SIT 789

Task 5.2: Minor research project

1. Introduction

Artificial Intelligence has been changing the way of software development across different verticals. Better deep learning models and algorithms are coming up owing to better hardware capabilities and increase in organically generated data. In [1] we can also see this impact on computer vision, where impact of deep learning in the domain of computer vision has been discussed at length. Object detection is a specific subproblem within the domain of computer vision where the objective is to find the exact location as bounding box coordinates on a given image frame. Over last few decades, several algorithms have been proposed for performing object detection. Earlier, classical machine learning methods based on hand crafted features like Haar Cascade as proposed by Viola-Jones in [2] and Histogram of Oriented Gradients (HOG) [3] were used across tasks related to object detection. The impact of deep learning can be seen in object detection scenarios as well, recent deep learning architectures like Faster RCNN [4], SSD [5] and YOLO [6] constitute some of the state-of-the-art object detection deep learning networks. This report focusses on summarising the working of YOLO9000 [7] and finally demonstrates the working using Road Sign Detection dataset [8].

2. The road to YOLO9000

At the time when YOLO [6] was introduced, detection systems used classifiers which used techniques like sliding window or region proposal to classify various regions of image at different scales. YOLO proposed a novel approach of reframing object detection problem as a regression problem, the algorithm uses a unified model to predict object coordinates and class probabilities using raw image pixels. The algorithm outputs multiple bounding boxes and probabilities representing associated class labels and then uses non-maximum suppression to choose dominating object bounding location and label (Shown in figure 1). An added advantage of this approach is that because the network looks at the complete image frame during the training stage, it also learns the contextual information associated with the object of interest through object's neighbourhood.

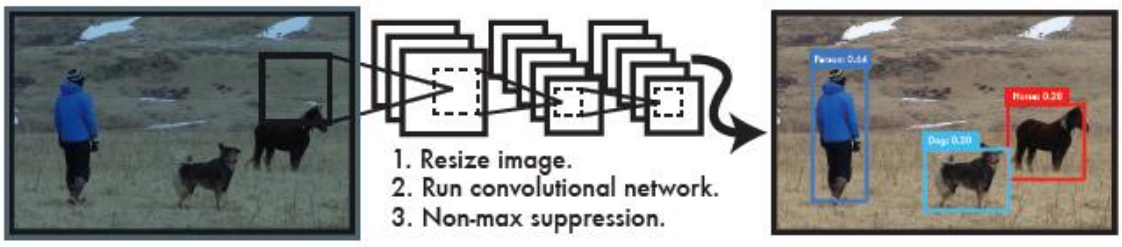


Fig 1: Image showing the working of YOLO [6].

While YOLO had its novelties, it suffered from multiple shortcomings, a significant error when compared to region proposal methods was the low recall of YOLO. YOLO9000 [7] or also known as YOLOv2 was introduced to address these shortcomings and take the YOLO architecture to at par or surpass the state-of-the-art approaches.

3. Why YOLO works?

This section discusses the additions and novel concepts introduced by YOLO9000, which make it the state-of-the-art object detection framework of the time.

YOLO9000 introduced **Batch Normalisation**, this helps the model to improve convergence and tackle regularisation issues. [7] reports 2% increase in mAP (mean Average Precision) after adding Batch Normalisation on all the convolution layers of the original YOLO architecture. Inspired from the use of priors in Faster R-CNN, YOLO9000 introduces the concept of **Anchor Boxes** to the YOLO architecture. To perform this modification, fully connected layer of the original YOLO architecture is removed, and the network learns to predicts offsets with respect to hard coded anchor boxes, this simplifies the learning process. Another key modification while introducing anchor boxes was the reducing the image resolution from 448 x 448 to 416 x416, this forces the network to output odd number of bounding box coordinates for the feature map and the network has only one centre cell. This also means that the output feature map is now of the dimension 13 x 13 as YOLO9000 has convolution layers which down sample the input image by a factor of 32.

With these modifications, another change to the YOLO architecture was needed, the original architecture predicted class probabilities based on actual locations of the object in the image, instead of this, the architecture now predicts class probabilities and *objectness score* for every anchor box. The concept of objectness score is preserved in the modified architecture as well, where objectness score denotes the IOU of the proposed bounding box and the ground truth bounding box and given there is an object, class probabilities denote the conditional probability that of the class labels associated with the object. These changes contribute to a significant increase in recall, taking the initial recall figure of 81% to 88%. While there is an increase in recall, the accuracy of the architecture takes a slight hit going down to 69.2 mAP from 69.5 mAP.

While the introduction of anchor boxes increased recall, it had some shortcomings, the first major shortcoming was the hand picked or hard coded anchors used, this makes it difficult for the network to predict better detections for different objects. To tackle this issue, authors use KMeans to select the anchor boxes (with K value of 5). This strategy results in much higher IOU as opposed to using hard coded anchor boxes.

Because the anchor boxes are predicted as offsets, they might be shifted to an inaccurate location in the image. This unconstrained nature of the anchor boxes prohibits the network to become stable, this is tackled by introducing logistic activation. This is like the approach used in YOLOv1 and the predicted bounding box coordinates are relative to the grid cell location. This squashes the input between 0 and 1 and makes the learning process easier as the offsets are localised the given grid cells and introduces additional stability on the network. Another key experiment was the introduction of **passthrough layer**, this allows the features from previous layers to be used deeper in the network. This brings higher resolution features and stacks them with lower resolution features, this provides the detector access to an elaborated feature map induced with fine grained features to perform detection.

Another powerful addition to the training process of the improved YOLO9000 architecture is the introduction of **multi-scale training**, during the training process the network chooses an image resolution randomly after every 10 batches. This is possible because the network only consists of convolution and pooling layer, this makes the network elastic enough to be resized during the training process. This also makes the network more robust to handle various input sizes, this makes YOLO9000 ideal for real time applications where such high frame rate is preferred. The range for these resizes

values varies from 320 x 320 to 608 x 608 (multiples of 32, this makes the down sampling convenient). The result of this multi scale training is that the network achieves very **high mAP of 78.6** for high resolution of **544 x 544 at an FPS of 40** whereas it performs reasonably well at low resolutions of **288 x 288** where it achieves **a decent mAP of 69.0 with very high 91 FPS**. This provides the end user a flexibility to use the network depending on the use case (high latency vs high accuracy).

4. Possible improvements on YOLO9000

The previous section describes how and why the YOLO9000 detector came to be known as one of the state-of-the-art detectors. While the modifications to YOLOv1 architecture made several improvements to design and performance, there is still a considerable room for future improvements to the architecture of YOLO9000. This section explores the possible improvements which can make this architecture even more efficient. Section 4.1 highlight some of the work that has already been done to improve YOLO9000 and section 4.2 highlights some proposals which can lay foundations to increase the performance even more.

4.1. The YOLO family

Over the years several implementations have contributed to adding features and improvements to the YOLO9000 architecture. Some of these are from the original authors (Yolov3) while others (YOLOv4, v5, v6, v7) are from different contributors. This is just a brief overview of the other architectures in this family.

YOLOv3 [9]: YOLOv3 aims to improve the accuracy of YOLOv2 and increases the complexity of the features extracted by the convolution layer. To achieve this, the convolution layers are increased from 19 to 53. The framework for training and testing YOLO is developed in C++ is called darknet, for YOLOv3 this framework is called as Darknet-53 and for YOLOv2 Darknet-19, the suffixed number denotes the number of convolution layers in each YOLO architecture. Because YOLOv3 is deeper, it can extract higher order features and thus there is an increase in the accuracy, this is coupled with shortcut connections which enable fine grained features.

YOLOv4 [10]: YOLOv4 builds on top of YOLOv3 and introduces universal features which improve a CNN networks performance, YOLOv4 uses **Weighted-Residual-Connections, Self-adversarial-training, Mish-activation, Cross mini-Batch Normalization, Cross-Stage-Partial-connections** to improve the performance. This also uses data augmentation techniques like CutMix, MixUp, Blurring, Mossaic to improve the robustness of the model.

YOLOv5 [11]: YOLOv5 is not a published work rather a PyTorch implementation of existing concepts with minor changes. This work is more focussed on improving integration of the YOLO architecture and is compatible with popular cloud platforms like AWS, GCP and containers like Docker. The focus of this work is to provide wide support for usage of YOLO architecture apart from Darknet framework.

Note: Due to the easy integration, PyTorch compatibility and most resemblance with YOLO9000, this repository is used to demonstrate the working of YOLO on Road Sign Detection Dataset in this report.

YOLOv6 [12]: Building on top of YOLOv4, YOLOv6 improves and modifies the architecture to improve both accuracy and speed using novel quantization method which is responsible for faster FLOPs.

YOLOv7 [13]: YOLOv7 introduces trainable bag of freebies methods, re-parameterization of original model, *compound scaling* and *extend* methods and reducing parameters to increase inference speed and accuracy.

4.2 Other improvements

While the above works suggest that there is ongoing research to increase the efficiency of YOLO architectures, it is important to evaluate these architectures with the AI bias viewpoint so that we can move forward towards a *fair* object detector (YOLO architectures are significantly used in pedestrian detection scenarios, hence it is important to evaluate them on terms of *AI bias*). This will help uncover any prevalent biases and introduce training methods which can help mitigate these.

Another important area of improvement for these architectures is focus on inference using lightweight hardware. As we move towards democratization of AI more and more mobile applications and other lightweight devices (FPGA based devices) will rely on AI models. YOLO has lightweight variants such as tiny-YOLO, but even these modifications are too heavy to run in real time on low power devices, YOLO can be stripped down to a lighter network architecture like [14].

