochs/weights/best_openvino_model/' (260.3 MB)

Export complete (36.8s)
Results saved to /content/runs/detect/yolov8x_ppe_css_50_epochs/weights
Predict:         yolo predict task=detect
model=runs/detect/yolov8x_ppe_css_50_epochs/weights/best_openvino_model
imgsz=640
Validate:        yolo val task=detect
model=runs/detect/yolov8x_ppe_css_50_epochs/weights/best_openvino_model
imgsz=640 data=./data.yaml
Visualize:       https://netron.app
```

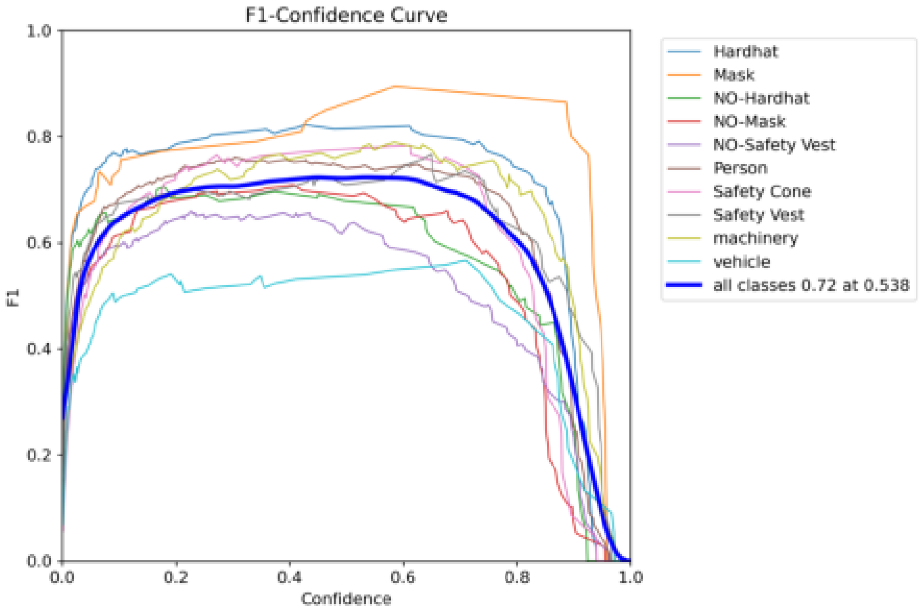
```
[28]: 'runs/detect/yolov8x_ppe_css_50_epochs/weights/best_openvino_model'
```

```
[29]: results_paths = [
          i for i in
          glob.glob(f'{CFG.OUTPUT_DIR}runs/detect/{CFG.BASE_MODEL}_{CFG.EXP_NAME}/*.
       ↪png') +
          glob.glob(f'{CFG.OUTPUT_DIR}runs/detect/{CFG.BASE_MODEL}_{CFG.EXP_NAME}/*.
       ↪jpg')
          if 'batch' not in i
      ]

      results_paths
```

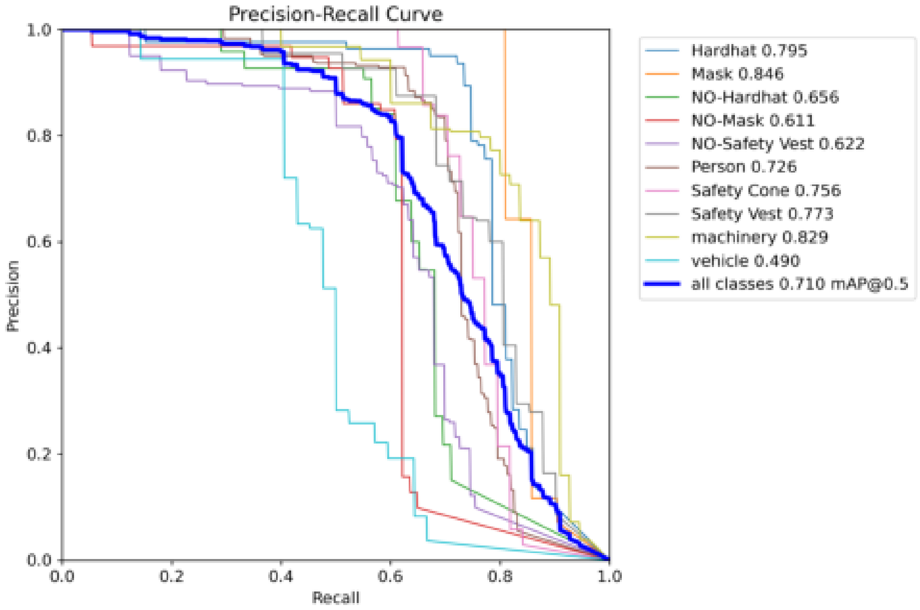
```
[29]: ['./runs/detect/yolov8x_ppe_css_50_epochs/confusion_matrix_normalized.png',
       './runs/detect/yolov8x_ppe_css_50_epochs/results.png',
       './runs/detect/yolov8x_ppe_css_50_epochs/confusion_matrix.png',
       './runs/detect/yolov8x_ppe_css_50_epochs/R_curve.png',
       './runs/detect/yolov8x_ppe_css_50_epochs/F1_curve.png',
       './runs/detect/yolov8x_ppe_css_50_epochs/P_curve.png',
       './runs/detect/yolov8x_ppe_css_50_epochs/PR_curve.png',
       './runs/detect/yolov8x_ppe_css_50_epochs/labels.jpg',
       './runs/detect/yolov8x_ppe_css_50_epochs/labels_correlogram.jpg']
```

