In [ ]:
```
# Install the ultralytics package using pip
!pip install ultralytics --upgrade
```

In [ ]:
```
import cv2
import pandas as pd
import numpy as np
from matplotlib import pyplot as plt
```

In [ ]:
```
### 영상 출력 함수
def fn_imshow(img, axis='on', **kwargs):
    img_rgb = cv2.cvtColor(img, cv2.COLOR_BGR2RGB)
    plt.figure(**kwargs)
    if axis!='on': plt.axis('off')
    plt.imshow(img_rgb)
    plt.show()
```

▢ Train

- https://docs.ultralytics.com/modes/train/
- 사용자 지정 데이터 세트에서 YOLOv8 모델을 학습
- 지정된 데이터 세트와 하이퍼파라미터를 사용하여 훈련

■ Usage Examples

- 이미지 크기(image size) 640에서 100 epoch 동안 COCO128 데이터 세트에서 YOLOv8n을 교육(training)

Single-GPU and CPU Training Example

Device is determined automatically. If a GPU is available then it will be used, otherwise training will start on CPU.

Python CLI

```
from ultralytics import YOLO

# Load a model
model = YOLO('yolov8n.yaml')  # build a new model from YAML
model = YOLO('yolov8n.pt')  # load a pretrained model (recommended for training)
model = YOLO('yolov8n.yaml').load('yolov8n.pt')  # build from YAML and transfer weights

# Train the model
model.train(data='coco128.yaml', epochs=100, imgsz=640)
```

Single-GPU and CPU Training Example

Device is determined automatically. If a GPU is available then it will be used, otherwise training will start on CPU.

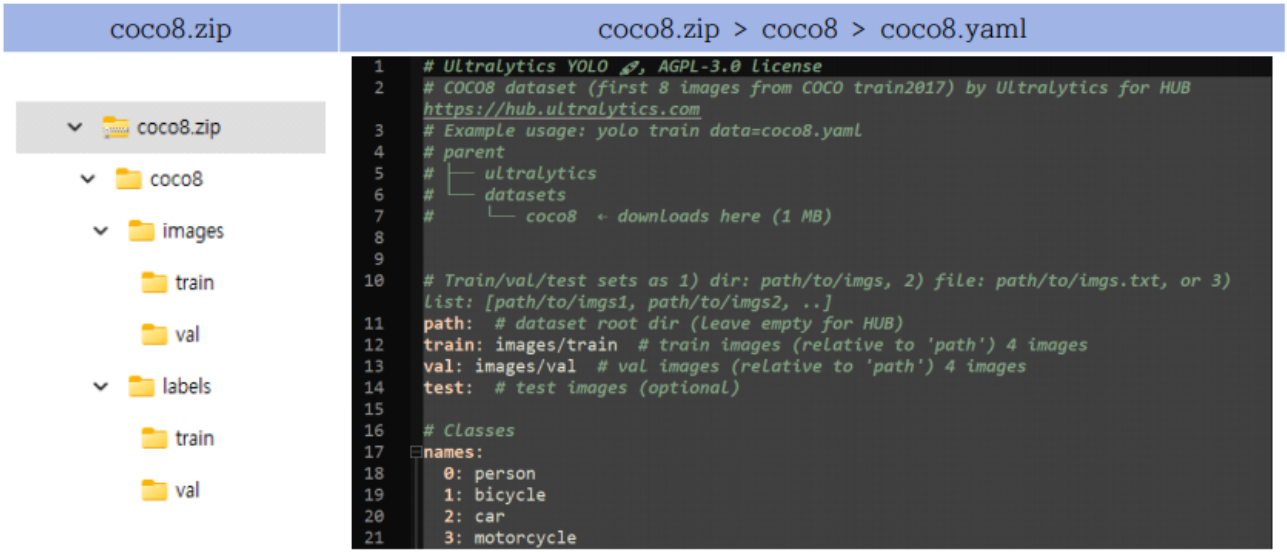
Python CLI

```
# Build a new model from YAML and start training from scratch
yolo detect train data=coco128.yaml model=yolov8n.yaml epochs=100 imgsz=640

# Start training from a pretrained *.pt model
yolo detect train data=coco128.yaml model=yolov8n.pt epochs=100 imgsz=640

# Build a new model from YAML, transfer pretrained weights to it and start training
yolo detect train data=coco128.yaml model=yolov8n.yaml pretrained=yolov8n.pt epochs=100 imgsz=640
```

■ Example dataset

- coco8.zip

- https://github.com/ultralytics/hub/raw/master/example_datasets/coco8.zip



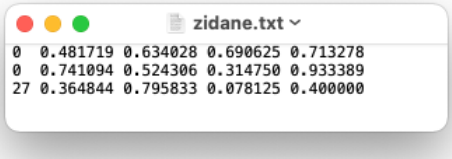
■ Labeling

- 영상의 객체의 종류와 영역에 대한 정보를 저장하는 과정으로 모형의 성능에 크게 영향을 줌
  - 많은 시간과 노력이 필요
- 라벨링 방법
  - 이미지당 하나의 텍스트 파일: 각 이미지당 하나의 레이블 파일(이미지 파일과 이름이 같고 확장자가 ".txt"인 해당 텍스트 파일)
  - 객체당 한 행: 텍스트 파일의 각 행은 이미지의 객체 인스턴스 하나에 해당