5. Experiment on Road Sign Detection Dataset

This section demonstrates how YOLO can be used to set up a training pipeline and inference pipeline using a custom dataset.

5.1 Dataset Details: The dataset [8] contains 877 samples which are divided as shown in table 1.

The dataset has these class labels:

- traffic light
- stop
- speed limit
- crosswalk

Train	701
Validation	88
Test	88

Table 1: Dataset split

5.2 Training: To train the YOLO model we use the train.py script from the official YOLOv5 repository and save the trained weights to the specified directory. It is important to note that because this is just a demonstration of the training process, we have trained the model till 100 epochs, whereas in real world scenarios the training process can go up in order of thousands of epochs.

This also includes changes to the training hyperparameter config file, where the number of classes parameter must be changed to 4 to reflect updated number of classes.

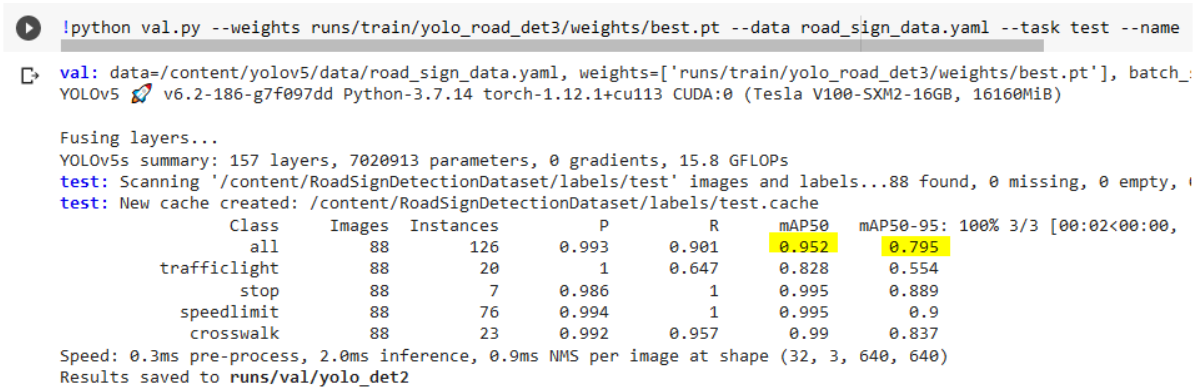
```
!python train.py --img 640 --cfg yolov5s.yaml --hyp hyp.scratch-high.yaml --batch 32
```

Fig 2: Training command for YOLO

5.3 Testing: There are several ways to test the trained model, the attached notebook shows using the test script to test on a given test set as well as using the API to test which can be used in real world applications and integrated into inference pipelines.

5.4 Results: Although the network is trained on a small dataset and only for 100 epochs, we can see that the network achieves high mAP of 95.2%, 99.3% Precision and 90.1% Recall. It is important to note that the training uses pretrained weights of YOLOv5 which contributes to such high evaluation

metrics. This also presents the case of how easily YOLO can be used for real world dataset and thus is fit for real world applications with minimal finetuning.



```
!python val.py --weights runs/train/yolo_road_det3/weights/best.pt --data road_sign_data.yaml --task test --name

val: data=/content/yolov5/data/road_sign_data.yaml, weights=['runs/train/yolo_road_det3/weights/best.pt'], batch_
YOLOv5 🚀 v6.2-186-g7f097dd Python-3.7.14 torch-1.12.1+cu113 CUDA:0 (Tesla V100-SXM2-16GB, 16160MiB)

Fusing layers...
YOLOv5s summary: 157 layers, 7020913 parameters, 0 gradients, 15.8 GFLOPs
test: Scanning '/content/RoadSignDetectionDataset/labels/test' images and labels...88 found, 0 missing, 0 empty,
test: New cache created: /content/RoadSignDetectionDataset/labels/test.cache
                 Class     Images  Instances          P          R      mAP50   mAP50-95: 100% 3/3 [00:02<00:00,
                   all         88        126      0.993      0.901      0.952      0.795
          trafficlight         88         20          1      0.647      0.828      0.554
                  stop         88          7      0.986          1      0.995      0.889
            speedlimit         88         76      0.994          1      0.995        0.9
             crosswalk         88         23      0.992      0.957       0.99      0.837
Speed: 0.3ms pre-process, 2.0ms inference, 0.9ms NMS per image at shape (32, 3, 640, 640)
Results saved to runs/val/yolo_det2
```

Fig 3: Result showing the overall mAP, Precision and Recall as well as class wise evaluation metrics.

Note: For entire training and testing process please refer to the attached notebook in Appendix – 1.

6. Conclusion

This report summarises the YOLO architecture and highlights the evolution of algorithm over different versions. This report also indicates future areas of improvement in YOLO9000 and other YOLO architectures. Finally, this report showcases the algorithm in practice using a real-world dataset, a similar model can be used in self driving car use-case to identify Road Signs.

7. References

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[2] P. Viola and M. Jones, “Rapid object detection using a boosted cascade of simple features,” in *Proceedings of the 2001 IEEE Computer Society Conference on Computer Vision and Pattern Recognition. CVPR 2001*, 2005, vol. 1, p. I–I.

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[4] S. Ren, K. He, R. Girshick, and J. Sun, “Faster R-CNN: Towards real-time object detection with region proposal networks,” *arXiv [cs.CV]*, 2015.

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[10] A. Bochkovskiy, C.-Y. Wang, and H.-Y. M. Liao, “YOLOv4: Optimal speed and accuracy of object detection,” *arXiv [cs.CV]*, 2020.

[11] *Yolov5*. .

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[13] C.-Y. Wang, A. Bochkovskiy, and H.-Y. M. Liao, “YOLOv7: Trainable bag-of-freebies sets new state-of-the-art for real-time object detectors,” *arXiv [cs.CV]*, 2022.

[14] J. Pedoeem and R. Huang, “YOLO-LITE: A real-time object detection algorithm optimized for non-GPU computers,” *arXiv [cs.CV]*, 2018.

APPENDIX - I

The following cells require the dataset to be in its respective location.

assignment_5_2

October 7, 2022

[1]:
```
gpu_info = !nvidia-smi
gpu_info = '\n'.join(gpu_info)
if gpu_info.find('failed') >= 0:
  print('Not connected to a GPU')
else:
  print(gpu_info)
```

```
Thu Oct  6 12:17:28 2022
+-----------------------------------------------------------------------------+
| NVIDIA-SMI 460.32.03    Driver Version: 460.32.03    CUDA Version: 11.2     |
|-------------------------------+----------------------+----------------------+
| GPU  Name        Persistence-M| Bus-Id        Disp.A | Volatile Uncorr. ECC |
| Fan  Temp  Perf  Pwr:Usage/Cap|         Memory-Usage | GPU-Util  Compute M. |
|                               |                      |               MIG M. |
|===============================+======================+======================|
|   0  Tesla V100-SXM2…  Off  | 00000000:00:04.0 Off |                    0 |
| N/A   33C    P0    23W / 300W |      0MiB / 16160MiB |      0%      Default |
|                               |                      |                  N/A |
+-------------------------------+----------------------+----------------------+

+-----------------------------------------------------------------------------+
| Processes:                                                                  |
|  GPU   GI   CI        PID   Type   Process name                  GPU Memory |
|        ID   ID                                                   Usage      |
|=============================================================================|
|  No running processes found                                                 |
+-----------------------------------------------------------------------------+
```

