HW2: Object Detection

TODO

- [x] Implement dataset
- [x] Implement evaluator

- [x] Implement Exp
- [x] Add SE module
- [x] Optimize trainer.py (Optional)
- [x] Optimize metrics visualization (Optional)
- [x] Produce val/test results via demo.py

Introduction

本專案為了易用、評估模型的訓練狀況，做了以下更動

1. *將 Object-Detection-Metrics 程式嵌入至自行撰寫的 evaluator (voc2012_evaluator.py)
2. 自行撰寫 dataset (gta_video.py)，無須事先轉換 dataset 即可直接執行
3. 改善 trainer.py 中的 tensorboard logging 方式，支援 logging training loss 與 evaluator 自訂義回傳的 metrics
4. 將 training data 加入至 evaluator，以便在 tensorboard 上查看是否有 overfitting 的情況
5. 更改 demo.py，輸出 prediction results

*雖然嵌入至 evaluator 中，但 validation results 部分還是會丟至原本指定的程式中執行，以示公平

Environment

- Anaconda: 4.13.0
- CUDA: 11.3
- Python: 3.9.13
- Pytorch: 1.12.1
- Torchvision: 0.13.1 (only used for data augmentation)
- Pandas: 1.5.1
- Numpy: 1.23.4
- Matplotlib: 3.6.1
- Opencv-python: 4.6.0.66
- 其他 YOLOX source code 用到的套件 (requirements.txt)

Experiment Setup

Data preprocessing

使用 YOLOX source code 寫好的 data augmentation classes (data_augment.py & mosaic.py)，更改超參數

- Mosaic
- Mix Up
- Affine Transformations (translation, rotation, scaling, shearing)
- Horizontal Flip
- HSV color jitter

YOLOX (original)

使用自行撰寫的 Dataset class 自動將 label 格式轉為 xyrb，不必事先轉換，即可 training/inference

YOLOX + SE module

使用自行撰寫的 Dataset class 自動將 label 格式轉為 xyrb，不必事先轉換，即可 training/inference

Hyperparameters

其餘未提及的部分皆為 Exp class(yolox_base.py) 的預設值

- Model: yolox_s (depth: 0.33, width: 0.5)
- Max epoch: 200
- No augment epochs: 20
- Max labels: 50
- Seed: 1234

YOLOX (original)

- Activation function: SiLU
- Loss function: IoU
- Depthwise: False

YOLOX + SE module

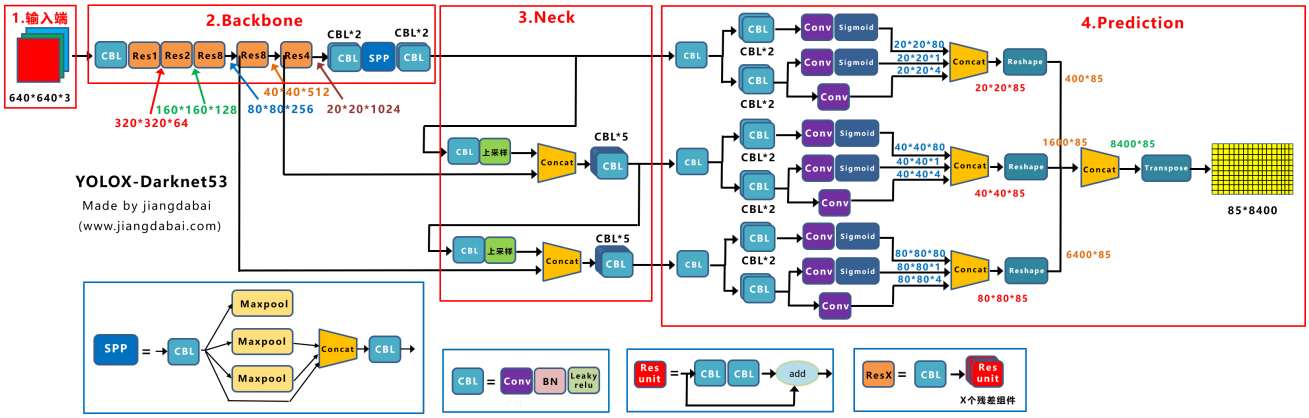
- Activation function: SiLU
- Loss function: IoU
- Depthwise: False

Model architecture

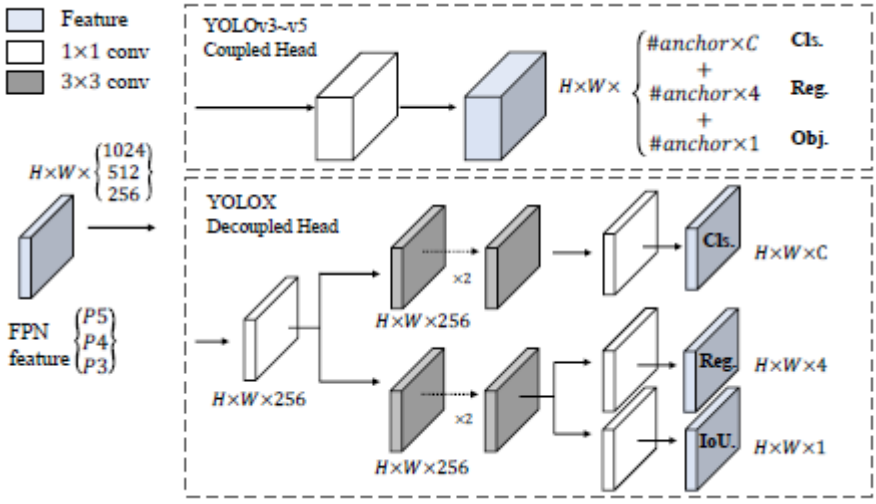
YOLOX (original)

依照 Paper 架構，無多做更改，詳細架構請見最後 Appendix A

下圖取自於 https://blog.csdn.net/nan355655600/article/details/119666304



下圖取自於 paper



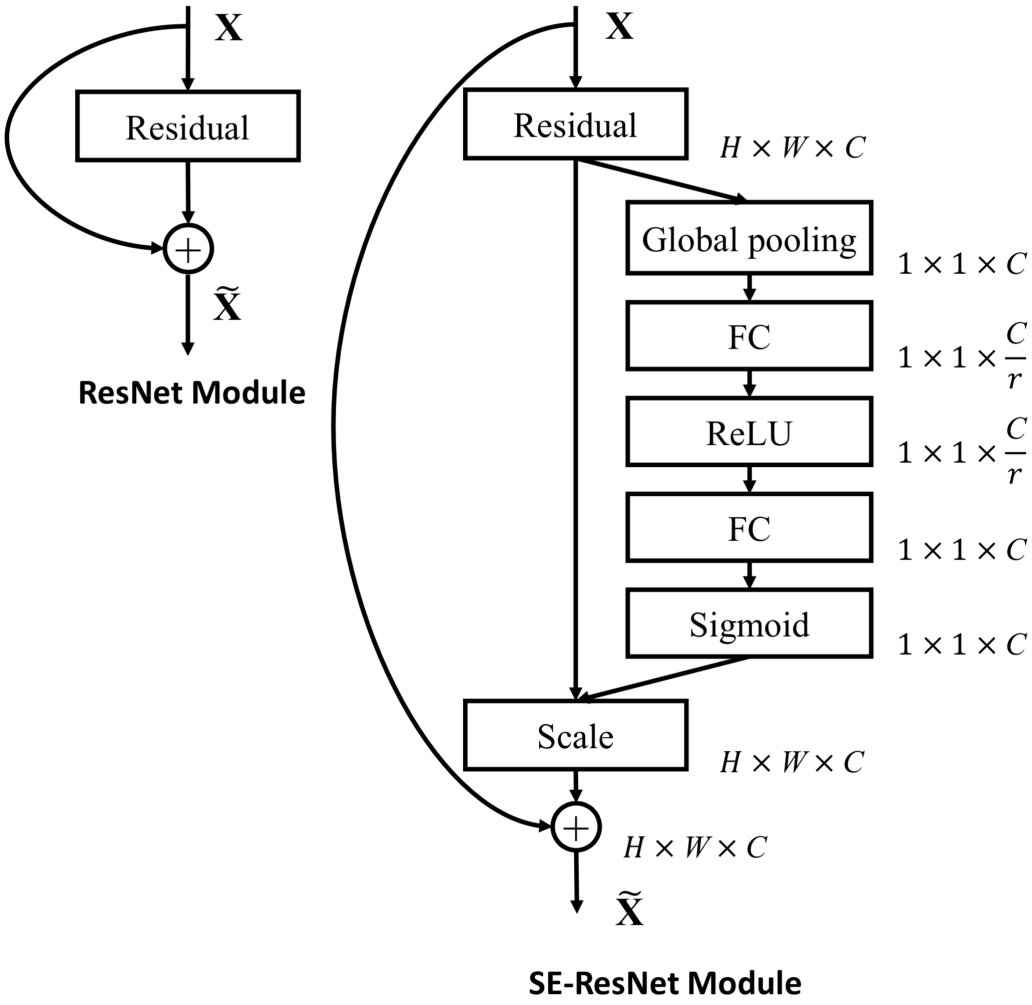
YOLOX + SE module

將 SE module 嵌入至 Bottleneck，Bottleneck 位於 CSPLayer 中，在 backbone(CSPDarknet53) 與 FPN(PANet) 皆有用到，詳細架構請見最後 Appendix B