○ Object detection dataset format

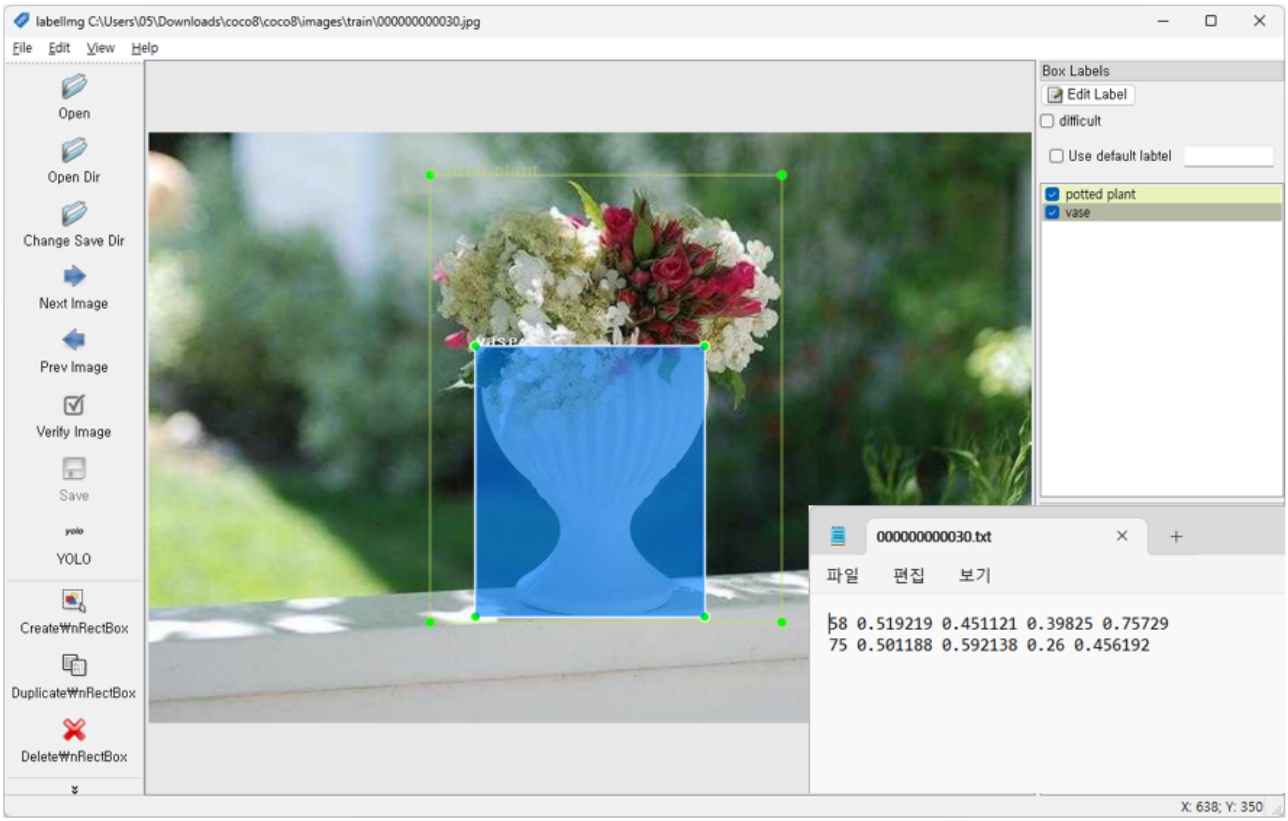
- https://docs.ultralytics.com/datasets/detect/
- Object class index와 Object box coordinates
  - `<class-index> <x_center> <y_center> <width> <height>`
  - Object class index: 개체의 클래스를 나타내는 정수(예: 0=사람, 1=자동차 등)
  - Object box coordinates: **normalized xywh** format (0과 1 사이의 값)

The label file corresponding to the above image contains 2 persons (class `0`) and a tie (class `27`):



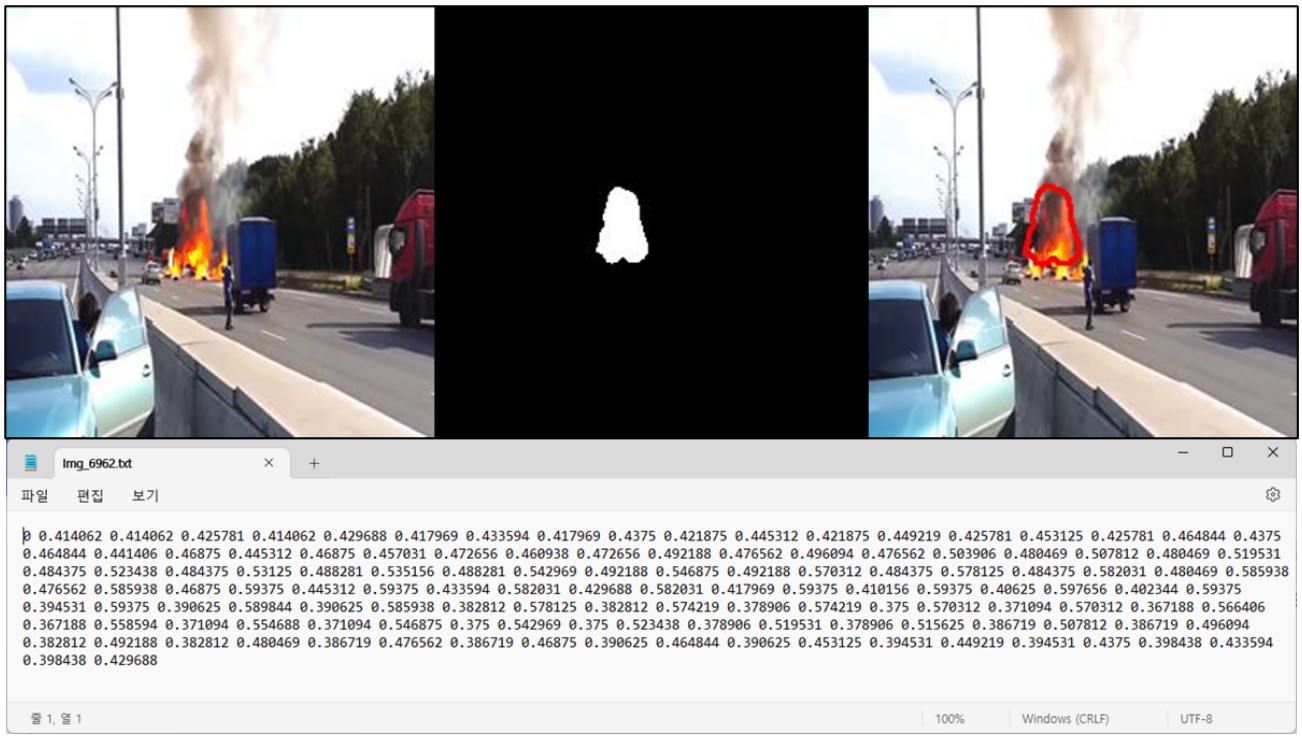
○ Labeling example

- 하나의 이미지당 하나의 레이블(txt) 파일: 동일한 파일명 사용
  - image file: `coco8\images\train\000000000030.jpg`
  - label file: `coco8\labels\train\000000000030.txt`