[2]:
```
!git clone https://github.com/ultralytics/yolov5  # clone
!pip install -r yolov5/requirements.txt  # install
```

```
fatal: destination path 'yolov5' already exists and is not an empty directory.
Looking in indexes: https://pypi.org/simple, https://us-python.pkg.dev/colab-
wheels/public/simple/
Requirement already satisfied: matplotlib>=3.2.2 in
/usr/local/lib/python3.7/dist-packages (from -r yolov5/requirements.txt (line
5)) (3.2.2)
Requirement already satisfied: numpy>=1.18.5 in /usr/local/lib/python3.7/dist-
packages (from -r yolov5/requirements.txt (line 6)) (1.21.6)
```

```
Requirement already satisfied: opencv-python>=4.1.1 in
/usr/local/lib/python3.7/dist-packages (from -r yolov5/requirements.txt (line
7)) (4.6.0.66)
Requirement already satisfied: Pillow>=7.1.2 in /usr/local/lib/python3.7/dist-
packages (from -r yolov5/requirements.txt (line 8)) (7.1.2)
Requirement already satisfied: PyYAML>=5.3.1 in /usr/local/lib/python3.7/dist-
packages (from -r yolov5/requirements.txt (line 9)) (6.0)
Requirement already satisfied: requests>=2.23.0 in
/usr/local/lib/python3.7/dist-packages (from -r yolov5/requirements.txt (line
10)) (2.23.0)
Requirement already satisfied: scipy>=1.4.1 in /usr/local/lib/python3.7/dist-
packages (from -r yolov5/requirements.txt (line 11)) (1.7.3)
Requirement already satisfied: torch>=1.7.0 in /usr/local/lib/python3.7/dist-
packages (from -r yolov5/requirements.txt (line 12)) (1.12.1+cu113)
Requirement already satisfied: torchvision>=0.8.1 in
/usr/local/lib/python3.7/dist-packages (from -r yolov5/requirements.txt (line
13)) (0.13.1+cu113)
Requirement already satisfied: tqdm>=4.64.0 in /usr/local/lib/python3.7/dist-
packages (from -r yolov5/requirements.txt (line 14)) (4.64.1)
Requirement already satisfied: tensorboard>=2.4.1 in
/usr/local/lib/python3.7/dist-packages (from -r yolov5/requirements.txt (line
18)) (2.8.0)
Requirement already satisfied: pandas>=1.1.4 in /usr/local/lib/python3.7/dist-
packages (from -r yolov5/requirements.txt (line 23)) (1.3.5)
Requirement already satisfied: seaborn>=0.11.0 in /usr/local/lib/python3.7/dist-
packages (from -r yolov5/requirements.txt (line 24)) (0.11.2)
Requirement already satisfied: ipython in /usr/local/lib/python3.7/dist-packages
(from -r yolov5/requirements.txt (line 41)) (7.9.0)
Requirement already satisfied: psutil in /usr/local/lib/python3.7/dist-packages
(from -r yolov5/requirements.txt (line 42)) (5.4.8)
Requirement already satisfied: thop>=0.1.1 in /usr/local/lib/python3.7/dist-
packages (from -r yolov5/requirements.txt (line 43)) (0.1.1.post2209072238)
Requirement already satisfied: cycler>=0.10 in /usr/local/lib/python3.7/dist-
packages (from matplotlib>=3.2.2->-r yolov5/requirements.txt (line 5)) (0.11.0)
Requirement already satisfied: pyparsing!=2.0.4,!=2.1.2,!=2.1.6,>=2.0.1 in
/usr/local/lib/python3.7/dist-packages (from matplotlib>=3.2.2->-r
yolov5/requirements.txt (line 5)) (3.0.9)
Requirement already satisfied: python-dateutil>=2.1 in
/usr/local/lib/python3.7/dist-packages (from matplotlib>=3.2.2->-r
yolov5/requirements.txt (line 5)) (2.8.2)
Requirement already satisfied: kiwisolver>=1.0.1 in
/usr/local/lib/python3.7/dist-packages (from matplotlib>=3.2.2->-r
yolov5/requirements.txt (line 5)) (1.4.4)
Requirement already satisfied: urllib3!=1.25.0,!=1.25.1,<1.26,>=1.21.1 in
/usr/local/lib/python3.7/dist-packages (from requests>=2.23.0->-r
yolov5/requirements.txt (line 10)) (1.24.3)
Requirement already satisfied: idna<3,>=2.5 in /usr/local/lib/python3.7/dist-
packages (from requests>=2.23.0->-r yolov5/requirements.txt (line 10)) (2.10)
```

```
Requirement already satisfied: certifi>=2017.4.17 in
/usr/local/lib/python3.7/dist-packages (from requests>=2.23.0->-r
yolov5/requirements.txt (line 10)) (2022.6.15)
Requirement already satisfied: chardet<4,>=3.0.2 in
/usr/local/lib/python3.7/dist-packages (from requests>=2.23.0->-r
yolov5/requirements.txt (line 10)) (3.0.4)
Requirement already satisfied: typing-extensions in
/usr/local/lib/python3.7/dist-packages (from torch>=1.7.0->-r
yolov5/requirements.txt (line 12)) (4.1.1)
Requirement already satisfied: tensorboard-data-server<0.7.0,>=0.6.0 in
/usr/local/lib/python3.7/dist-packages (from tensorboard>=2.4.1->-r
yolov5/requirements.txt (line 18)) (0.6.1)
Requirement already satisfied: wheel>=0.26 in /usr/local/lib/python3.7/dist-
packages (from tensorboard>=2.4.1->-r yolov5/requirements.txt (line 18))
(0.37.1)
Requirement already satisfied: absl-py>=0.4 in /usr/local/lib/python3.7/dist-
packages (from tensorboard>=2.4.1->-r yolov5/requirements.txt (line 18)) (1.2.0)
Requirement already satisfied: werkzeug>=0.11.15 in
/usr/local/lib/python3.7/dist-packages (from tensorboard>=2.4.1->-r
yolov5/requirements.txt (line 18)) (1.0.1)
Requirement already satisfied: protobuf>=3.6.0 in /usr/local/lib/python3.7/dist-
packages (from tensorboard>=2.4.1->-r yolov5/requirements.txt (line 18))
(3.17.3)
Requirement already satisfied: google-auth<3,>=1.6.3 in
/usr/local/lib/python3.7/dist-packages (from tensorboard>=2.4.1->-r
yolov5/requirements.txt (line 18)) (1.35.0)
Requirement already satisfied: setuptools>=41.0.0 in
/usr/local/lib/python3.7/dist-packages (from tensorboard>=2.4.1->-r
yolov5/requirements.txt (line 18)) (57.4.0)
Requirement already satisfied: grpcio>=1.24.3 in /usr/local/lib/python3.7/dist-
packages (from tensorboard>=2.4.1->-r yolov5/requirements.txt (line 18))
(1.48.1)
Requirement already satisfied: google-auth-oauthlib<0.5,>=0.4.1 in
/usr/local/lib/python3.7/dist-packages (from tensorboard>=2.4.1->-r
yolov5/requirements.txt (line 18)) (0.4.6)
Requirement already satisfied: tensorboard-plugin-wit>=1.6.0 in
/usr/local/lib/python3.7/dist-packages (from tensorboard>=2.4.1->-r
yolov5/requirements.txt (line 18)) (1.8.1)
Requirement already satisfied: markdown>=2.6.8 in /usr/local/lib/python3.7/dist-
packages (from tensorboard>=2.4.1->-r yolov5/requirements.txt (line 18)) (3.4.1)
Requirement already satisfied: pytz>=2017.3 in /usr/local/lib/python3.7/dist-
packages (from pandas>=1.1.4->-r yolov5/requirements.txt (line 23)) (2022.2.1)
Requirement already satisfied: six>=1.9.0 in /usr/local/lib/python3.7/dist-
packages (from google-auth<3,>=1.6.3->tensorboard>=2.4.1->-r
yolov5/requirements.txt (line 18)) (1.15.0)
Requirement already satisfied: rsa<5,>=3.1.4 in /usr/local/lib/python3.7/dist-
packages (from google-auth<3,>=1.6.3->tensorboard>=2.4.1->-r
yolov5/requirements.txt (line 18)) (4.9)
```

```
Requirement already satisfied: pyasn1-modules>=0.2.1 in
/usr/local/lib/python3.7/dist-packages (from google-
auth<3,>=1.6.3->tensorboard>=2.4.1->-r yolov5/requirements.txt (line 18))
(0.2.8)
Requirement already satisfied: cachetools<5.0,>=2.0.0 in
/usr/local/lib/python3.7/dist-packages (from google-
auth<3,>=1.6.3->tensorboard>=2.4.1->-r yolov5/requirements.txt (line 18))
(4.2.4)
Requirement already satisfied: requests-oauthlib>=0.7.0 in
/usr/local/lib/python3.7/dist-packages (from google-auth-
oauthlib<0.5,>=0.4.1->tensorboard>=2.4.1->-r yolov5/requirements.txt (line 18))
(1.3.1)
Requirement already satisfied: importlib-metadata>=4.4 in
/usr/local/lib/python3.7/dist-packages (from
markdown>=2.6.8->tensorboard>=2.4.1->-r yolov5/requirements.txt (line 18))
(4.12.0)
Requirement already satisfied: zipp>=0.5 in /usr/local/lib/python3.7/dist-
packages (from importlib-metadata>=4.4->markdown>=2.6.8->tensorboard>=2.4.1->-r
yolov5/requirements.txt (line 18)) (3.8.1)
Requirement already satisfied: pyasn1<0.5.0,>=0.4.6 in
/usr/local/lib/python3.7/dist-packages (from pyasn1-modules>=0.2.1->google-
auth<3,>=1.6.3->tensorboard>=2.4.1->-r yolov5/requirements.txt (line 18))
(0.4.8)
Requirement already satisfied: oauthlib>=3.0.0 in /usr/local/lib/python3.7/dist-
packages (from requests-oauthlib>=0.7.0->google-auth-
oauthlib<0.5,>=0.4.1->tensorboard>=2.4.1->-r yolov5/requirements.txt (line 18))
(3.2.0)
Requirement already satisfied: pexpect in /usr/local/lib/python3.7/dist-packages
(from ipython->-r yolov5/requirements.txt (line 41)) (4.8.0)
Requirement already satisfied: pygments in /usr/local/lib/python3.7/dist-
packages (from ipython->-r yolov5/requirements.txt (line 41)) (2.6.1)
Requirement already satisfied: decorator in /usr/local/lib/python3.7/dist-
packages (from ipython->-r yolov5/requirements.txt (line 41)) (4.4.2)
Requirement already satisfied: backcall in /usr/local/lib/python3.7/dist-
packages (from ipython->-r yolov5/requirements.txt (line 41)) (0.2.0)
Requirement already satisfied: traitlets>=4.2 in /usr/local/lib/python3.7/dist-
packages (from ipython->-r yolov5/requirements.txt (line 41)) (5.1.1)
Requirement already satisfied: prompt-toolkit<2.1.0,>=2.0.0 in
/usr/local/lib/python3.7/dist-packages (from ipython->-r yolov5/requirements.txt
(line 41)) (2.0.10)
Requirement already satisfied: pickleshare in /usr/local/lib/python3.7/dist-
packages (from ipython->-r yolov5/requirements.txt (line 41)) (0.7.5)
Requirement already satisfied: jedi>=0.10 in /usr/local/lib/python3.7/dist-
packages (from ipython->-r yolov5/requirements.txt (line 41)) (0.18.1)
Requirement already satisfied: parso<0.9.0,>=0.8.0 in
/usr/local/lib/python3.7/dist-packages (from jedi>=0.10->ipython->-r
yolov5/requirements.txt (line 41)) (0.8.3)
Requirement already satisfied: wcwidth in /usr/local/lib/python3.7/dist-packages
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```
(from prompt-toolkit<2.1.0,>=2.0.0->ipython->-r yolov5/requirements.txt (line
41)) (0.2.5)
Requirement already satisfied: ptyprocess>=0.5 in /usr/local/lib/python3.7/dist-
packages (from pexpect->ipython->-r yolov5/requirements.txt (line 41)) (0.7.0)
```