```
[30]: for file in sorted(results_paths):
          print(file)
          display_image(file, print_info = False, hide_axis = True)
          print('\n')
```

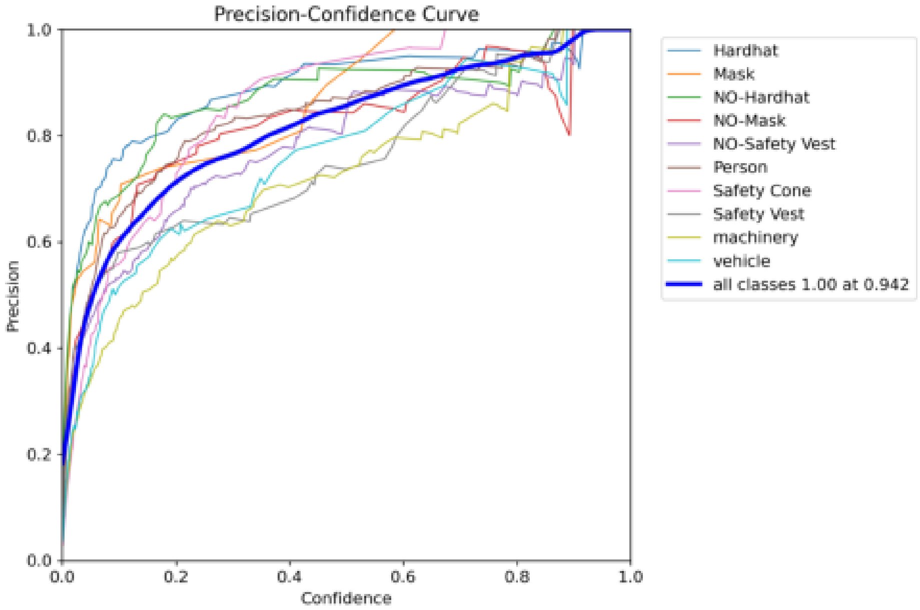
./runs/detect/yolov8x_ppe_css_50_epochs/F1_curve.png



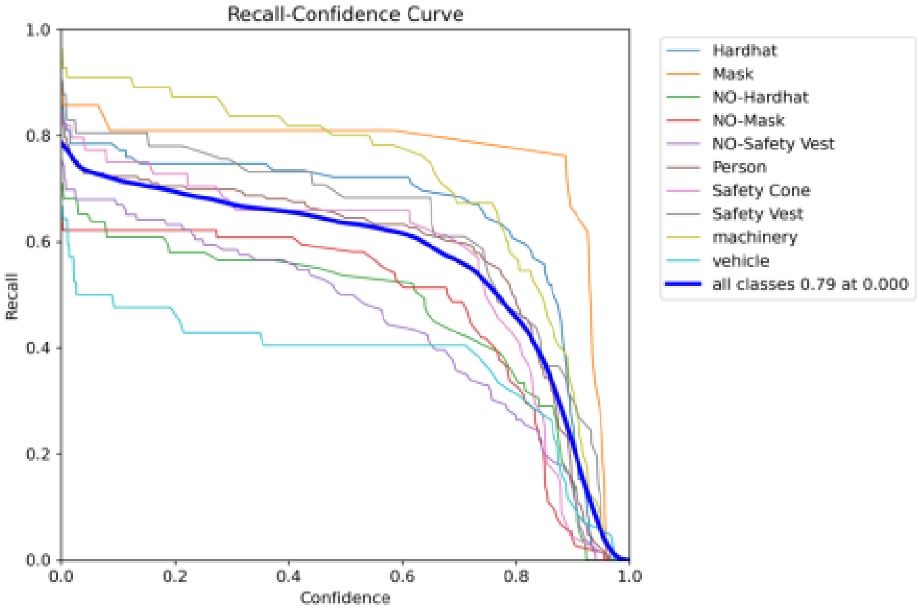
./runs/detect/yolov8x_ppe_css_50_epochs/PR_curve.png



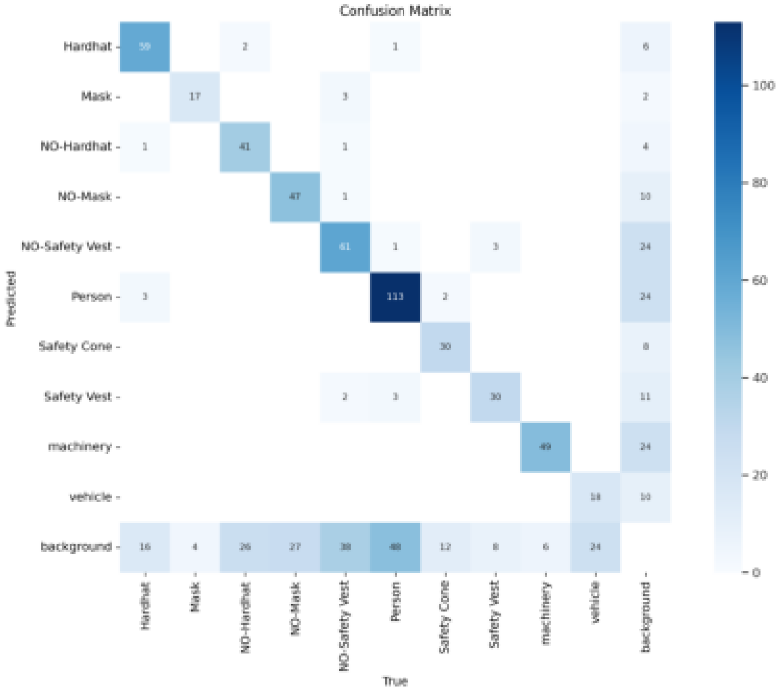
```
./runs/detect/yolov8x_ppe_css_50_epochs/P_curve.png
```