- SE module in Bottleneck，其中 FC layer 為 Conv2d 1x1

```
Bottleneck(
    (conv1): BaseConv(
        (conv): Conv2d(32, 32, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn): BatchNorm2d(32, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
        (act): SiLU(inplace=True)
    )
    (conv2): BaseConv(
        (conv): Conv2d(32, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
        (bn): BatchNorm2d(32, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
        (act): SiLU(inplace=True)
    )
    (se_m): SELayer(
        (avg_pool): AdaptiveAvgPool2d(output_size=1)
        (fcn): Sequential(
            (0): Conv2d(32, 2, kernel_size=(1, 1), stride=(1, 1))
            (1): ReLU(inplace=True)
            (2): Conv2d(2, 32, kernel_size=(1, 1), stride=(1, 1))
            (3): Sigmoid()
        )
    )
)
```

下圖取自於: https://raw.githubusercontent.com/hujie-frank/SENet/master/figures/SE-ResNet-module.jpg



Brief explain your code

> 使用 YOLOX official code 進行訓練

由於訓練時間占大部分時間，來不及實驗加入其他 module，因此只加入 SE module

SE module

從 SENet 的 source code 中得知，是使用 Conv2d 1x1，而不是 Linear layer，因此在此使用 Conv2d 1x1

下面為 SE module 實作

```
class SELayer(nn.Module):
    def __init__(self, in_channels: int, reduction: int = 16) -> None:
        super().__init__()
        inner_channel = in_channels // reduction
        self.avg_pool = nn.AdaptiveAvgPool2d(1)
        self.fcn = nn.Sequential(
            nn.Conv2d(in_channels, inner_channel, kernel_size=1),
            nn.ReLU(inplace=True),
            nn.Conv2d(inner_channel, in_channels, kernel_size=1),
            nn.Sigmoid(),
        )

    def forward(self, x: torch.Tensor) -> torch.Tensor:
        y = self.avg_pool(x)
        y = self.fcn(y)
        return x * y
```

How to setup?

> 請按照以下順序，依序 setup

Installation

```
conda create -n yolox python=3.9.13
conda activate yolox

cd Code/Original
# or cd Code/SE

# 兩種安裝套件方式
# 1. environment.yml
conda env create -f environment.yml
# 注意: 如果在 Original/SE 間切換，須再執行一次下面指令
pip install -v -e .

# 2. Manually
# cudatoolkit 版本請自行更改成目前安裝的 cuda 版本，支援 CUDA 10.2, CUDA 11.3, CUDA 11.6
conda install pytorch==1.12.1 torchvision==0.13.1 cudatoolkit=11.3 -c pytorch
# 注意: 如果在 Original/SE 間切換，須再執行一次下面指令
pip install -v -e .
```

Place the GTA dataset

1. 建立資料夾，名稱為 `GTA`
2. 解壓縮 dataset 至 `GTA` 資料夾
3. 將 GTA 資料夾移至 `Code/Original/datasets` 與 `Code/SE/datasets` 資料夾裡

Place the pretrained/trained weights

已放置在對應資料夾中，`Code/Original/weights` 與 `Code/SE/weights`

How to reproduce?

```
conda activate yolox
```

Training

```
# YOLOX (original)
cd Code/Original
python -m yolox.tools.train -expn yolox_s_gta -b 8 -d 1 -f ./exps/yolox_gta.py -c
./weights/yolox_s.pth -o -l tensorboard

# YOLOX + SE module
cd Code/SE
python -m yolox.tools.train -expn yolox_s_gta_se -b 8 -d 1 -f ./exps/yolox_gta_se.py -c
./weights/yolox_s.pth -o -l tensorboard
```

Inference

Validation set

```
# YOLOX (original)
# 輸出資料夾: ./YOLOX_outputs/val_yolox/vis_res/{最新 timestamp}
cd Code/Original
python -m yolox.tools.demo -expn val_yolox --path ./datasets/GTA/val --device {gpu, cpu}
--save_result -f ./exps/yolox_gta.py -c ./weights/yolox_s_gta.pth --fp16 image

# YOLOX + SE module
# 輸出資料夾: ./YOLOX_outputs/val_yolox_se/vis_res/{最新 timestamp}
cd Code/SE
python -m yolox.tools.demo -expn val_yolox_se --path ./datasets/GTA/val --device {gpu,
cpu} --save_result -f ./exps/yolox_gta_se.py -c ./weights/yolox_s_gta_se.pth --fp16 image
```

```
# for evaluating validation results
git clone https://github.com/rafaelpadilla/Object-Detection-Metrics

cd Object-Detection-Metrics
pip install -r requirements.txt
mkdir results

# copy datasets/GTA/val_labels folder to Object-Detection-Metrics/gta_groundtruths_rel
# copy YOLOX_outputs/{val_yolox, val_yolox_se}/vis_res/{any timestamp} folder to Object-
Detection-Metrics/gta_detections

# 輸出資料夾: ./results
python pascalvoc.py -gt ./gta_groundtruths_rel -det ./gta_detections -t 0.85 -gtformat
xywh -detformat xyrb -gtcoords rel -detcoords abs -imgsize "(1920,1080)" -sp results
```

Test set

```
# YOLOX (original)
# 輸出資料夾: ./YOLOX_outputs/test_yolox/vis_res/{最新 timestamp}
cd Code/Original
python -m yolox.tools.demo -expn test_yolox --path ./datasets/GTA/test --device {gpu,
cpu} --save_result -f ./exps/yolox_gta.py -c .\weights\yolox_s_gta.pth --fp16 image

# YOLOX + SE module
# 輸出資料夾: ./YOLOX_outputs/test_yolox_se/vis_res/{最新 timestamp}
cd Code/SE
python -m yolox.tools.demo -expn test_yolox_se --path ./datasets/GTA/test --device {gpu,
cpu} --save_result -f ./exps/yolox_gta_se.py -c ./weights/yolox_s_gta_se.pth --fp16 image
```

Validation results (best)

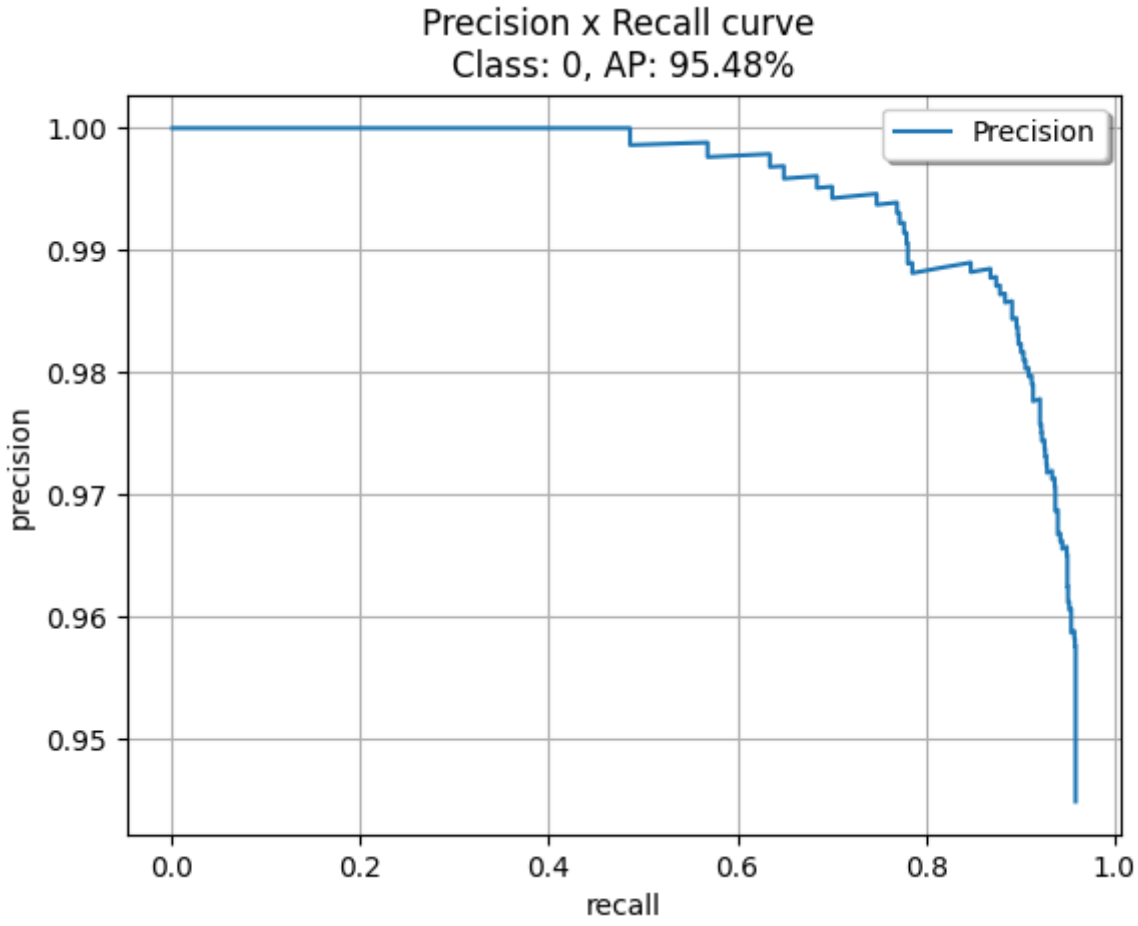
不管是 Original 或加了 SE module 的模型，兩者準確度皆差不多

在兩者輸出的圖片中，常常看到遠處的車子無法正確偵測的問題，目前猜測需要調整 augmentation，例如增加圖片放大/縮小倍率範圍，或將輸入 resolution 提高，實驗是否增加對小物件偵測的準確度