[34]:
```
import torch
from IPython.display import Image  # for displaying images
import os
import random
import shutil
from sklearn.model_selection import train_test_split
import xml.etree.ElementTree as ET
from xml.dom import minidom
from tqdm import tqdm
from PIL import Image, ImageDraw
import numpy as np
import matplotlib.pyplot as plt
import glob
import cv2
```

[4]:
```
from google.colab import drive
drive.mount('/content/gdrive')
!cp -f '/content/gdrive/MyDrive/sit789_assignment_5_2_data/
 ↪RoadSignDetectionDataset.zip' '/content/'
!rm -rf RoadSignDetectionDataset
!mkdir RoadSignDetectionDataset
!unzip /content/RoadSignDetectionDataset.zip -d /content/
 ↪RoadSignDetectionDataset/
```

```
Drive already mounted at /content/gdrive; to attempt to forcibly remount, call
drive.mount("/content/gdrive", force_remount=True).
Archive:  /content/RoadSignDetectionDataset.zip
  inflating: /content/RoadSignDetectionDataset/annotations/road0.xml
  inflating: /content/RoadSignDetectionDataset/annotations/road1.xml
  inflating: /content/RoadSignDetectionDataset/annotations/road10.xml
  inflating: /content/RoadSignDetectionDataset/annotations/road100.xml
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  inflating: /content/RoadSignDetectionDataset/annotations/road103.xml
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  inflating: /content/RoadSignDetectionDataset/images/road94.png
  inflating: /content/RoadSignDetectionDataset/images/road95.png
  inflating: /content/RoadSignDetectionDataset/images/road96.png
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  inflating: /content/RoadSignDetectionDataset/images/road99.png
```

[5]:
```python
def extract_info_from_xml(xml_file):
    root = ET.parse(xml_file).getroot()

    # Initialise the info dict
    info_dict = {}
    info_dict['bboxes'] = []

    # Parse the XML Tree
    for elem in root:
        # Get the file name
        if elem.tag == "filename":
            info_dict['filename'] = elem.text

        # Get the image size
        elif elem.tag == "size":
            image_size = []
            for subelem in elem:
                image_size.append(int(subelem.text))

            info_dict['image_size'] = tuple(image_size)

        # Get details of the bounding box
        elif elem.tag == "object":
            bbox = {}
            for subelem in elem:
                if subelem.tag == "name":
                    bbox["class"] = subelem.text

                elif subelem.tag == "bndbox":
                    for subsubelem in subelem:
                        bbox[subsubelem.tag] = int(subsubelem.text)
            info_dict['bboxes'].append(bbox)

    return info_dict
```

[6]:
```
print(extract_info_from_xml('/content/RoadSignDetectionDataset/annotations/
↪road4.xml'))
```

```
{'bboxes': [{'class': 'trafficlight', 'xmin': 20, 'ymin': 109, 'xmax': 81,
'ymax': 237}, {'class': 'trafficlight', 'xmin': 116, 'ymin': 162, 'xmax': 163,
'ymax': 272}, {'class': 'trafficlight', 'xmin': 189, 'ymin': 189, 'xmax': 233,
'ymax': 295}], 'filename': 'road4.png', 'image_size': (267, 400, 3)}
```

[7]:
```
# Dictionary that maps class names to IDs
class_name_to_id_mapping = {"trafficlight": 0,
                            "stop": 1,
                            "speedlimit": 2,
                            "crosswalk": 3}

# Convert the info dict to the required yolo format and write it to disk
def convert_to_yolov5(info_dict):
    print_buffer = []

    # For each bounding box
    for b in info_dict["bboxes"]:
        try:
            class_id = class_name_to_id_mapping[b["class"]]
        except KeyError:
            print("Invalid Class. Must be one from ", class_name_to_id_mapping.
↪keys())

        # Transform the bbox co-ordinates as per the format required by YOLO v5
        b_center_x = (b["xmin"] + b["xmax"]) / 2
        b_center_y = (b["ymin"] + b["ymax"]) / 2
        b_width    = (b["xmax"] - b["xmin"])
        b_height   = (b["ymax"] - b["ymin"])

        # Normalise the co-ordinates by the dimensions of the image
        image_w, image_h, image_c = info_dict["image_size"]
        b_center_x /= image_w
        b_center_y /= image_h
        b_width    /= image_w
        b_height   /= image_h

        #Write the bbox details to the file
        print_buffer.append("{} {:.3f} {:.3f} {:.3f} {:.3f}".format(class_id,␣
↪b_center_x, b_center_y, b_width, b_height))

    # Name of the file which we have to save
    save_file_name = os.path.join("./annotations", info_dict["filename"].
↪replace("png", "txt"))
```

```
    # Save the annotation to disk
    print("\n".join(print_buffer), file= open(save_file_name, "w"))
```

[11]:
```
%cd /content/RoadSignDetectionDataset
```

```
/content/RoadSignDetectionDataset
/content/RoadSignDetectionDataset
```

[12]:
```
# Get the annotations
annotations = [os.path.join('./annotations', x) for x in os.listdir('./
 ↪annotations') if x[-3:] == "xml"]
annotations.sort()

# Convert and save the annotations
for ann in tqdm(annotations):
    info_dict = extract_info_from_xml(ann)
    convert_to_yolov5(info_dict)
annotations = [os.path.join('./annotations', x) for x in os.listdir('./
 ↪annotations') if x[-3:] == "txt"]
```

```
100%|      | 877/877 [00:00<00:00, 6939.27it/s]
```

[19]:
```
class_id_to_name_mapping = dict(zip(class_name_to_id_mapping.values(),␣
 ↪class_name_to_id_mapping.keys()))

def plot_bounding_box(image, annotation_list):
    annotations = np.array(annotation_list)
    w, h = image.size

    plotted_image = ImageDraw.Draw(image)

    transformed_annotations = np.copy(annotations)
    transformed_annotations[:,[1,3]] = annotations[:,[1,3]] * w
    transformed_annotations[:,[2,4]] = annotations[:,[2,4]] * h

    transformed_annotations[:,1] = transformed_annotations[:,1] -␣
 ↪(transformed_annotations[:,3] / 2)
    transformed_annotations[:,2] = transformed_annotations[:,2] -␣
 ↪(transformed_annotations[:,4] / 2)
    transformed_annotations[:,3] = transformed_annotations[:,1] +␣
 ↪transformed_annotations[:,3]
    transformed_annotations[:,4] = transformed_annotations[:,2] +␣
 ↪transformed_annotations[:,4]

    for ann in transformed_annotations:
        obj_cls, x0, y0, x1, y1 = ann
        plotted_image.rectangle(((x0,y0), (x1,y1)))
```

```
        plotted_image.text((x0, y0 - 10),␣
 ↪class_id_to_name_mapping[(int(obj_cls))])

    plt.imshow(np.array(image))
    plt.show()

# Get any random annotation file
annotation_file = random.choice(annotations)
with open(annotation_file, "r") as file:
    annotation_list = file.read().split("\n")[:-1]
    annotation_list = [x.split(" ") for x in annotation_list]
    annotation_list = [[float(y) for y in x ] for x in annotation_list]

#Get the corresponding image file
image_file = annotation_file.replace("annotations", "images").replace("txt",␣
 ↪"png")
assert os.path.exists(image_file)

#Load the image
image = Image.open(image_file)

#Plot the Bounding Box
plot_bounding_box(image, annotation_list)
```

[20]:
```
# Read images and annotations
images = [os.path.join('images', x) for x in os.listdir('images')]
annotations = [os.path.join('annotations', x) for x in os.
 ↪listdir('annotations') if x[-3:] == "txt"]

images.sort()
annotations.sort()

# Split the dataset into train-valid-test splits
train_images, val_images, train_annotations, val_annotations =␣
 ↪train_test_split(images, annotations, test_size = 0.2, random_state = 1)
val_images, test_images, val_annotations, test_annotations =␣
 ↪train_test_split(val_images, val_annotations, test_size = 0.5, random_state␣
 ↪= 1)
```

[21]:
```
!mkdir images/train images/val images/test annotations/train annotations/val␣
 ↪annotations/test
```

[22]:
```
#Utility function to move images
def move_files_to_folder(list_of_files, destination_folder):
    for f in list_of_files:
        try:
            shutil.move(f, destination_folder)
        except:
            print(f)
            assert False

# Move the splits into their folders
move_files_to_folder(train_images, 'images/train')
move_files_to_folder(val_images, 'images/val/')
move_files_to_folder(test_images, 'images/test/')
move_files_to_folder(train_annotations, 'annotations/train/')
move_files_to_folder(val_annotations, 'annotations/val/')
move_files_to_folder(test_annotations, 'annotations/test/')
```

[26]:
```
!mv annotations labels
%cd ../yolov5
```

```
mv: cannot stat 'annotations': No such file or directory
/content/yolov5
```