```
./runs/detect/yolov8x_ppe_css_50_epochs/R_curve.png
```

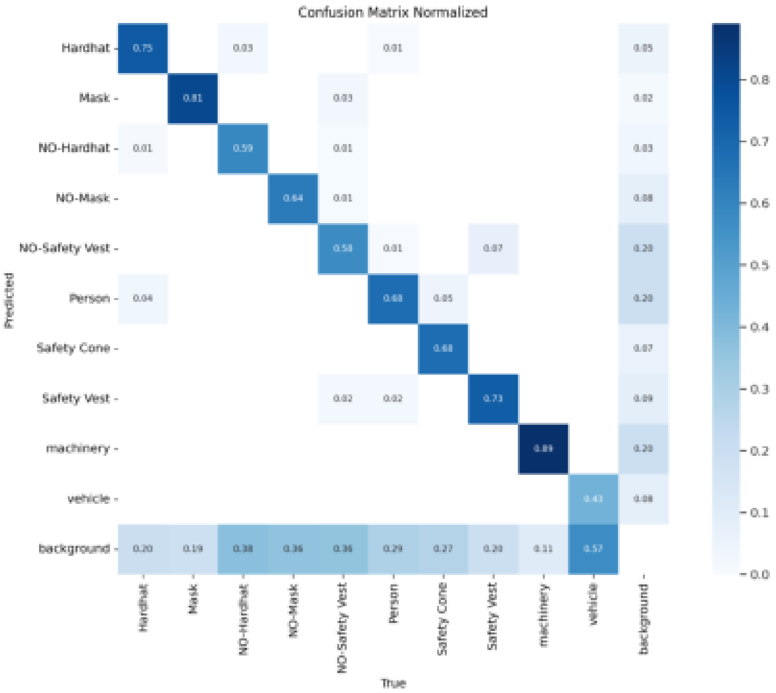


./runs/detect/yolov8x_ppe_css_50_epochs/confusion_matrix.png

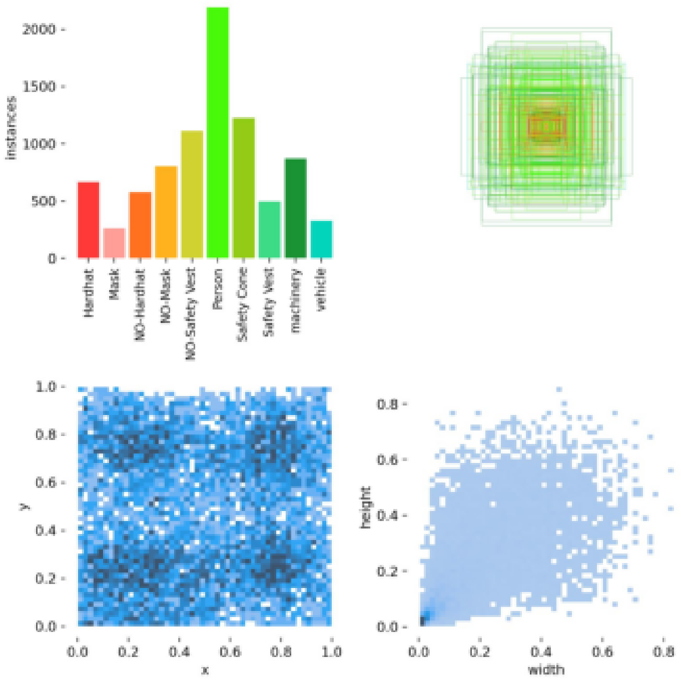


	Hardhat	Mask	NO-Hardhat	NO-Mask	NO-Safety Vest	Person	Safety Cone	Safety Vest	machinery	vehicle	background
Hardhat	59		2			1					6
Mask		17			3						2
NO-Hardhat	1		41		1						4
NO-Mask				47	1						10