但礙於時間不足的問題，只能先將看法提出，之後再作驗證

YOLOX (original)

Precision-Recall curve



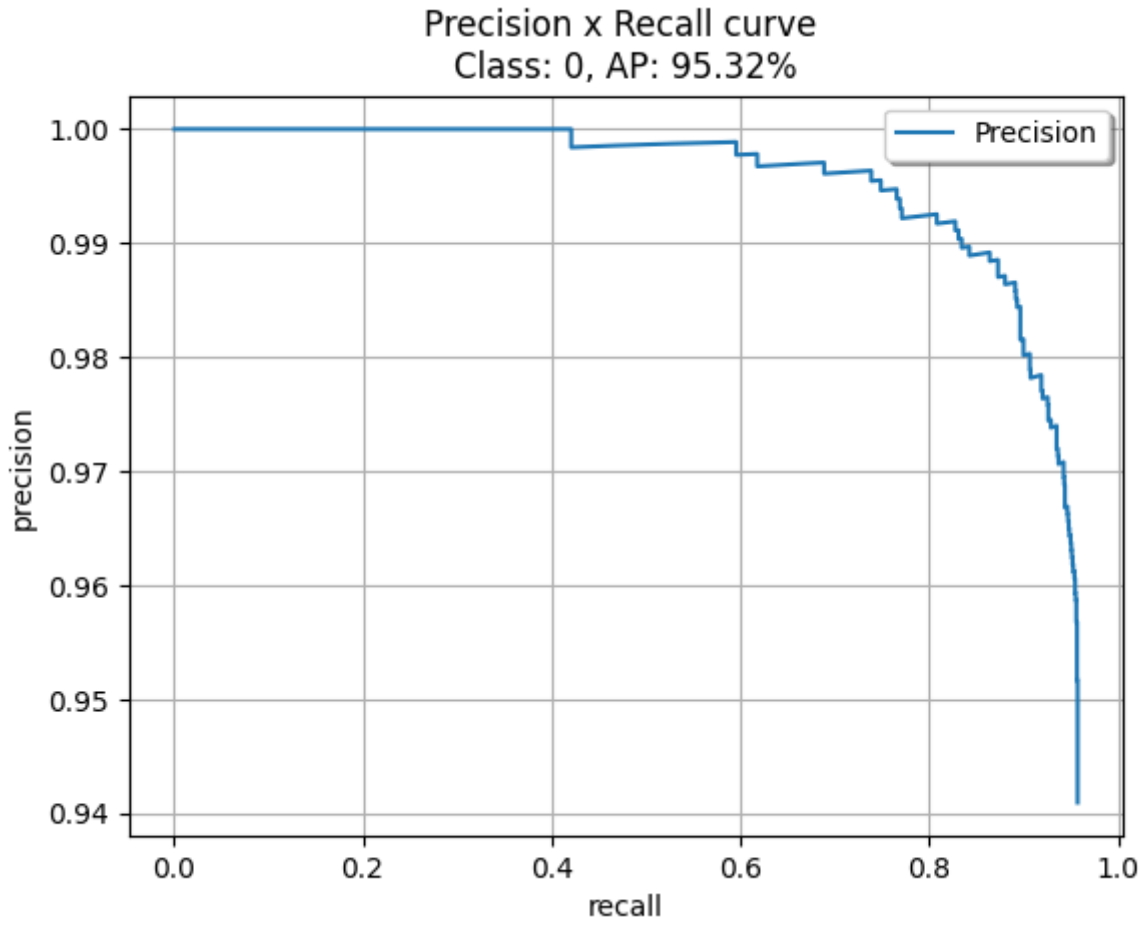
AP_{85}

```
#########################################################################################################
#                                                                                                       #
# THE CURRENT VERSION WAS UPDATED WITH A VISUAL INTERFACE, INCLUDING MORE METRICS AND SUPPORTING        #
# OTHER FILE FORMATS.                                                                                   #
#                                                                                                       #
# PLEASE ACCESS IT ACCESSED AT:                                                                         #
# https://github.com/rafaelpadilla/review_object_detection_metrics                                      #
#                                                                                                       #
# @Article{electronics10030279,                                                                         #
#     author         = {Padilla, Rafael and Passos, Wesley L. and Dias, Thadeu L. B. and Netto,         #
#                       Sergio L. and da Silva, Eduardo A. B.},                                         #
#     title          = {A Comparative Analysis of Object Detection Metrics with a Companion           #
#                       Open-Source Toolkit},                                                           #
#     journal        = {Electronics},                                                                   #
#     volume         = {10},                                                                            #
#     year           = {2021},                                                                          #
#     number         = {3},                                                                             #
#     article-number = {279},                                                                           #
#     url            = {https://www.mdpi.com/2079-9292/10/3/279},                                       #
#     issn           = {2079-9292},                                                                     #
#     doi            = {10.3390/electronics10030279}, }                                                 #
#                                                                                                       #
#########################################################################################################


AP: 95.48% (0)
mAP: 95.48%
```

YOLOX + SE module (backbone + FPN)

Precision-Recall curve



AP_{85}

```
##################################################################################################
#                                                                                                #
# THE CURRENT VERSION WAS UPDATED WITH A VISUAL INTERFACE, INCLUDING MORE METRICS AND SUPPORTING  #
# OTHER FILE FORMATS.                                                                            #
#                                                                                                #
# PLEASE ACCESS IT ACCESSED AT:                                                                  #
# https://github.com/rafaelpadilla/review_object_detection_metrics                               #
#                                                                                                #
# @Article{electronics10030279,                                                                  #
#     author         = {Padilla, Rafael and Passos, Wesley L. and Dias, Thadeu L. B. and Netto,  #
#                       Sergio L. and da Silva, Eduardo A. B.},                                  #
#     title          = {A Comparative Analysis of Object Detection Metrics with a Companion     #
#                       Open-Source Toolkit},                                                    #
#     journal        = {Electronics},                                                           #
#     volume         = {10},                                                                    #
#     year           = {2021},                                                                  #
#     number         = {3},                                                                     #
#     article-number = {279},                                                                   #
#     url            = {https://www.mdpi.com/2079-9292/10/3/279},                               #
#     issn           = {2079-9292},                                                             #
#     doi            = {10.3390/electronics10030279}, }                                         #
#                                                                                                #
##################################################################################################


Folder E:\Git\Object-Detection-Metrics\.\results\yolox_gta_se_fp16 already exists and may contain important results.

Enter 'Y' to continue. WARNING: THIS WILL REMOVE ALL THE CONTENTS OF THE FOLDER!
Or enter 'N' to abort and choose another folder to save the results.
Y
AP: 95.32% (0)
mAP: 95.32%
```

Discussion

Training 時，發現 mAP 分數都是 0 的問題

> 心得: 好坑啊，比 C/C++ 還難 debug

花了近 3 天時間在 debug code 上面，最後在 GTAVideoDataset 中發現，Pandas 透過 read_csv 讀取 label files 時，dtype 會是 float64。

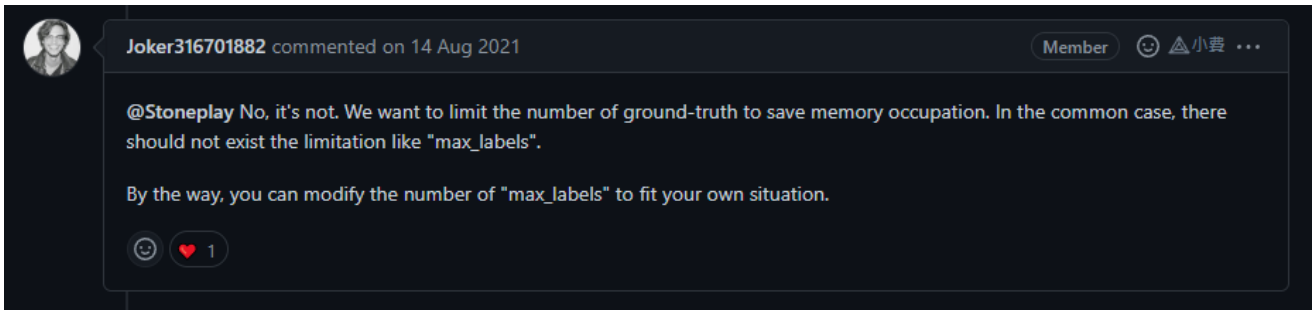
但在做 data preprocessing 時，是會轉換成 float32，導致 float64 downcast to float32 時發生問題

因此在讀取 label file 後，將 YOLO format 轉換為 VOC format 時做 float32 轉換，因為轉成 VOC format 時，可以確定 bbox 座標皆為整數