[27]:
```
!pwd
```

```
/content/yolov5
```

[31]:
```
!python train.py --img 640 --cfg yolov5s.yaml --hyp hyp.scratch-high.yaml␣
 ↪--batch 32 --epochs 100 --data road_sign_data.yaml --weights yolov5s.pt␣
 ↪--workers 24 --name yolo_road_det
```

```
train: weights=yolov5s.pt, cfg=yolov5s.yaml,
data=road_sign_data.yaml, hyp=hyp.scratch-high.yaml, epochs=100, batch_size=32,
imgsz=640, rect=False, resume=False, nosave=False, noval=False,
noautoanchor=False, noplots=False, evolve=None, bucket=, cache=None,
image_weights=False, device=, multi_scale=False, single_cls=False,
optimizer=SGD, sync_bn=False, workers=24, project=runs/train,
name=yolo_road_det, exist_ok=False, quad=False, cos_lr=False,
label_smoothing=0.0, patience=100, freeze=[0], save_period=-1, seed=0,
local_rank=-1, entity=None, upload_dataset=False, bbox_interval=-1,
artifact_alias=latest
github: up to date with https://github.com/ultralytics/yolov5
YOLOv5  v6.2-186-g7f097dd Python-3.7.14 torch-1.12.1+cu113 CUDA:0 (Tesla
V100-SXM2-16GB, 16160MiB)

hyperparameters: lr0=0.01, lrf=0.1, momentum=0.937,
weight_decay=0.0005, warmup_epochs=3.0, warmup_momentum=0.8, warmup_bias_lr=0.1,
box=0.05, cls=0.3, cls_pw=1.0, obj=0.7, obj_pw=1.0, iou_t=0.2, anchor_t=4.0,
fl_gamma=0.0, hsv_h=0.015, hsv_s=0.7, hsv_v=0.4, degrees=0.0, translate=0.1,
scale=0.9, shear=0.0, perspective=0.0, flipud=0.0, fliplr=0.5, mosaic=1.0,
mixup=0.1, copy_paste=0.1
Weights & Biases: run 'pip install wandb' to automatically track
and visualize YOLOv5  runs in Weights & Biases
ClearML: run 'pip install clearml' to automatically track,
visualize and remotely train YOLOv5  in ClearML
Comet: run 'pip install comet_ml' to automatically track and
visualize YOLOv5  runs in Comet
TensorBoard: Start with 'tensorboard --logdir runs/train', view at
http://localhost:6006/
Downloading https://ultralytics.com/assets/Arial.ttf to
/root/.config/Ultralytics/Arial.ttf…
100% 755k/755k [00:00<00:00, 51.0MB/s]
Downloading
https://github.com/ultralytics/yolov5/releases/download/v6.2/yolov5s.pt to
yolov5s.pt…
100% 14.1M/14.1M [00:00<00:00, 41.4MB/s]

Overriding model.yaml nc=80 with nc=4

                from  n    params  module
arguments
  0                -1  1      3520  models.common.Conv                      [3,
32, 6, 2, 2]
  1                -1  1     18560  models.common.Conv                      [32,
64, 3, 2]
  2                -1  1     18816  models.common.C3                        [64,
64, 1]
  3                -1  1     73984  models.common.Conv                      [64,
128, 3, 2]
```

```
  4                -1  2    115712  models.common.C3
[128, 128, 2]
  5                -1  1    295424  models.common.Conv
[128, 256, 3, 2]
  6                -1  3    625152  models.common.C3
[256, 256, 3]
  7                -1  1   1180672  models.common.Conv
[256, 512, 3, 2]
  8                -1  1   1182720  models.common.C3
[512, 512, 1]
  9                -1  1    656896  models.common.SPPF
[512, 512, 5]
 10                -1  1    131584  models.common.Conv
[512, 256, 1, 1]
 11                -1  1         0  torch.nn.modules.upsampling.Upsample
[None, 2, 'nearest']
 12           [-1, 6]  1         0  models.common.Concat                    [1]
 13                -1  1    361984  models.common.C3
[512, 256, 1, False]
 14                -1  1     33024  models.common.Conv
[256, 128, 1, 1]
 15                -1  1         0  torch.nn.modules.upsampling.Upsample
[None, 2, 'nearest']
 16           [-1, 4]  1         0  models.common.Concat                    [1]
 17                -1  1     90880  models.common.C3
[256, 128, 1, False]
 18                -1  1    147712  models.common.Conv
[128, 128, 3, 2]
 19          [-1, 14]  1         0  models.common.Concat                    [1]
 20                -1  1    296448  models.common.C3
[256, 256, 1, False]
 21                -1  1    590336  models.common.Conv
[256, 256, 3, 2]
 22          [-1, 10]  1         0  models.common.Concat                    [1]
 23                -1  1   1182720  models.common.C3
[512, 512, 1, False]
 24      [17, 20, 23]  1     24273  models.yolo.Detect                      [4,
[[10, 13, 16, 30, 33, 23], [30, 61, 62, 45, 59, 119], [116, 90, 156, 198, 373,
326]], [128, 256, 512]]
YOLOv5s summary: 214 layers, 7030417 parameters, 7030417 gradients, 16.0 GFLOPs

Transferred 342/349 items from yolov5s.pt
AMP: checks passed
optimizer: SGD(lr=0.01) with parameter groups 57 weight(decay=0.0),
60 weight(decay=0.0005), 60 bias
albumentations: Blur(p=0.01, blur_limit=(3, 7)), MedianBlur(p=0.01,
blur_limit=(3, 7)), ToGray(p=0.01), CLAHE(p=0.01, clip_limit=(1, 4.0),
tile_grid_size=(8, 8))
```

```
train: Scanning '/content/RoadSignDetectionDataset/labels/train'
images and labels…701 found, 0 missing, 0 empty, 0 corrupt: 100% 701/701
[00:00<00:00, 5610.25it/s]
train: New cache created:
/content/RoadSignDetectionDataset/labels/train.cache
val: Scanning '/content/RoadSignDetectionDataset/labels/val' images
and labels…88 found, 0 missing, 0 empty, 0 corrupt: 100% 88/88 [00:00<00:00,
909.22it/s]
val: New cache created:
/content/RoadSignDetectionDataset/labels/val.cache

AutoAnchor: 5.59 anchors/target, 1.000 Best Possible Recall (BPR).
Current anchors are a good fit to dataset
Plotting labels to runs/train/yolo_road_det3/labels.jpg…
Image sizes 640 train, 640 val
Using 8 dataloader workers
Logging results to runs/train/yolo_road_det3
Starting training for 100 epochs…

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
       0/99      6.46G     0.1083    0.02287    0.02311         87        640:
100% 22/22 [00:08<00:00,  2.70it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:02<00:00,  1.48s/it]
                   all         88        132      0.696      0.205       0.17
0.0441

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
       1/99      8.08G    0.06918    0.02491    0.01784        100        640:
100% 22/22 [00:04<00:00,  4.46it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:01<00:00,  1.50it/s]
                   all         88        132      0.727      0.182      0.184
0.067

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
       2/99      8.08G    0.05932    0.02193    0.01667        112        640:
100% 22/22 [00:04<00:00,  4.75it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:01<00:00,  1.46it/s]
                   all         88        132      0.623      0.195      0.125
0.0459

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
       3/99      8.08G    0.05778    0.01939    0.01546         95        640:
100% 22/22 [00:05<00:00,  3.87it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:01<00:00,  1.70it/s]
```

```
                 all         88        132      0.738      0.239      0.197
0.106

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
       4/99      8.08G    0.05523    0.01759    0.01424         72        640:
100% 22/22 [00:05<00:00,  4.17it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:01<00:00,  1.95it/s]
                 all         88        132      0.371      0.429      0.441
0.211

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
       5/99      8.08G    0.05157    0.01466    0.01197        105        640:
100% 22/22 [00:06<00:00,  3.34it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:01<00:00,  1.47it/s]
                 all         88        132      0.466      0.647      0.598
0.275

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
       6/99      8.08G     0.0483    0.01302     0.0103         93        640:
100% 22/22 [00:04<00:00,  4.85it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.27it/s]
                 all         88        132      0.832      0.629      0.787
0.358

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
       7/99      8.08G    0.04301    0.01145   0.008366         93        640:
100% 22/22 [00:05<00:00,  3.89it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.22it/s]
                 all         88        132      0.741      0.789      0.826
0.405

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
       8/99      8.08G     0.0423    0.01024   0.007336         93        640:
100% 22/22 [00:05<00:00,  4.03it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.04it/s]
                 all         88        132      0.863      0.802      0.882
0.446

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
       9/99      8.08G    0.03994   0.009085   0.006396        107        640:
100% 22/22 [00:05<00:00,  4.12it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:01<00:00,  1.57it/s]
```

```
                 all         88        132      0.811      0.833      0.846
0.473

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      10/99      8.08G    0.03822    0.00921   0.005511         82        640:
100% 22/22 [00:05<00:00,  4.04it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.30it/s]
                 all         88        132      0.912      0.882      0.925
0.503

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      11/99      8.08G    0.03782   0.009302   0.005117        106        640:
100% 22/22 [00:06<00:00,  3.39it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:01<00:00,  1.99it/s]
                 all         88        132      0.839      0.868      0.856
0.501

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      12/99      8.08G    0.03578   0.008653   0.004564        107        640:
100% 22/22 [00:04<00:00,  4.76it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.33it/s]
                 all         88        132      0.931      0.914      0.931
0.527

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      13/99      8.08G    0.03421   0.008664   0.004032         81        640:
100% 22/22 [00:05<00:00,  3.83it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:01<00:00,  1.81it/s]
                 all         88        132      0.826      0.917      0.909
0.541

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      14/99      8.08G    0.03359   0.008406   0.003831         81        640:
100% 22/22 [00:05<00:00,  3.88it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.15it/s]
                 all         88        132      0.922      0.888       0.94
0.585

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      15/99      8.08G    0.03281   0.008031   0.003723         88        640:
100% 22/22 [00:05<00:00,  3.93it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:01<00:00,  1.99it/s]
```

```
                 all         88        132      0.965       0.88      0.941
0.579

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      16/99      8.08G     0.0319   0.008042   0.003496         92        640:
100% 22/22 [00:05<00:00,  3.98it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.02it/s]
                 all         88        132      0.974      0.905      0.967
0.594

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      17/99      8.08G    0.03269   0.007651   0.003462         72        640:
100% 22/22 [00:05<00:00,  4.38it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.55it/s]
                 all         88        132      0.938      0.941      0.962
0.644

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      18/99      8.08G    0.03105   0.008038   0.003225        129        640:
100% 22/22 [00:05<00:00,  3.71it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.14it/s]
                 all         88        132      0.942      0.937      0.963
0.602

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      19/99      8.08G    0.03093   0.007821    0.00322         78        640:
100% 22/22 [00:06<00:00,  3.54it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:01<00:00,  1.82it/s]
                 all         88        132      0.964      0.953      0.975
0.637

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      20/99      8.08G    0.02957   0.007462   0.002836         95        640:
100% 22/22 [00:05<00:00,  4.15it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.04it/s]
                 all         88        132      0.956      0.938      0.962
0.639

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      21/99      8.08G    0.02988   0.007722    0.00294         72        640:
100% 22/22 [00:06<00:00,  3.65it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:01<00:00,  1.50it/s]
```

```
                 all         88        132      0.918      0.924      0.953
0.614

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      22/99      8.08G     0.0289   0.007662   0.002786        100        640:
100% 22/22 [00:05<00:00,  3.77it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.16it/s]
                 all         88        132      0.975      0.924      0.948
0.606

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      23/99      8.08G    0.02918   0.007114   0.002713         90        640:
100% 22/22 [00:06<00:00,  3.56it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.45it/s]
                 all         88        132      0.981      0.921      0.953
0.597

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      24/99      8.08G    0.02908   0.007546   0.002646         93        640:
100% 22/22 [00:05<00:00,  4.13it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:01<00:00,  1.82it/s]
                 all         88        132       0.95      0.949      0.978
0.695

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      25/99      8.08G    0.02719   0.006949   0.002307         91        640:
100% 22/22 [00:05<00:00,  3.96it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:01<00:00,  1.87it/s]
                 all         88        132      0.951      0.944      0.965
0.672

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      26/99      8.08G    0.02712   0.007153   0.002457         95        640:
100% 22/22 [00:05<00:00,  3.89it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:01<00:00,  1.93it/s]
                 all         88        132      0.942      0.928      0.966
0.686

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      27/99      8.08G    0.02743   0.007378    0.00251         98        640:
100% 22/22 [00:05<00:00,  3.86it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.43it/s]
```

```
                 all         88        132      0.981      0.943      0.961
0.717

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      28/99      8.08G     0.0266    0.00686   0.002348        107        640:
100% 22/22 [00:05<00:00,  3.80it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.33it/s]
                 all         88        132      0.963       0.95      0.974
0.723

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      29/99      8.08G    0.02687   0.007231   0.002493         75        640:
100% 22/22 [00:05<00:00,  3.97it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:01<00:00,  1.88it/s]
                 all         88        132      0.958      0.981      0.989
0.705

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      30/99      8.08G    0.02619   0.007012    0.00217         75        640:
100% 22/22 [00:06<00:00,  3.64it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:01<00:00,  1.56it/s]
                 all         88        132      0.954      0.971       0.98
0.694

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      31/99      8.08G    0.02723   0.007169   0.002381        113        640:
100% 22/22 [00:06<00:00,  3.59it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.47it/s]
                 all         88        132      0.966      0.944      0.977
0.713

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      32/99      8.08G    0.02561   0.007232    0.00223         85        640:
100% 22/22 [00:07<00:00,  3.10it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:01<00:00,  1.77it/s]
                 all         88        132      0.957      0.965       0.98
0.716

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      33/99      8.08G    0.02568   0.006736   0.002239         93        640:
100% 22/22 [00:05<00:00,  4.34it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.16it/s]
```

```
                 all         88        132      0.971      0.897      0.966
0.672

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      34/99      8.08G    0.02528   0.006985   0.002148         84        640:
100% 22/22 [00:05<00:00,  3.85it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.51it/s]
                 all         88        132       0.95      0.926       0.97
0.725

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      35/99      8.08G    0.02457   0.006875   0.001967         78        640:
100% 22/22 [00:05<00:00,  4.13it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.27it/s]
                 all         88        132      0.928      0.965      0.976
0.718

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      36/99      8.08G    0.02456    0.00686   0.002048        129        640:
100% 22/22 [00:07<00:00,  3.07it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.03it/s]
                 all         88        132      0.977       0.92      0.981
0.704

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      37/99      8.08G    0.02389   0.006842   0.002111         81        640:
100% 22/22 [00:05<00:00,  3.77it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:01<00:00,  1.74it/s]
                 all         88        132      0.968      0.943      0.962
0.731

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      38/99      8.08G    0.02478   0.006474   0.001945         92        640:
100% 22/22 [00:05<00:00,  4.31it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:01<00:00,  1.72it/s]
                 all         88        132      0.965      0.924      0.974
0.744

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      39/99      8.08G     0.0245   0.006911   0.001883        103        640:
100% 22/22 [00:05<00:00,  4.05it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:01<00:00,  1.64it/s]
```

```
                 all         88        132      0.986      0.924      0.978
0.73

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      40/99      8.08G    0.02318   0.006571   0.001915         87        640:
100% 22/22 [00:06<00:00,  3.34it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.36it/s]
                 all         88        132      0.968      0.948      0.977
0.757

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      41/99      8.08G    0.02357   0.006809   0.001882        120        640:
100% 22/22 [00:05<00:00,  3.76it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:01<00:00,  1.97it/s]
                 all         88        132      0.983      0.941       0.98
0.728

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      42/99      8.08G    0.02328    0.00653   0.001925         78        640:
100% 22/22 [00:05<00:00,  3.97it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.02it/s]