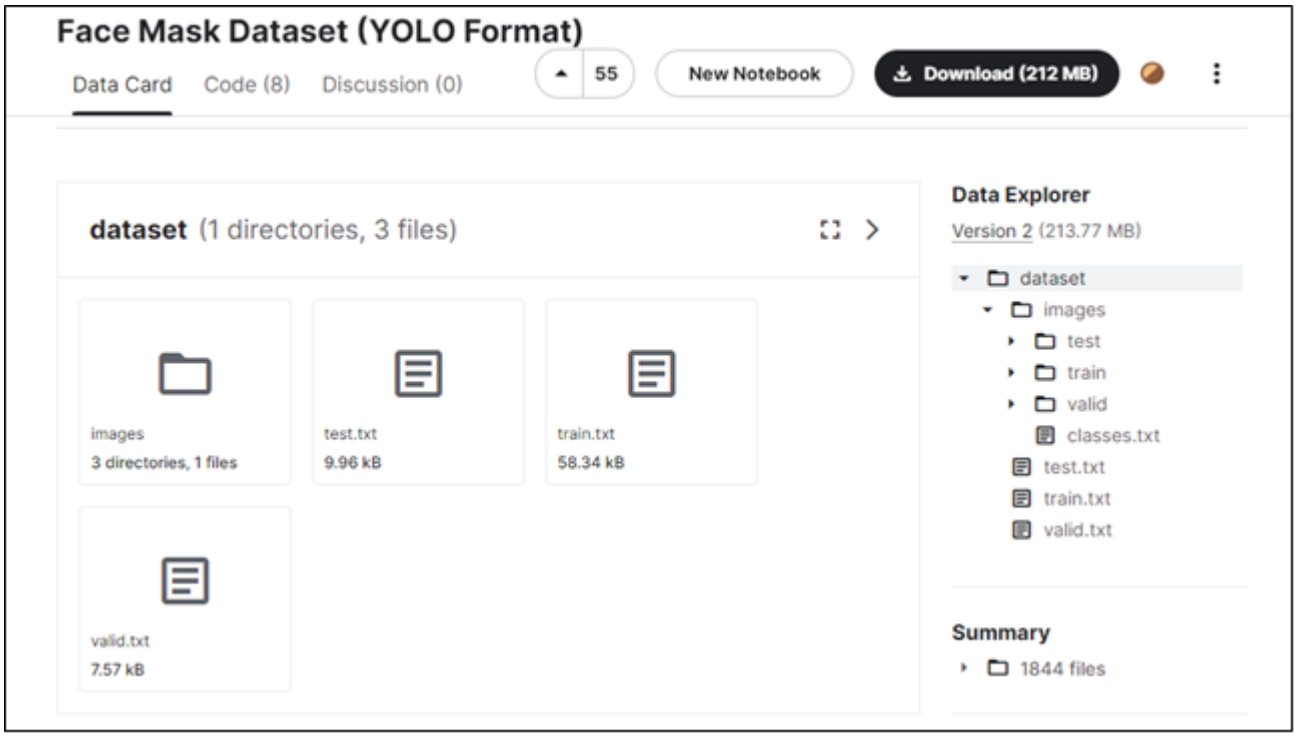
○ Segmentation dataset format

- https://docs.ultralytics.com/datasets/segment/
- Object class index와 Object bounding coordinates
  - `<class-index> <x1> <y1> <x2> <y2> ... <xn> <yn>`
  - Object class index: 개체의 클래스를 나타내는 정수(예: 0=사람, 1=자동차 등)
  - Object bounding coordinates: 0과 1 사이로 정규화된 마스크 영역 주변의 경계 좌표
- Tip
  - 각 행의 길이는 같을 필요가 없습니다.
  - 각 분할 레이블에는 최소 3개의 xy 점이 있어야 합니다.
    - `<class-index> <x1> <y1> <x2> <y2> <x3> <y3>`



▣ Face Mask Dataset (YOLO Format) – kaggle

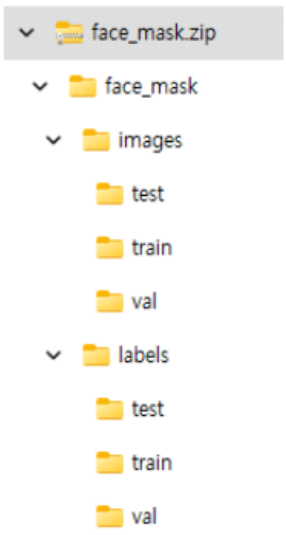
- https://www.kaggle.com/datasets/aditya276/face-mask-dataset-yolo-format



○ Dataset 만들기

- 강의자료(Google Drive) > YOLOv8 > face_mask.zip
  - Download: https://drive.google.com/file/d/1p-VKfhsk0737t-K0JbknKHVOdaKT58Q7/view?usp=drive_link

face_mask.zip



face_mask.zip > face_mask > face_mask.yaml

```yaml
# Ultralytics YOLO 🚀, AGPL-3.0 license
# COCO8 dataset (first 8 images from COCO train2017) by Ultralytics for HUB
https://hub.ultralytics.com
# Example usage: yolo train data=coco8.yaml
# parent
# ├── ultralytics
# └── datasets
#     └── coco8  ← downloads here (1 MB)


# Train/val/test sets as 1) dir: path/to/imgs, 2) file: path/to/imgs.txt, or 3) list: [path/to/imgs1, path/to/imgs2, ..]
path:  # dataset root dir (leave empty for HUB)
train: images/train  # train images (relative to 'path') 4 images
val: images/val  # val images (relative to 'path') 4 images
test:  images/test  # test images (optional)

# Classes
names:
  0: no_mask
  1: mask

# Download script/URL (optional)
download:
```

▶ Training

In [1]:
```
from ultralytics import YOLO, checks
```

In [2]:
```
checks()
```

```
Ultralytics YOLOv8.0.147  Python-3.10.9 torch-2.0.0+cu117 CUDA:0 (NVIDIA GeForce RTX 3090, 24576MiB)
Setup complete  (32 CPUs, 127.9 GB RAM, 428.0/1862.3 GB disk)
```

In [3]:
```
# Load a model
model = YOLO('yolov8n.yaml').load('yolov8n.pt')  # build from YAML and transfer weights
```

```
                   from  n    params  module                                       arguments
  0                  -1  1       464  ultralytics.nn.modules.conv.Conv             [3, 16, 3,
2]
  1                  -1  1      4672  ultralytics.nn.modules.conv.Conv             [16, 32, 3,
2]
  2                  -1  1      7360  ultralytics.nn.modules.block.C2f             [32, 32, 1,
True]
  3                  -1  1     18560  ultralytics.nn.modules.conv.Conv             [32, 64, 3,
2]
  4                  -1  2     49664  ultralytics.nn.modules.block.C2f             [64, 64, 2,
True]
  5                  -1  1     73984  ultralytics.nn.modules.conv.Conv             [64, 128, 3,
2]
  6                  -1  2    197632  ultralytics.nn.modules.block.C2f             [128, 128,
2, True]
  7                  -1  1    295424  ultralytics.nn.modules.conv.Conv             [128, 256,
3, 2]
  8                  -1  1    460288  ultralytics.nn.modules.block.C2f             [256, 256,
1, True]
  9                  -1  1    164608  ultralytics.nn.modules.block.SPPF            [256, 256,
5]
 10                  -1  1         0  torch.nn.modules.upsampling.Upsample         [None, 2, 'n
earest']
 11             [-1, 6]  1         0  ultralytics.nn.modules.conv.Concat           [1]
 12                  -1  1    148224  ultralytics.nn.modules.block.C2f             [384, 128,
1]
 13                  -1  1         0  torch.nn.modules.upsampling.Upsample         [None, 2, 'n
earest']
 14             [-1, 4]  1         0  ultralytics.nn.modules.conv.Concat           [1]
 15                  -1  1     37248  ultralytics.nn.modules.block.C2f             [192, 64, 1]
 16                  -1  1     36992  ultralytics.nn.modules.conv.Conv             [64, 64, 3,
2]
 17            [-1, 12]  1         0  ultralytics.nn.modules.conv.Concat           [1]
 18                  -1  1    123648  ultralytics.nn.modules.block.C2f             [192, 128,
1]
 19                  -1  1    147712  ultralytics.nn.modules.conv.Conv             [128, 128,
3, 2]
 20             [-1, 9]  1         0  ultralytics.nn.modules.conv.Concat           [1]
 21                  -1  1    493056  ultralytics.nn.modules.block.C2f             [384, 256,
1]
 22        [15, 18, 21]  1    897664  ultralytics.nn.modules.head.Detect           [80, [64, 12
8, 256]]
YOLOv8n summary: 225 layers, 3157200 parameters, 3157184 gradients

Transferred 355/355 items from pretrained weights
```