關於 hyperparameters 中的 max_labels 之必要性

原先有自行撰寫 data augmentation，但後來沒時間測試就不用了，改用預設的 TrainTransform 與 ValTransform

在 TrainTransform 中，發現需要設定 max_labels，那時還很不解為何需要，於是上網找到了這篇解釋



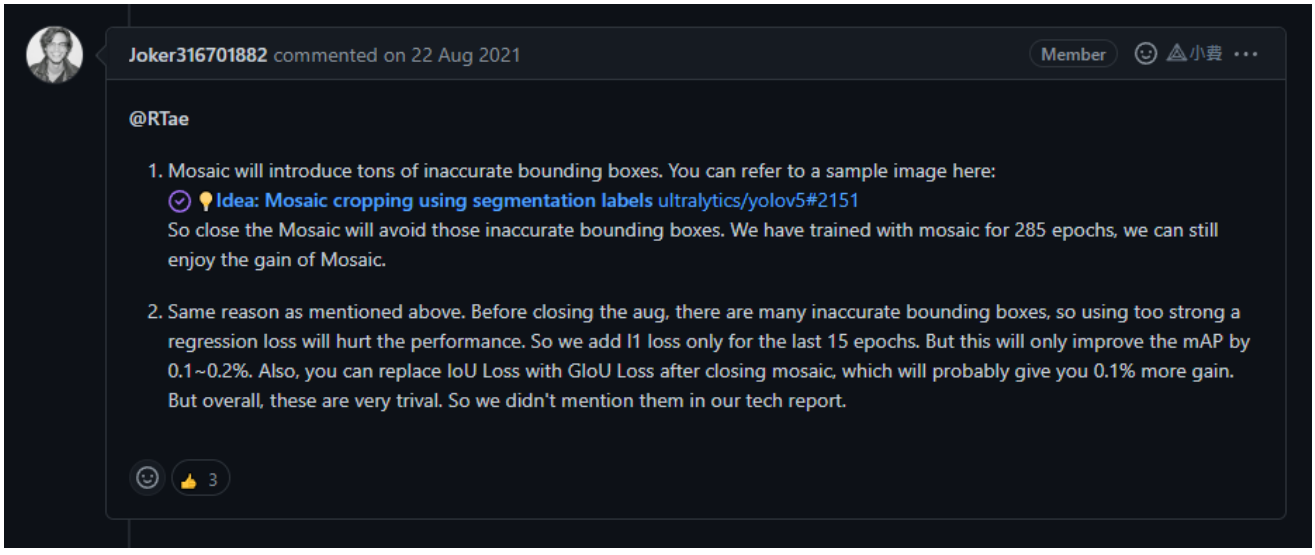
當下僅僅是認為為了節省 memory 空間，而限制 labels 的數量，但在實驗的過程中，把 max_labels 的限制拿掉時會發生錯誤。

以下為錯誤訊息

> RuntimeError: *stack expects each tensor to be equal size*, but got [13, 5] at entry 0 and [10, 5] at entry 11.

發現 YOLOX official code 在訓練時有最佳化 data fetching，其限制為 size 必須在相同的情況下才能訓練，但這樣也會有缺點，就是 max_labels 取太多時，反而占用過多的 memory，因為假如實際數量沒有到 max_labels 的話，就會 padding zero 至 max_labels 的大小。

為何 L1 regression loss 只在最後 15 個 epochs 時，才加入到 loss 計算中

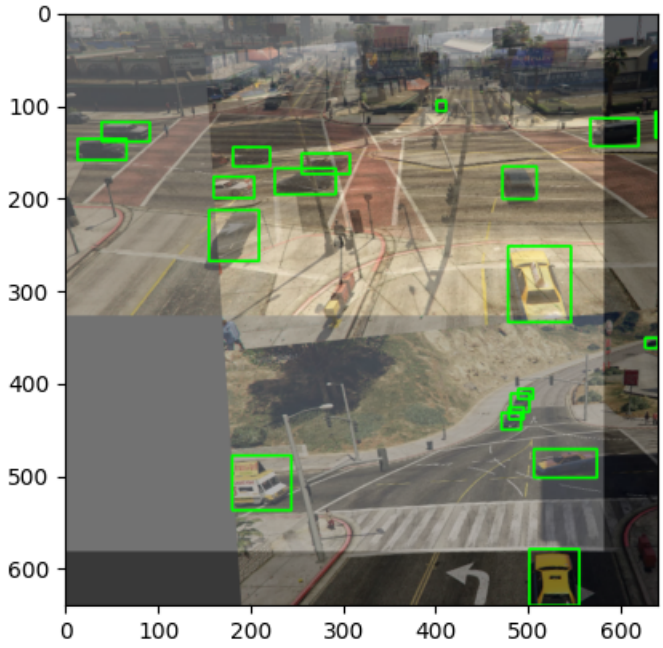


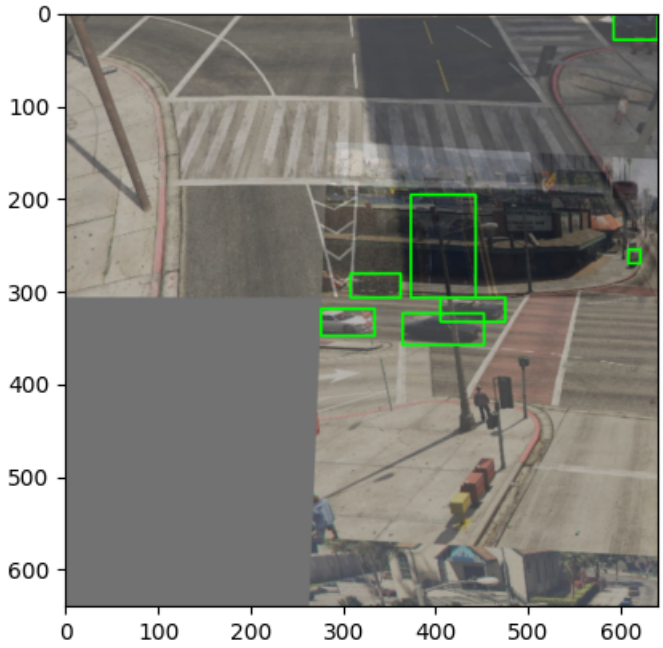
作者提到有兩個原因

1. Mosaic data augmentation 會造成 bounding box 被切掉卻沒有過濾到的問題，如果在開啟 Mosaic 的情況下開啟 L1 regression loss，會學習到不正確的資訊
2. 同上，如果開啟 L1 regression loss，regression loss 可能會過強，然後又學習錯誤的髒資料，讓 model performance 造成不好的影響

實際上，自己在經過 data augmentation 後的 data 進行 visualize，發現的確有多處 bounding box 被切掉的情況，甚至小到只剩一條線在圖片邊緣 (實際上可能座標已經超出 size 範圍)，有嘗試設定 area threshold，來過濾掉錯誤的 bounding box，但效果有限。