                 all         88        132      0.922      0.979      0.974
0.712

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      43/99      8.08G     0.0228   0.006247   0.001741         80        640:
100% 22/22 [00:05<00:00,  3.93it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.35it/s]
                 all         88        132      0.948      0.962      0.981
0.719

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      44/99      8.08G    0.02229    0.00612   0.001663         79        640:
100% 22/22 [00:06<00:00,  3.43it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.10it/s]
                 all         88        132      0.889      0.974      0.972
0.738

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      45/99      8.08G    0.02211   0.006153    0.00182         90        640:
100% 22/22 [00:06<00:00,  3.50it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.24it/s]
```

```
                 all         88        132      0.979      0.933      0.975
0.735

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      46/99      8.08G    0.02258   0.006025   0.001796        105        640:
100% 22/22 [00:06<00:00,  3.29it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.73it/s]
                 all         88        132      0.981      0.944      0.977
0.743

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      47/99      8.08G    0.02194   0.006173   0.001674         59        640:
100% 22/22 [00:06<00:00,  3.60it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:01<00:00,  1.73it/s]
                 all         88        132      0.956      0.966      0.967
0.741

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      48/99      8.08G     0.0216   0.006345   0.001681         90        640:
100% 22/22 [00:05<00:00,  3.80it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.12it/s]
                 all         88        132      0.979      0.931      0.968
0.746

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      49/99      8.08G    0.02123    0.00614   0.001655         82        640:
100% 22/22 [00:05<00:00,  3.88it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:01<00:00,  1.93it/s]
                 all         88        132      0.974      0.968      0.981
0.764

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      50/99      8.08G    0.02203   0.006111   0.001561         89        640:
100% 22/22 [00:05<00:00,  4.02it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.16it/s]
                 all         88        132       0.98      0.925      0.962
0.736

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      51/99      8.08G    0.02125   0.006039   0.001574         57        640:
100% 22/22 [00:05<00:00,  3.67it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:01<00:00,  1.97it/s]
```

```
                 all         88        132      0.979      0.962      0.975
0.748

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      52/99      8.08G    0.02105   0.006075   0.001573         81        640:
100% 22/22 [00:05<00:00,  4.35it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.45it/s]
                 all         88        132      0.971      0.967      0.972
0.732

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      53/99      8.08G    0.02138   0.006079   0.001534         88        640:
100% 22/22 [00:06<00:00,  3.22it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.22it/s]
                 all         88        132      0.928      0.973      0.975
0.76

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      54/99      8.08G    0.02074    0.00584   0.001547         86        640:
100% 22/22 [00:06<00:00,  3.40it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:01<00:00,  1.68it/s]
                 all         88        132      0.932      0.974       0.97
0.771

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      55/99      8.08G    0.02098   0.005952   0.001354         97        640:
100% 22/22 [00:07<00:00,  2.99it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:01<00:00,  1.97it/s]
                 all         88        132      0.942       0.97      0.983
0.764

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      56/99      8.08G    0.02078   0.006223   0.001337        107        640:
100% 22/22 [00:05<00:00,  3.75it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:01<00:00,  1.92it/s]
                 all         88        132      0.936      0.971      0.984
0.75

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      57/99      8.08G    0.02053    0.00623    0.00144         57        640:
100% 22/22 [00:06<00:00,  3.38it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.04it/s]
```

```
                 all         88        132      0.918      0.984      0.984
0.763

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      58/99      8.08G    0.02003   0.005945   0.001456         97        640:
100% 22/22 [00:05<00:00,  3.77it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:01<00:00,  1.74it/s]
                 all         88        132      0.944      0.959      0.984
0.763

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      59/99      8.08G    0.02022   0.005878   0.001516         97        640:
100% 22/22 [00:05<00:00,  3.67it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.31it/s]
                 all         88        132      0.954       0.97      0.981
0.766

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      60/99      8.08G    0.01931   0.005838   0.001416         83        640:
100% 22/22 [00:04<00:00,  4.49it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:01<00:00,  1.87it/s]
                 all         88        132      0.984      0.914      0.975
0.765

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      61/99      8.08G    0.02001   0.005658   0.001352         91        640:
100% 22/22 [00:06<00:00,  3.58it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:01<00:00,  1.92it/s]
                 all         88        132      0.951       0.97      0.984
0.77

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      62/99      8.08G    0.01964   0.005909   0.001306         78        640:
100% 22/22 [00:05<00:00,  4.09it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.03it/s]
                 all         88        132      0.978      0.979      0.991
0.782

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      63/99      8.08G    0.01921   0.005922   0.001344         81        640:
100% 22/22 [00:06<00:00,  3.60it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:01<00:00,  1.90it/s]
```

```
                 all         88        132      0.924      0.983      0.971
0.776

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      64/99      8.08G      0.018   0.005566   0.001249        108        640:
100% 22/22 [00:05<00:00,  4.07it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.62it/s]
                 all         88        132      0.965      0.934      0.976
0.755

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      65/99      8.08G    0.01843   0.005869   0.001095         95        640:
100% 22/22 [00:06<00:00,  3.38it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.26it/s]
                 all         88        132      0.937      0.984      0.974
0.775

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      66/99      8.08G    0.01883   0.005993   0.001225         85        640:
100% 22/22 [00:06<00:00,  3.24it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.48it/s]
                 all         88        132      0.959       0.98      0.985
0.767

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      67/99      8.08G    0.01945   0.005669   0.001283         98        640:
100% 22/22 [00:06<00:00,  3.60it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.08it/s]
                 all         88        132      0.966       0.95      0.984
0.78

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      68/99      8.08G    0.01815   0.005539    0.00129         87        640:
100% 22/22 [00:05<00:00,  3.76it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:01<00:00,  1.92it/s]
                 all         88        132      0.962      0.933      0.984
0.779

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      69/99      8.08G    0.01852   0.005758   0.001265        102        640:
100% 22/22 [00:05<00:00,  3.82it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:01<00:00,  1.68it/s]
```

```
                 all         88        132       0.94      0.962      0.973
0.768

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      70/99      8.08G    0.01787   0.005545   0.001143         96        640:
100% 22/22 [00:06<00:00,  3.58it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.44it/s]
                 all         88        132      0.977      0.947      0.973
0.79

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      71/99      8.08G    0.01814   0.005644   0.001157        110        640:
100% 22/22 [00:05<00:00,  4.03it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.18it/s]
                 all         88        132      0.947      0.952      0.974
0.77

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      72/99      8.08G    0.01739   0.005552   0.000976         80        640:
100% 22/22 [00:05<00:00,  3.88it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.88it/s]
                 all         88        132      0.921      0.961      0.981
0.784

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      73/99      8.08G     0.0177   0.005701   0.001083        101        640:
100% 22/22 [00:06<00:00,  3.57it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.24it/s]
                 all         88        132      0.965      0.911      0.979
0.773

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      74/99      8.08G    0.01706   0.005411   0.001092         71        640:
100% 22/22 [00:06<00:00,  3.29it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:01<00:00,  1.75it/s]
                 all         88        132      0.952      0.955      0.985
0.799

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      75/99      8.08G    0.01731   0.005856   0.001112        107        640:
100% 22/22 [00:05<00:00,  3.86it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.63it/s]
```

```
                 all         88        132       0.95      0.976      0.988
0.792

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      76/99      8.08G    0.01718   0.005293   0.001084         88        640:
100% 22/22 [00:06<00:00,  3.60it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.01it/s]
                 all         88        132      0.956      0.944      0.987
0.802

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      77/99      8.08G    0.01741   0.005503   0.001028         88        640:
100% 22/22 [00:04<00:00,  4.50it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.95it/s]
                 all         88        132       0.95      0.982      0.989
0.783

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      78/99      8.08G    0.01702   0.005364   0.001006         81        640:
100% 22/22 [00:06<00:00,  3.28it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.21it/s]
                 all         88        132      0.971      0.985      0.993
0.786

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      79/99      8.08G    0.01664   0.005333  0.0009713         96        640:
100% 22/22 [00:06<00:00,  3.61it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:01<00:00,  1.77it/s]
                 all         88        132      0.981      0.965      0.989
0.809

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      80/99      8.08G     0.0164   0.005115  0.0009684         96        640:
100% 22/22 [00:04<00:00,  4.84it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:01<00:00,  1.53it/s]
                 all         88        132      0.966      0.967      0.988
0.796

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      81/99      8.08G    0.01661   0.005311  0.0009634         90        640:
100% 22/22 [00:05<00:00,  3.78it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.11it/s]
```

```
                 all         88        132      0.972       0.96      0.988
0.798

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      82/99      8.08G    0.01619    0.00552  0.0009595        106        640:
100% 22/22 [00:06<00:00,  3.16it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.33it/s]
                 all         88        132      0.959       0.98      0.988
0.802

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      83/99      8.08G    0.01606   0.005174  0.0009515         85        640:
100% 22/22 [00:05<00:00,  3.67it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:01<00:00,  1.71it/s]
                 all         88        132      0.939       0.97      0.983
0.792

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      84/99      8.08G    0.01631   0.005249  0.0009134         60        640:
100% 22/22 [00:05<00:00,  4.34it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.51it/s]
                 all         88        132      0.943      0.961      0.977
0.796

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      85/99      8.08G    0.01593   0.005192  0.0009041         98        640:
100% 22/22 [00:06<00:00,  3.39it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.18it/s]
                 all         88        132      0.974      0.928      0.976
0.794

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      86/99      8.08G    0.01652   0.005258  0.0008908         69        640:
100% 22/22 [00:05<00:00,  3.72it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.10it/s]
                 all         88        132      0.902      0.992      0.984
0.787

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      87/99      8.08G     0.0157   0.005241  0.0009021         54        640:
100% 22/22 [00:06<00:00,  3.53it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.18it/s]
```

```
                 all         88        132      0.941      0.986      0.985
0.785

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      88/99      8.08G    0.01559   0.005297  0.0008223         84        640:
100% 22/22 [00:06<00:00,  3.42it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.22it/s]
                 all         88        132      0.971      0.955      0.985
0.795

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      89/99      8.08G    0.01606   0.005096  0.0008322        100        640:
100% 22/22 [00:05<00:00,  4.06it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.81it/s]
                 all         88        132      0.939      0.972      0.984
0.797

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      90/99      8.08G    0.01604   0.005375  0.0008942         75        640:
100% 22/22 [00:06<00:00,  3.48it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.62it/s]
                 all         88        132      0.972      0.969      0.989
0.794

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      91/99      8.08G    0.01549    0.00493  0.0009987         79        640:
100% 22/22 [00:06<00:00,  3.63it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:01<00:00,  1.87it/s]
                 all         88        132      0.976      0.968      0.989
0.799

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      92/99      8.08G      0.015   0.005198  0.0007106         84        640:
100% 22/22 [00:05<00:00,  3.93it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.12it/s]
                 all         88        132      0.977      0.958      0.988
0.793

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      93/99      8.08G    0.01462   0.004842  0.0008006         89        640:
100% 22/22 [00:06<00:00,  3.52it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.05it/s]
```

```
                 all         88        132      0.943      0.974      0.981
0.805

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      94/99      8.08G    0.01492   0.004959  0.0008217        100        640:
100% 22/22 [00:06<00:00,  3.45it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:01<00:00,  1.84it/s]
                 all         88        132       0.99      0.924      0.972
0.797

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      95/99      8.08G    0.01456   0.005134  0.0008545         89        640:
100% 22/22 [00:06<00:00,  3.29it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.54it/s]
                 all         88        132      0.989      0.925      0.972
0.808

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      96/99      8.08G    0.01425   0.004754  0.0006507         68        640:
100% 22/22 [00:05<00:00,  4.09it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:01<00:00,  1.66it/s]
                 all         88        132      0.992      0.928      0.971
0.802

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      97/99      8.08G    0.01453   0.004586  0.0007498         82        640:
100% 22/22 [00:05<00:00,  4.05it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.01it/s]
                 all         88        132      0.985      0.937      0.974
0.819

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      98/99      8.08G    0.01493   0.005011  0.0006505         85        640:
100% 22/22 [00:05<00:00,  3.81it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:01<00:00,  1.76it/s]
                 all         88        132       0.96       0.97      0.985
0.82

      Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
      99/99      8.08G    0.01428   0.004918  0.0009268         90        640:
100% 22/22 [00:05<00:00,  4.35it/s]
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:00<00:00,  2.60it/s]
```

```
                   all         88        132      0.993      0.922      0.983
0.812

100 epochs completed in 0.215 hours.
Optimizer stripped from runs/train/yolo_road_det3/weights/last.pt, 14.4MB
Optimizer stripped from runs/train/yolo_road_det3/weights/best.pt, 14.4MB

Validating runs/train/yolo_road_det3/weights/best.pt…
Fusing layers…
YOLOv5s summary: 157 layers, 7020913 parameters, 0 gradients, 15.8 GFLOPs
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 2/2 [00:01<00:00,  1.27it/s]
                   all         88        132       0.96       0.97      0.985
0.823
          trafficlight         88         19      0.894       0.89      0.956
0.626
                  stop         88         10      0.972          1      0.995
0.923
            speedlimit         88         81      0.972          1      0.995
0.906
             crosswalk         88         22          1      0.989      0.995
0.835
Results saved to runs/train/yolo_road_det3
```