NO-Safety Vest					61	1		3			24
Person	3					113	2				24
Safety Cone							30				8
Safety Vest					2	3		30			11
machinery									49		24
vehicle										18	10
background	16	4	26	27	38	48	12	8	6	24	

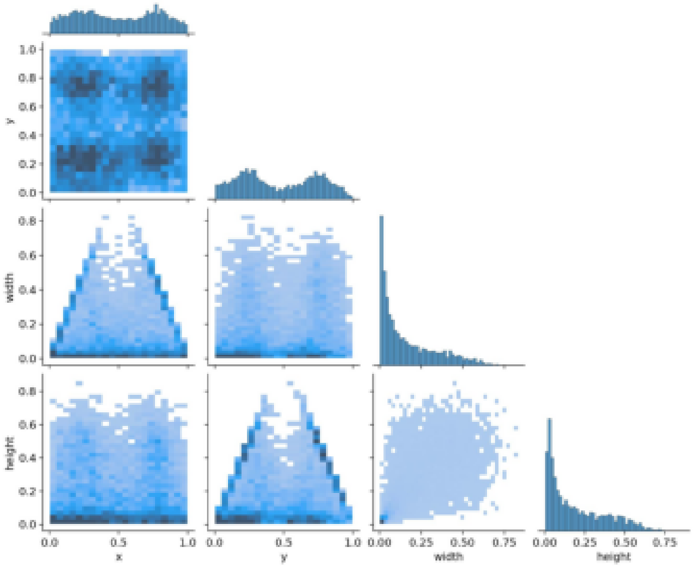
./runs/detect/yolov8x_ppe_css_50_epochs/confusion_matrix_normalized.png



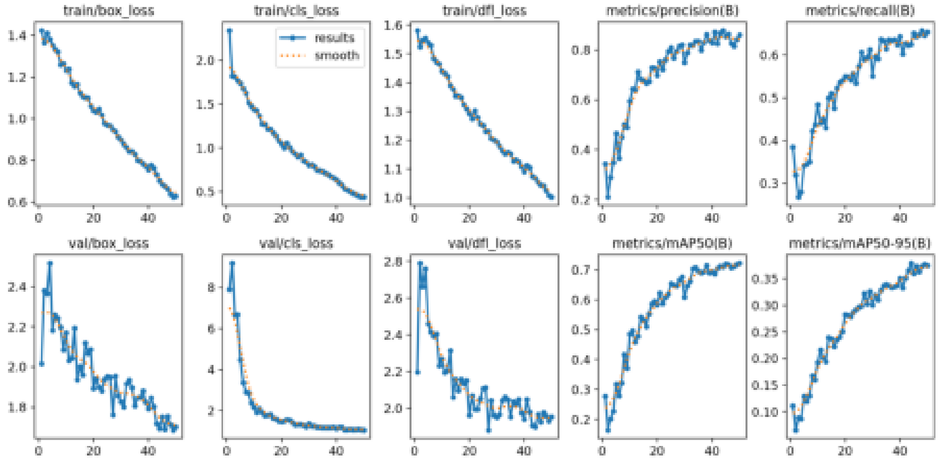
./runs/detect/yolov8x_ppe_css_50_epochs/labels.jpg



```
./runs/detect/yolov8x_ppe_css_50_epochs/labels_correlogram.jpg
```



./runs/detect/yolov8x_ppe_css_50_epochs/results.png



```
[31]: df = pd.read_csv(f'{CFG.OUTPUT_DIR}runs/detect/{CFG.BASE_MODEL}_{CFG.EXP_NAME}/
       ↪results.csv')
      df = df.rename(columns=lambda x: x.replace(" ", ""))
      df.to_csv(f'{CFG.OUTPUT_DIR}training_log_df.csv', index=False)
      df
```

```
[31]:     epoch  train/box_loss  train/cls_loss  train/dfl_loss  \
      0       1         1.42400         2.34370          1.5817
      1       2         1.36470         1.81960          1.5241
      2       3         1.41020         1.81300          1.5476
      3       4         1.38060         1.77140          1.5550
      4       5         1.35160         1.73770          1.5392
      5       6         1.33390         1.68040          1.5304
      6       7         1.32120         1.62450          1.4833
      7       8         1.25940         1.51610          1.4722
      8       9         1.26460         1.47450          1.4647
      9      10         1.23200         1.44220          1.4398
      10     11         1.23800         1.42610          1.4324
      11     12         1.17300         1.36560          1.4214
      12     13         1.15670         1.27530          1.3893
      13     14         1.16540         1.27080          1.3776
      14     15         1.12350         1.21700          1.3537
      15     16         1.10720         1.21620          1.3542
      16     17         1.10230         1.17200          1.3475
      17     18         1.09990         1.13750          1.3228
      18     19         1.06050         1.08460          1.3091
      19     20         1.04090         1.04270          1.2930
      20     21         1.03310         1.00120          1.2746
      21     22         1.04530         1.05370          1.3029
      22     23         1.01690         1.00320          1.2793
      23     24         0.97900         0.95822          1.2559
      24     25         0.96837         0.93330          1.2512
      25     26         0.96627         0.90041          1.2301
      26     27         0.94603         0.91813          1.2306
      27     28         0.93807         0.85403          1.2066
      28     29         0.91320         0.83754          1.2009
      29     30         0.89889         0.79952          1.1938
      30     31         0.87769         0.80790          1.1795
      31     32         0.86164         0.78464          1.1641
      32     33         0.84266         0.74699          1.1526
      33     34         0.84270         0.73874          1.1582
      34     35         0.82991         0.73224          1.1524
      35     36         0.80098         0.71440          1.1275
      36     37         0.79786         0.69670          1.1321
      37     38         0.78406         0.67392          1.1242
      38     39         0.77333         0.65614          1.1075
      39     40         0.75435         0.63694          1.0897
```

```
40     41         0.77842         0.60114          1.1121
41     42         0.76274         0.57545          1.1038
42     43         0.73110         0.53361          1.0741
43     44         0.70358         0.52125          1.0678
44     45         0.68521         0.50217          1.0535
45     46         0.67569         0.47905          1.0440
46     47         0.66302         0.47008          1.0412
47     48         0.63831         0.45417          1.0246
48     49         0.62432         0.43957          1.0081
49     50         0.62814         0.43851          1.0025

    metrics/precision(B)  metrics/recall(B)  metrics/mAP50(B)  \
0                0.34346            0.38447           0.27705
1                0.20989            0.31966           0.16448
2                0.28798            0.26784           0.20156
3                0.34736            0.27936           0.22656
4                0.46445            0.34183           0.31786
5                0.36602            0.34484           0.27855
6                0.45069            0.35016           0.32186
7                0.50019            0.42169           0.41671
8                0.48880            0.43661           0.37168
9                0.59518            0.48381           0.48595
10               0.64430            0.44216           0.49623
11               0.63793            0.44918           0.45970
12               0.71179            0.42954           0.47844
13               0.68305            0.49966           0.54233
14               0.67757            0.50968           0.53143
15               0.66626            0.47546           0.51072
16               0.67309            0.52305           0.55288
17               0.72820            0.53613           0.58613
18               0.72673            0.54115           0.59597
19               0.69929            0.54993           0.58344
20               0.75260            0.54956           0.62166
21               0.72033            0.54195           0.58699
22               0.76111            0.55689           0.60912
23               0.79446            0.53433           0.61972
24               0.80913            0.57311           0.65484
25               0.76696            0.60738           0.64854
26               0.79508            0.58912           0.64692
27               0.81486            0.59363           0.66584
28               0.82096            0.61284           0.67684
29               0.74940            0.55096           0.60839
30               0.78770            0.59616           0.64679
31               0.82005            0.59079           0.66296
32               0.81890            0.63687           0.70358
33               0.83464            0.63322           0.70826
34               0.83498            0.61465           0.69521
```

```
35               0.79885            0.63607           0.68989
36               0.82927            0.63422           0.69483
37               0.86230            0.63599           0.71450
38               0.83758            0.62425           0.69080
39               0.82789            0.64347           0.69454
40               0.87101            0.60212           0.68657
41               0.82541            0.62776           0.70464
42               0.86710            0.62254           0.71184
43               0.87864            0.62515           0.71044
44               0.85464            0.65119           0.72022
45               0.86426            0.64346           0.71741
46               0.82607            0.64759           0.70844
47               0.81603            0.65785           0.71145
48               0.84319            0.64606           0.71787
49               0.85958            0.65402           0.72241

    metrics/mAP50-95(B)  val/box_loss  val/cls_loss  val/dfl_loss    lr/pg0  \
0               0.11102        2.0152        7.8957        2.1976  0.000231
1               0.06580        2.3786        9.1811        2.7896  0.000460
2               0.08897        2.3663        6.6512        2.6620  0.000679
3               0.08665        2.5165        6.6706        2.7594  0.000672
4               0.12914        2.1826        4.4810        2.4594  0.000672
5               0.11958        2.2584        3.3641        2.4151  0.000657
6               0.12982        2.2415        2.9022        2.3924  0.000643
7               0.16760        2.1972        2.8539        2.4043  0.000629
8               0.15997        2.0860        2.3836        2.2318  0.000615
9               0.19240        2.1700        2.1563        2.2686  0.000601
10              0.21630        2.0320        1.9025        2.1934  0.000587
11              0.20192        2.0441        2.1058        2.2045  0.000573
12              0.19368        2.1934        1.9139        2.3128  0.000558
13              0.23996        1.9361        1.7618        2.0598  0.000544
14              0.23714        2.0019        1.7653        2.1584  0.000530
15              0.22223        1.9603        1.8115        2.0970  0.000516
16              0.23509        2.1195        1.6430        2.1570  0.000502
17              0.24035        2.0681        1.5976        2.1344  0.000488
18              0.25075        2.0870        1.4815        2.1505  0.000474
19              0.28278        1.8934        1.4729        1.9615  0.000460
20              0.28106        1.9429        1.4731        2.0685  0.000445
21              0.27855        1.8989        1.5589        1.9945  0.000431
22              0.28680        1.8814        1.5362        1.9947  0.000417
23              0.29233        1.9387        1.4280        2.0528  0.000403
24              0.29649        1.9527        1.3053        2.1077  0.000389
25              0.29889        1.9489        1.3341        2.1112  0.000375
26              0.32235        1.7604        1.3252        1.8822  0.000361
27              0.30297        1.9539        1.2862        2.0418  0.000346
28              0.32603        1.8568        1.2129        1.9612  0.000332
29              0.30017        1.8268        1.3727        1.9500  0.000318
```

```
30                 0.31928          1.8006          1.2481          1.9673  0.000304
31                 0.31052          1.9173          1.2434          2.0422  0.000290
32                 0.32806          1.9349          1.1861          2.0615  0.000276
33                 0.33689          1.8971          1.1872          2.0469  0.000262
34                 0.33942          1.8075          1.1726          1.9537  0.000247
35                 0.33694          1.8470          1.1727          2.0363  0.000233
36                 0.33368          1.8493          1.1799          2.0197  0.000219
37                 0.33525          1.8810          1.1647          2.0488  0.000205
38                 0.33701          1.8240          1.1879          1.9742  0.000191
39                 0.35075          1.7913          1.1267          1.9412  0.000177
40                 0.33280          1.8476          1.1831          2.0485  0.000163
41                 0.35148          1.8027          1.1901          1.9787  0.000149
42                 0.36540          1.7167          1.0667          1.9064  0.000134
43                 0.37921          1.6930          1.0782          1.8980  0.000120
44                 0.36002          1.7508          1.1016          1.9657  0.000106
45                 0.37350          1.6908          1.0787          1.9249  0.000092
46                 0.36381          1.7540          1.0839          1.9772  0.000078
47                 0.37355          1.7117          1.0866          1.9578  0.000064
48                 0.37677          1.6865          1.0742          1.9298  0.000050
49                 0.37462          1.7014          1.0614          1.9525  0.000035

      lr/pg1    lr/pg2
0   0.000231  0.000231
1   0.000460  0.000460
2   0.000679  0.000679
3   0.000672  0.000672
4   0.000672  0.000672
5   0.000657  0.000657
6   0.000643  0.000643
7   0.000629  0.000629
8   0.000615  0.000615
9   0.000601  0.000601
10  0.000587  0.000587
11  0.000573  0.000573
12  0.000558  0.000558
13  0.000544  0.000544
14  0.000530  0.000530
15  0.000516  0.000516
16  0.000502  0.000502
17  0.000488  0.000488
18  0.000474  0.000474
19  0.000460  0.000460
20  0.000445  0.000445
21  0.000431  0.000431
22  0.000417  0.000417
23  0.000403  0.000403
24  0.000389  0.000389
```

```
25  0.000375  0.000375
26  0.000361  0.000361
27  0.000346  0.000346
28  0.000332  0.000332
29  0.000318  0.000318
30  0.000304  0.000304
31  0.000290  0.000290
32  0.000276  0.000276
33  0.000262  0.000262
34  0.000247  0.000247
35  0.000233  0.000233
36  0.000219  0.000219
37  0.000205  0.000205
38  0.000191  0.000191
39  0.000177  0.000177
40  0.000163  0.000163
41  0.000149  0.000149
42  0.000134  0.000134
43  0.000120  0.000120
44  0.000106  0.000106
45  0.000092  0.000092
46  0.000078  0.000078
47  0.000064  0.000064
48  0.000050  0.000050
49  0.000035  0.000035
```

[32]:

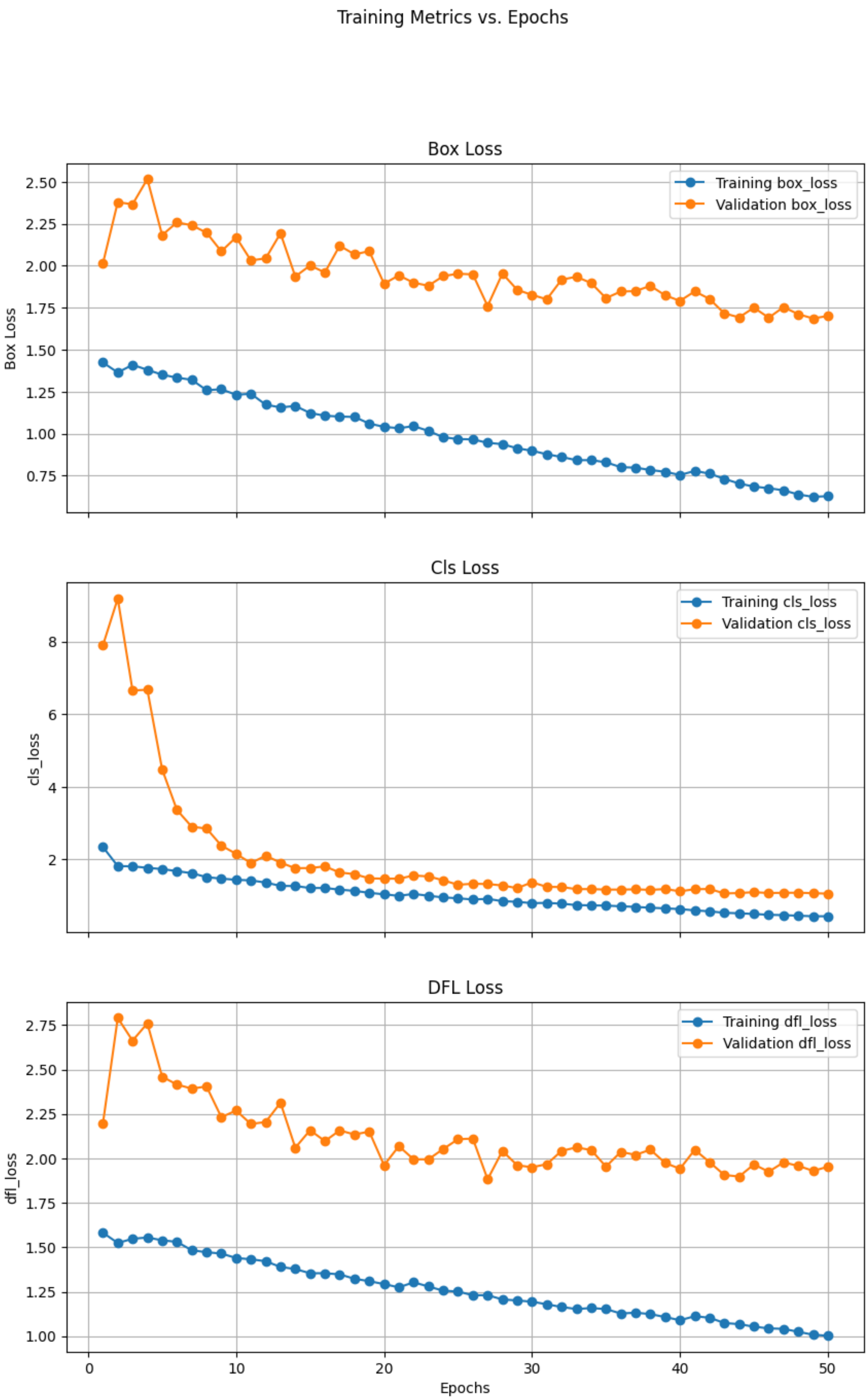
```
print('*'*50)
print('\nBest Training Box loss: ', df['train/box_loss'].min(), ', on epoch: ',␣
 ↪df['train/box_loss'].argmin() + 1, '\n')
print('\nBest Validation Box loss: ', df['val/box_loss'].min(), ', on epoch: ',␣
 ↪df['val/box_loss'].argmin() + 1, '\n')

print('='*50)
print('\nBest Training Cls loss: ', df['train/cls_loss'].min(), ', on epoch: ',␣
 ↪df['train/box_loss'].argmin() + 1, '\n')
print('\nBest Validation Cls loss: ', df['val/cls_loss'].min(), ', on epoch: ',␣
 ↪df['val/box_loss'].argmin() + 1, '\n')

print('='*50)
print('\nBest Training DFL loss: ', df['train/dfl_loss'].min(), ', on epoch: ',␣
 ↪df['train/box_loss'].argmin() + 1, '\n')
print('\nBest Validation DFL loss: ', df['val/dfl_loss'].min(), ', on epoch: ',␣
 ↪df['val/box_loss'].argmin() + 1, '\n')
```

```
**************************************************

Best Training Box loss:  0.62432 , on epoch:  49
Best Validation Box loss:  1.6865 , on epoch:  49

==================================================

Best Training Cls loss:  0.43851 , on epoch:  49


Best Validation Cls loss:  1.0614 , on epoch:  49

==================================================

Best Training DFL loss:  1.0025 , on epoch:  49


Best Validation DFL loss:  1.8822 , on epoch:  49
```

[33]:

```python
fig, (ax1, ax2, ax3) = plt.subplots(3, 1, figsize=(10, 15), sharex=True)

### Training and Validation Box Loss
ax1.set_title('Box Loss')
ax1.plot(df['epoch'], df['train/box_loss'], label='Training box_loss',␣
 ↪marker='o', linestyle='-')
ax1.plot(df['epoch'], df['val/box_loss'], label='Validation box_loss',␣
 ↪marker='o', linestyle='-')
ax1.set_ylabel('Box Loss')
ax1.legend()
ax1.grid(True)

### Training and Validation cls_loss
ax2.set_title('Cls Loss')
ax2.plot(df['epoch'], df['train/cls_loss'], label='Training cls_loss',␣
 ↪marker='o', linestyle='-')
ax2.plot(df['epoch'], df['val/cls_loss'], label='Validation cls_loss',␣
 ↪marker='o', linestyle='-')
ax2.set_ylabel('cls_loss')
ax2.legend()
ax2.grid(True)

### Training and Validation dfl_loss
ax3.set_title('DFL Loss')
ax3.plot(df['epoch'], df['train/dfl_loss'], label='Training dfl_loss',␣
 ↪marker='o', linestyle='-')
ax3.plot(df['epoch'], df['val/dfl_loss'], label='Validation dfl_loss',␣
 ↪marker='o', linestyle='-')
```

```
ax3.set_xlabel('Epochs')
ax3.set_ylabel('dfl_loss')
ax3.legend()
ax3.grid(True)

plt.suptitle('Training Metrics vs. Epochs')
plt.show()
```


Training Metrics vs. Epochs
Box Loss
Training box_loss
Validation box_loss
Box Loss
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
Cls Loss
Training cls_loss
Validation cls_loss
cls_loss
8
6
4
2
DFL Loss
Training dfl_loss
Validation dfl_loss
dfl_loss
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0
10
20
30
40
50
Epochs

[34]:

```
validation_results_paths = [
    i for i in
    glob.glob(f'{CFG.OUTPUT_DIR}runs/detect/{CFG.BASE_MODEL}_{CFG.EXP_NAME}/*.
 ↪png') +
    glob.glob(f'{CFG.OUTPUT_DIR}runs/detect/{CFG.BASE_MODEL}_{CFG.EXP_NAME}/*.
 ↪jpg')
    if 'val_batch' in i
]

len(validation_results_paths)
```

[34]:

```
6
```

[35]:

```
if len(validation_results_paths) >= 1:
    print(validation_results_paths[-1])
```

```
./runs/detect/yolov8x_ppe_css_50_epochs/val_batch0_labels.jpg
```

[36]:

```
### check predictions or labels from a random validation batch
if len(validation_results_paths) >= 1:
    val_img_path = random.choice(validation_results_paths)
    print(val_img_path)
    display_image(val_img_path, print_info = False, hide_axis = True)
```

```
./runs/detect/yolov8x_ppe_css_50_epochs/val_batch2_labels.jpg
```

Safety Cone
Person
Hardhat
NO-Mask
NO-Safety Vest
machinery
NO-Safety Vest
Person
Person
NO-Safety Vest
Safety Cone
Hardhat
Person
NO-Mask
NO-Safety Vest
Person
Person
Person
Person
Hardhat
NO-Safety Vest
Person
NO-Mask
NO-Safety Vest
Person
Hardhat
NO-Hardhat
Person
NO-Hardhat
NO-Mask
NO-Safety Vest
Person
NO-Hardhat
NO-Mask
NO-Safety Vest
Person
Person
NO-Safety Vest
NO-Mask
NO-Safety Vest
Person
Hardhat
NO-Safety Vest
2009_003991_jpg
Person
Hardhat
NO-Safety Vest
Safety Cone
Safety Cone
Person
Mask
Safety Vest
Person
Safety Vest
Hardhat
Person
Safety Vest
NO-Mask
Person
Safety Vest