問題如下兩張圖所示，可以看到第一張圖右上角的 bounding box 只剩下一點，第二章圖則是物體特徵只有黑黑一坨無法辨認為汽車



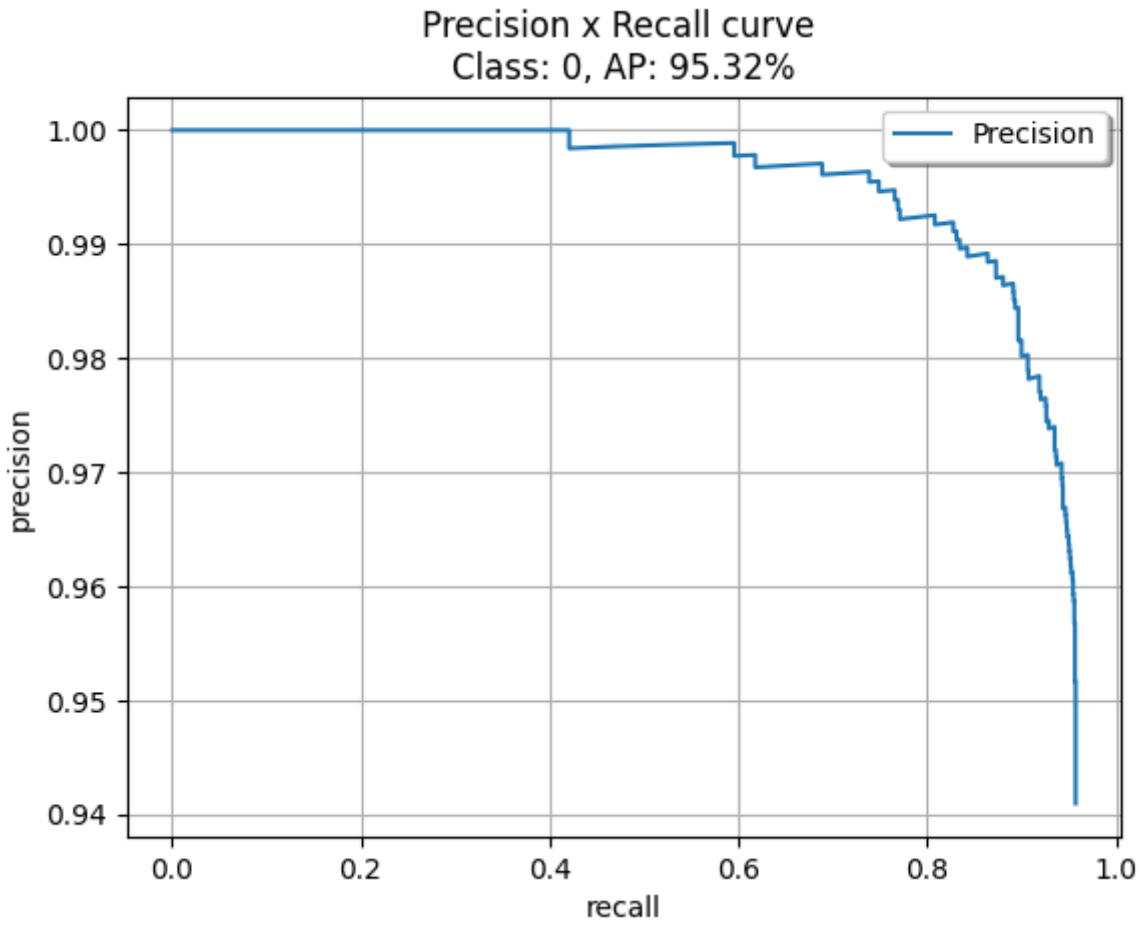


詳細可以參考: https://github.com/Megvii-BaseDetection/YOLOX/issues/555

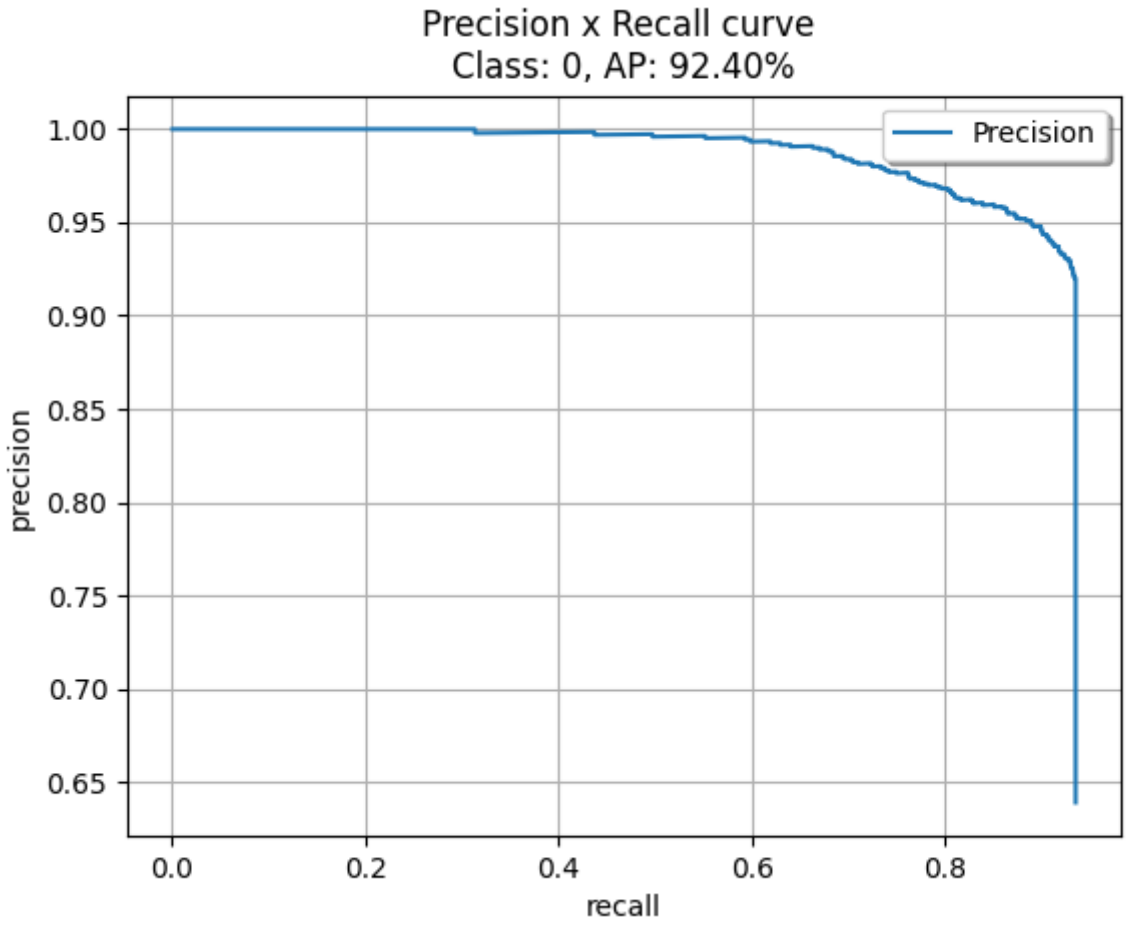
Which layer you add SE modules to and compare the corresponding results

分為兩部分，Backbone(CSPDarknet53) 與 FPN(PANet)，由於時間來不及，後者來不及訓練完成，依訓練情況來看，只加 backbone 會有比較好的效果

If SE module in Backbone is on and FPN is on



If SE module in Backbone is on and FPN is off



References

- YOLOX official code: https://github.com/Megvii-BaseDetection/YOLOX/tree/main/yolox
- SENet official code: https://github.com/hujie-frank/SENet
- YOLOX paper: https://arxiv.org/abs/2107.08430