[43]:
```python
model_name = "/content/yolov5/runs/train/yolo_road_det3/weights/best.pt"
test_model = torch.hub.load("ultralytics/yolov5", 'custom', model_name)
test_model.conf = 0.25  # confidence threshold (0-1)
test_model.iou = 0.45
test_model.eval()

test_path = "/content/RoadSignDetectionDataset/"
test_files = glob.glob(test_path + "/images/test/*")
labels = ["trafficlight", "stop", "speedlimit", "crosswalk"]

for files in test_files:
  test_image = cv2.imread(files)
  file_basename = os.path.basename(files)
  print (file_basename)
  txt_name = file_basename[:file_basename.rfind(".")] + ".txt"
  txt_file = open(test_path + "/labels/test/" + txt_name, "r")
  data = txt_file.read()
  data_into_list = data.split("\n")
  #print(data_into_list)

  results = test_model(test_image, size=640)
  results_df = results.pandas().xyxy
  print (results_df[0].name)
```

```
  print("\n")
```

```
Using cache found in /root/.cache/torch/hub/ultralytics_yolov5_master
YOLOv5  2022-10-6 Python-3.7.14 torch-1.12.1+cu113 CUDA:0 (Tesla
V100-SXM2-16GB, 16160MiB)

Fusing layers…
YOLOv5s summary: 157 layers, 7020913 parameters, 0 gradients, 15.8 GFLOPs
Adding AutoShape…
```

```
road113.png
0    speedlimit
Name: name, dtype: object


road801.png
0    speedlimit
Name: name, dtype: object


road486.png
0      speedlimit
1    trafficlight
Name: name, dtype: object


road385.png
0    speedlimit
Name: name, dtype: object


road679.png
0    speedlimit
Name: name, dtype: object


road360.png
0    speedlimit
Name: name, dtype: object


road599.png
0    speedlimit
Name: name, dtype: object


road563.png
```

```
0    speedlimit
1     crosswalk
Name: name, dtype: object


road731.png
0    speedlimit
1    speedlimit
Name: name, dtype: object


road418.png
0    speedlimit
Name: name, dtype: object


road316.png
0    speedlimit
1    speedlimit
2     crosswalk
Name: name, dtype: object


road709.png
0    speedlimit
1    speedlimit
Name: name, dtype: object


road80.png
0    stop
Name: name, dtype: object


road50.png
0    trafficlight
Name: name, dtype: object


road809.png
0    speedlimit
Name: name, dtype: object


road403.png
0    speedlimit
Name: name, dtype: object
```

```
road590.png
0    speedlimit
Name: name, dtype: object


road337.png
0    speedlimit
Name: name, dtype: object


road803.png
0    speedlimit
Name: name, dtype: object


road445.png
0    speedlimit
1    speedlimit
Name: name, dtype: object


road417.png
0    speedlimit
Name: name, dtype: object


road661.png
0    speedlimit
1          stop
Name: name, dtype: object


road600.png
0    speedlimit
1          stop
Name: name, dtype: object


road206.png
0    speedlimit
Name: name, dtype: object


road18.png
0    trafficlight
Name: name, dtype: object
```

```
road129.png
0       crosswalk
1    trafficlight
Name: name, dtype: object


road796.png
0    speedlimit
Name: name, dtype: object


road543.png
0    speedlimit
1     crosswalk
Name: name, dtype: object


road854.png
0    speedlimit
Name: name, dtype: object


road819.png
0            stop
1    trafficlight
2    trafficlight
Name: name, dtype: object


road321.png
0    speedlimit
1     crosswalk
2          stop
Name: name, dtype: object


road433.png
0    speedlimit
1          stop
Name: name, dtype: object


road367.png
0    speedlimit
Name: name, dtype: object
```

```
road67.png
0    stop
Name: name, dtype: object


road37.png
0    trafficlight
Name: name, dtype: object


road174.png
0    speedlimit
Name: name, dtype: object


road356.png
0    stop
Name: name, dtype: object


road199.png
0    speedlimit
Name: name, dtype: object


road494.png
0    speedlimit
Name: name, dtype: object


road408.png
0    speedlimit
Name: name, dtype: object


road315.png
0    speedlimit
1     crosswalk
Name: name, dtype: object


road293.png
0    speedlimit
1     crosswalk
Name: name, dtype: object


road804.png
```

```
0    speedlimit
Name: name, dtype: object


road318.png
0    speedlimit
1     crosswalk
Name: name, dtype: object


road764.png
0    speedlimit
Name: name, dtype: object


road91.png
0          stop
1    speedlimit
Name: name, dtype: object


road267.png
0    speedlimit
Name: name, dtype: object


road667.png
0    speedlimit
Name: name, dtype: object


road142.png
0    crosswalk
Name: name, dtype: object


road564.png
0    speedlimit
1     crosswalk
Name: name, dtype: object


road160.png
0         stop
1    crosswalk
Name: name, dtype: object
```

```
road665.png
0    speedlimit
Name: name, dtype: object


road672.png
0    speedlimit
1          stop
Name: name, dtype: object


road498.png
0    speedlimit
Name: name, dtype: object


road183.png
0       crosswalk
1       crosswalk
2    trafficlight
Name: name, dtype: object


road3.png
0    trafficlight
1    trafficlight
Name: name, dtype: object


road558.png
0    speedlimit
Name: name, dtype: object


road643.png
0    speedlimit
Name: name, dtype: object


road695.png
0    speedlimit
1    speedlimit
2          stop
Name: name, dtype: object


road261.png
0    speedlimit
```

```
Name: name, dtype: object


road609.png
0    speedlimit
1     crosswalk
Name: name, dtype: object


road789.png
0    speedlimit
Name: name, dtype: object


road490.png
0    speedlimit
Name: name, dtype: object


road328.png
0    speedlimit
Name: name, dtype: object


road164.png
0    trafficlight
Name: name, dtype: object


road43.png
0    trafficlight
1    trafficlight
2    trafficlight
3    trafficlight
4    trafficlight
5    trafficlight
6    trafficlight
7    trafficlight
8    trafficlight
Name: name, dtype: object


road617.png
0    speedlimit
Name: name, dtype: object


road157.png
```

```
0    speedlimit
Name: name, dtype: object


road143.png
0    crosswalk
Name: name, dtype: object


road841.png
0    speedlimit
1     crosswalk
Name: name, dtype: object


road194.png
0       crosswalk
1    trafficlight
Name: name, dtype: object


road47.png
0    trafficlight
Name: name, dtype: object


road96.png
0    stop
Name: name, dtype: object


road550.png
0    speedlimit
Name: name, dtype: object


road748.png
0    speedlimit
1    speedlimit
Name: name, dtype: object


road784.png
0    speedlimit
1     crosswalk
Name: name, dtype: object
```

```
road640.png
0    speedlimit
1    speedlimit
Name: name, dtype: object


road721.png
0    speedlimit
Name: name, dtype: object


road492.png
0    speedlimit
Name: name, dtype: object


road100.png
0    speedlimit
Name: name, dtype: object


road712.png
0    speedlimit
1    speedlimit
Name: name, dtype: object


road140.png
0    crosswalk
Name: name, dtype: object


road730.png
0    speedlimit
1    speedlimit
Name: name, dtype: object


road431.png
0    speedlimit
Name: name, dtype: object


road547.png
0    speedlimit
1     crosswalk
2     crosswalk
Name: name, dtype: object
```

```
road33.png
0    trafficlight
Name: name, dtype: object


road175.png
0    speedlimit
Name: name, dtype: object


road625.png
0    speedlimit
Name: name, dtype: object
```