In [7]:

```
# Train the model
model.train(data=r"C:WUsersWO5WDownloadsWface_maskWface_maskWface_mask.yaml", epochs=100, imgsz
```

```
Ultralytics YOLOv8.0.147  Python-3.10.9 torch-2.0.0+cu117 CUDA:0 (NVIDIA GeForce RTX 3090, 2457
6MiB)
engine\trainer: task=detect, mode=train, model=yolov8n.yaml, data=C:\Users\05\Downloads\face_
mask\face_mask\face_mask.yaml, epochs=100, patience=50, batch=16, imgsz=640, save=True, save_pe
riod=-1, cache=False, device=None, workers=8, project=None, name=None, exist_ok=False, pretrain
ed=True, optimizer=auto, verbose=True, seed=0, deterministic=True, single_cls=False, rect=Fals
e, cos_lr=False, close_mosaic=10, resume=False, amp=True, fraction=1.0, profile=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, show=False, sa
ve_txt=False, save_conf=False, save_crop=False, show_labels=True, show_conf=True, vid_stride=1,
line_width=None, visualize=False, augment=False, agnostic_nms=False, classes=None, retina_masks
=False, boxes=True, format=torchscript, keras=False, optimize=False, int8=False, dynamic=False,
simplify=False, opset=None, workspace=4, nms=False, lr0=0.01, 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, degr
ees=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, cfg=None, tracker=botsort.yaml, save_dir=runs\detect\train5

                   from  n    params  module                                       arguments
  0                  -1  1       464  ultralytics.nn.modules.conv.Conv             [3, 16, 3,
2]
  1                  -1  1      4672  ultralytics.nn.modules.conv.Conv             [16, 32, 3,
2]
  2                  -1  1      7360  ultralytics.nn.modules.block.C2f             [32, 32, 1,
True]
  3                  -1  1     18560  ultralytics.nn.modules.conv.Conv             [32, 64, 3,
2]
  4                  -1  2     49664  ultralytics.nn.modules.block.C2f             [64, 64, 2,
True]
  5                  -1  1     73984  ultralytics.nn.modules.conv.Conv             [64, 128, 3,
2]
  6                  -1  2    197632  ultralytics.nn.modules.block.C2f             [128, 128,
2, True]
  7                  -1  1    295424  ultralytics.nn.modules.conv.Conv             [128, 256,
3, 2]
  8                  -1  1    460288  ultralytics.nn.modules.block.C2f             [256, 256,
1, True]
  9                  -1  1    164608  ultralytics.nn.modules.block.SPPF            [256, 256,
5]
 10                  -1  1         0  torch.nn.modules.upsampling.Upsample         [None, 2, 'n
earest']
 11             [-1, 6]  1         0  ultralytics.nn.modules.conv.Concat           [1]
 12                  -1  1    148224  ultralytics.nn.modules.block.C2f             [384, 128,
1]
 13                  -1  1         0  torch.nn.modules.upsampling.Upsample         [None, 2, 'n
earest']
 14             [-1, 4]  1         0  ultralytics.nn.modules.conv.Concat           [1]
 15                  -1  1     37248  ultralytics.nn.modules.block.C2f             [192, 64, 1]
 16                  -1  1     36992  ultralytics.nn.modules.conv.Conv             [64, 64, 3,
2]
 17            [-1, 12]  1         0  ultralytics.nn.modules.conv.Concat           [1]
 18                  -1  1    123648  ultralytics.nn.modules.block.C2f             [192, 128,
1]
 19                  -1  1    147712  ultralytics.nn.modules.conv.Conv             [128, 128,
3, 2]
 20             [-1, 9]  1         0  ultralytics.nn.modules.conv.Concat           [1]
 21                  -1  1    493056  ultralytics.nn.modules.block.C2f             [384, 256,
1]
 22        [15, 18, 21]  1    751702  ultralytics.nn.modules.head.Detect           [2, [64, 12
8, 256]]
YOLOv8n summary: 225 layers, 3011238 parameters, 3011222 gradients

Transferred 355/355 items from pretrained weights
AMP: running Automatic Mixed Precision (AMP) checks with YOLOv8n...
AMP: checks passed
train: Scanning C:\Users\05\Downloads\face_mask\face_mask\labels\train... 697 images, 0 backgr
ounds, 0 corrupt: 100%|██
train: New cache created: C:\Users\05\Downloads\face_mask\face_mask\labels\train.cache
```

```
val: Scanning C:₩Users₩05₩Downloads₩face_mask₩face_mask₩labels₩val... 100 images, 0 backgrounds, 0 corrupt: 100%|██████
val: New cache created: C:₩Users₩05₩Downloads₩face_mask₩face_mask₩labels₩val.cache
Plotting labels to runs₩detect₩train5₩labels.jpg...
optimizer: AdamW(lr=0.001667, momentum=0.9) with parameter groups 57 weight(decay=0.0), 64 weight(decay=0.0005), 63 bias(decay=0.0)
Image sizes 640 train, 640 val
Using 8 dataloader workers
Logging results to runs₩detect₩train5
Starting training for 100 epochs...

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
      1/100      2.69G      1.888      2.621      1.445        145        640: 100%|██████████| 44/44 [00:07<00:00,  5.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 4/4 [00:05<0
                   all        100        327    0.00853      0.735      0.192     0.0944

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
      2/100      2.59G       1.56      1.462      1.181         63        640: 100%|██████████| 44/44 [00:03<00:00, 11.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 4/4 [00:00<0
                   all        100        327      0.679      0.451      0.519       0.26

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
      3/100      2.78G       1.52      1.294      1.175        188        640: 100%|██████████| 44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 4/4 [00:00<0
                   all        100        327      0.549      0.564      0.558       0.29

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
      4/100      2.76G      1.485      1.193      1.182         66        640: 100%|██████████| 44/44 [00:03<00:00, 12.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 4/4 [00:00<0
                   all        100        327      0.646      0.598       0.61      0.333

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
      5/100      2.81G       1.42      1.107      1.153         52        640: 100%|██████████| 44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 4/4 [00:00<0
                   all        100        327       0.66      0.576      0.603      0.315

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
      6/100       2.6G      1.416      1.058      1.138         70        640: 100%|██████████| 44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 4/4 [00:00<0
                   all        100        327      0.798      0.683      0.711      0.387

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
      7/100       3.2G      1.402       1.02      1.145        115        640: 100%|██████████| 44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 4/4 [00:00<0
                   all        100        327      0.798      0.632      0.738      0.393

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
      8/100      2.77G      1.386     0.9728      1.131         81        640: 100%|██████████| 44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 4/4 [00:00<0
                   all        100        327      0.789      0.661      0.755      0.431

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
      9/100      2.97G      1.367     0.9161       1.13         73        640: 100%|██████████|
```

```
44/44 [00:03<00:00, 13.
               Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                 all        100        327      0.683      0.626      0.716      0.405

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     10/100      2.69G      1.367      0.934      1.131         39        640: 100%|██████████|
44/44 [00:03<00:00, 13.
               Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                 all        100        327      0.862      0.686      0.783      0.418

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     11/100      2.91G       1.34     0.9134      1.122         86        640: 100%|██████████|
44/44 [00:03<00:00, 13.
               Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                 all        100        327      0.807      0.707      0.775      0.442

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     12/100      2.72G       1.34     0.8724       1.11         83        640: 100%|██████████|
44/44 [00:03<00:00, 13.
               Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                 all        100        327      0.741      0.713       0.76      0.403

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     13/100      2.57G      1.325     0.8594      1.114         64        640: 100%|██████████|
44/44 [00:03<00:00, 13.
               Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                 all        100        327       0.83      0.723      0.809      0.464

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     14/100       2.7G      1.314     0.8497      1.095         87        640: 100%|██████████|
44/44 [00:03<00:00, 13.
               Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                 all        100        327      0.797      0.627      0.712      0.397

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     15/100      2.64G      1.336     0.8572      1.096         81        640: 100%|██████████|
44/44 [00:03<00:00, 13.
               Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                 all        100        327      0.716      0.733      0.777       0.43

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     16/100      2.34G      1.294     0.8083      1.102         92        640: 100%|██████████|
44/44 [00:03<00:00, 13.
               Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                 all        100        327      0.832      0.711      0.827      0.486

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     17/100      2.69G      1.285     0.8037      1.084         96        640: 100%|██████████|
44/44 [00:03<00:00, 13.
               Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                 all        100        327      0.776      0.792      0.836      0.489

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     18/100      2.79G      1.266     0.7718      1.077         86        640: 100%|██████████|
44/44 [00:03<00:00, 13.
               Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                 all        100        327      0.905      0.734      0.822       0.47

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
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      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     19/100      2.64G      1.261     0.7693      1.074        138        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.876      0.743      0.814      0.469

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     20/100      2.68G      1.232     0.7731      1.064        101        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.835      0.786      0.831      0.474

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     21/100       2.6G      1.217      0.731      1.062         63        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.817      0.757      0.832      0.481

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     22/100      2.65G      1.236     0.7306      1.058        116        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.823      0.753       0.82      0.475

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     23/100      2.67G      1.235     0.7504      1.065         60        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.851      0.678      0.797       0.46

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     24/100      2.42G      1.253     0.7723      1.077        106        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.912      0.747      0.845      0.475

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     25/100      2.49G      1.237     0.7339      1.071        106        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.888      0.722       0.83        0.5

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     26/100      2.48G      1.206     0.7089      1.057         79        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.763      0.786       0.81      0.467

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     27/100      2.53G       1.22     0.7188      1.047         74        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327       0.89      0.735      0.846      0.487

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     28/100      2.81G      1.214     0.7209      1.063         70        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.915      0.749      0.851      0.481
```

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      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     29/100      2.63G      1.199     0.7009      1.047         95        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.846      0.772      0.834      0.466

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     30/100      2.71G      1.214     0.7113      1.061         76        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.891       0.78      0.874      0.524

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     31/100      2.89G      1.214      0.704      1.046         85        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.849      0.784       0.87       0.49

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     32/100      2.43G      1.209     0.6948      1.058         66        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.882       0.77       0.85       0.48

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     33/100      2.38G      1.215     0.6805      1.063         56        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.903      0.769      0.866       0.53

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     34/100      2.67G      1.207     0.6712      1.048         67        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.839      0.813      0.858      0.488

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     35/100      2.52G       1.17     0.6693      1.045        134        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.903      0.773      0.859      0.511

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     36/100      2.84G      1.185     0.6685      1.033        167        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.847      0.822      0.867        0.5

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     37/100      2.33G      1.209     0.6694       1.04         88        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.798      0.827      0.872      0.504

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     38/100      2.82G      1.169     0.6592      1.039         78        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.828      0.762      0.834      0.489
```

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      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     39/100      3.07G      1.142     0.6474      1.026         53        640: 100%|██████████|
44/44 [00:03<00:00, 11.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327        0.8       0.83      0.869      0.508

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     40/100      2.71G      1.146     0.6288      1.021         92        640: 100%|██████████|
44/44 [00:03<00:00, 12.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.881      0.758      0.861      0.517

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     41/100      2.95G      1.164     0.6286      1.023         58        640: 100%|██████████|
44/44 [00:03<00:00, 11.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.826      0.825      0.844       0.49

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     42/100      2.72G      1.164     0.6401      1.035         90        640: 100%|██████████|
44/44 [00:03<00:00, 11.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.893      0.801       0.87       0.51

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     43/100      3.06G      1.177     0.6386      1.019         76        640: 100%|██████████|
44/44 [00:03<00:00, 12.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.927      0.759      0.864      0.512

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     44/100       2.8G      1.118     0.6149      1.014        182        640: 100%|██████████|
44/44 [00:03<00:00, 12.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.827      0.804      0.859       0.49

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     45/100      2.49G      1.103     0.6036      1.011         50        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.843      0.818       0.87      0.488

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     46/100      2.75G      1.125     0.6155      1.015        100        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.856      0.773      0.846      0.487

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     47/100      2.65G      1.111     0.6065      1.005         88        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.843      0.816      0.864      0.509

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     48/100      2.67G      1.129     0.6081      1.018         77        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
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                   all        100        327      0.853      0.825      0.876      0.495

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     49/100      2.48G      1.131     0.6155      1.018         80        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.909      0.799      0.889      0.511

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     50/100      2.75G      1.134     0.6059      1.013         95        640: 100%|██████████|
44/44 [00:03<00:00, 12.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.851      0.798      0.862      0.484

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     51/100      2.49G      1.119     0.6031      1.009         47        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.854       0.79      0.848      0.491

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     52/100      2.43G      1.094     0.5881      1.005         36        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.868      0.803      0.866      0.514

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     53/100      2.68G      1.082     0.5788     0.9958         63        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327       0.88      0.803      0.874      0.528

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     54/100       2.8G      1.074     0.5803     0.9899         82        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.866      0.809      0.884      0.531

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     55/100      2.65G      1.101     0.5887      1.005        100        640: 100%|██████████|
44/44 [00:03<00:00, 12.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.893      0.806      0.883      0.516

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     56/100      2.58G      1.088     0.5774     0.9984        224        640: 100%|██████████|
44/44 [00:03<00:00, 12.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.868      0.789      0.864      0.498

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     57/100      2.78G      1.092     0.5767     0.9967         70        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.925      0.779      0.858      0.488

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     58/100      2.83G       1.08     0.5703     0.9802         77        640: 100%|██████████|
44/44 [00:03<00:00, 12.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
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██████████| 4/4 [00:00<0
                   all        100        327      0.884      0.793      0.853      0.488

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     59/100      2.58G      1.089     0.5738     0.9883         98        640: 100%|██████████|
44/44 [00:03<00:00, 12.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.889      0.794      0.873      0.495

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     60/100      2.34G      1.067     0.5599     0.9922        120        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.919      0.816      0.875      0.521

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     61/100      2.81G       1.04     0.5468     0.9776         91        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.869      0.822      0.859      0.519

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     62/100      2.45G      1.041     0.5454     0.9818         49        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.901      0.789      0.871      0.489

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     63/100      2.69G      1.062     0.5555     0.9893         47        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.844      0.792      0.871      0.511

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     64/100       2.6G      1.042     0.5428      0.979         82        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.866      0.812      0.878      0.511

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     65/100      2.85G      1.034     0.5369     0.9825         72        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.908      0.762      0.871      0.525

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     66/100       2.8G      1.048     0.5472     0.9776        101        640: 100%|██████████|
44/44 [00:03<00:00, 12.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.905       0.76      0.862      0.527

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     67/100      2.65G      1.038     0.5358     0.9738         63        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327       0.87      0.808      0.871      0.521

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     68/100      2.48G      1.051     0.5487     0.9746         84        640: 100%|██████████|
44/44 [00:03<00:00, 12.
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                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.913      0.774      0.865      0.519

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     69/100      2.61G      1.031     0.5376     0.9838         65        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.892      0.789      0.862      0.495

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     70/100      2.54G      1.027     0.5361     0.9659        108        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327       0.86      0.828      0.879      0.518

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     71/100      2.76G      1.022     0.5283     0.9693         46        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.899      0.827      0.883      0.527

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     72/100      2.68G      1.012     0.5197     0.9559         65        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.922      0.803      0.878      0.521

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     73/100      2.59G      0.999     0.5127     0.9556         82        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.884      0.808      0.856      0.504

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     74/100       2.7G     0.9995     0.5084     0.9615        118        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.891      0.819      0.878      0.532

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     75/100      2.59G     0.9974     0.5152      0.963         69        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.869       0.81      0.876      0.529

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     76/100      2.36G      1.002      0.505     0.9552         52        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.909      0.835       0.88      0.509

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     77/100         3G     0.9894     0.5029     0.9584         49        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.873      0.849      0.878      0.511

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     78/100      2.51G       1.01     0.5042       0.96         94        640: 100%|██████████|
```

```
44/44 [00:03<00:00, 13.
               Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                 all        100        327      0.881       0.81      0.858      0.513

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     79/100      2.37G     0.9645     0.4917     0.9569         85        640: 100%|██████████|
44/44 [00:03<00:00, 13.
               Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                 all        100        327      0.901      0.809      0.881       0.53

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     80/100      2.54G     0.9695      0.502     0.9531         79        640: 100%|██████████|
44/44 [00:03<00:00, 13.
               Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                 all        100        327      0.866      0.827      0.882      0.523

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     81/100       2.6G     0.9662     0.4936     0.9532         58        640: 100%|██████████|
44/44 [00:03<00:00, 13.
               Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                 all        100        327      0.938      0.794      0.882      0.529

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     82/100      2.76G     0.9473     0.4814     0.9413         89        640: 100%|██████████|
44/44 [00:03<00:00, 12.
               Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                 all        100        327      0.891      0.821      0.879      0.531

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     83/100      2.72G     0.9512      0.483     0.9481        117        640: 100%|██████████|
44/44 [00:03<00:00, 13.
               Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                 all        100        327      0.896      0.791      0.877       0.52

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     84/100      2.58G     0.9558     0.4826     0.9331         82        640: 100%|██████████|
44/44 [00:03<00:00, 13.
               Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                 all        100        327      0.884      0.822      0.865      0.512

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     85/100      2.58G     0.9595     0.4825      0.944         81        640: 100%|██████████|
44/44 [00:03<00:00, 13.
               Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                 all        100        327       0.93      0.797      0.871      0.518

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     86/100       2.5G     0.9576     0.4847     0.9496         82        640: 100%|██████████|
44/44 [00:03<00:00, 13.
               Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                 all        100        327      0.916      0.797      0.875      0.516

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     87/100      2.37G     0.9616      0.476     0.9443         54        640: 100%|██████████|
44/44 [00:03<00:00, 13.
               Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                 all        100        327      0.878      0.822      0.886      0.527

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
```

```
     88/100      2.64G     0.9454      0.474     0.9409         63        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.926      0.807      0.889       0.53

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     89/100      2.51G     0.9358      0.472     0.9415         61        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.903        0.8       0.88       0.53

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     90/100       2.4G     0.9274     0.4678     0.9447         32        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.888       0.83      0.881      0.531
Closing dataloader mosaic

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     91/100      2.59G     0.9351     0.4585     0.9433         61        640: 100%|██████████|
44/44 [00:03<00:00, 11.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327       0.87       0.84      0.882      0.515

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     92/100      2.65G     0.9104     0.4308     0.9257         93        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.888      0.815      0.884      0.516

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     93/100      2.54G     0.9118     0.4313     0.9325         27        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.904      0.831      0.886      0.523

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     94/100      2.59G     0.8907     0.4247     0.9211         92        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.881      0.821      0.885      0.527

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     95/100      2.35G     0.8798     0.4224     0.9155        119        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.902      0.821      0.896      0.526

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     96/100      2.66G     0.8914     0.4227     0.9191         40        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.889      0.834      0.884      0.516

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     97/100      2.36G     0.8775     0.4198     0.9195         21        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.911       0.82       0.89      0.531
```

```
      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     98/100       2.5G     0.8937     0.4264     0.9262         90        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.881      0.846      0.896      0.529

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     99/100      2.46G     0.8828     0.4214     0.9105         48        640: 100%|██████████|
44/44 [00:03<00:00, 13.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.872      0.841       0.89      0.526

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
    100/100      2.54G     0.8648     0.4114     0.9126         44        640: 100%|██████████|
44/44 [00:03<00:00, 12.
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:00<0
                   all        100        327      0.881      0.817      0.882      0.521

100 epochs completed in 0.142 hours.
Optimizer stripped from runsWdetectWtrain5WweightsWlast.pt, 6.2MB
Optimizer stripped from runsWdetectWtrain5WweightsWbest.pt, 6.2MB

Validating runsWdetectWtrain5WweightsWbest.pt...
Ultralytics YOLOv8.0.147  Python-3.10.9 torch-2.0.0+cu117 CUDA:0 (NVIDIA GeForce RTX 3090, 2457
6MiB)
YOLOv8n summary (fused): 168 layers, 3006038 parameters, 0 gradients
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|
██████████| 4/4 [00:01<0
                   all        100        327      0.912       0.82       0.89      0.532
               no_mask        100         49      0.902      0.755      0.836      0.441
                  mask        100        278      0.921      0.884      0.945      0.624
Speed: 0.5ms preprocess, 1.5ms inference, 0.0ms loss, 1.8ms postprocess per image
Results saved to runsWdetectWtrain5
```

▶ Predict - Object Detection

In [27]:
```
import cv2
import pandas as pd
import numpy as np
from matplotlib import pyplot as plt
```

In [28]:
```
### 영상 출력 함수
def fn_imshow(img, axis='on', **kwargs):
    img_rgb = cv2.cvtColor(img, cv2.COLOR_BGR2RGB)
    plt.figure(**kwargs)
    if axis!='on': plt.axis('off')
    plt.imshow(img_rgb)
    plt.show()
```

In [29]:
```
# Load trained YOLOv8n model
pt_path = r"runsWdetectWtrain5WweightsWbest.pt"
model_best = YOLO(pt_path)
```

- Test image
  - https://www.sciencedirect.com/science/article/pii/S2352648320300362

In [30]:
```
# Read an image using OpenCV
src =r"C:WUsersW05WDownloadsW1-s2.0-S2352648320300362-gr5.jpg"
source = cv2.imread(src)
```

```
# Run inference on the source
results = model_best(source)
```

```
0: 384x640 5 no_masks, 4 masks, 55.9ms
Speed: 2.0ms preprocess, 55.9ms inference, 2.0ms postprocess per image at shape (1, 3, 384, 640)
```

In [31]:
```
# Plotting results
res_plotted = results[0].plot()
fn_imshow(res_plotted, figsize=(6,8), axis='')
```

In [32]:
```
### Boxes
boxes = results[0].boxes

### Classe names
face_mask_classnames = {
  0: 'no_mask',
  1: 'mask'
}

### DataFrame
boxes_arr = boxes.data.cpu().numpy()
col_names = ['xMin', 'yMin', 'xMax', 'yMax', 'conf', 'class']
boxes_df = pd.DataFrame(boxes_arr, columns=col_names)

### Add class names
boxes_df['class'] = boxes_df['class'].astype('int')
boxes_df['class_nm'] = [face_mask_classnames[i] for i in boxes_df['class']]
boxes_df
```

Out[32]:

	xMin	yMin	xMax	yMax	conf	class	class_nm
0	43.257614	44.958241	127.073853	146.586395	0.930645	0	no_mask
1	408.542999	44.916779	491.309509	145.446075	0.921293	0	no_mask
2	42.676460	257.065826	126.374008	351.458679	0.916511	1	mask
3	589.909790	44.735687	675.179871	147.543610	0.910676	0	no_mask
4	408.773773	256.781006	492.503815	352.131927	0.910666	1	mask
5	225.354279	46.715656	309.268280	145.254105	0.893392	0	no_mask
6	589.809875	256.118195	675.015930	350.027527	0.853538	0	no_mask
7	225.800171	256.066193	310.301880	332.835266	0.851785	1	mask
8	590.240967	256.016357	675.282837	350.159790	0.611279	1	mask

In [33]:
```
# Plotting results
img_out = source.copy()
for i in range(boxes_df.shape[0]):
    ind_box = boxes_df.iloc[i][0:4].astype('int')
    ind_class = boxes_df.iloc[i][5].astype('int')
    ind_col = (0,0,255) if ind_class==0 else (255,0,0)
    cv2.rectangle(img_out, ind_box[:2], ind_box[2:], ind_col, 2)
    ind_class_nm = boxes_df.iloc[i][6]
    cv2.putText(img_out,ind_class_nm,ind_box[:2], 0, 1,ind_col,2,cv2.LINE_AA)

fn_imshow(img_out, figsize=(6,8), axis='')
```

(a) Detected landmarks. (b) Detected landmarks. (c) Detected landmarks. (d) Detected landmarks.

(e) Correctly masked. (f) Incorrectly masked. (g) Incorrectly masked. (h) Incorrecly masked.

■ 중단된 교육 재개 - Resuming Interrupted Trainings

- 학습 프로세스가 예기치 않게 중단된 경우
- 새 데이터로 모델을 계속 학습시키려는 경우
- 더 많은 epoch으로 모델을 학습하려는 경우

Resume Training Example

Python CLI

```python
from ultralytics import YOLO

# Load a model
model = YOLO('path/to/last.pt')  # load a partially trained model

# Resume training
model.train(resume=True)
```

Resume Training Example

Python CLI

```
# Resume an interrupted training
yolo train resume model=path/to/last.pt
```

■ 최상의 학습 결과를 위한 팁 - YOLOv5

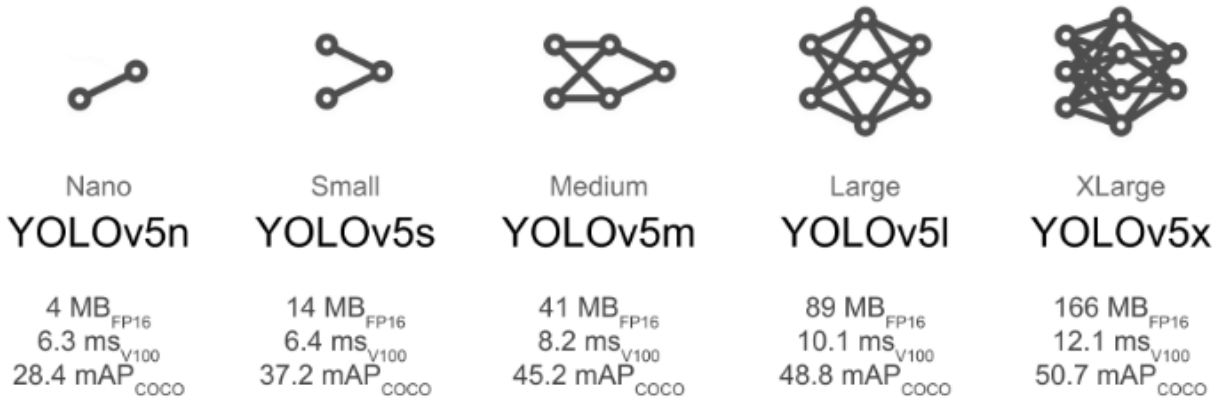
- https://docs.ultralytics.com/yolov5/tutorials/tips_for_best_training_results/
- 대부분의 경우 **데이터 세트가 충분히 크고 레이블이 잘 지정된 경우** 모델이나 교육 설정을 변경하지 않고도 좋은 결과를 얻을 수 있음
- 우선 **기본 설정으로 교육**한 후, 성능을 개선하기 위해 **모형 설정을 조정**할 수 있음

○ Dataset

- **Images per class**: ≥ 클래스당 1500개 이미지 권장
- **Instances per class**: 클래스당 ≥ 10000개 인스턴스(레이블이 지정된 개체) 권장
- **Image variety(다양성)**: 다른 시간대, 다른 계절, 다른 날씨, 다른 조명, 다른 각도, 다른 소스(온라인 스크랩, 로컬에서 수집, 다른 카메라) 등의 이미지 권장
- **Label consistency(일관성)**: 모든 이미지에 있는 모든 클래스의 모든 인스턴스에 레이블을 지정(부분 라벨링은 작동하지 않음)
- **Label accuracy(정확도)**: 레이블은 각 개체를 밀접하게 둘러싸고, 개체와 경계 상자 사이에 공간이 없어야 함. 레이블이 누락된 개체가 없어야 함
- **Label verification(확인)**: 라벨이 올바르게 표시되는지 확인
- **Background images**: 배경 이미지는 개체가 없는 이미지. False Positives를 줄이는 데 도움이 되도록 배경 이미지를 0~10% 정도 권장. 배경 이미지에는 레이블이 필요하지 않음

○ Model Selection

- YOLOv5x 및 YOLOv5x6 과 같은 더 큰 모델 은 거의 모든 경우에 더 나은 결과를 생성하지만 매개변수가 더 많고 훈련하는 데 더 많은 CUDA 메모리가 필요하며 실행 속도가 느림
- **mobile** 배포 의 경우 YOLOv5s/m을 권장하고, **cloud** 배포의 경우 YOLOv5l/x를 권장



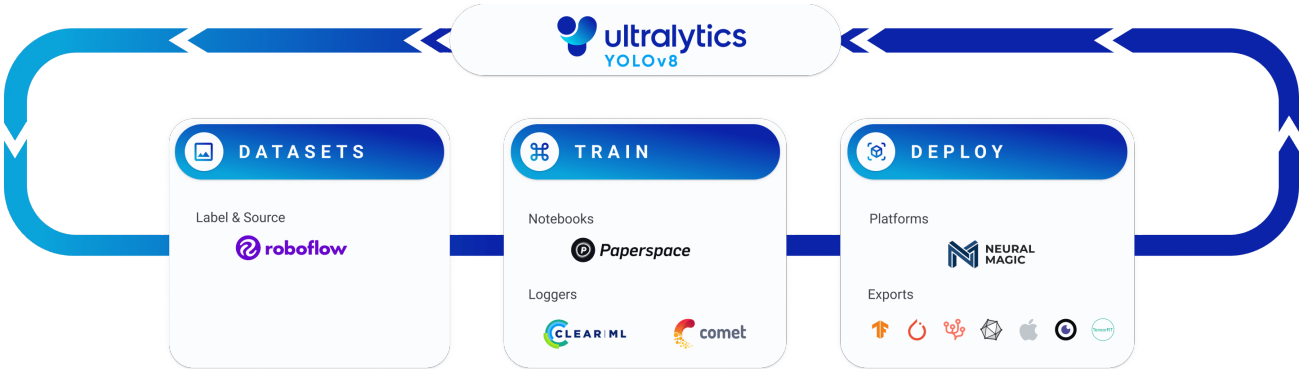
- 중소 규모의 데이터 세트는 사전 훈련된 가중치 사용을 권장
- 대규모 데이터 세트는 사전 훈련된 가중치 없이 처음부터 시작을 권장

○ Training Settings

- **Epochs**: 300 epoch로 시작. 300 epoch 후에도 과대적합(overfitting)이 발생하지 않으면 더 길게 훈련(예: 600, 1200 등)
- **Image size**: 데이터 세트에 있는 작은 개체의 양이 많으면 더 높은 해상도에서 훈련하는 것이 도움이 됨.
- **Batch size**: 하드웨어가 허용하는 가장 큰 것을 사용
- **Hyperparameters**: 수정하기 전에 먼저 기본 하이퍼파라미터로 학습하는 것을 권장

▢ Export

- https://docs.ultralytics.com/modes/export/
- YOLOv8 모델을 배포에 사용할 수 있는 형식으로 내보내는 데 사용
- 다른 소프트웨어 응용 프로그램이나 하드웨어 장치에서 사용할 수 있는 형식으로 변환(배포)



■ Export Formats

Format	`format` Argument	Model	Metadata	Arguments
PyTorch	-	`yolov8n.pt`	✅	-
TorchScript	`torchscript`	`yolov8n.torchscript`	✅	`imgsz`, `optimize`
ONNX	`onnx`	`yolov8n.onnx`	✅	`imgsz`, `half`, `dynamic`, `simplify`, `opset`
OpenVINO	`openvino`	`yolov8n_openvino_model/`	✅	`imgsz`, `half`
TensorRT	`engine`	`yolov8n.engine`	✅	`imgsz`, `half`, `dynamic`, `simplify`, `workspace`
CoreML	`coreml`	`yolov8n.mlmodel`	✅	`imgsz`, `half`, `int8`, `nms`
TF SavedModel	`saved_model`	`yolov8n_saved_model/`	✅	`imgsz`, `keras`
TF GraphDef	`pb`	`yolov8n.pb`	❌	`imgsz`
TF Lite	`tflite`	`yolov8n.tflite`	✅	`imgsz`, `half`, `int8`
TF Edge TPU	`edgetpu`	`yolov8n_edgetpu.tflite`	✅	`imgsz`
TF.js	`tfjs`	`yolov8n_web_model/`	✅	`imgsz`
PaddlePaddle	`paddle`	`yolov8n_paddle_model/`	✅	`imgsz`
ncnn	`ncnn`	`yolov8n_ncnn_model/`	✅	`imgsz`, `half`