Appendix

A

> YOLOX

```
YOLOX(
  (backbone): YOLOPAFPN(
    (backbone): CSPDarknet(
      (stem): Focus(
        (conv): BaseConv(
          (conv): Conv2d(12, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
          (bn): BatchNorm2d(32, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
          (act): SiLU(inplace=True)
        )
      )
      (dark2): Sequential(
        (0): BaseConv(
          (conv): Conv2d(32, 64, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1),
bias=False)
```

```
          (bn): BatchNorm2d(64, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
          (act): SiLU(inplace=True)
        )
        (1): CSPLayer(
          (conv1): BaseConv(
            (conv): Conv2d(64, 32, kernel_size=(1, 1), stride=(1, 1), bias=False)
            (bn): BatchNorm2d(32, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
            (act): SiLU(inplace=True)
          )
          (conv2): BaseConv(
            (conv): Conv2d(64, 32, kernel_size=(1, 1), stride=(1, 1), bias=False)
            (bn): BatchNorm2d(32, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
            (act): SiLU(inplace=True)
          )
          (conv3): BaseConv(
            (conv): Conv2d(64, 64, kernel_size=(1, 1), stride=(1, 1), bias=False)
            (bn): BatchNorm2d(64, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
            (act): SiLU(inplace=True)
          )
          (m): Sequential(
            (0): Bottleneck(
              (conv1): BaseConv(
                (conv): Conv2d(32, 32, kernel_size=(1, 1), stride=(1, 1), bias=False)
                (bn): BatchNorm2d(32, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
                (act): SiLU(inplace=True)
              )
              (conv2): BaseConv(
                (conv): Conv2d(32, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
                (bn): BatchNorm2d(32, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
                (act): SiLU(inplace=True)
              )
            )
          )
        )
      )
      (dark3): Sequential(
        (0): BaseConv(
          (conv): Conv2d(64, 128, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1),
bias=False)
          (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
          (act): SiLU(inplace=True)
        )
        (1): CSPLayer(
          (conv1): BaseConv(
            (conv): Conv2d(128, 64, kernel_size=(1, 1), stride=(1, 1), bias=False)
            (bn): BatchNorm2d(64, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
            (act): SiLU(inplace=True)
```

```
          )
          (conv2): BaseConv(
            (conv): Conv2d(128, 64, kernel_size=(1, 1), stride=(1, 1), bias=False)
            (bn): BatchNorm2d(64, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
            (act): SiLU(inplace=True)
          )
          (conv3): BaseConv(
            (conv): Conv2d(128, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
            (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
            (act): SiLU(inplace=True)
          )
          (m): Sequential(
            (0): Bottleneck(
              (conv1): BaseConv(
                (conv): Conv2d(64, 64, kernel_size=(1, 1), stride=(1, 1), bias=False)
                (bn): BatchNorm2d(64, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
                (act): SiLU(inplace=True)
              )
              (conv2): BaseConv(
                (conv): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
                (bn): BatchNorm2d(64, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
                (act): SiLU(inplace=True)
              )
            )
            (1): Bottleneck(
              (conv1): BaseConv(
                (conv): Conv2d(64, 64, kernel_size=(1, 1), stride=(1, 1), bias=False)
                (bn): BatchNorm2d(64, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
                (act): SiLU(inplace=True)
              )
              (conv2): BaseConv(
                (conv): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
                (bn): BatchNorm2d(64, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
                (act): SiLU(inplace=True)
              )
            )
            (2): Bottleneck(
              (conv1): BaseConv(
                (conv): Conv2d(64, 64, kernel_size=(1, 1), stride=(1, 1), bias=False)
                (bn): BatchNorm2d(64, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
                (act): SiLU(inplace=True)
              )
              (conv2): BaseConv(
                (conv): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
                (bn): BatchNorm2d(64, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
```

```
            (act): SiLU(inplace=True)
          )
        )
      )
    )
    (dark4): Sequential(
      (0): BaseConv(
        (conv): Conv2d(128, 256, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1),
bias=False)
        (bn): BatchNorm2d(256, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
        (act): SiLU(inplace=True)
      )
      (1): CSPLayer(
        (conv1): BaseConv(
          (conv): Conv2d(256, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
          (act): SiLU(inplace=True)
        )
        (conv2): BaseConv(
          (conv): Conv2d(256, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
          (act): SiLU(inplace=True)
        )
        (conv3): BaseConv(
          (conv): Conv2d(256, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (bn): BatchNorm2d(256, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
          (act): SiLU(inplace=True)
        )
        (m): Sequential(
          (0): Bottleneck(
            (conv1): BaseConv(
              (conv): Conv2d(128, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
              (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
              (act): SiLU(inplace=True)
            )
            (conv2): BaseConv(
              (conv): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1,
1), bias=False)
              (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
              (act): SiLU(inplace=True)
            )
          )
          (1): Bottleneck(
            (conv1): BaseConv(
              (conv): Conv2d(128, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
              (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
              (act): SiLU(inplace=True)
            )
```

```
              (conv2): BaseConv(
                (conv): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1,
1), bias=False)
                (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
                (act): SiLU(inplace=True)
              )
            )
            (2): Bottleneck(
              (conv1): BaseConv(
                (conv): Conv2d(128, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
                (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
                (act): SiLU(inplace=True)
              )
              (conv2): BaseConv(
                (conv): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1,
1), bias=False)
                (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
                (act): SiLU(inplace=True)
              )
            )
          )
        )
      )
      (dark5): Sequential(
        (0): BaseConv(
          (conv): Conv2d(256, 512, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1),
bias=False)
          (bn): BatchNorm2d(512, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
          (act): SiLU(inplace=True)
        )
        (1): SPPBottleneck(
          (conv1): BaseConv(
            (conv): Conv2d(512, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
            (bn): BatchNorm2d(256, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
            (act): SiLU(inplace=True)
          )
          (m): ModuleList(
            (0): MaxPool2d(kernel_size=5, stride=1, padding=2, dilation=1,
ceil_mode=False)
            (1): MaxPool2d(kernel_size=9, stride=1, padding=4, dilation=1,
ceil_mode=False)
            (2): MaxPool2d(kernel_size=13, stride=1, padding=6, dilation=1,
ceil_mode=False)
          )
          (conv2): BaseConv(
            (conv): Conv2d(1024, 512, kernel_size=(1, 1), stride=(1, 1), bias=False)
            (bn): BatchNorm2d(512, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
            (act): SiLU(inplace=True)
          )
        )
```

```
        (2): CSPLayer(
          (conv1): BaseConv(
            (conv): Conv2d(512, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
            (bn): BatchNorm2d(256, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
            (act): SiLU(inplace=True)
          )
          (conv2): BaseConv(
            (conv): Conv2d(512, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
            (bn): BatchNorm2d(256, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
            (act): SiLU(inplace=True)
          )
          (conv3): BaseConv(
            (conv): Conv2d(512, 512, kernel_size=(1, 1), stride=(1, 1), bias=False)
            (bn): BatchNorm2d(512, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
            (act): SiLU(inplace=True)
          )
          (m): Sequential(
            (0): Bottleneck(
              (conv1): BaseConv(
                (conv): Conv2d(256, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
                (bn): BatchNorm2d(256, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
                (act): SiLU(inplace=True)
              )
              (conv2): BaseConv(
                (conv): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1,
1), bias=False)
                (bn): BatchNorm2d(256, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
                (act): SiLU(inplace=True)
              )
            )
          )
        )
      )
    )
    (upsample): Upsample(scale_factor=2.0, mode=nearest)
    (lateral_conv0): BaseConv(
      (conv): Conv2d(512, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(256, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
      (act): SiLU(inplace=True)
    )
    (C3_p4): CSPLayer(
      (conv1): BaseConv(
        (conv): Conv2d(512, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
        (act): SiLU(inplace=True)
      )
      (conv2): BaseConv(
        (conv): Conv2d(512, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
```

```
        (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
        (act): SiLU(inplace=True)
      )
      (conv3): BaseConv(
        (conv): Conv2d(256, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn): BatchNorm2d(256, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
        (act): SiLU(inplace=True)
      )
      (m): Sequential(
        (0): Bottleneck(
          (conv1): BaseConv(
            (conv): Conv2d(128, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
            (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
            (act): SiLU(inplace=True)
          )
          (conv2): BaseConv(
            (conv): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
            (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
            (act): SiLU(inplace=True)
          )
        )
      )
    )
    (reduce_conv1): BaseConv(
      (conv): Conv2d(256, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
      (act): SiLU(inplace=True)
    )
    (C3_p3): CSPLayer(
      (conv1): BaseConv(
        (conv): Conv2d(256, 64, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn): BatchNorm2d(64, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
        (act): SiLU(inplace=True)
      )
      (conv2): BaseConv(
        (conv): Conv2d(256, 64, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn): BatchNorm2d(64, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
        (act): SiLU(inplace=True)
      )
      (conv3): BaseConv(
        (conv): Conv2d(128, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
        (act): SiLU(inplace=True)
      )
      (m): Sequential(
        (0): Bottleneck(
          (conv1): BaseConv(
```

```
            (conv): Conv2d(64, 64, kernel_size=(1, 1), stride=(1, 1), bias=False)
            (bn): BatchNorm2d(64, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
            (act): SiLU(inplace=True)
          )
          (conv2): BaseConv(
            (conv): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
            (bn): BatchNorm2d(64, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
            (act): SiLU(inplace=True)
          )
        )
      )
    )
    (bu_conv2): BaseConv(
      (conv): Conv2d(128, 128, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1),
bias=False)
      (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
      (act): SiLU(inplace=True)
    )
    (C3_n3): CSPLayer(
      (conv1): BaseConv(
        (conv): Conv2d(256, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
        (act): SiLU(inplace=True)
      )
      (conv2): BaseConv(
        (conv): Conv2d(256, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
        (act): SiLU(inplace=True)
      )
      (conv3): BaseConv(
        (conv): Conv2d(256, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn): BatchNorm2d(256, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
        (act): SiLU(inplace=True)
      )
      (m): Sequential(
        (0): Bottleneck(
          (conv1): BaseConv(
            (conv): Conv2d(128, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
            (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
            (act): SiLU(inplace=True)
          )
          (conv2): BaseConv(
            (conv): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
            (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
            (act): SiLU(inplace=True)
          )
```

```
        )
      )
    )
    (bu_conv1): BaseConv(
      (conv): Conv2d(256, 256, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1),
bias=False)
      (bn): BatchNorm2d(256, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
      (act): SiLU(inplace=True)
    )
    (C3_n4): CSPLayer(
      (conv1): BaseConv(
        (conv): Conv2d(512, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn): BatchNorm2d(256, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
        (act): SiLU(inplace=True)
      )
      (conv2): BaseConv(
        (conv): Conv2d(512, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn): BatchNorm2d(256, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
        (act): SiLU(inplace=True)
      )
      (conv3): BaseConv(
        (conv): Conv2d(512, 512, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn): BatchNorm2d(512, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
        (act): SiLU(inplace=True)
      )
      (m): Sequential(
        (0): Bottleneck(
          (conv1): BaseConv(
            (conv): Conv2d(256, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
            (bn): BatchNorm2d(256, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
            (act): SiLU(inplace=True)
          )
          (conv2): BaseConv(
            (conv): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
            (bn): BatchNorm2d(256, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
            (act): SiLU(inplace=True)
          )
        )
      )
    )
  )
  (head): YOLOXHead(
    (cls_convs): ModuleList(
      (0): Sequential(
        (0): BaseConv(
          (conv): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
          (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
```

```
          (act): SiLU(inplace=True)
        )
        (1): BaseConv(
          (conv): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
          (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
          (act): SiLU(inplace=True)
        )
      )
      (1): Sequential(
        (0): BaseConv(
          (conv): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
          (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
          (act): SiLU(inplace=True)
        )
        (1): BaseConv(
          (conv): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
          (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
          (act): SiLU(inplace=True)
        )
      )
      (2): Sequential(
        (0): BaseConv(
          (conv): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
          (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
          (act): SiLU(inplace=True)
        )
        (1): BaseConv(
          (conv): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
          (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
          (act): SiLU(inplace=True)
        )
      )
    )
    (reg_convs): ModuleList(
      (0): Sequential(
        (0): BaseConv(
          (conv): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
          (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
          (act): SiLU(inplace=True)
        )
        (1): BaseConv(
          (conv): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
```

```
          (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
          (act): SiLU(inplace=True)
        )
      )
      (1): Sequential(
        (0): BaseConv(
          (conv): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
          (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
          (act): SiLU(inplace=True)
        )
        (1): BaseConv(
          (conv): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
          (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
          (act): SiLU(inplace=True)
        )
      )
      (2): Sequential(
        (0): BaseConv(
          (conv): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
          (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
          (act): SiLU(inplace=True)
        )
        (1): BaseConv(
          (conv): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
          (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
          (act): SiLU(inplace=True)
        )
      )
    )
    (cls_preds): ModuleList(
      (0): Conv2d(128, 1, kernel_size=(1, 1), stride=(1, 1))
      (1): Conv2d(128, 1, kernel_size=(1, 1), stride=(1, 1))
      (2): Conv2d(128, 1, kernel_size=(1, 1), stride=(1, 1))
    )
    (reg_preds): ModuleList(
      (0): Conv2d(128, 4, kernel_size=(1, 1), stride=(1, 1))
      (1): Conv2d(128, 4, kernel_size=(1, 1), stride=(1, 1))
      (2): Conv2d(128, 4, kernel_size=(1, 1), stride=(1, 1))
    )
    (obj_preds): ModuleList(
      (0): Conv2d(128, 1, kernel_size=(1, 1), stride=(1, 1))
      (1): Conv2d(128, 1, kernel_size=(1, 1), stride=(1, 1))
      (2): Conv2d(128, 1, kernel_size=(1, 1), stride=(1, 1))
    )
    (stems): ModuleList(
      (0): BaseConv(
        (conv): Conv2d(128, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
```

```
        (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
        (act): SiLU(inplace=True)
      )
      (1): BaseConv(
        (conv): Conv2d(256, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
        (act): SiLU(inplace=True)
      )
      (2): BaseConv(
        (conv): Conv2d(512, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
        (act): SiLU(inplace=True)
      )
    )
    (l1_loss): L1Loss()
    (bcewithlog_loss): BCEWithLogitsLoss()
    (iou_loss): IOUloss()
  )
)
```

B

> YOLOX + SE module

```
YOLOX(
  (backbone): YOLOPAFPN(
    (backbone): CSPDarknet(
      (stem): Focus(
        (conv): BaseConv(
          (conv): Conv2d(12, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
          (bn): BatchNorm2d(32, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
          (act): SiLU(inplace=True)
        )
      )
      (dark2): Sequential(
        (0): BaseConv(
          (conv): Conv2d(32, 64, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1),
bias=False)
          (bn): BatchNorm2d(64, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
          (act): SiLU(inplace=True)
        )
        (1): CSPLayer(
          (conv1): BaseConv(
            (conv): Conv2d(64, 32, kernel_size=(1, 1), stride=(1, 1), bias=False)
            (bn): BatchNorm2d(32, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
            (act): SiLU(inplace=True)
          )
          (conv2): BaseConv(
```

```
            (conv): Conv2d(64, 32, kernel_size=(1, 1), stride=(1, 1), bias=False)
            (bn): BatchNorm2d(32, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
            (act): SiLU(inplace=True)
          )
          (conv3): BaseConv(
            (conv): Conv2d(64, 64, kernel_size=(1, 1), stride=(1, 1), bias=False)
            (bn): BatchNorm2d(64, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
            (act): SiLU(inplace=True)
          )
          (m): Sequential(
            (0): Bottleneck(
              (conv1): BaseConv(
                (conv): Conv2d(32, 32, kernel_size=(1, 1), stride=(1, 1), bias=False)
                (bn): BatchNorm2d(32, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
                (act): SiLU(inplace=True)
              )
              (conv2): BaseConv(
                (conv): Conv2d(32, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
                (bn): BatchNorm2d(32, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
                (act): SiLU(inplace=True)
              )
              (se_m): SELayer(
                (avg_pool): AdaptiveAvgPool2d(output_size=1)
                (fcn): Sequential(
                  (0): Conv2d(32, 2, kernel_size=(1, 1), stride=(1, 1))
                  (1): ReLU(inplace=True)
                  (2): Conv2d(2, 32, kernel_size=(1, 1), stride=(1, 1))
                  (3): Sigmoid()
                )
              )
            )
          )
        )
      )
      (dark3): Sequential(
        (0): BaseConv(
          (conv): Conv2d(64, 128, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1),
bias=False)
          (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
          (act): SiLU(inplace=True)
        )
        (1): CSPLayer(
          (conv1): BaseConv(
            (conv): Conv2d(128, 64, kernel_size=(1, 1), stride=(1, 1), bias=False)
            (bn): BatchNorm2d(64, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
            (act): SiLU(inplace=True)
          )
          (conv2): BaseConv(
            (conv): Conv2d(128, 64, kernel_size=(1, 1), stride=(1, 1), bias=False)
```

```
            (bn): BatchNorm2d(64, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
            (act): SiLU(inplace=True)
          )
          (conv3): BaseConv(
            (conv): Conv2d(128, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
            (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
            (act): SiLU(inplace=True)
          )
          (m): Sequential(
            (0): Bottleneck(
              (conv1): BaseConv(
                (conv): Conv2d(64, 64, kernel_size=(1, 1), stride=(1, 1), bias=False)
                (bn): BatchNorm2d(64, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
                (act): SiLU(inplace=True)
              )
              (conv2): BaseConv(
                (conv): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
                (bn): BatchNorm2d(64, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
                (act): SiLU(inplace=True)
              )
              (se_m): SELayer(
                (avg_pool): AdaptiveAvgPool2d(output_size=1)
                (fcn): Sequential(
                  (0): Conv2d(64, 4, kernel_size=(1, 1), stride=(1, 1))
                  (1): ReLU(inplace=True)
                  (2): Conv2d(4, 64, kernel_size=(1, 1), stride=(1, 1))
                  (3): Sigmoid()
                )
              )
            )
            (1): Bottleneck(
              (conv1): BaseConv(
                (conv): Conv2d(64, 64, kernel_size=(1, 1), stride=(1, 1), bias=False)
                (bn): BatchNorm2d(64, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
                (act): SiLU(inplace=True)
              )
              (conv2): BaseConv(
                (conv): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
                (bn): BatchNorm2d(64, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
                (act): SiLU(inplace=True)
              )
              (se_m): SELayer(
                (avg_pool): AdaptiveAvgPool2d(output_size=1)
                (fcn): Sequential(
                  (0): Conv2d(64, 4, kernel_size=(1, 1), stride=(1, 1))
                  (1): ReLU(inplace=True)
                  (2): Conv2d(4, 64, kernel_size=(1, 1), stride=(1, 1))
                  (3): Sigmoid()
```

```
              )
            )
          )
          (2): Bottleneck(
            (conv1): BaseConv(
              (conv): Conv2d(64, 64, kernel_size=(1, 1), stride=(1, 1), bias=False)
              (bn): BatchNorm2d(64, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
              (act): SiLU(inplace=True)
            )
            (conv2): BaseConv(
              (conv): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
              (bn): BatchNorm2d(64, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
              (act): SiLU(inplace=True)
            )
            (se_m): SELayer(
              (avg_pool): AdaptiveAvgPool2d(output_size=1)
              (fcn): Sequential(
                (0): Conv2d(64, 4, kernel_size=(1, 1), stride=(1, 1))
                (1): ReLU(inplace=True)
                (2): Conv2d(4, 64, kernel_size=(1, 1), stride=(1, 1))
                (3): Sigmoid()
              )
            )
          )
        )
      )
    )
    (dark4): Sequential(
      (0): BaseConv(
        (conv): Conv2d(128, 256, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1),
bias=False)
        (bn): BatchNorm2d(256, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
        (act): SiLU(inplace=True)
      )
      (1): CSPLayer(
        (conv1): BaseConv(
          (conv): Conv2d(256, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
          (act): SiLU(inplace=True)
        )
        (conv2): BaseConv(
          (conv): Conv2d(256, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
          (act): SiLU(inplace=True)
        )
        (conv3): BaseConv(
          (conv): Conv2d(256, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (bn): BatchNorm2d(256, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
          (act): SiLU(inplace=True)
```

```
          )
          (m): Sequential(
            (0): Bottleneck(
              (conv1): BaseConv(
                (conv): Conv2d(128, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
                (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
                (act): SiLU(inplace=True)
              )
              (conv2): BaseConv(
                (conv): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1,
1), bias=False)
                (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
                (act): SiLU(inplace=True)
              )
              (se_m): SELayer(
                (avg_pool): AdaptiveAvgPool2d(output_size=1)
                (fcn): Sequential(
                  (0): Conv2d(128, 8, kernel_size=(1, 1), stride=(1, 1))
                  (1): ReLU(inplace=True)
                  (2): Conv2d(8, 128, kernel_size=(1, 1), stride=(1, 1))
                  (3): Sigmoid()
                )
              )
            )
            (1): Bottleneck(
              (conv1): BaseConv(
                (conv): Conv2d(128, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
                (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
                (act): SiLU(inplace=True)
              )
              (conv2): BaseConv(
                (conv): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1,
1), bias=False)
                (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
                (act): SiLU(inplace=True)
              )
              (se_m): SELayer(
                (avg_pool): AdaptiveAvgPool2d(output_size=1)
                (fcn): Sequential(
                  (0): Conv2d(128, 8, kernel_size=(1, 1), stride=(1, 1))
                  (1): ReLU(inplace=True)
                  (2): Conv2d(8, 128, kernel_size=(1, 1), stride=(1, 1))
                  (3): Sigmoid()
                )
              )
            )
            (2): Bottleneck(
              (conv1): BaseConv(
                (conv): Conv2d(128, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
                (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
                (act): SiLU(inplace=True)
```

```
              )
              (conv2): BaseConv(
                (conv): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1,
1), bias=False)
                (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
                (act): SiLU(inplace=True)
              )
              (se_m): SELayer(
                (avg_pool): AdaptiveAvgPool2d(output_size=1)
                (fcn): Sequential(
                  (0): Conv2d(128, 8, kernel_size=(1, 1), stride=(1, 1))
                  (1): ReLU(inplace=True)
                  (2): Conv2d(8, 128, kernel_size=(1, 1), stride=(1, 1))
                  (3): Sigmoid()
                )
              )
            )
          )
        )
      )
      (dark5): Sequential(
        (0): BaseConv(
          (conv): Conv2d(256, 512, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1),
bias=False)
          (bn): BatchNorm2d(512, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
          (act): SiLU(inplace=True)
        )
        (1): SPPBottleneck(
          (conv1): BaseConv(
            (conv): Conv2d(512, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
            (bn): BatchNorm2d(256, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
            (act): SiLU(inplace=True)
          )
          (m): ModuleList(
            (0): MaxPool2d(kernel_size=5, stride=1, padding=2, dilation=1,
ceil_mode=False)
            (1): MaxPool2d(kernel_size=9, stride=1, padding=4, dilation=1,
ceil_mode=False)
            (2): MaxPool2d(kernel_size=13, stride=1, padding=6, dilation=1,
ceil_mode=False)
          )
          (conv2): BaseConv(
            (conv): Conv2d(1024, 512, kernel_size=(1, 1), stride=(1, 1), bias=False)
            (bn): BatchNorm2d(512, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
            (act): SiLU(inplace=True)
          )
        )
        (2): CSPLayer(
          (conv1): BaseConv(
            (conv): Conv2d(512, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
            (bn): BatchNorm2d(256, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
```

```
            (act): SiLU(inplace=True)
          )
          (conv2): BaseConv(
            (conv): Conv2d(512, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
            (bn): BatchNorm2d(256, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
            (act): SiLU(inplace=True)
          )
          (conv3): BaseConv(
            (conv): Conv2d(512, 512, kernel_size=(1, 1), stride=(1, 1), bias=False)
            (bn): BatchNorm2d(512, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
            (act): SiLU(inplace=True)
          )
          (m): Sequential(
            (0): Bottleneck(
              (conv1): BaseConv(
                (conv): Conv2d(256, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
                (bn): BatchNorm2d(256, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
                (act): SiLU(inplace=True)
              )
              (conv2): BaseConv(
                (conv): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1,
1), bias=False)
                (bn): BatchNorm2d(256, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
                (act): SiLU(inplace=True)
              )
              (se_m): SELayer(
                (avg_pool): AdaptiveAvgPool2d(output_size=1)
                (fcn): Sequential(
                  (0): Conv2d(256, 16, kernel_size=(1, 1), stride=(1, 1))
                  (1): ReLU(inplace=True)
                  (2): Conv2d(16, 256, kernel_size=(1, 1), stride=(1, 1))
                  (3): Sigmoid()
                )
              )
            )
          )
        )
      )
    )
    (upsample): Upsample(scale_factor=2.0, mode=nearest)
    (lateral_conv0): BaseConv(
      (conv): Conv2d(512, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(256, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
      (act): SiLU(inplace=True)
    )
    (C3_p4): CSPLayer(
      (conv1): BaseConv(
        (conv): Conv2d(512, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
        (act): SiLU(inplace=True)
```

```
      )
      (conv2): BaseConv(
        (conv): Conv2d(512, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
        (act): SiLU(inplace=True)
      )
      (conv3): BaseConv(
        (conv): Conv2d(256, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn): BatchNorm2d(256, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
        (act): SiLU(inplace=True)
      )
      (m): Sequential(
        (0): Bottleneck(
          (conv1): BaseConv(
            (conv): Conv2d(128, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
            (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
            (act): SiLU(inplace=True)
          )
          (conv2): BaseConv(
            (conv): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
            (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
            (act): SiLU(inplace=True)
          )
          (se_m): SELayer(
            (avg_pool): AdaptiveAvgPool2d(output_size=1)
            (fcn): Sequential(
              (0): Conv2d(128, 8, kernel_size=(1, 1), stride=(1, 1))
              (1): ReLU(inplace=True)
              (2): Conv2d(8, 128, kernel_size=(1, 1), stride=(1, 1))
              (3): Sigmoid()
            )
          )
        )
      )
    )
    (reduce_conv1): BaseConv(
      (conv): Conv2d(256, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
      (act): SiLU(inplace=True)
    )
    (C3_p3): CSPLayer(
      (conv1): BaseConv(
        (conv): Conv2d(256, 64, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn): BatchNorm2d(64, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
        (act): SiLU(inplace=True)
      )
      (conv2): BaseConv(
        (conv): Conv2d(256, 64, kernel_size=(1, 1), stride=(1, 1), bias=False)
```

```
        (bn): BatchNorm2d(64, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
        (act): SiLU(inplace=True)
      )
      (conv3): BaseConv(
        (conv): Conv2d(128, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
        (act): SiLU(inplace=True)
      )
      (m): Sequential(
        (0): Bottleneck(
          (conv1): BaseConv(
            (conv): Conv2d(64, 64, kernel_size=(1, 1), stride=(1, 1), bias=False)
            (bn): BatchNorm2d(64, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
            (act): SiLU(inplace=True)
          )
          (conv2): BaseConv(
            (conv): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
            (bn): BatchNorm2d(64, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
            (act): SiLU(inplace=True)
          )
          (se_m): SELayer(
            (avg_pool): AdaptiveAvgPool2d(output_size=1)
            (fcn): Sequential(
              (0): Conv2d(64, 4, kernel_size=(1, 1), stride=(1, 1))
              (1): ReLU(inplace=True)
              (2): Conv2d(4, 64, kernel_size=(1, 1), stride=(1, 1))
              (3): Sigmoid()
            )
          )
        )
      )
    )
    (bu_conv2): BaseConv(
      (conv): Conv2d(128, 128, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1),
bias=False)
      (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
      (act): SiLU(inplace=True)
    )
    (C3_n3): CSPLayer(
      (conv1): BaseConv(
        (conv): Conv2d(256, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
        (act): SiLU(inplace=True)
      )
      (conv2): BaseConv(
        (conv): Conv2d(256, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
        (act): SiLU(inplace=True)
```

```
      )
      (conv3): BaseConv(
        (conv): Conv2d(256, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn): BatchNorm2d(256, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
        (act): SiLU(inplace=True)
      )
      (m): Sequential(
        (0): Bottleneck(
          (conv1): BaseConv(
            (conv): Conv2d(128, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
            (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
            (act): SiLU(inplace=True)
          )
          (conv2): BaseConv(
            (conv): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
            (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
            (act): SiLU(inplace=True)
          )
          (se_m): SELayer(
            (avg_pool): AdaptiveAvgPool2d(output_size=1)
            (fcn): Sequential(
              (0): Conv2d(128, 8, kernel_size=(1, 1), stride=(1, 1))
              (1): ReLU(inplace=True)
              (2): Conv2d(8, 128, kernel_size=(1, 1), stride=(1, 1))
              (3): Sigmoid()
            )
          )
        )
      )
    )
    (bu_conv1): BaseConv(
      (conv): Conv2d(256, 256, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1),
bias=False)
      (bn): BatchNorm2d(256, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
      (act): SiLU(inplace=True)
    )
    (C3_n4): CSPLayer(
      (conv1): BaseConv(
        (conv): Conv2d(512, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn): BatchNorm2d(256, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
        (act): SiLU(inplace=True)
      )
      (conv2): BaseConv(
        (conv): Conv2d(512, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn): BatchNorm2d(256, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
        (act): SiLU(inplace=True)
      )
      (conv3): BaseConv(
        (conv): Conv2d(512, 512, kernel_size=(1, 1), stride=(1, 1), bias=False)
```

```
        (bn): BatchNorm2d(512, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
        (act): SiLU(inplace=True)
      )
      (m): Sequential(
        (0): Bottleneck(
          (conv1): BaseConv(
            (conv): Conv2d(256, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
            (bn): BatchNorm2d(256, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
            (act): SiLU(inplace=True)
          )
          (conv2): BaseConv(
            (conv): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
            (bn): BatchNorm2d(256, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
            (act): SiLU(inplace=True)
          )
          (se_m): SELayer(
            (avg_pool): AdaptiveAvgPool2d(output_size=1)
            (fcn): Sequential(
              (0): Conv2d(256, 16, kernel_size=(1, 1), stride=(1, 1))
              (1): ReLU(inplace=True)
              (2): Conv2d(16, 256, kernel_size=(1, 1), stride=(1, 1))
              (3): Sigmoid()
            )
          )
        )
      )
    )
  )
  (head): YOLOXHead(
    (cls_convs): ModuleList(
      (0): Sequential(
        (0): BaseConv(
          (conv): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
          (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
          (act): SiLU(inplace=True)
        )
        (1): BaseConv(
          (conv): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
          (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
          (act): SiLU(inplace=True)
        )
      )
      (1): Sequential(
        (0): BaseConv(
          (conv): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
          (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
```

```
          (act): SiLU(inplace=True)
        )
        (1): BaseConv(
          (conv): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
          (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
          (act): SiLU(inplace=True)
        )
      )
      (2): Sequential(
        (0): BaseConv(
          (conv): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
          (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
          (act): SiLU(inplace=True)
        )
        (1): BaseConv(
          (conv): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
          (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
          (act): SiLU(inplace=True)
        )
      )
    )
    (reg_convs): ModuleList(
      (0): Sequential(
        (0): BaseConv(
          (conv): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
          (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
          (act): SiLU(inplace=True)
        )
        (1): BaseConv(
          (conv): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
          (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
          (act): SiLU(inplace=True)
        )
      )
      (1): Sequential(
        (0): BaseConv(
          (conv): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
          (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
          (act): SiLU(inplace=True)
        )
        (1): BaseConv(
          (conv): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
```

```
          (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
          (act): SiLU(inplace=True)
        )
      )
      (2): Sequential(
        (0): BaseConv(
          (conv): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
          (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
          (act): SiLU(inplace=True)
        )
        (1): BaseConv(
          (conv): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
          (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
          (act): SiLU(inplace=True)
        )
      )
    )
    (cls_preds): ModuleList(
      (0): Conv2d(128, 1, kernel_size=(1, 1), stride=(1, 1))
      (1): Conv2d(128, 1, kernel_size=(1, 1), stride=(1, 1))
      (2): Conv2d(128, 1, kernel_size=(1, 1), stride=(1, 1))
    )
    (reg_preds): ModuleList(
      (0): Conv2d(128, 4, kernel_size=(1, 1), stride=(1, 1))
      (1): Conv2d(128, 4, kernel_size=(1, 1), stride=(1, 1))
      (2): Conv2d(128, 4, kernel_size=(1, 1), stride=(1, 1))
    )
    (obj_preds): ModuleList(
      (0): Conv2d(128, 1, kernel_size=(1, 1), stride=(1, 1))
      (1): Conv2d(128, 1, kernel_size=(1, 1), stride=(1, 1))
      (2): Conv2d(128, 1, kernel_size=(1, 1), stride=(1, 1))
    )
    (stems): ModuleList(
      (0): BaseConv(
        (conv): Conv2d(128, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
        (act): SiLU(inplace=True)
      )
      (1): BaseConv(
        (conv): Conv2d(256, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
        (act): SiLU(inplace=True)
      )
      (2): BaseConv(
        (conv): Conv2d(512, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn): BatchNorm2d(128, eps=0.001, momentum=0.03, affine=True,
track_running_stats=True)
        (act): SiLU(inplace=True)
      )
```

```
    )
    (l1_loss): L1Loss()
    (bcewithlog_loss): BCEWithLogitsLoss()
    (iou_loss): IOUloss()
  )
)
```