[42]:
```
!python val.py --weights runs/train/yolo_road_det3/weights/best.pt --data␣
↪road_sign_data.yaml --task test --name yolo_det
```

```
val: data=/content/yolov5/data/road_sign_data.yaml,
weights=['runs/train/yolo_road_det3/weights/best.pt'], batch_size=32, imgsz=640,
conf_thres=0.001, iou_thres=0.6, max_det=300, task=test, device=, workers=8,
single_cls=False, augment=False, verbose=False, save_txt=False,
save_hybrid=False, save_conf=False, save_json=False, project=runs/val,
name=yolo_det, exist_ok=False, half=False, dnn=False
YOLOv5  v6.2-186-g7f097dd Python-3.7.14 torch-1.12.1+cu113 CUDA:0 (Tesla
V100-SXM2-16GB, 16160MiB)

Fusing layers…
YOLOv5s summary: 157 layers, 7020913 parameters, 0 gradients, 15.8 GFLOPs
test: Scanning '/content/RoadSignDetectionDataset/labels/test'
images and labels…88 found, 0 missing, 0 empty, 0 corrupt: 100% 88/88
[00:00<00:00, 2895.35it/s]
test: New cache created:
/content/RoadSignDetectionDataset/labels/test.cache
                 Class     Images  Instances          P          R      mAP50
mAP50-95: 100% 3/3 [00:02<00:00,  1.14it/s]
                   all         88        126      0.993      0.901      0.952
0.795
          trafficlight         88         20          1      0.647      0.828
0.554
                  stop         88          7      0.986          1      0.995
0.889
            speedlimit         88         76      0.994          1      0.995
0.9
             crosswalk         88         23      0.992      0.957       0.99
```

```
0.837
Speed: 0.3ms pre-process, 2.0ms inference, 0.9ms NMS per image at shape (32, 3,
640, 640)
Results saved to runs/val/yolo_det2
```

[ ]: