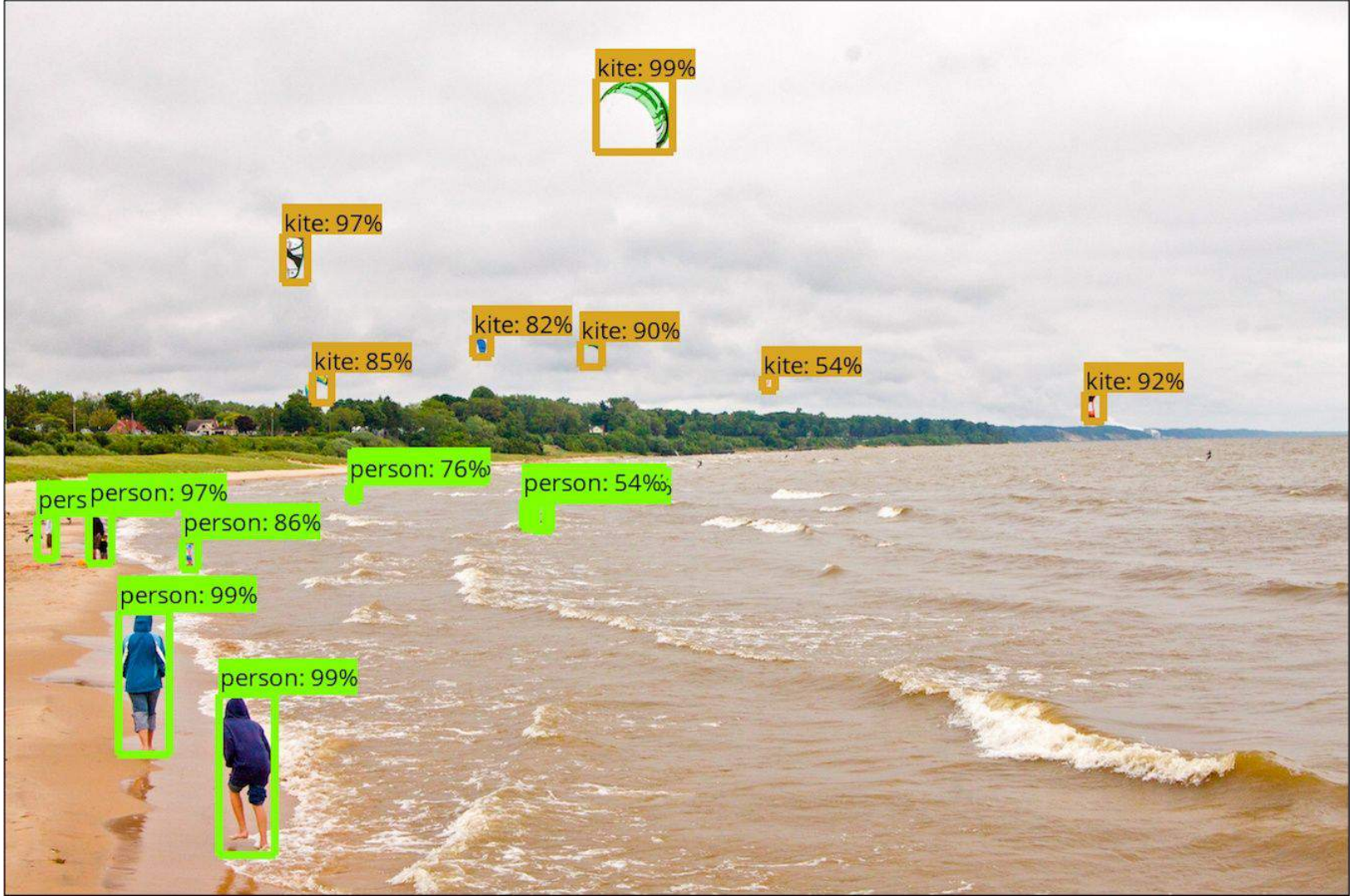
kite: 99%
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kite: 82%
kite: 90%
kite: 85%
kite: 54%
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person: 76%
person: 54%
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person: 97%
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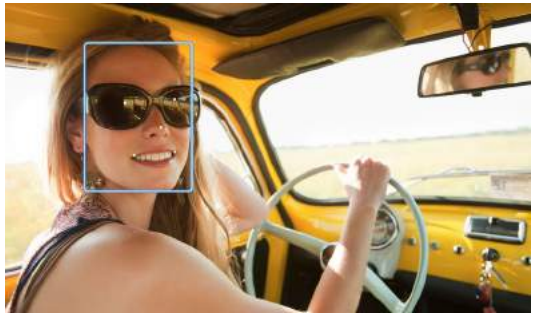
Object Detection examples



Facial Detection / Recognition
Amazon Rekognition

https://docs.aws.amazon.com/rekognition/latest/dg/faces.html

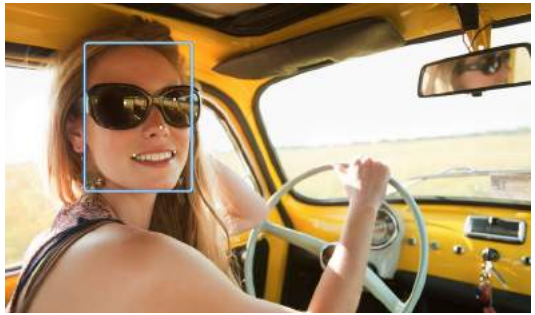
Counting vehicles
PowerAI

https://github.com/IBM/powerai-counting-cars

Analyzing aerial imagery
DIGITS

https://devblogs.nvidia.com/detectnet-deep-neural-network-object-detection-digits/

Object Detection examples



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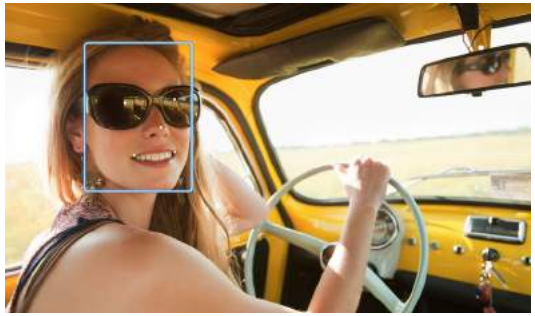

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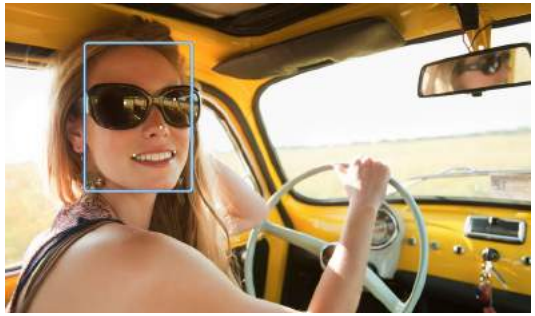

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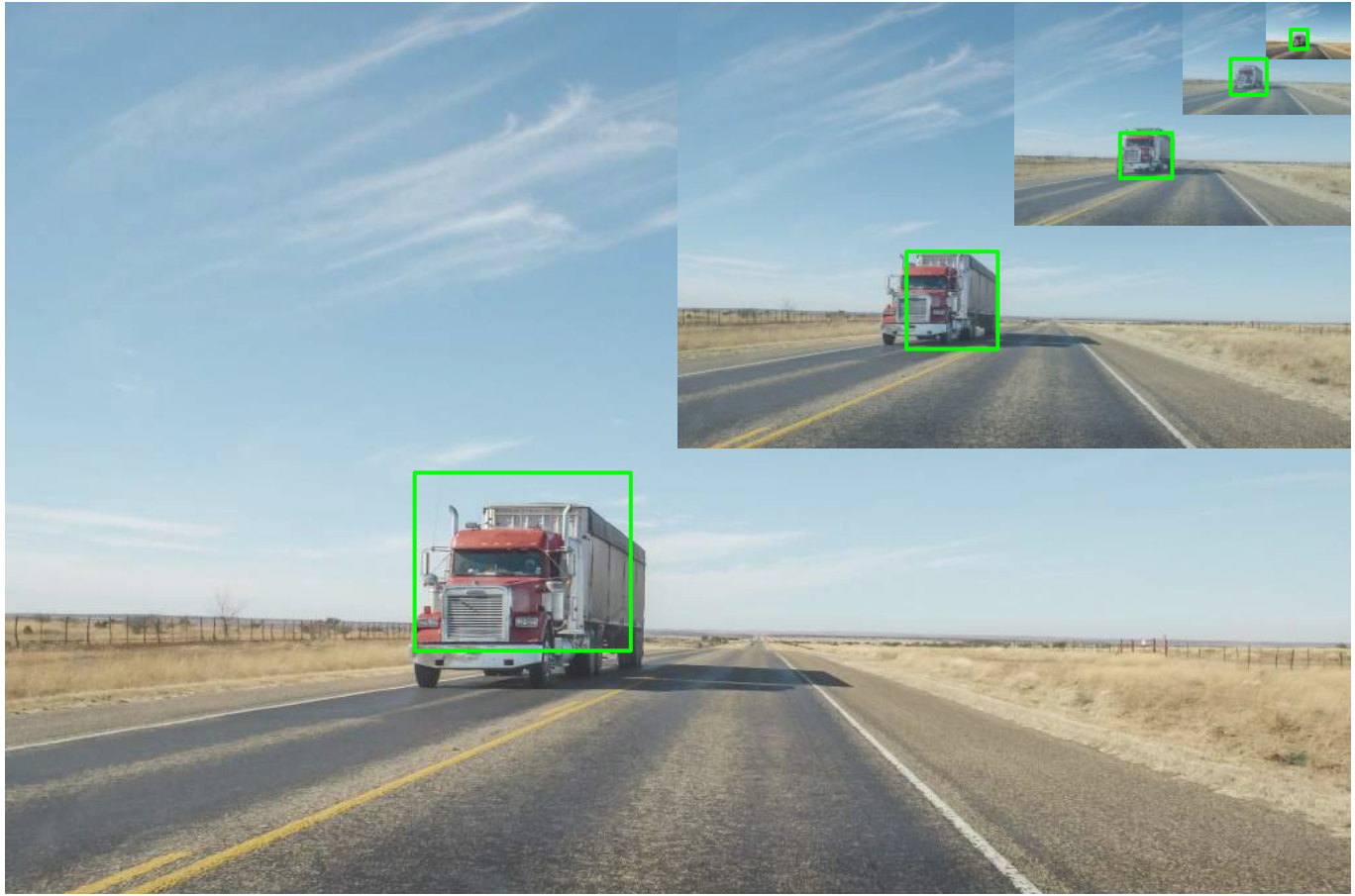
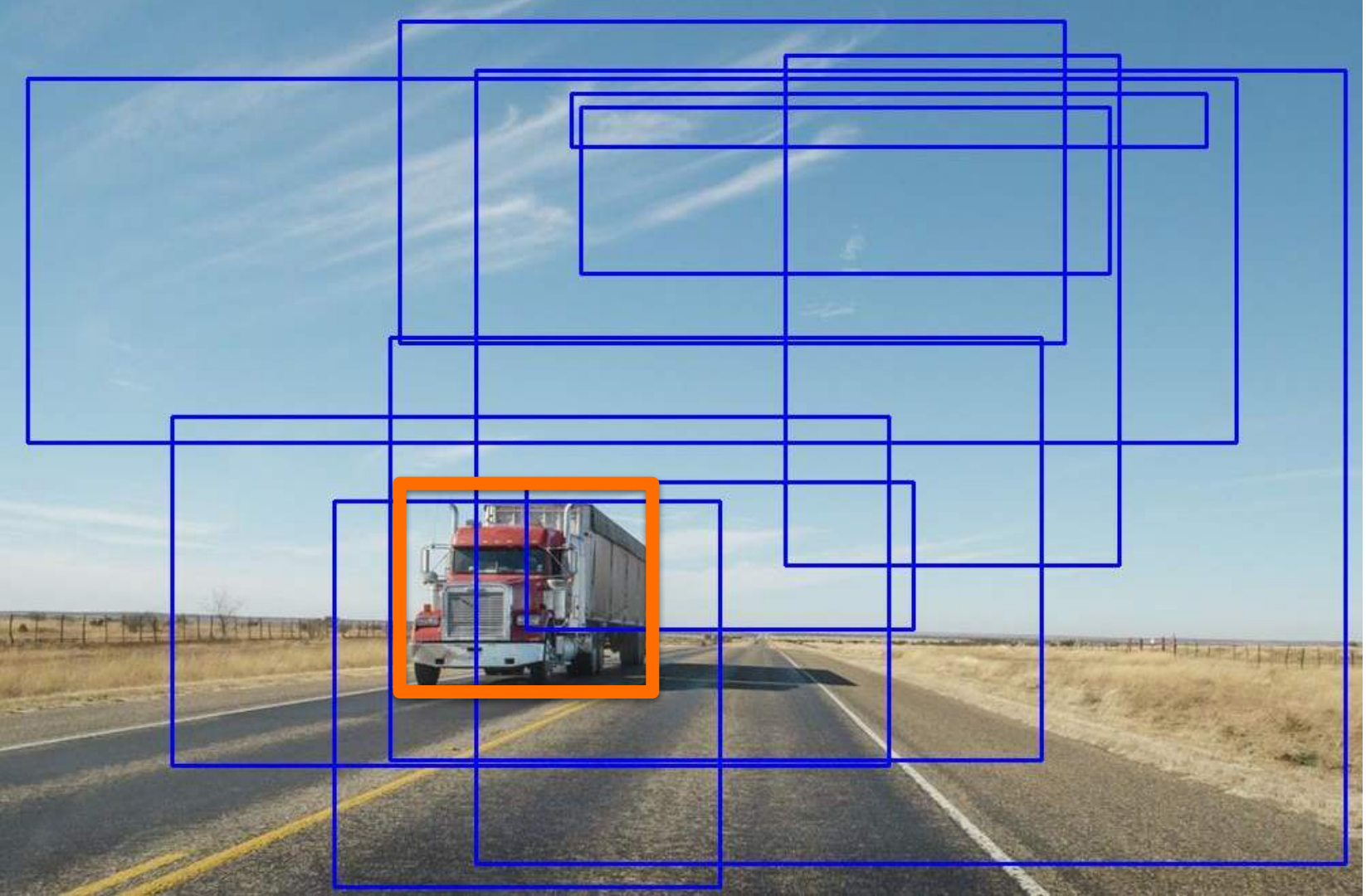
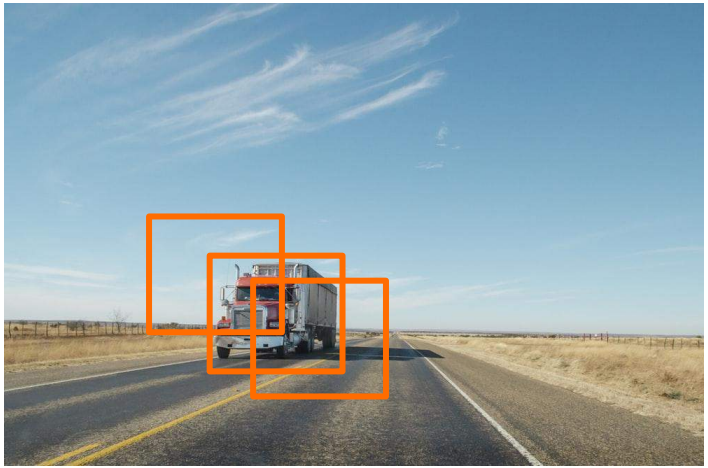


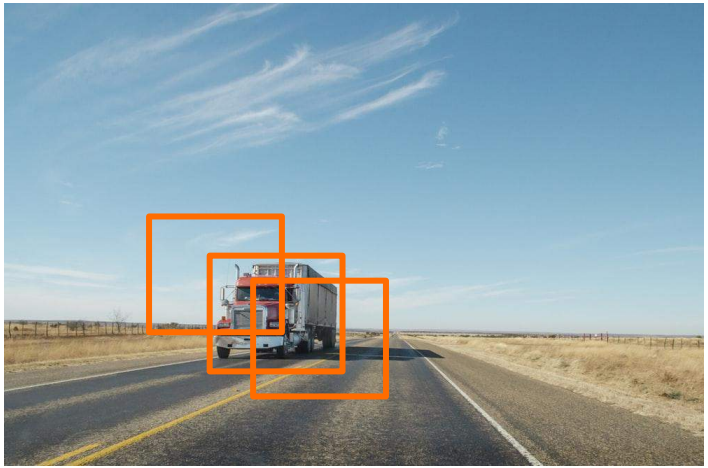


Sliding Window



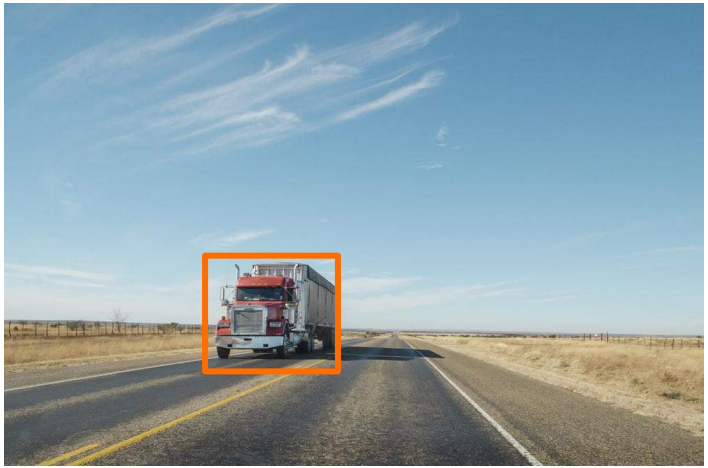
Before NMS

Non-maximum suppression (NMS)



Before NMS

NMS

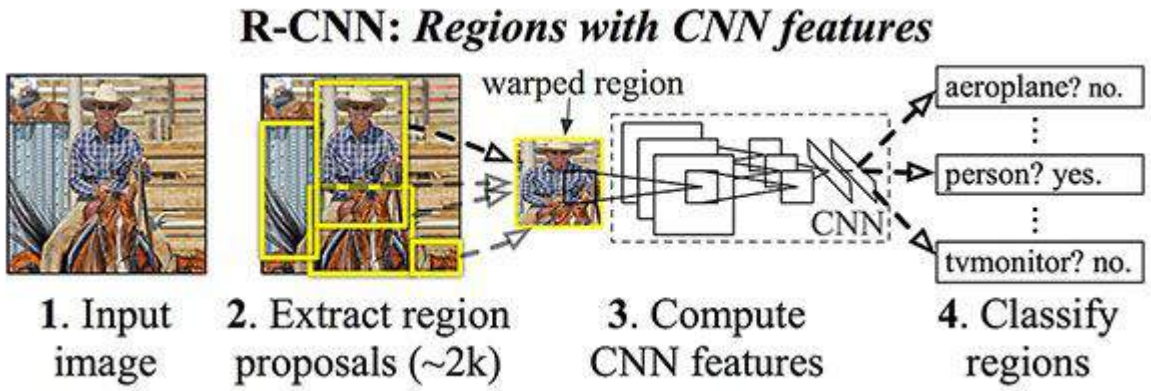


After NMS

Two Stages to Object Detection:

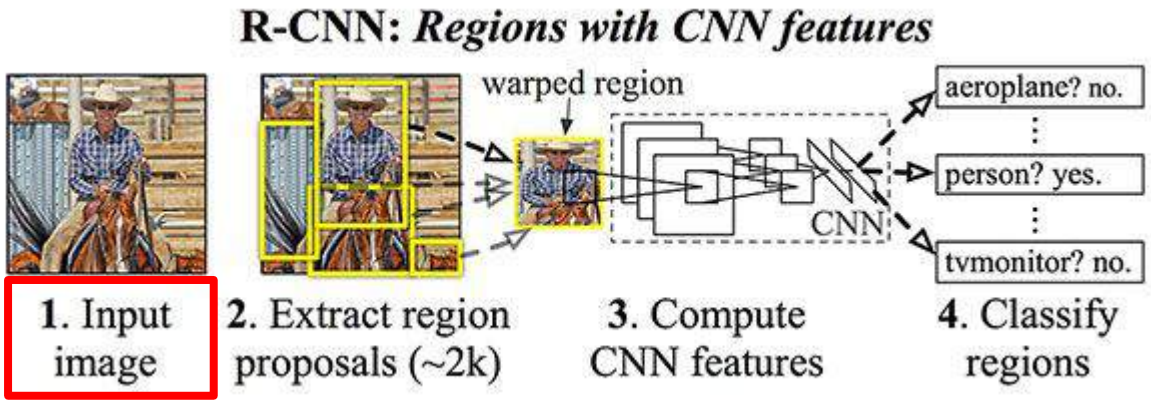
1. Region proposal
2. Object detection and classification

R-CNN



The R-CNN architecture (source: Girshick et al,. 2013)

R-CNN



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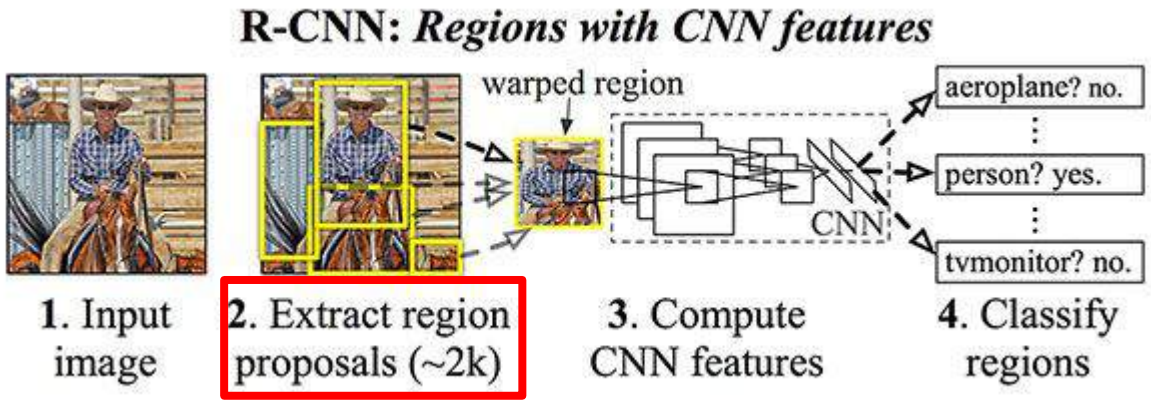
R-CNN



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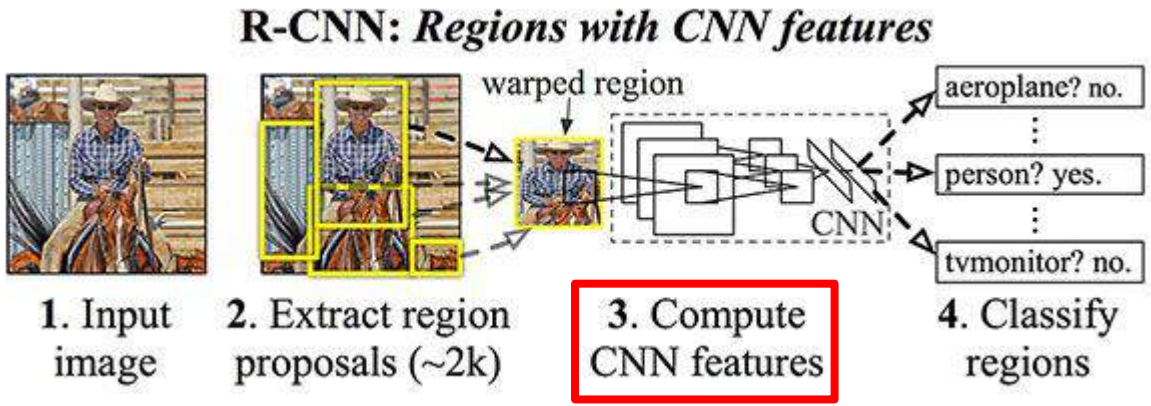
R-CNN



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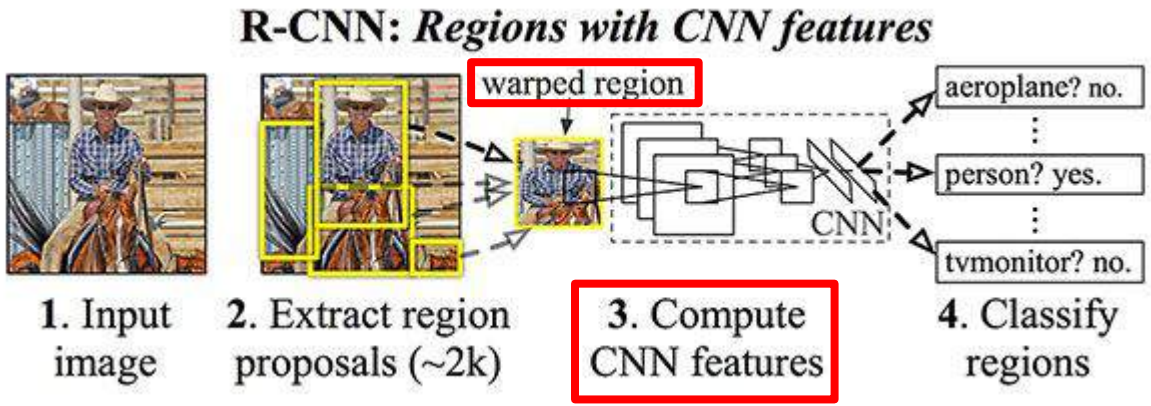
R-CNN



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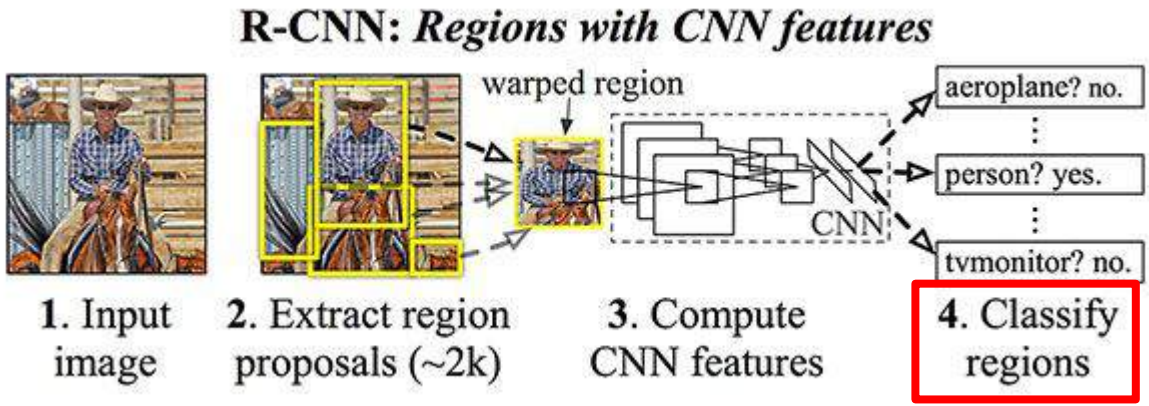
R-CNN



The R-CNN architecture (source: Girshick et al,. 2013)

https://arxiv.org/pdf/1311.2524.pdf

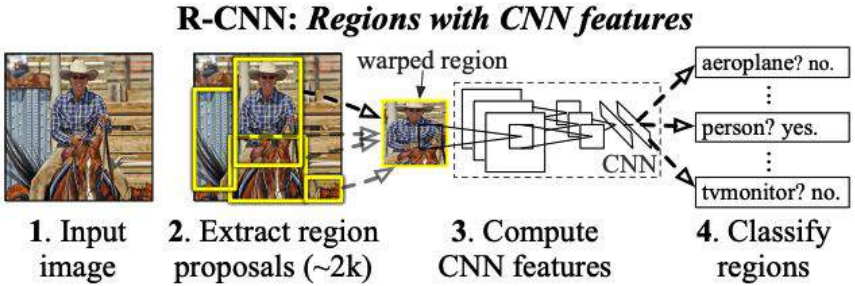
Rich feature hierarchies for accurate object detection and semantic segmentation

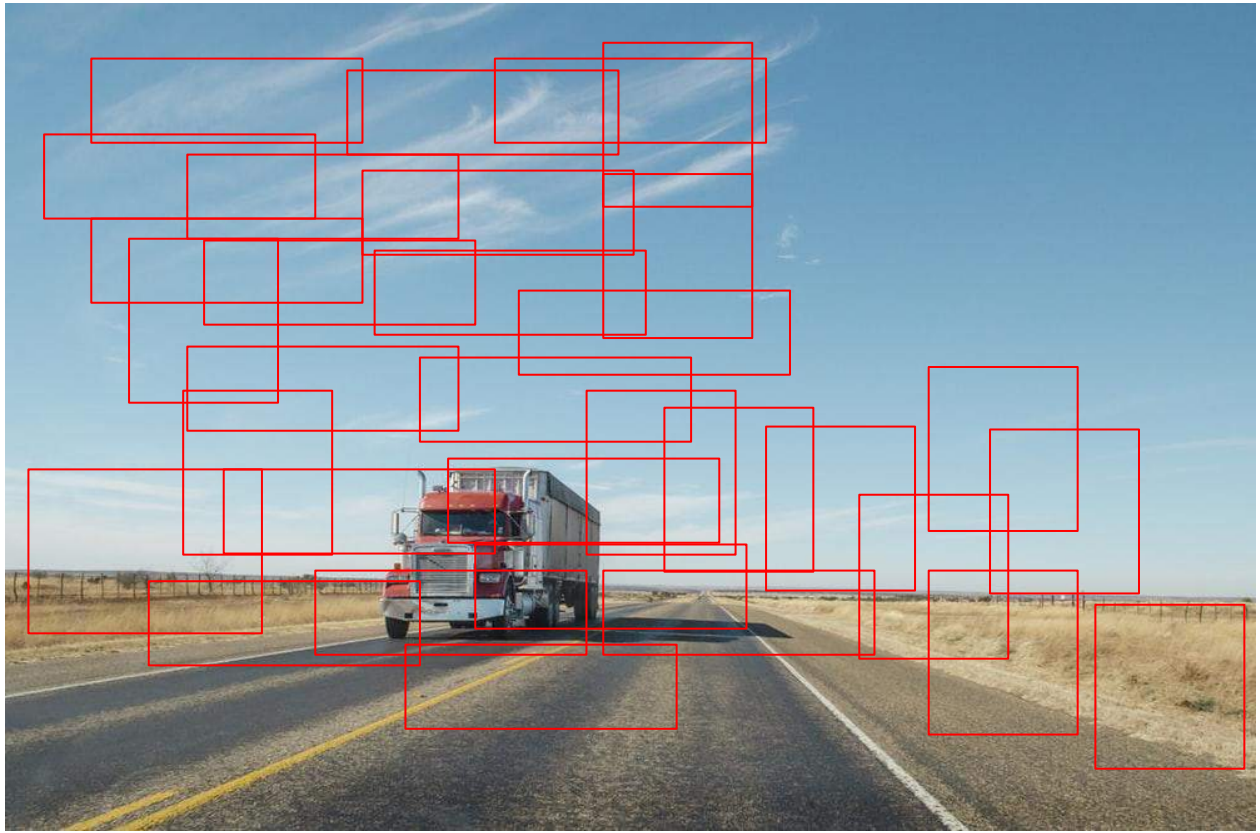
Tech report (v5)

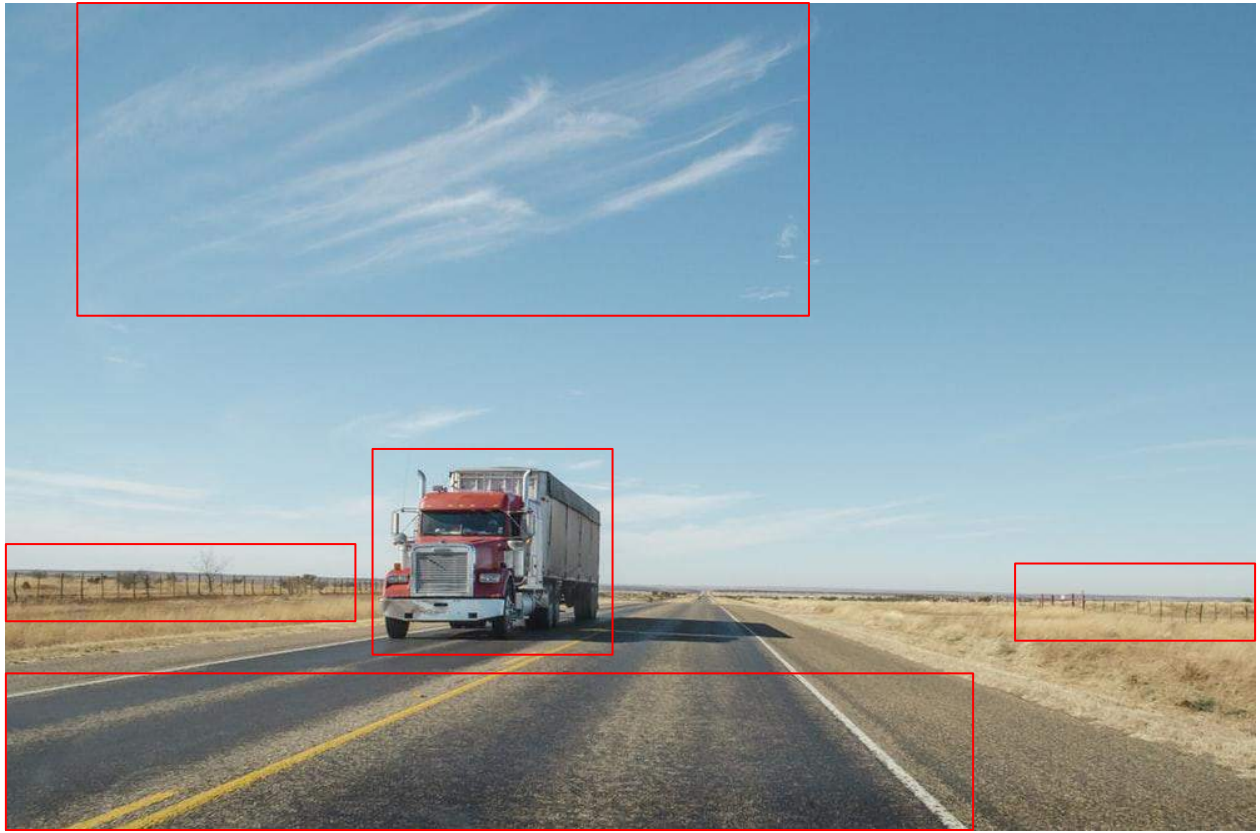
Ross Girshick Jeff Donahue Trevor Darrell Jitendra Malik
UC Berkeley
{rbg,jdonahue,trevor,malik}@eecs.berkeley.edu

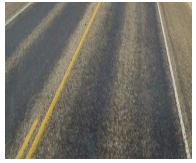
Abstract

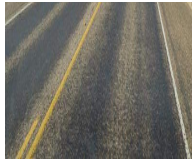
Object detection performance, as measured on the canonical PASCAL VOC dataset, has plateaued in the last few years. The best-performing methods are complex ensemble systems that typically combine multiple low-level image features with high-level context. In this paper, we

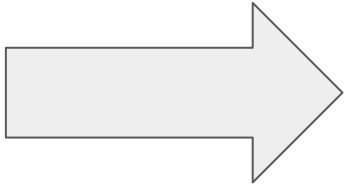












ConvNet

Feature Extraction

ConvNet

Feature Extraction

SVM

Classification

ConvNet

Feature Extraction

SVM

Classification

Regression

Bounding Boxes

Transfer Learning for R-CNN

Pre-train: auxiliary task

Large auxiliary Data Set

Fine-tune: domain specific task

Warped region proposals

Transfer Learning for R-CNN

Pre-train: auxiliary task

Large auxiliary Data Set

Fine-tune: domain specific task

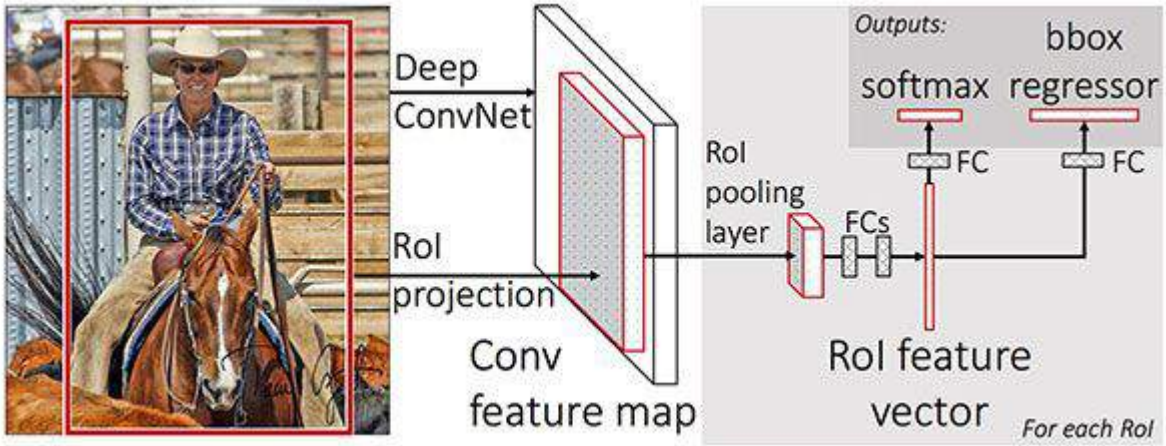
Warped region proposals

R-CNN disadvantages

Slow

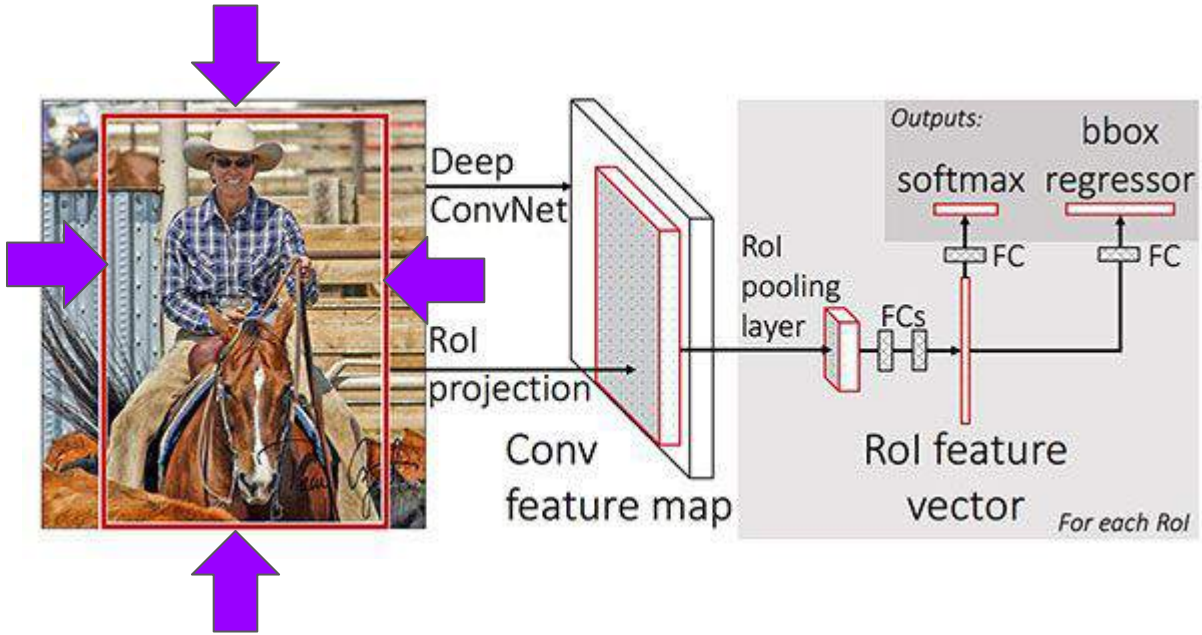
memory

Fast R-CNN



The Fast R-CNN architecture (source: Girshick et al., 2015).

Fast R-CNN



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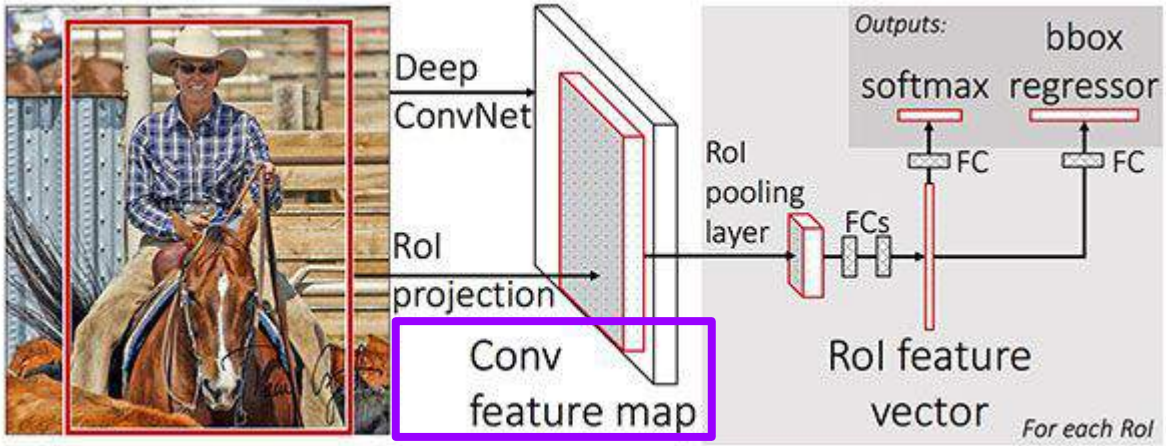
Fast R-CNN



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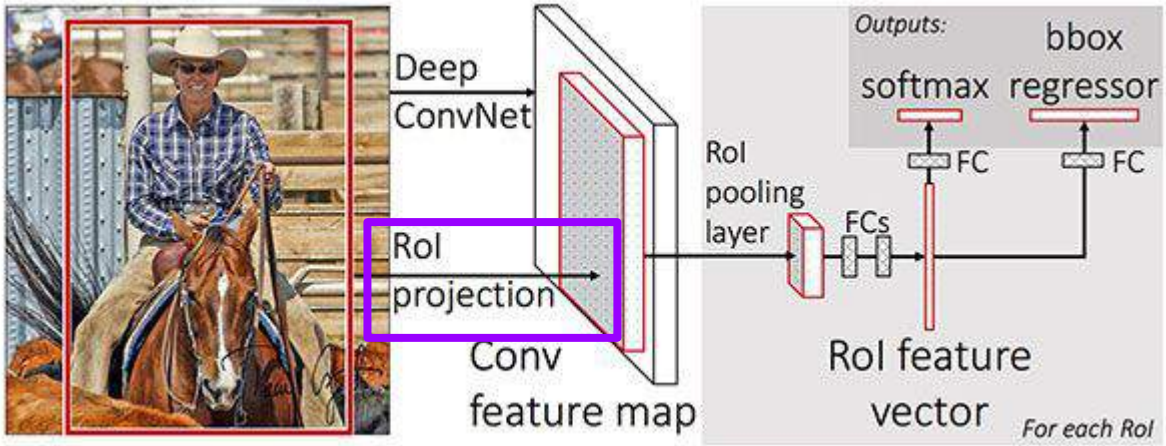

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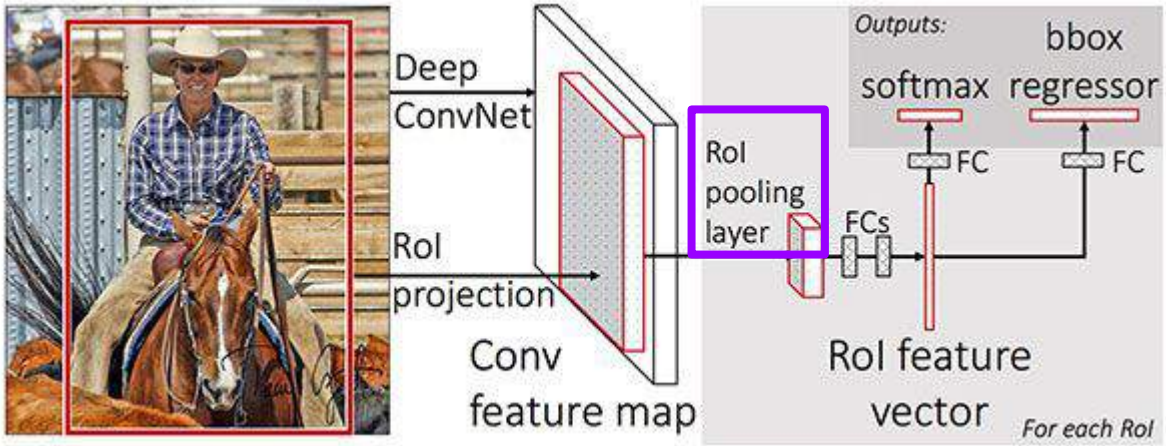

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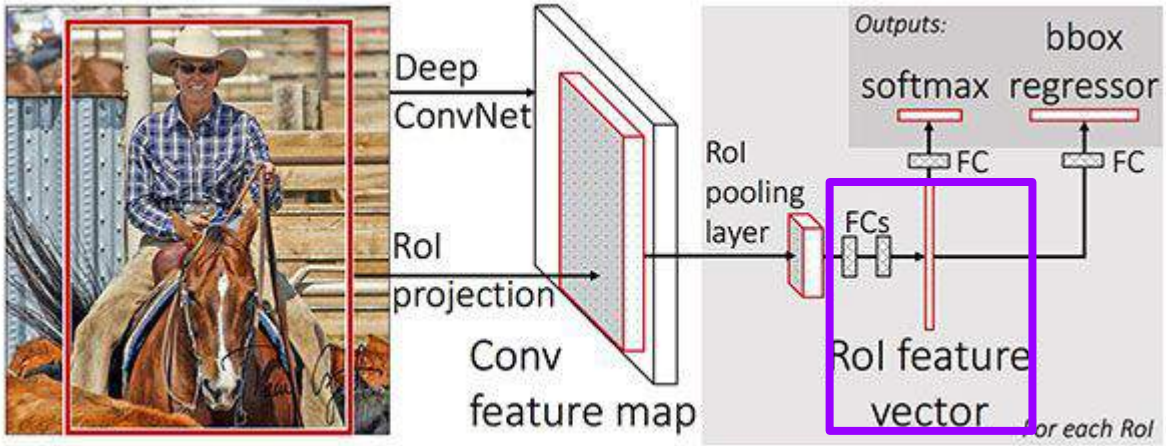

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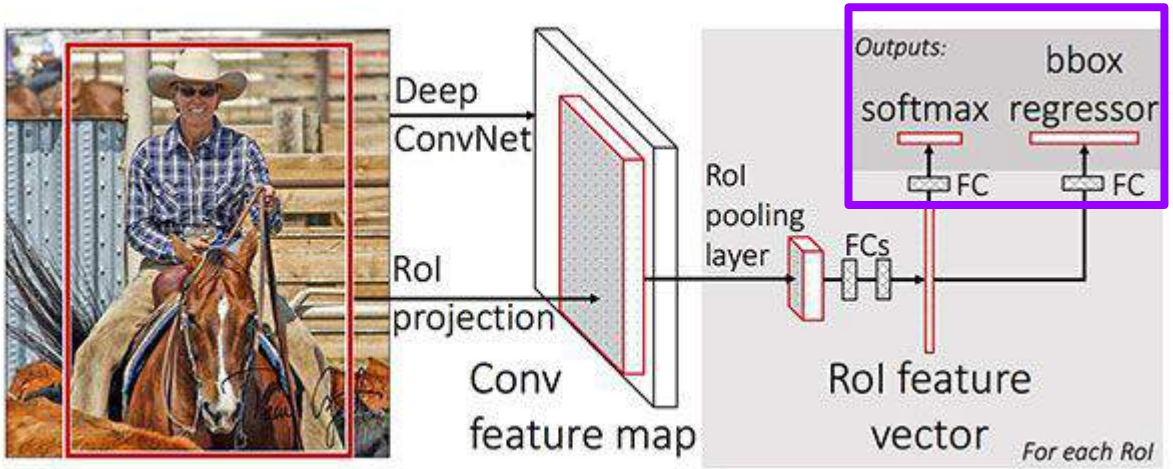

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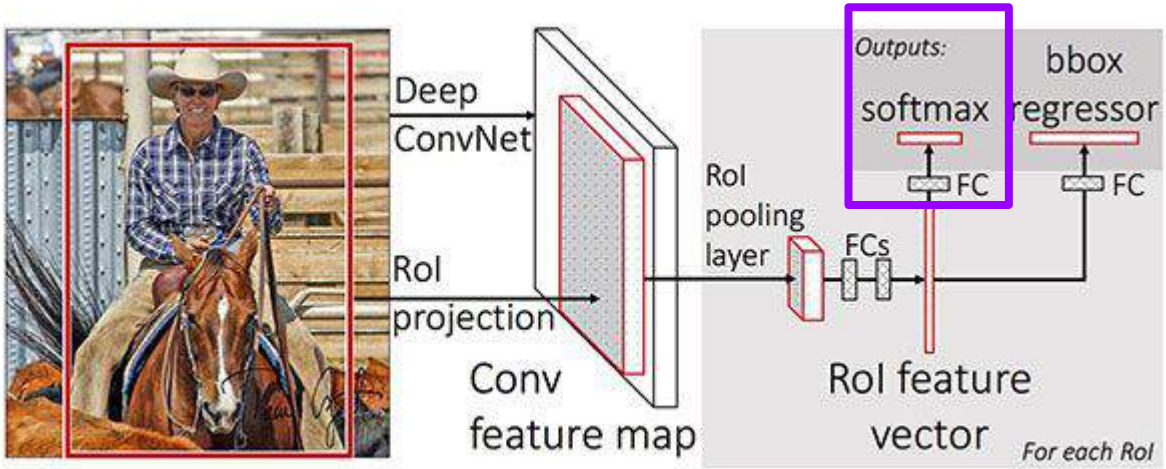

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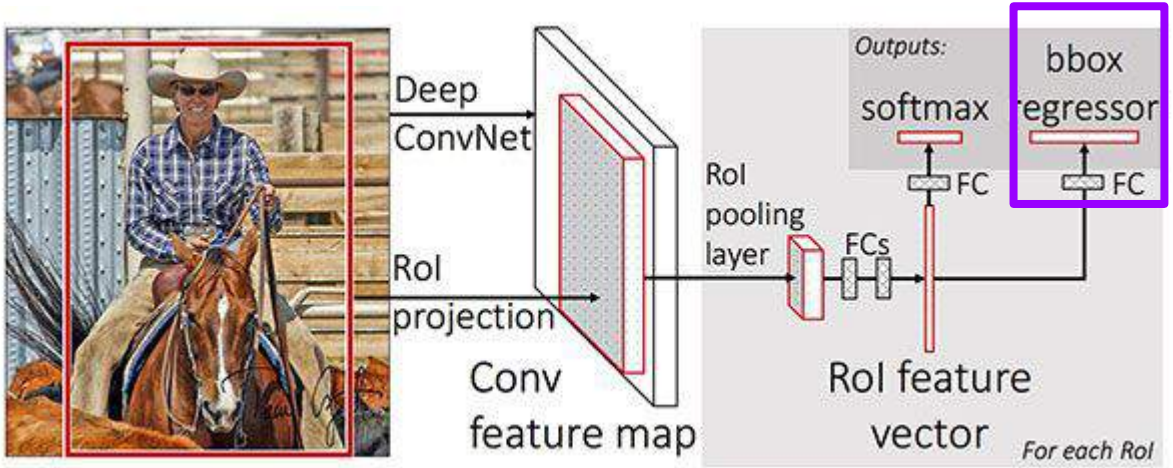


The Fast R-CNN architecture (source: Girshick et al., 2015).

https://arxiv.org/pdf/1504.08083.pdf

Fast R-CNN

Ross Girshick
Microsoft Research
rbg@microsoft.com

Abstract

This paper proposes a Fast Region-based Convolutional Network method (Fast R-CNN) *for object detection. Fast R-CNN builds on previous work to efficiently classify object proposals using deep convolutional networks. Compared to previous work, Fast R-CNN employs several innovations to improve training and testing speed while also increasing detection accuracy. Fast R-CNN trains the very deep VGG16 network 9× faster than R-CNN, is 213× faster at test-time, and achieves a higher mAP on PASCAL VOC 2012. Compared to SPPnet, Fast R-CNN trains VGG16 3×*

while achieving top accuracy on PASCAL VOC 2012 [7] with a mAP of 66% (vs. 62% for R-CNN).[1]

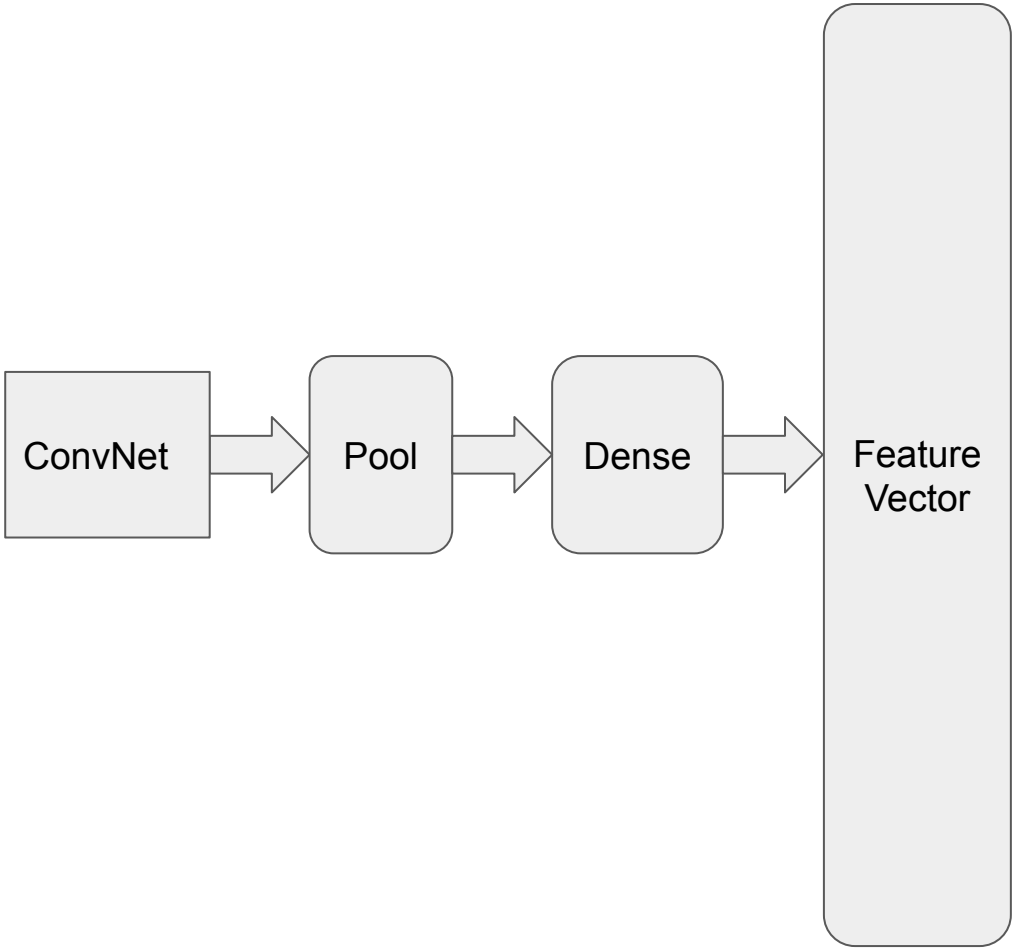
1.1. R-CNN and SPPnet

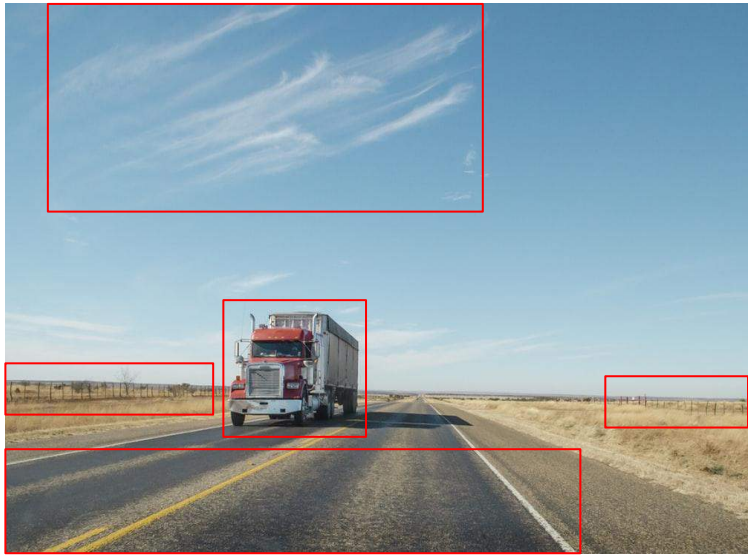
The Region-based Convolutional Network method (R-CNN) [9] achieves excellent object detection accuracy by using a deep ConvNet to classify object proposals. R-CNN, however, has notable drawbacks:

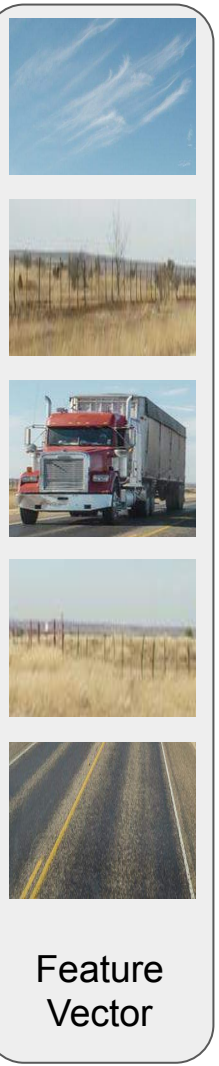
1. **Training is a multi-stage pipeline.** R-CNN first fine-tunes a ConvNet on object proposals using log loss. Then, it fits SVMs to ConvNet features. These SVMs

ConvNet

Feature Extraction


ConvNet
Pool
Dense
Feature Vector





Dense

Softmax

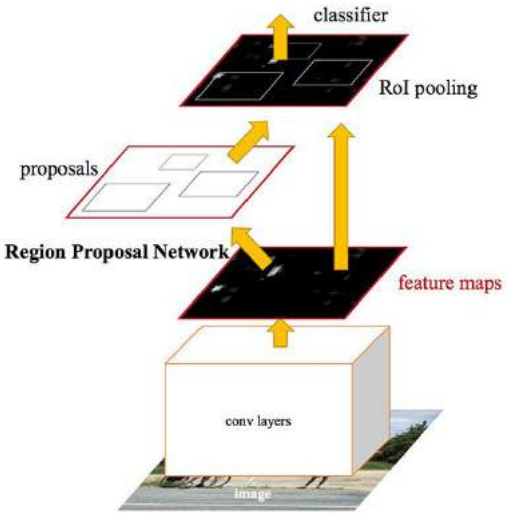
Classification

Dense

Regression

Bounding Boxes

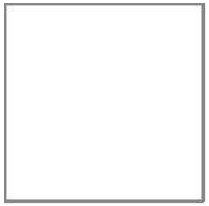
Faster R-CNN



source: Deep Learning for Computer Vision with Python

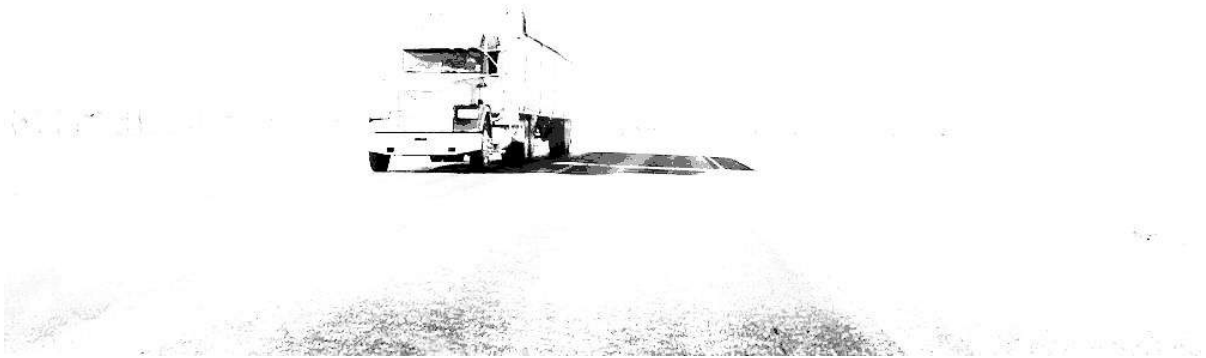
ConvNet

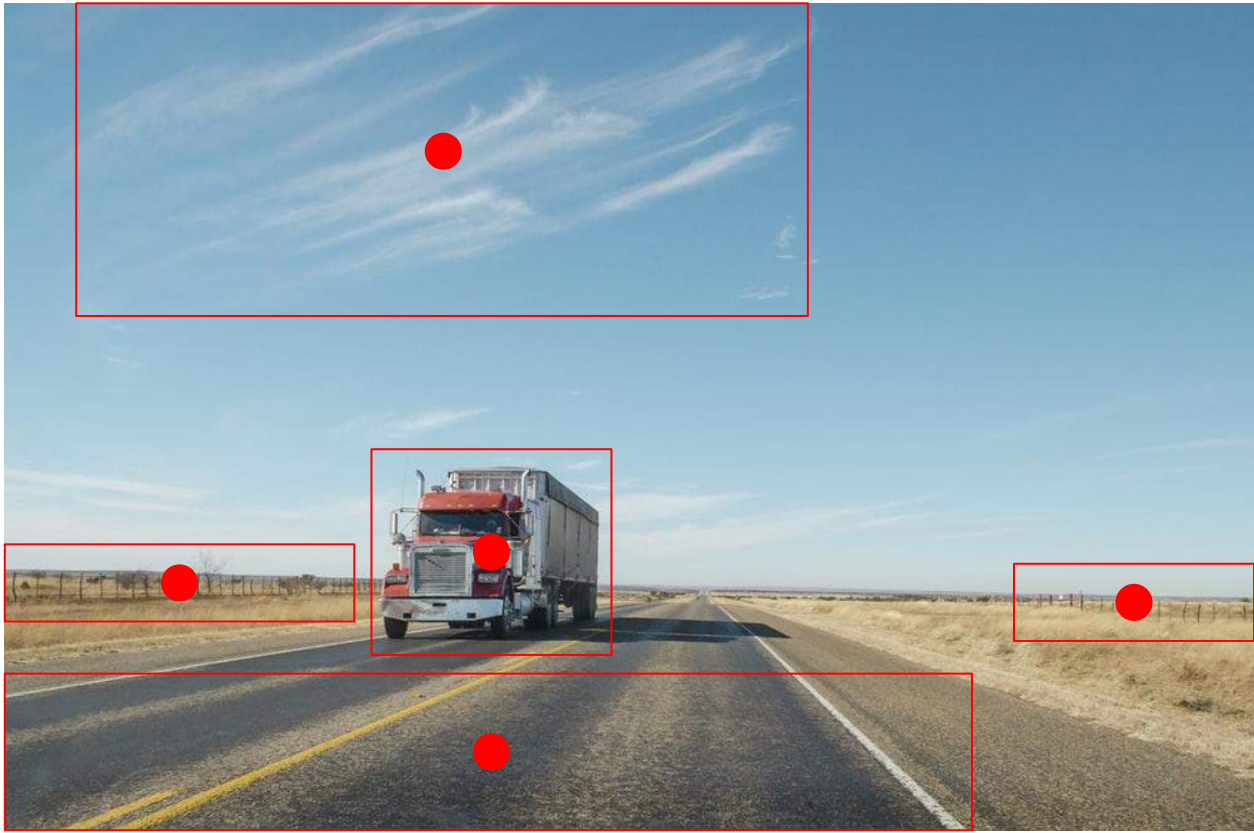
Feature Extraction

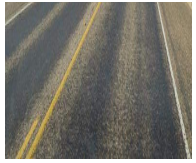


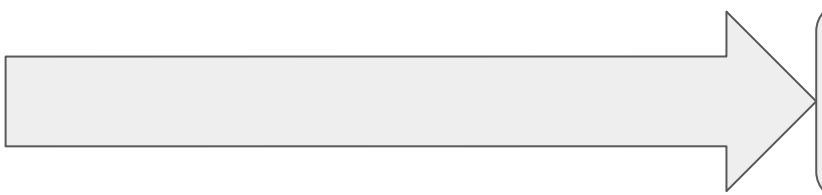
ConvNet

Feature Extraction









Dense

Softmax

Classification

Dense

Regression

Bounding Boxes

```
import tensorflow as tf
import tensorflow_hub as hub

module_handle = ...




detector = ...
```

```
import tensorflow as tf
import tensorflow_hub as hub

module_handle = ...




detector = ...
```

TensorFlow Hub

Search for models, collections & publishers

Send feedback

Back

Image object detection

faster_rcnn/openimages_v4/inception_resnet_v2

Object detection model trained on Open Images V4 with ImageNet pre-trained Inception Resnet V2 as image feature extractor.

Publisher: **Google** Updated: 08/25/2020 License: **Apache-2.0**

Architecture: Faster R-CNN

Dataset: OpenImagesV4

FasterRCNN Openimages v4

Results

Label: Boat

Label: Person

Go to:
https://www.tensorflow.org/hub

TensorFlow Hub

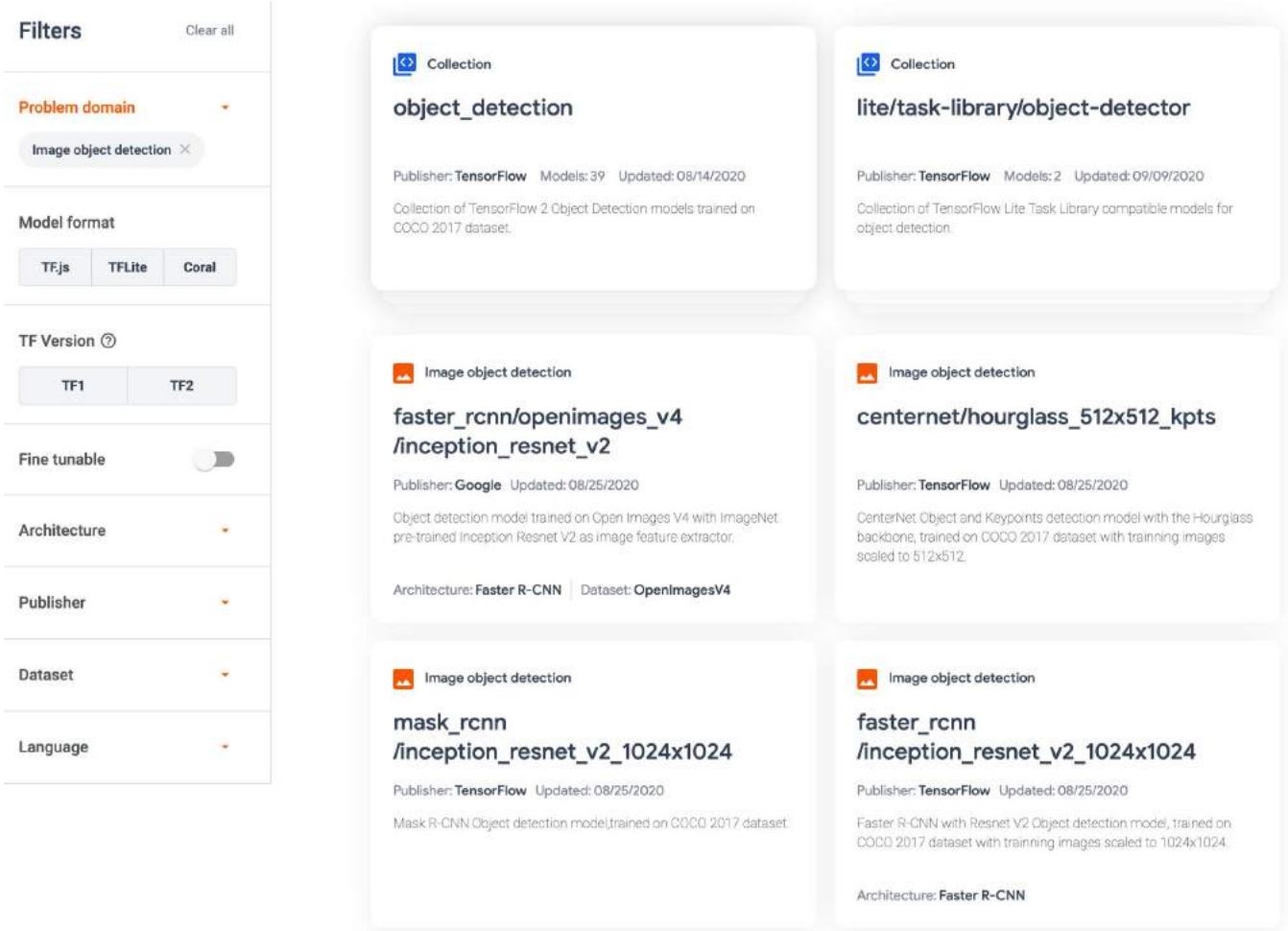
Search for models, col

Back

Image object detection

faster_rcnn/openimages_v4/i

https://tfhub.dev/s?module-type=image-object-detection



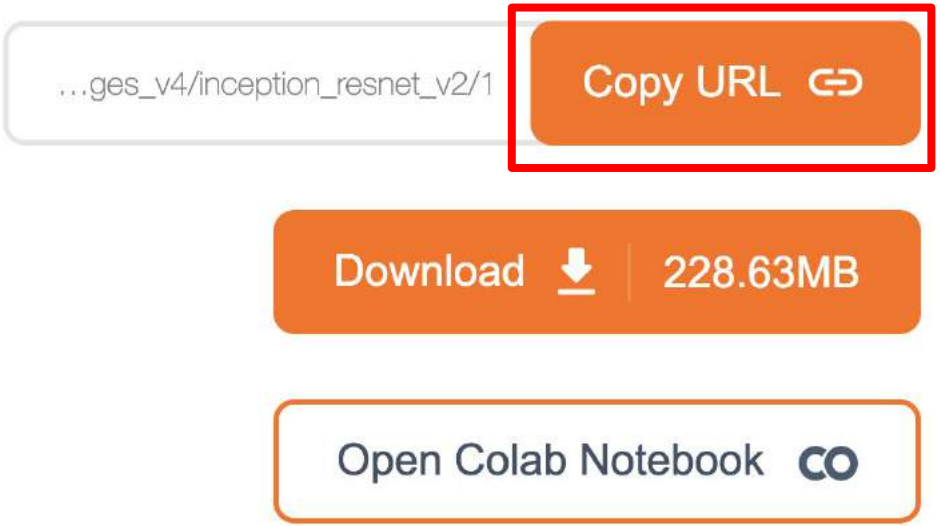
Hub module (v1)

Fine tunable: No License: Apache-2.0

Last updated: 08/25/2020

Format: Hub module

Object detection model trained on Open Images V4 with ImageNet pre-trained Inception Resnet V2 as image feature extractor.



```
import tensorflow as tf
import tensorflow_hub as hub

module_handle =
"https://tfhub.dev/google/faster_rcnn/openimages_v4/
        inception_resnet_v2/1"



detector = ...
```

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import tensorflow as tf
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module_handle =
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import tensorflow as tf
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module_handle =
"https://tfhub.dev/google/faster_rcnn/openimages_v4/
        inception_resnet_v2/1"



detector = hub.load(module_handle).signatures['default']
```

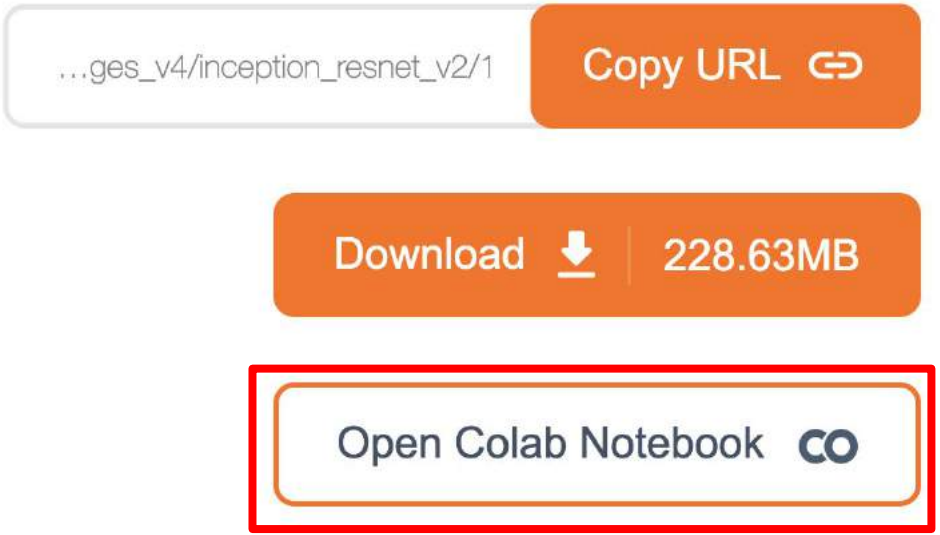
Hub module (v1)

Fine tunable: No License: Apache-2.0

Last updated: 08/25/2020

Format: Hub module

Object detection model trained on Open Images V4 with ImageNet pre-trained Inception Resnet V2 as image feature extractor.



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Information about reusing

```
image_url =
"https://upload.wikimedia.org/wikipedia/commons/f/fb/20130807_dublin014.JPG"

downloaded_image_path = ...
```

```
image_url =
"https://upload.wikimedia.org/wikipedia/commons/f/fb/20130807_dublin014.JPG"

downloaded_image_path = download_and_resize_image(url=image_url
                                                  new_width=3872,
                                                  new_height=2592)
```

```
img = tf.io.read_file(downloaded_image_path)
img = tf.image.decode_jpeg(img, channels=3)
converted_img  = tf.image.convert_image_dtype(img, tf.float32)[tf.newaxis, ...]


result = detector(converted_img)
```

```
img = tf.io.read_file(downloaded_image_path)
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```
Found 100 objects.
[0.43670595 0.34758776 0.2438663  0.23315561 0.22782972 0.21416378
 0.2057755  0.20488328 0.20278934 0.19843656 0.18925622 0.18167153
...]
[b'Person' b'Footwear' b'Footwear' b'Building' b'Person' b'Footwear'
 b'Window' b'Building' b'Person' b'Window' b'Window' b'Window' b'Window'
...]
[[0.5130533  0.9170097  0.82187796 0.99240506]
 [0.80095136 0.954444   0.83115625 0.98134536]
 [0.79767334 0.94279504 0.8265182  0.9654046 ]
```

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 [0.79767334 0.94279504 0.8265182  0.9654046 ]
```

Probability

Class

Bounding box

```
# Clone the tensorflow models repository
!git clone --depth 1 https://github.com/tensorflow/models
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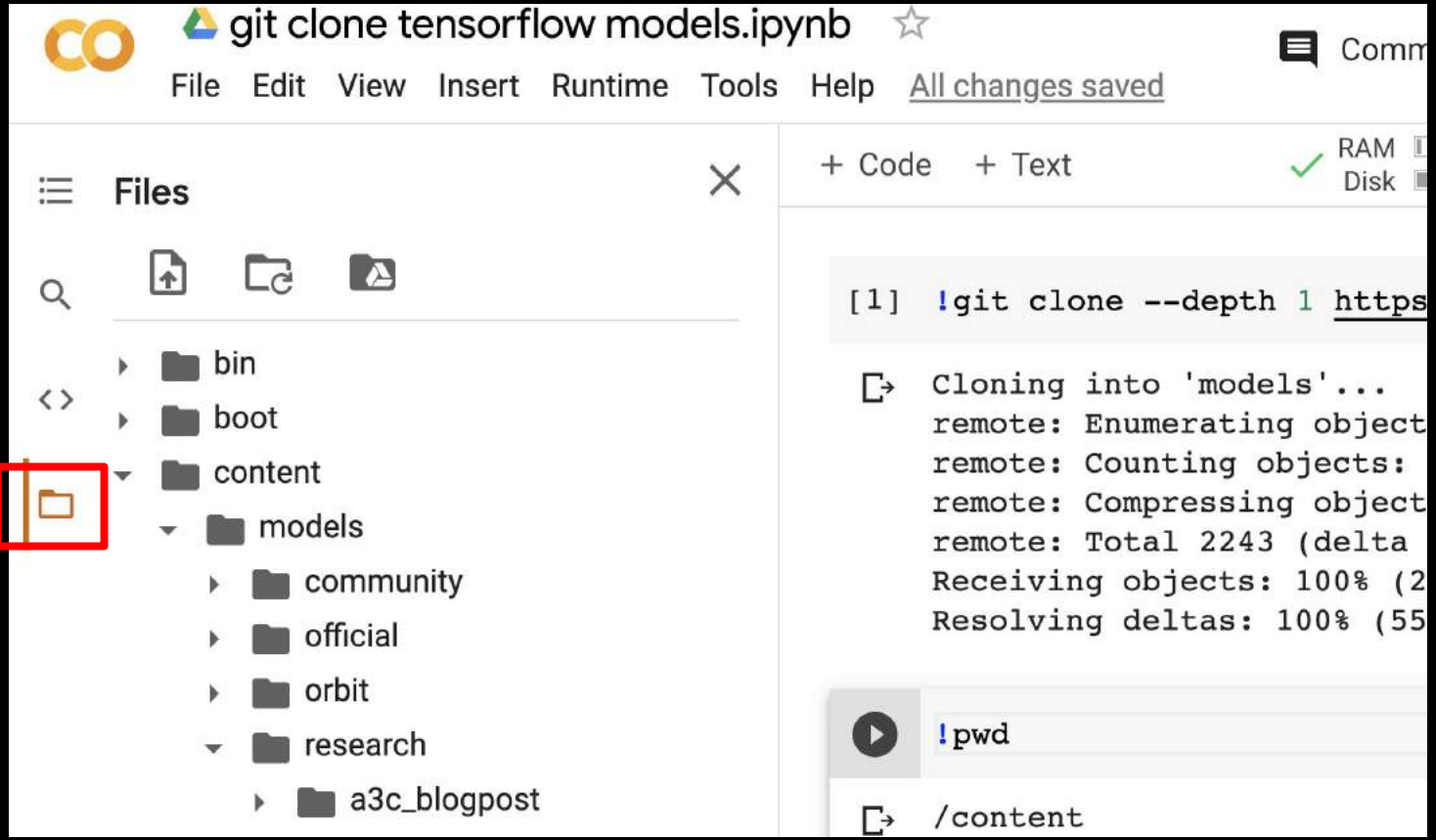

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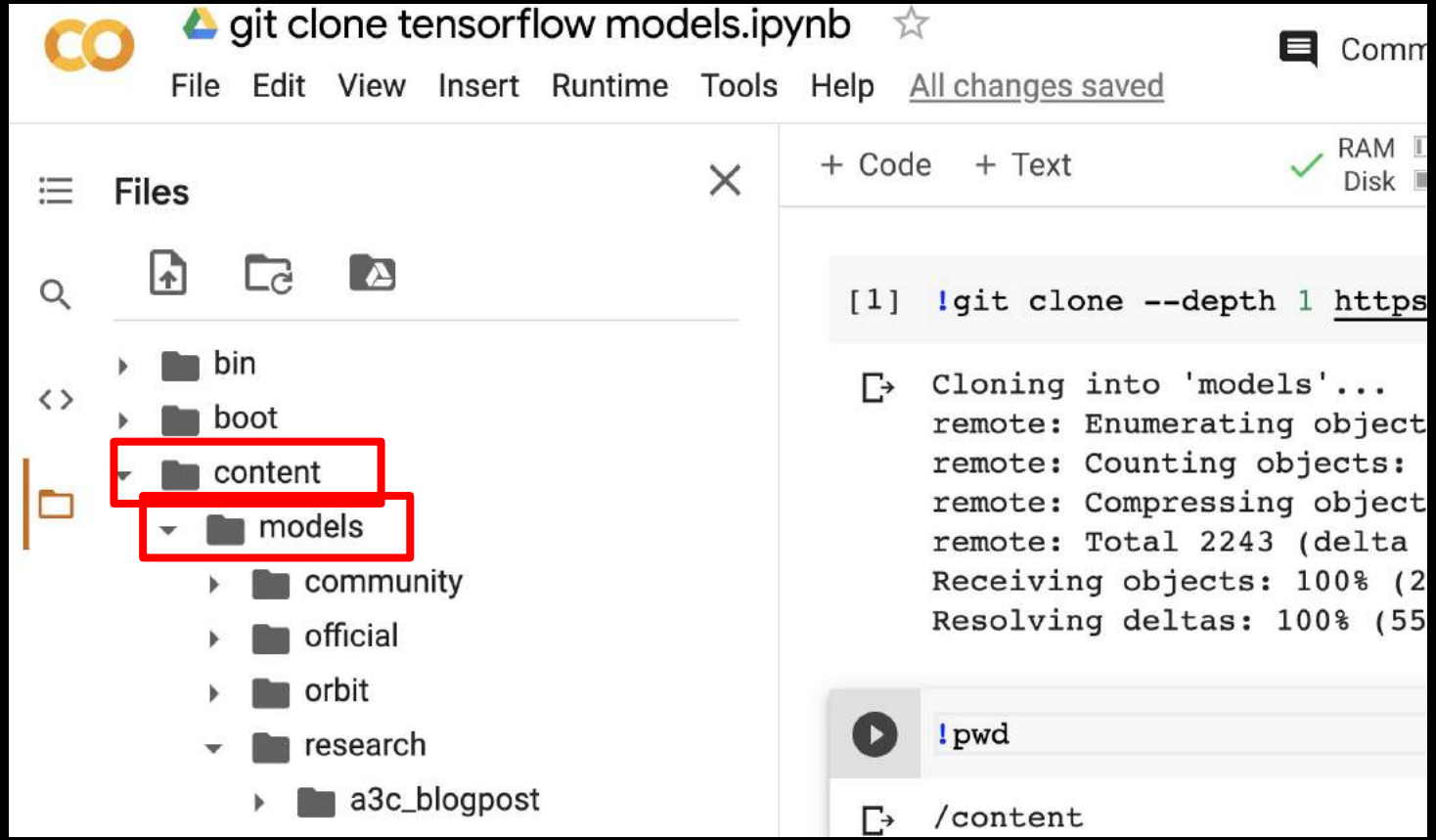

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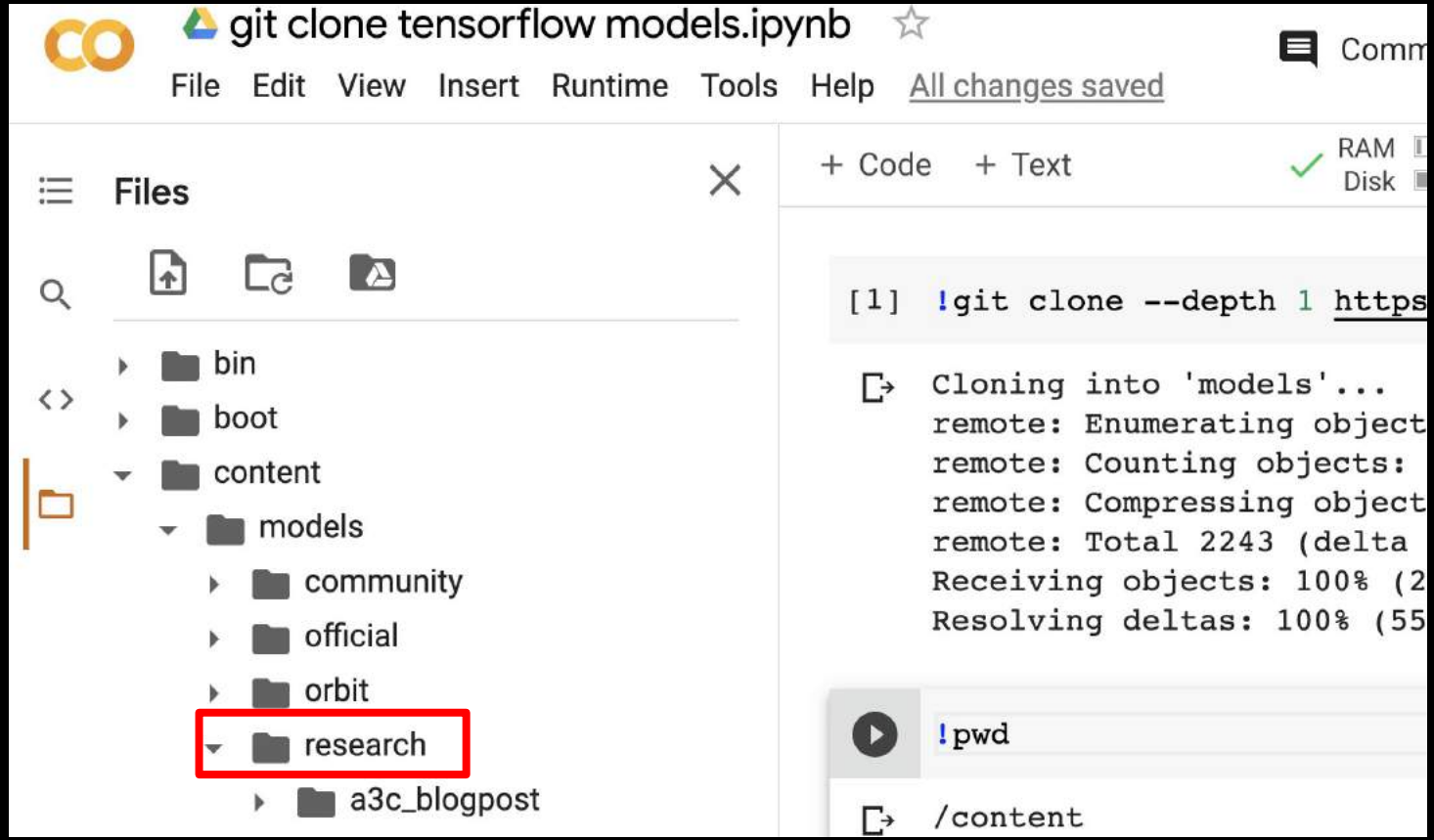

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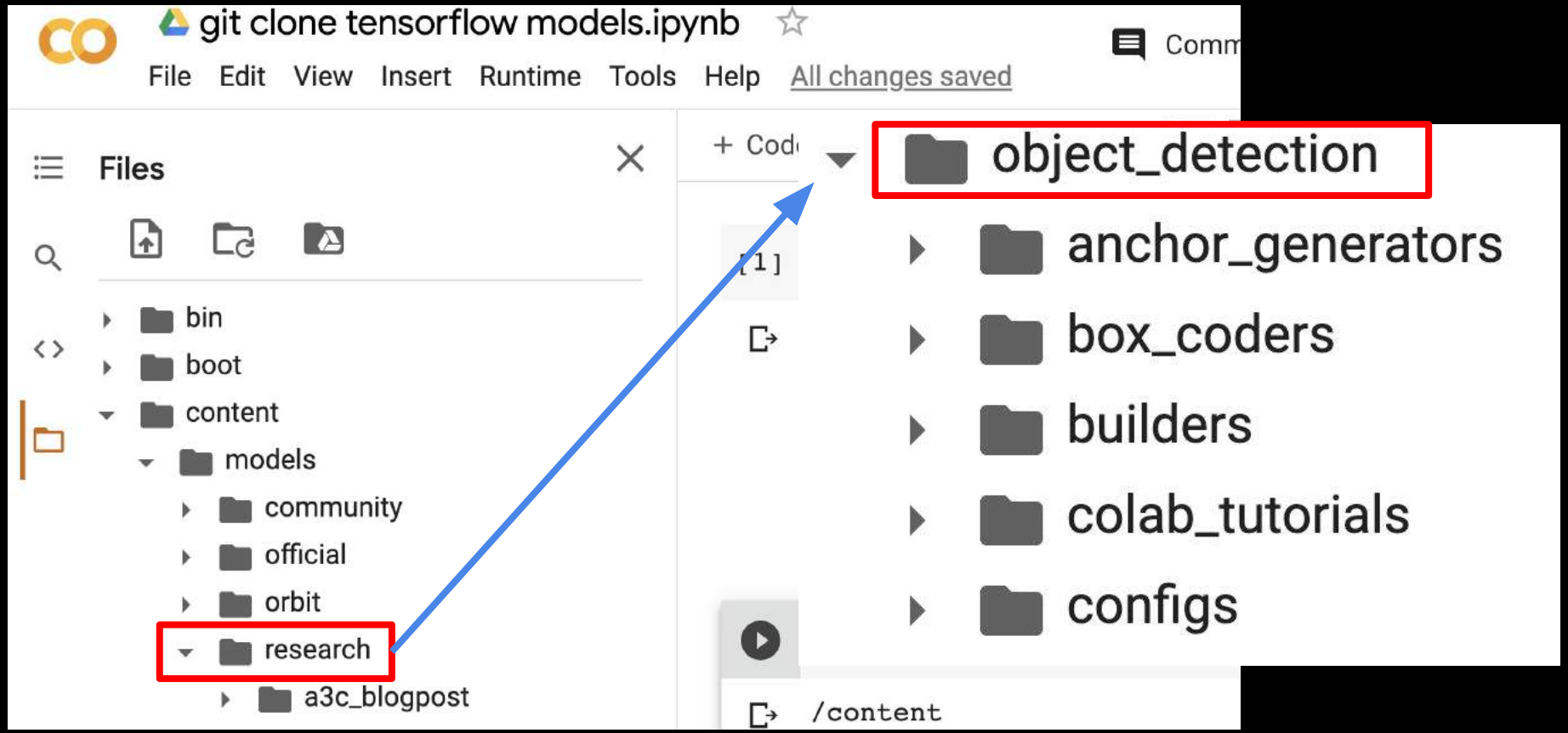

```
%%bash
sudo apt install -y protobuf-compiler
cd models/research/
protoc object_detection/protos/*.proto --python_out=.
cp object_detection/packages/tf2/setup.py .
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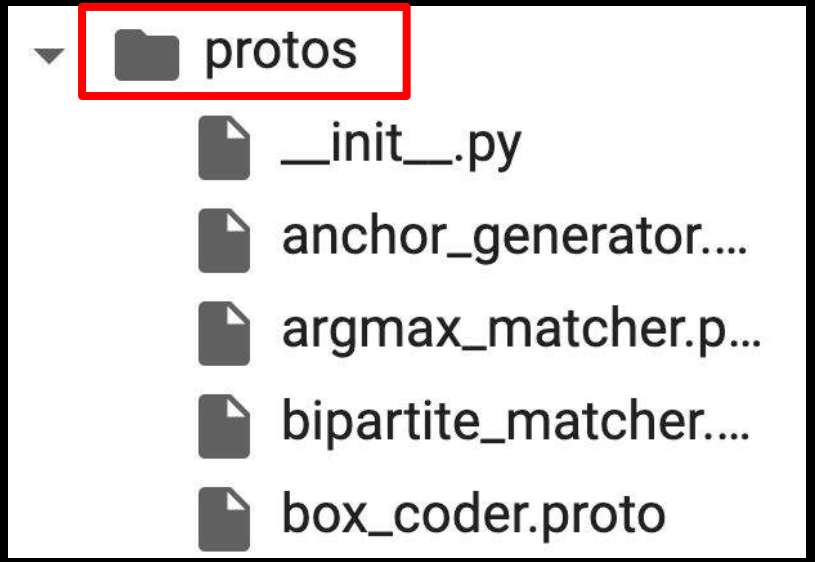

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from object_detection.utils import label_map_util
from object_detection.utils import visualization_utils as viz_utils
from object_detection.utils import ops as utils_ops
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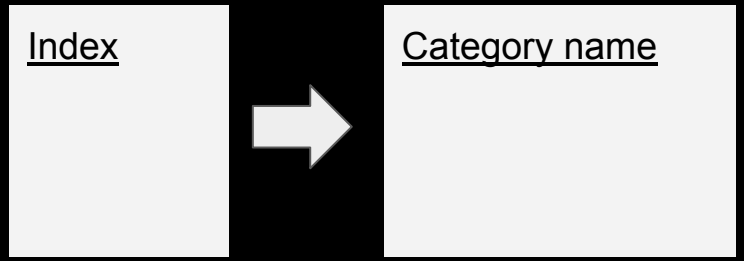

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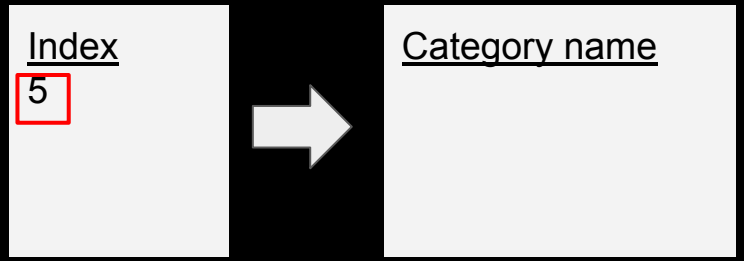

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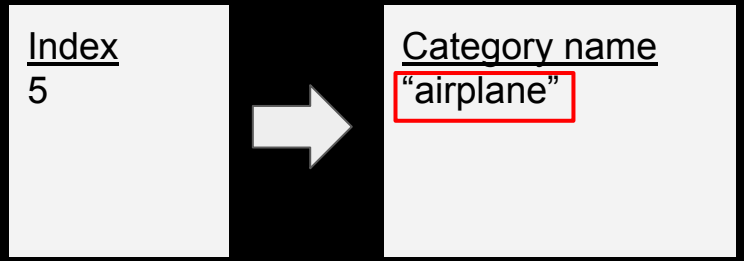

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from object_detection.utils import label_map_util
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pbtxt

```
item {
  name: "/m/04_sv"
  id: 4
  display_name: "motorcycle"
}
item {
  name: "/m/05czz6l"
  id: 5
  display_name: "airplane"
}
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PATH_TO_LABELS =
'./models/research/object_detection/data/mscoco_label_map.pbtxt'


category_index = label_map_util.create_category_index_from_labelmap(
                    PATH_TO_LABELS, use_display_name=True)
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```
category_index

{1: {'id': 1, 'name': 'person'},
 2: {'id': 2, 'name': 'bicycle'},
 3: {'id': 3, 'name': 'car'},
 4: {'id': 4, 'name': 'motorcycle'},
 5: {'id': 5, 'name': 'airplane'},
```

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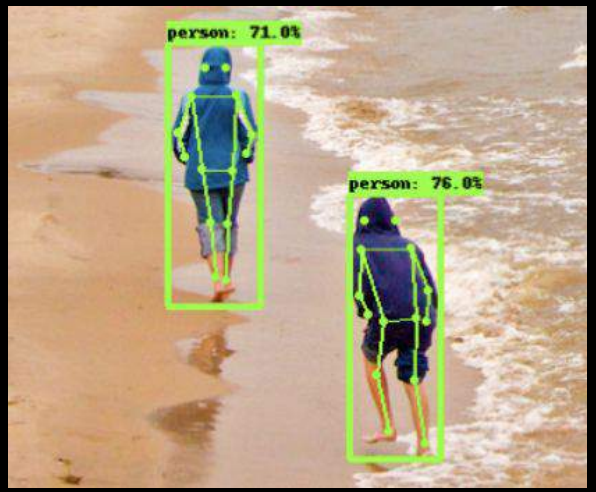
```

```
viz_utils.visualize_boxes_and_labels_on_image_array(
  image=...,
  boxes=...,
  classes=...,
  scores=...,
  ...)
```



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from object_detection.utils import label_map_util
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```

```
results['detection_scores']
```

```
<tf.Tensor: shape=(1, 100), dtype=float32, numpy=
array([[0.78741133, 0.7599586 , 0.7120807 , 0.7035178 ,
```

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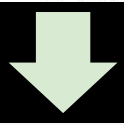

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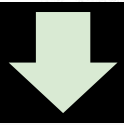

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```
results = hub_model(image_np)

result = {key:value.numpy() for key,value in results.items()}
```

```
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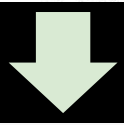

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results = hub_model(image_np)

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```

```
result.keys()
```

```
detection_scores
detection_keypoint_scores
detection_classes
detection_keypoints
num_detections
detection_boxes
```

```
result.keys()
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```
detection_scores
detection_keypoint_scores
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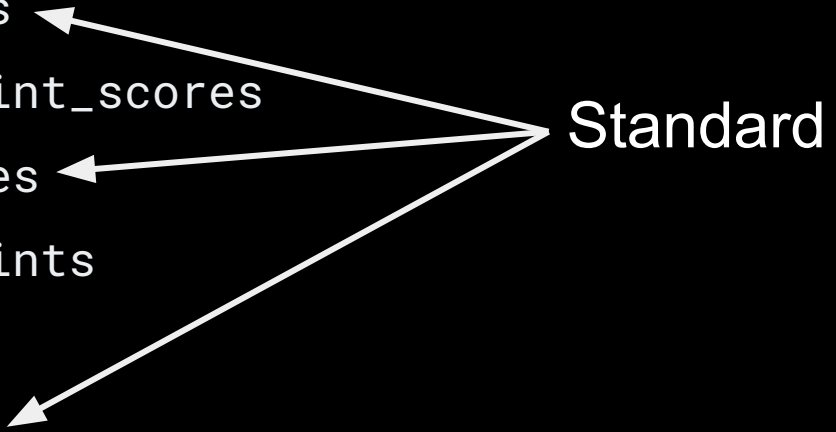
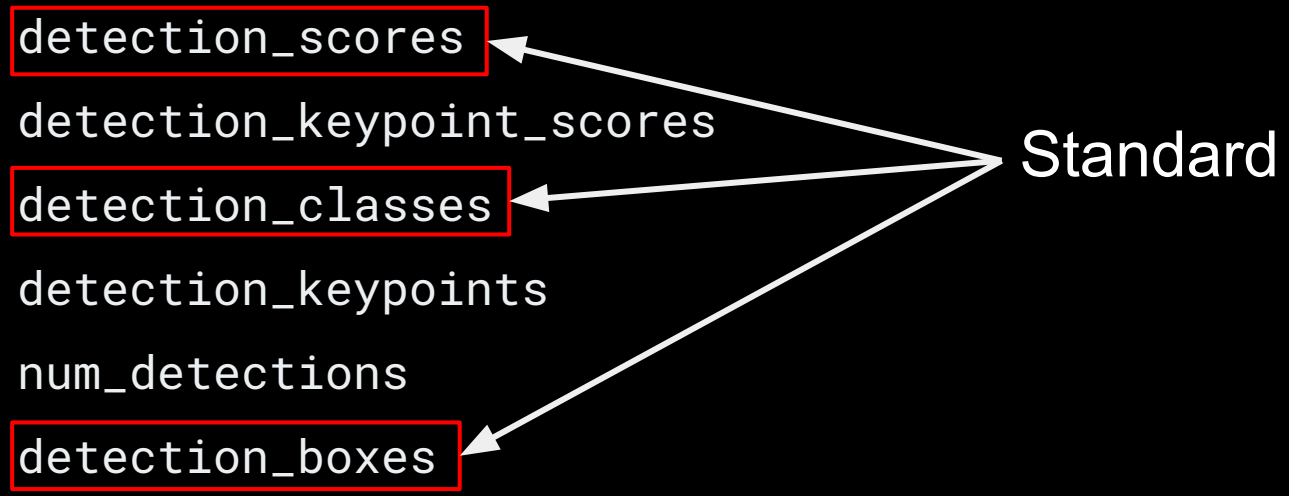
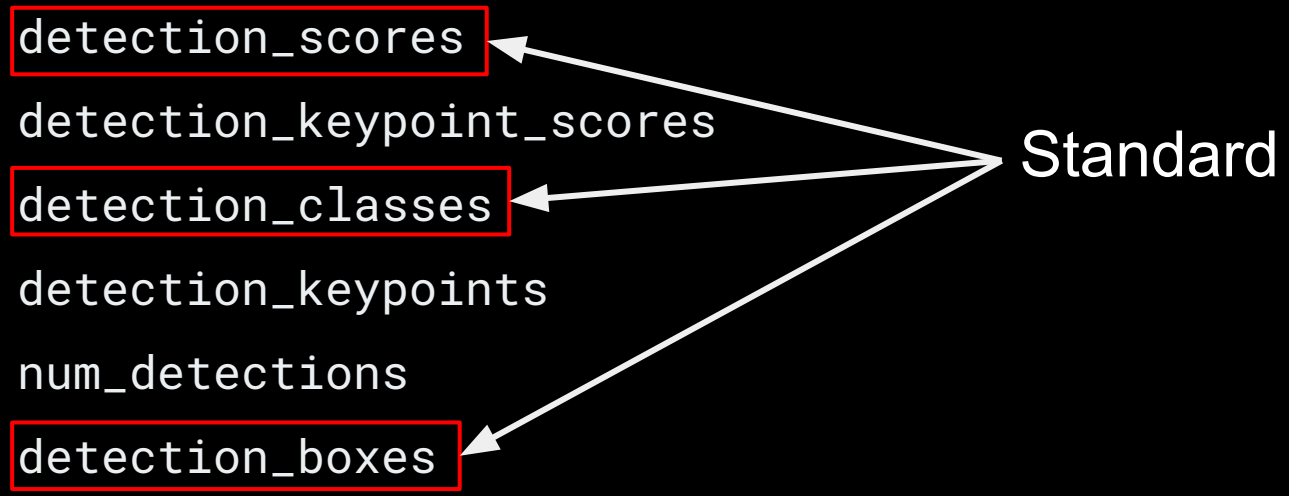
```



result.keys()


detection_scores
detection_keypoint_scores
detection_classes
detection_keypoints
num_detections
detection_boxes
Standard

```
result.keys()
```




```
result['detection_classes']

array([[38.,  1.,  1., 38., 38., 38.,
```

```
viz_utils.visualize_boxes_and_labels_on_image_array(
      image=
      boxes=
      classes=

      scores=
      category_index=
      use_normalized_coordinates=
      min_score_thresh=
      )
```

```
viz_utils.visualize_boxes_and_labels_on_image_array(
      image=image_np_with_detections[0],
      boxes=
      classes=

      scores=
      category_index=
      use_normalized_coordinates=
      min_score_thresh=
      )
```

```
viz_utils.visualize_boxes_and_labels_on_image_array(
      image=image_np_with_detections[0],
      boxes=result['detection_boxes'][0],
      classes=

      scores=
      category_index=
      use_normalized_coordinates=
      min_score_thresh=
      )
```

```
viz_utils.visualize_boxes_and_labels_on_image_array(
      image=image_np_with_detections[0],
      boxes=result['detection_boxes'][0],
      classes=(result['detection_classes'][0] +
               label_id_offset).astype(int),
      scores=
      category_index=
      use_normalized_coordinates=
      min_score_thresh=
      )
```

```
viz_utils.visualize_boxes_and_labels_on_image_array(
      image=image_np_with_detections[0],
      boxes=result['detection_boxes'][0],
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      use_normalized_coordinates=True,
      min_score_thresh=
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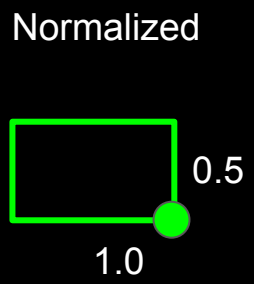

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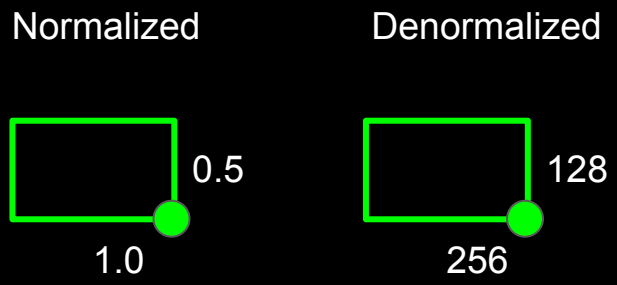

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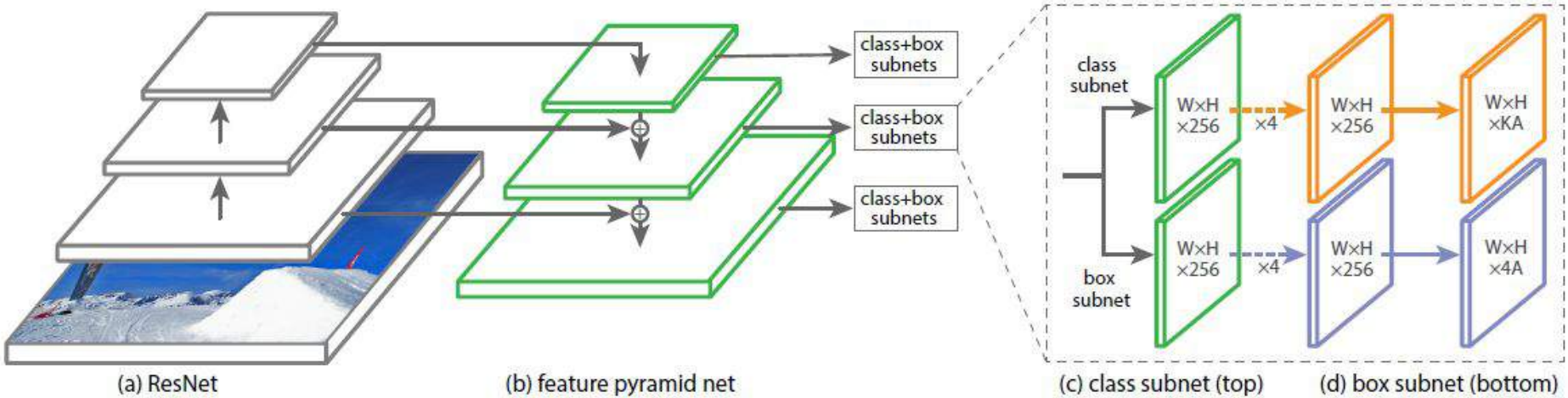
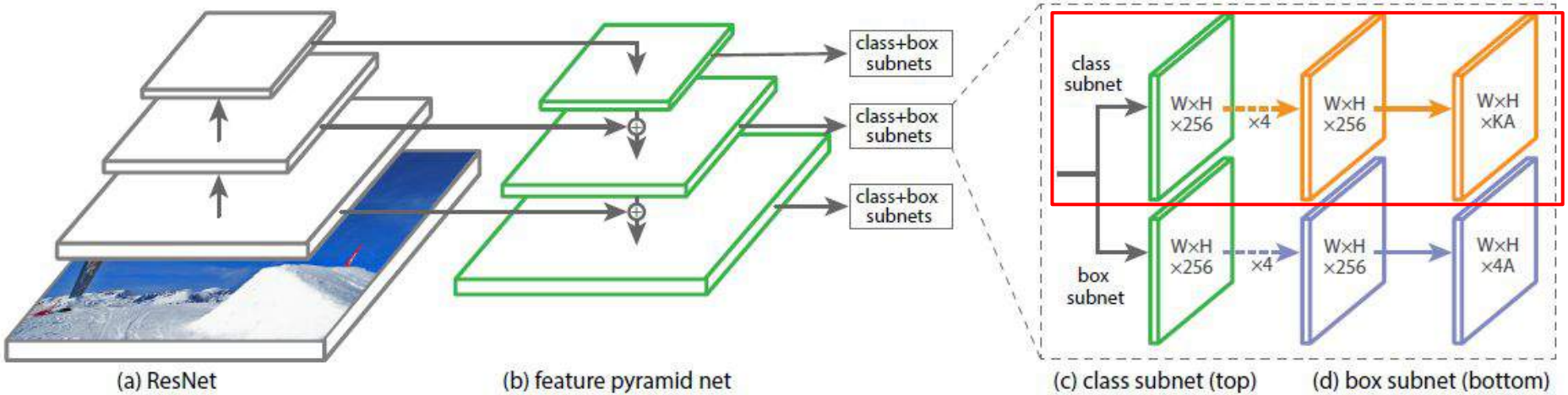
      scores=result['detection_scores'][0],
      category_index=category_index,
      use_normalized_coordinates=True,
      min_score_thresh=.40
      )
```


kite: 100.0%
kkite: 60.0%
kite: 49.0%
kite: 61.0%
person: 56.0%
person: 43.0%
on: 88.0%
person: 61.0%
Pperson: 52.0%
person: 99.0%
person: 99.0%

“Focal Loss for Dense Object Detection”
By: Tsung-Yi Lin, Priya Goyal, Ross Girshick, Kaiming He, Piotr Dollár

https://arxiv.org/abs/1708.02002





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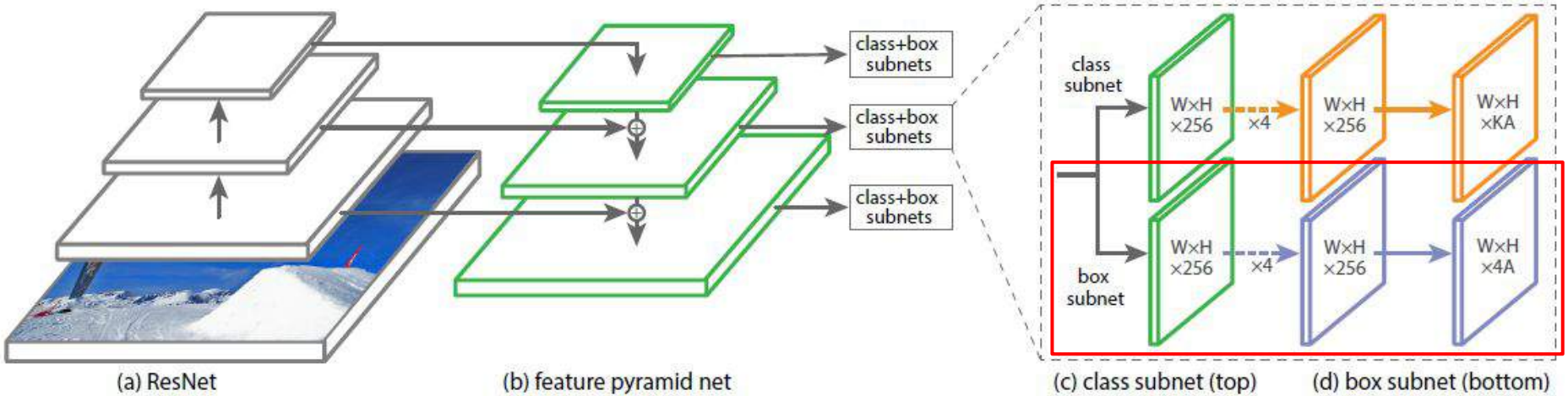

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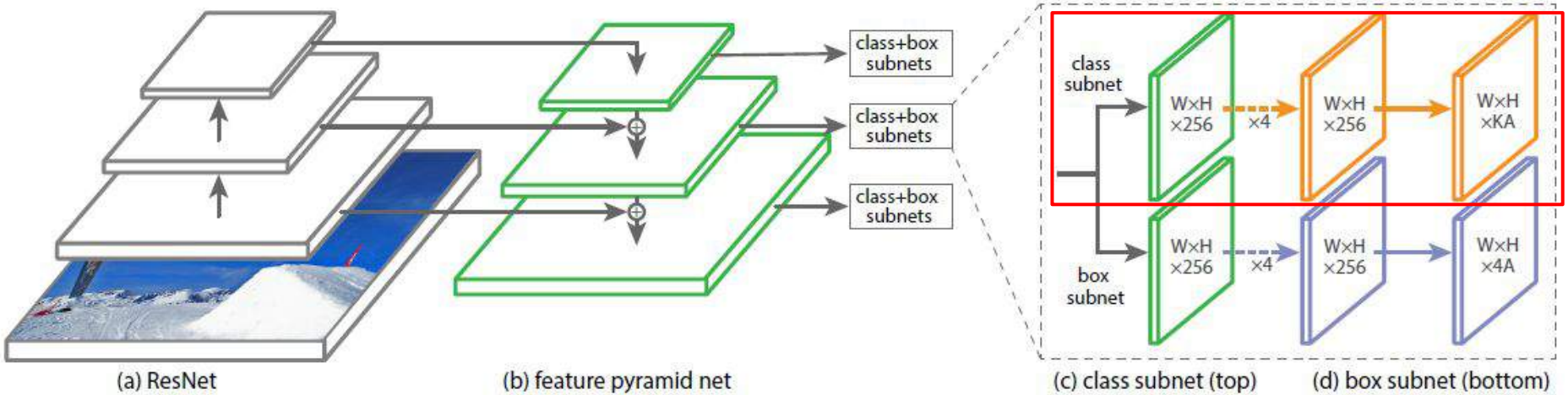

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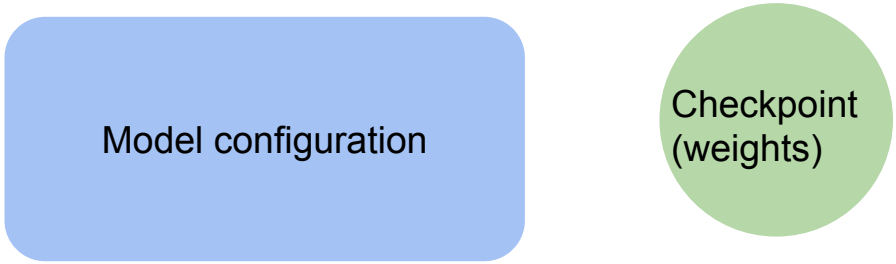
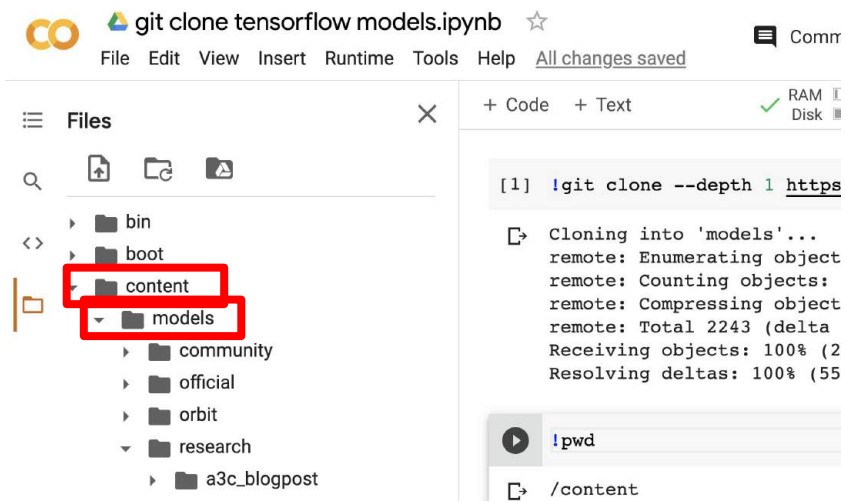
Model configuration


Model configuration
Checkpoint
(weights)

Model configuration

Checkpoint (weights)



```
!wget http://download.tensorflow.org/models/object_detection/tf2/20200711/
                ssd_resnet50_v1_fpn_640x640_coco17_tpu-8.tar.gz
```

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!tar -xf ssd_resnet50_v1_fpn_640x640_coco17_tpu-8.tar.gz
```

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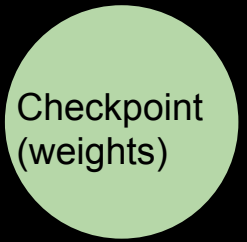
!mv ssd_resnet50_v1_fpn_640x640_coco17_tpu-8/checkpoint
    models/research/object_detection/test_data/
```



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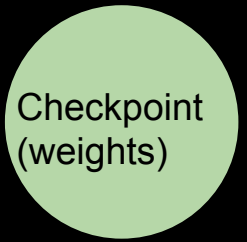

https://github.com/tensorflow/models

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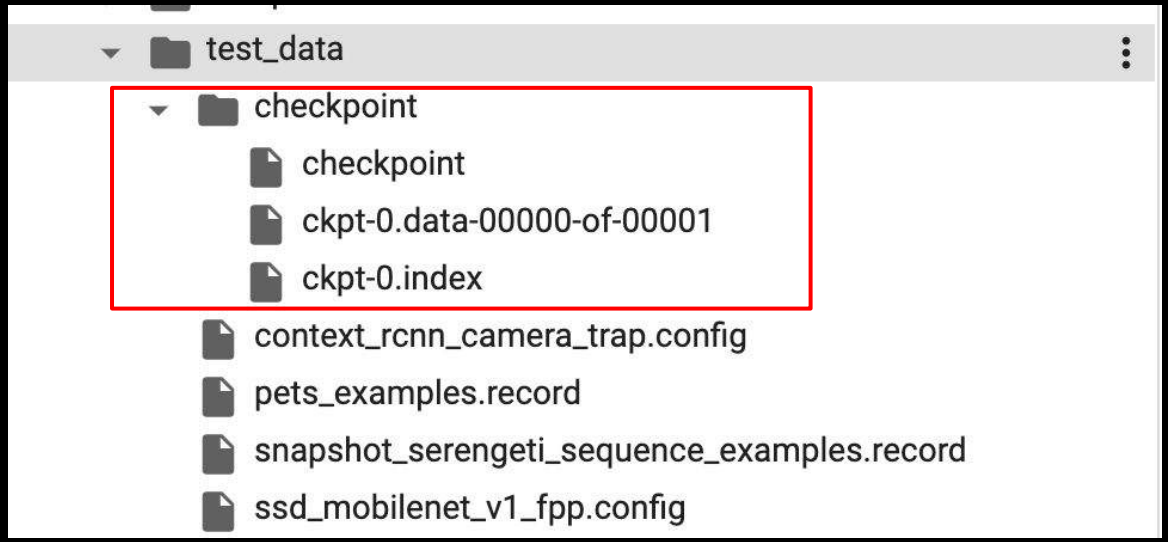
Checkpoint (weights)



```
from object_detection.utils import label_map_util
from object_detection.utils import config_util
from object_detection.utils import visualization_utils as viz_utils
from object_detection.utils import colab_utils
from object_detection.builders import model_builder
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```
pipeline_config = 'models/research/object_detection/configs/tf2/
                   ssd_resnet50_v1_fpn_640x640_coco17_tpu-8.config'


checkpoint_path = 'models/research/object_detection/
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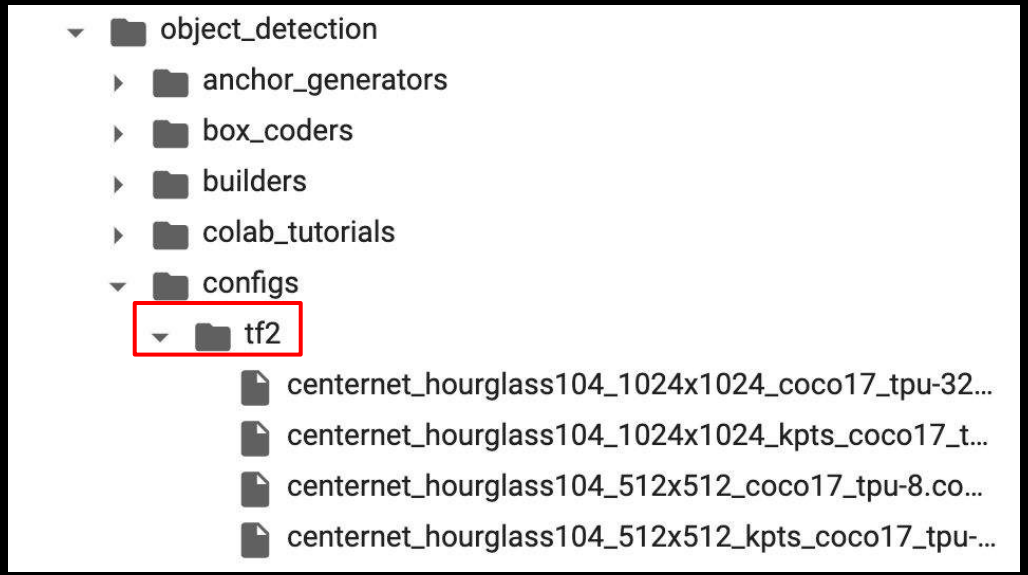

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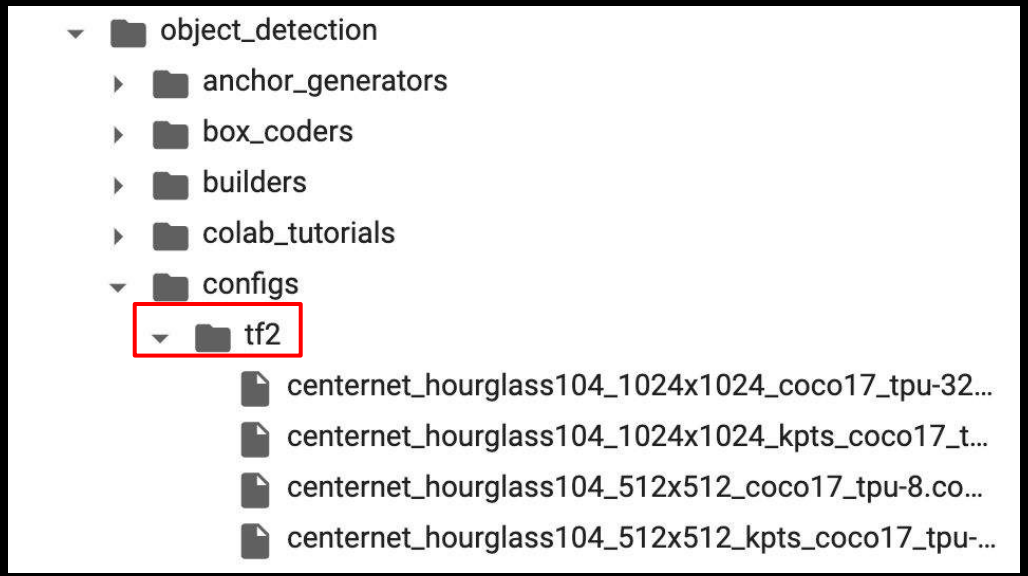

ssd_resnet50_v1_fpn_640x640_coco17_tpu-8.config

```
# SSD with Resnet 50 v1 FPN feature extracto
# loss (a.k.a Retinanet).
# See Lin et al, https://arxiv.org/abs/1708.
# Trained on COCO, initialized from Imagenet
# Train on TPU-8
#
# Achieves 34.3 mAP on COCO17 Val

model {
  ssd {
    inplace_batchnorm_update: true
    freeze_batchnorm: false
    num_classes: 90
    box_coder {
      faster_rcnn_box_coder {
        y_scale: 10.0
        x_scale: 10.0
        height_scale: 5.0
        width_scale: 5.0
      }
```

```
configs = config_util.get_configs_from_pipeline_file(pipeline_config)

model_config = configs['model']
model_config.ssd.num_classes = num_classes
model_config.ssd.freeze_batchnorm = True

detection_model = model_builder.build(
      model_config=model_config, is_training=True)
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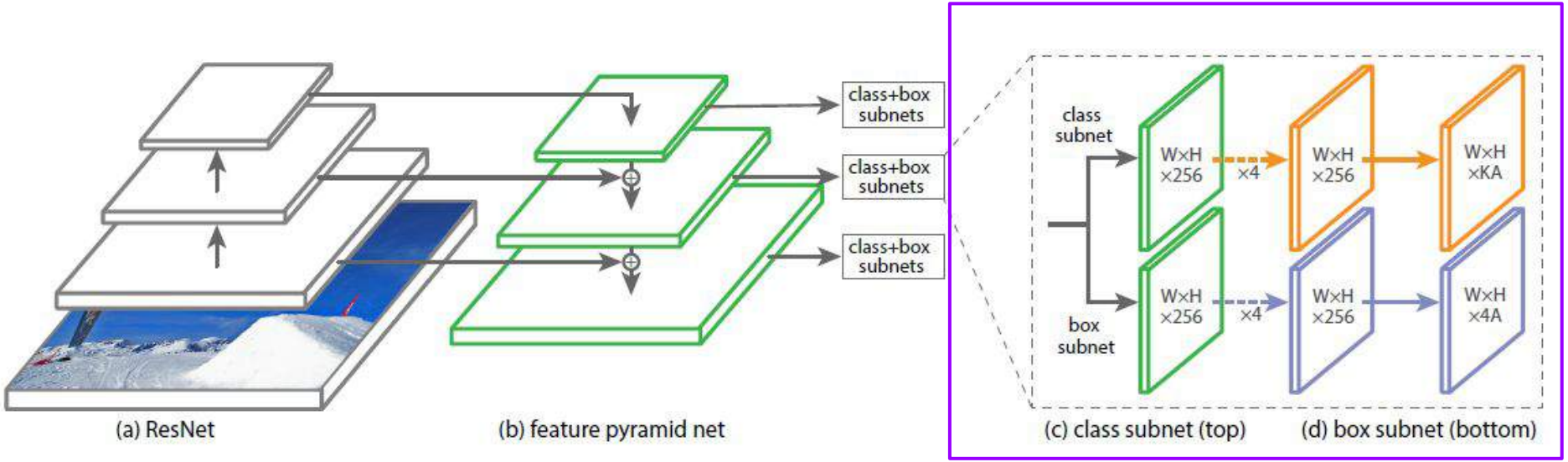
Model configuration



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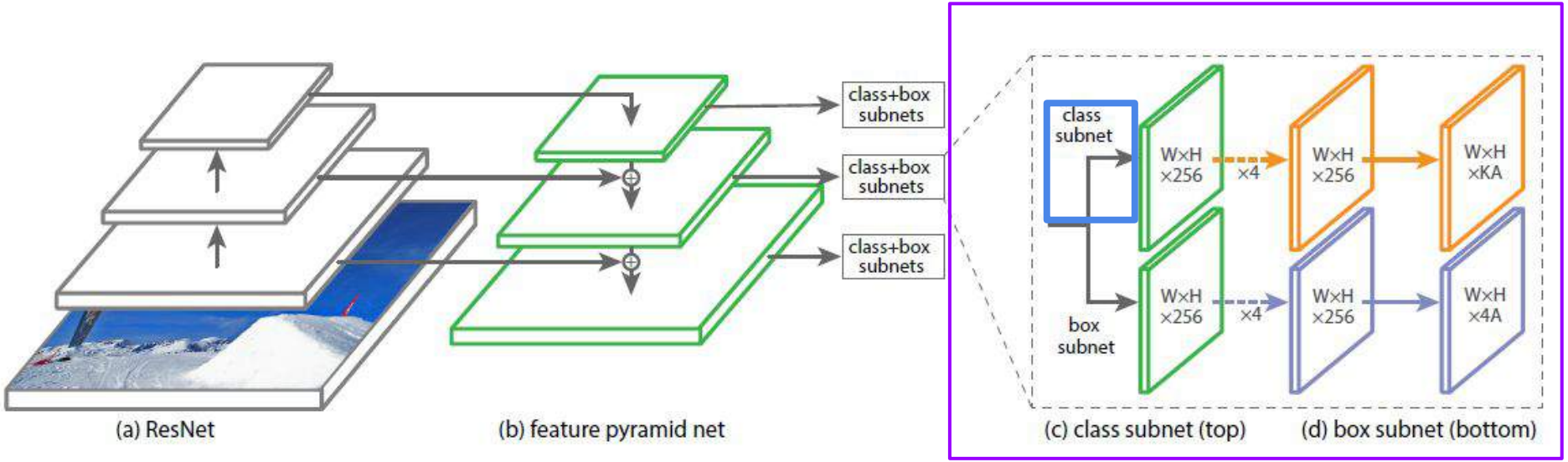

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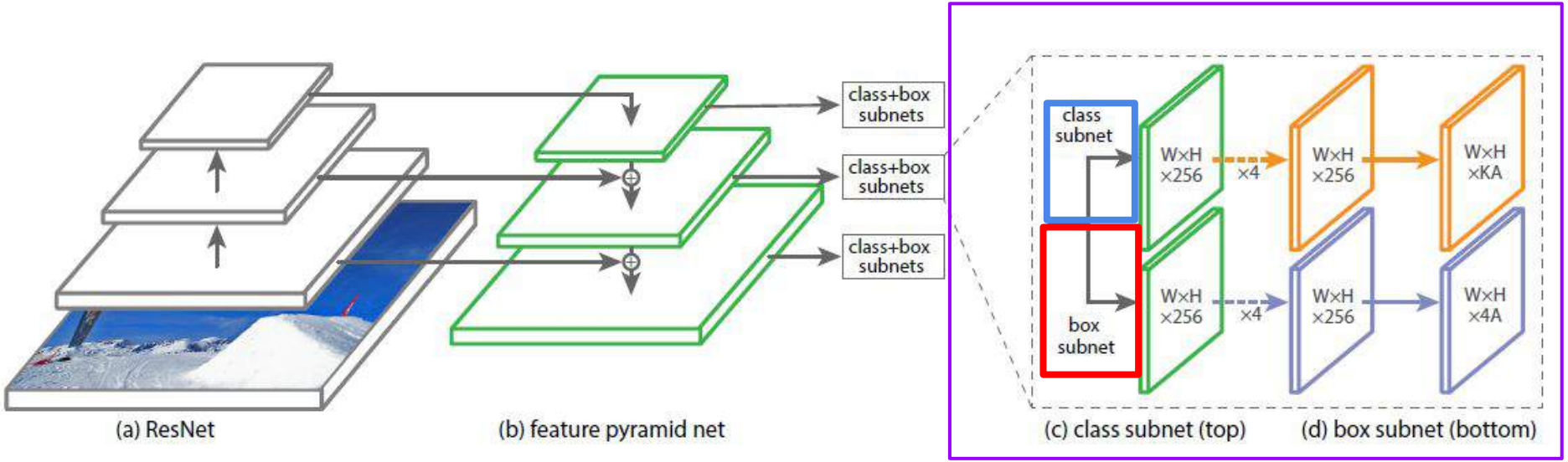

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Restoring weights

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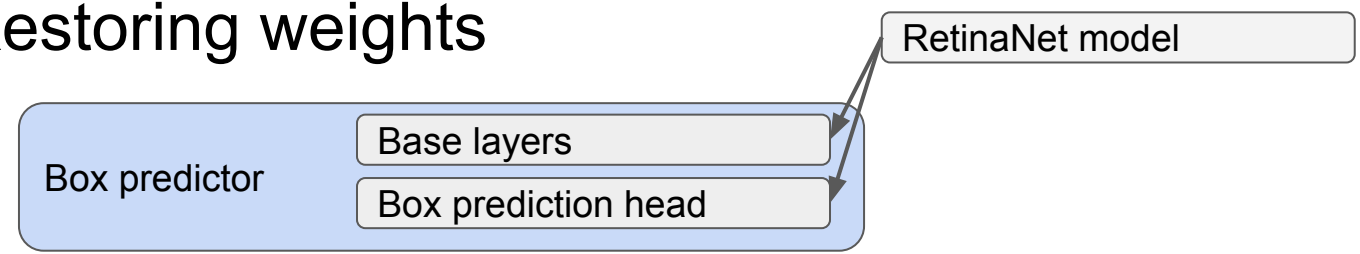

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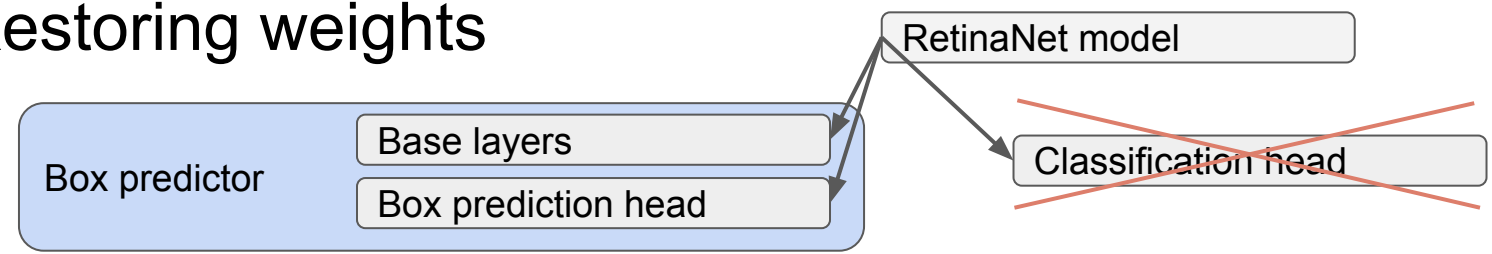

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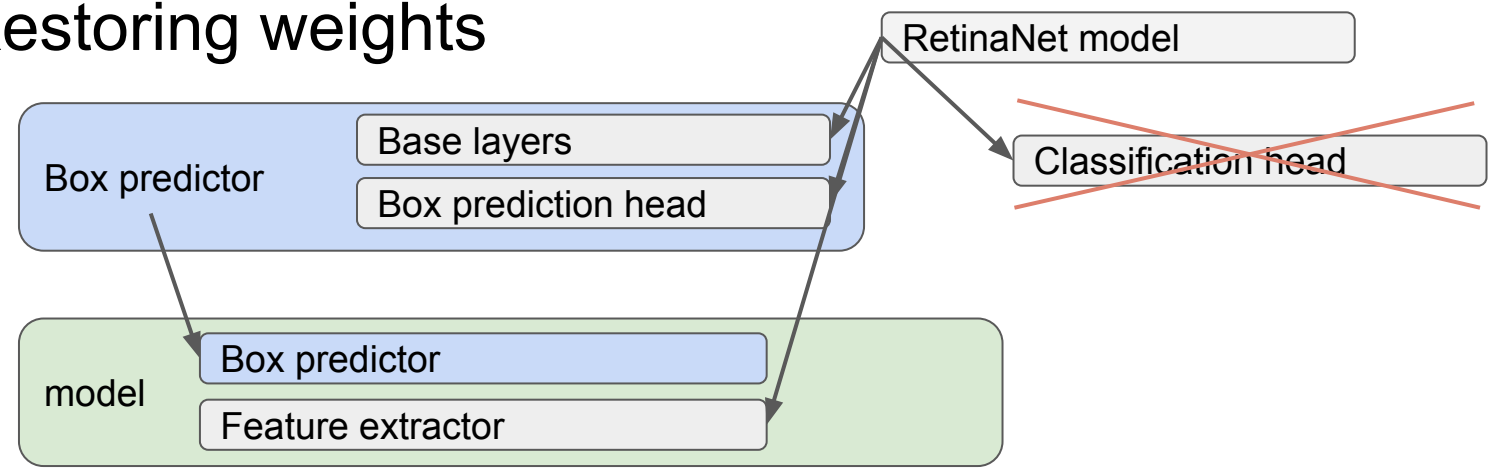

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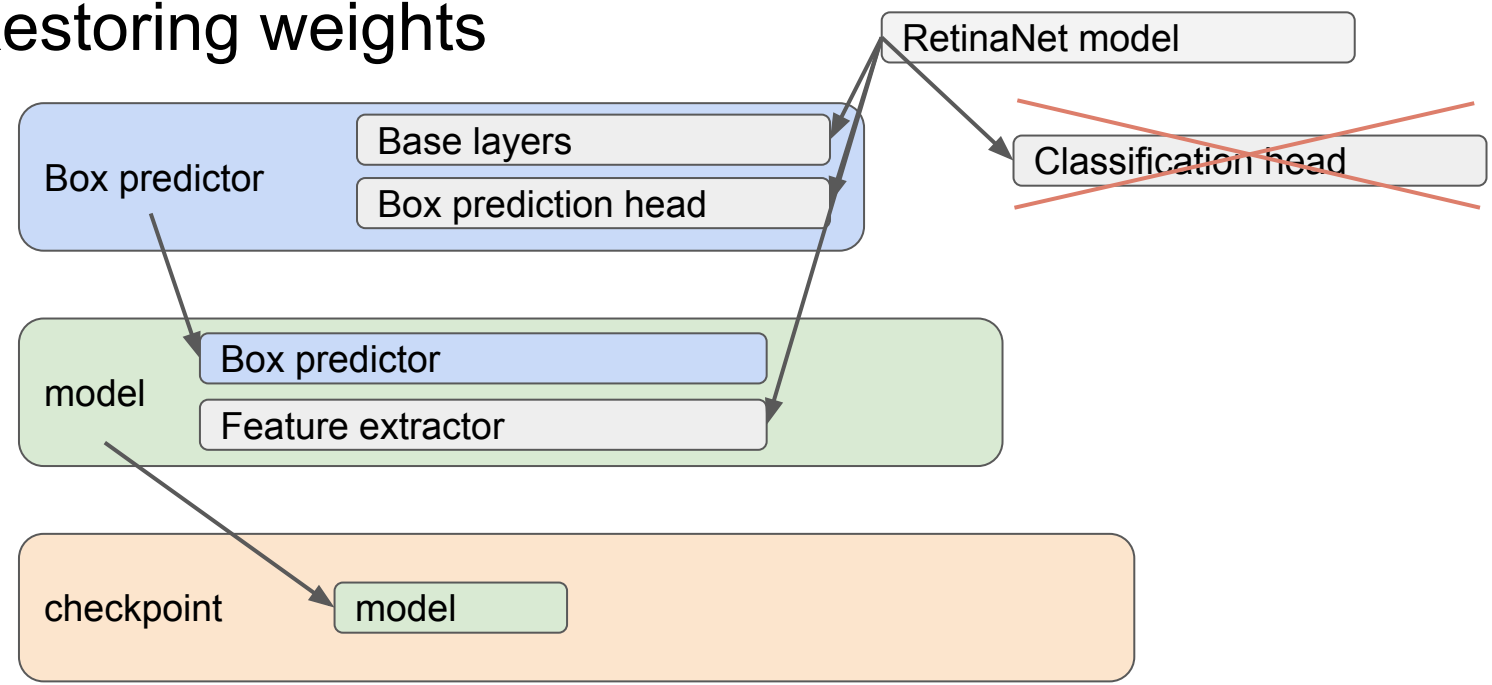

```
fake_box_predictor = tf.compat.v2.train.Checkpoint(
    _base_tower_layers_for_heads=detection_model._box_predictor._base_tower_layers_for_heads,
    _box_prediction_head=detection_model._box_predictor._box_prediction_head,
    )

fake_model = tf.compat.v2.train.Checkpoint(
          _feature_extractor=detection_model._feature_extractor,
          _box_predictor=fake_box_predictor)

ckpt = tf.compat.v2.train.Checkpoint(model=fake_model)
ckpt.restore(checkpoint_path).expect_partial()
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Box predictor

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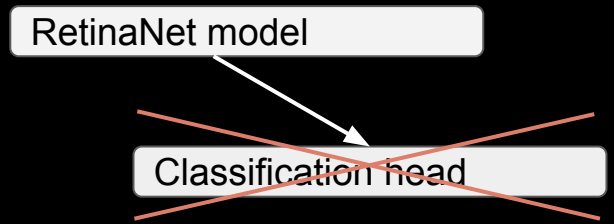

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ckpt = tf.compat.v2.train.Checkpoint(model=fake_model)
ckpt.restore(checkpoint_path).expect_partial()
```

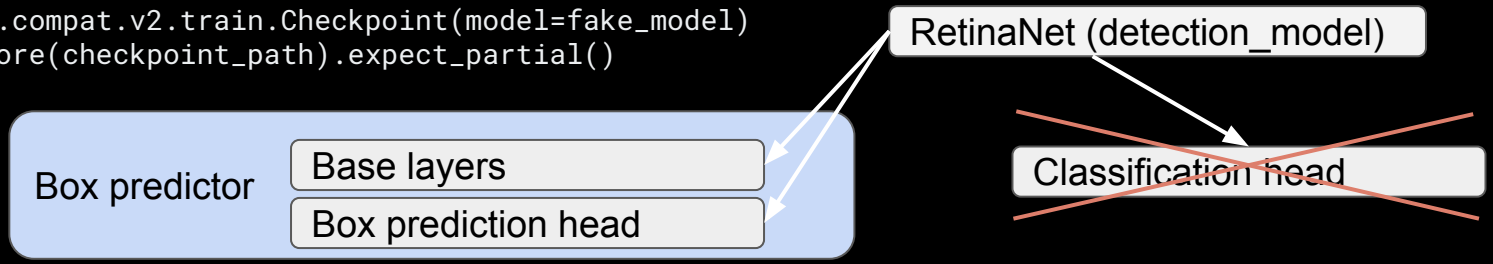

```
fake_box_predictor = tf.compat.v2.train.Checkpoint(
    _base_tower_layers_for_heads=detection_model._box_predictor._base_tower_layers_for_heads,
    _box_prediction_head=detection_model._box_predictor._box_prediction_head,
    )

fake_model = tf.compat.v2.train.Checkpoint(
          _feature_extractor=detection_model._feature_extractor,
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ckpt = tf.compat.v2.train.Checkpoint(model=fake_model)
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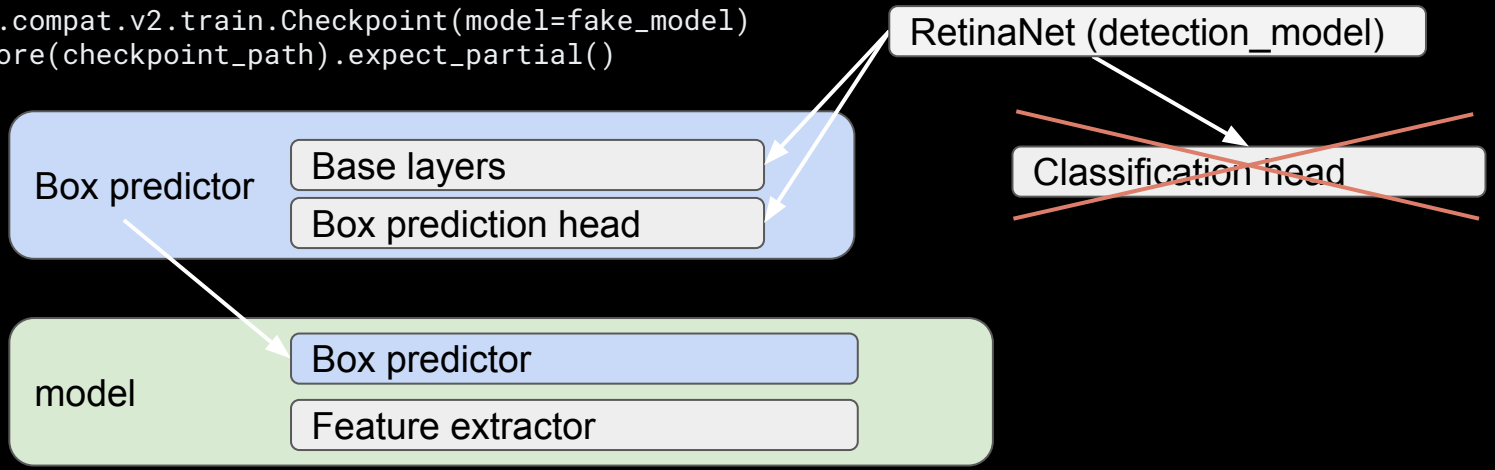

```
fake_box_predictor = tf.compat.v2.train.Checkpoint(
    _base_tower_layers_for_heads=detection_model._box_predictor._base_tower_layers_for_heads,
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          _feature_extractor=detection_model._feature_extractor,
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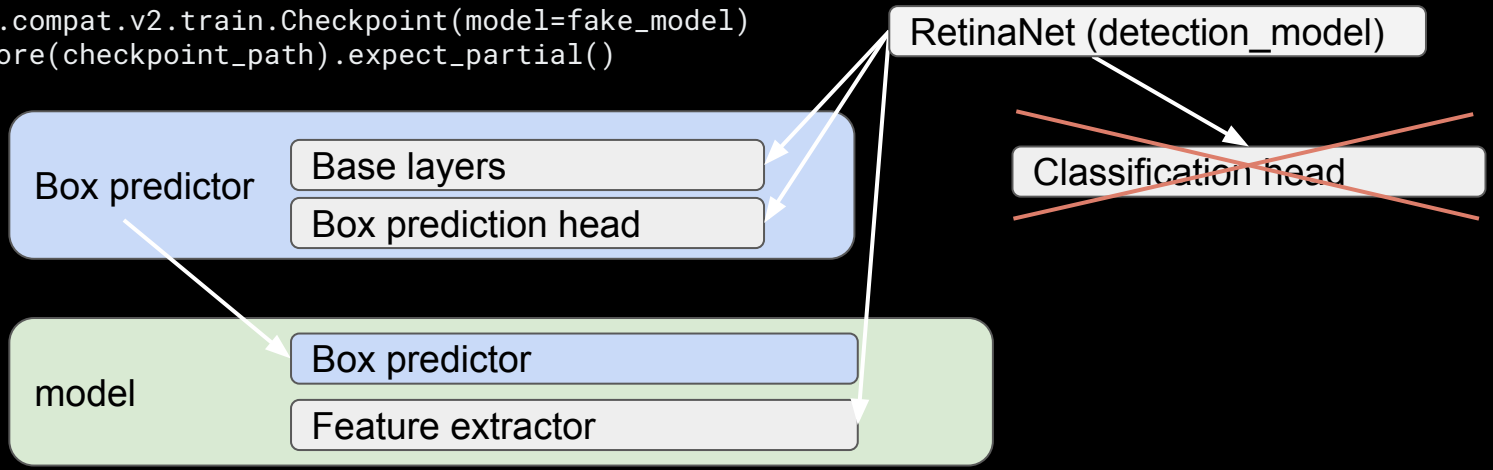

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    _base_tower_layers_for_heads=detection_model._box_predictor._base_tower_layers_for_heads,
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          _feature_extractor=detection_model._feature_extractor,
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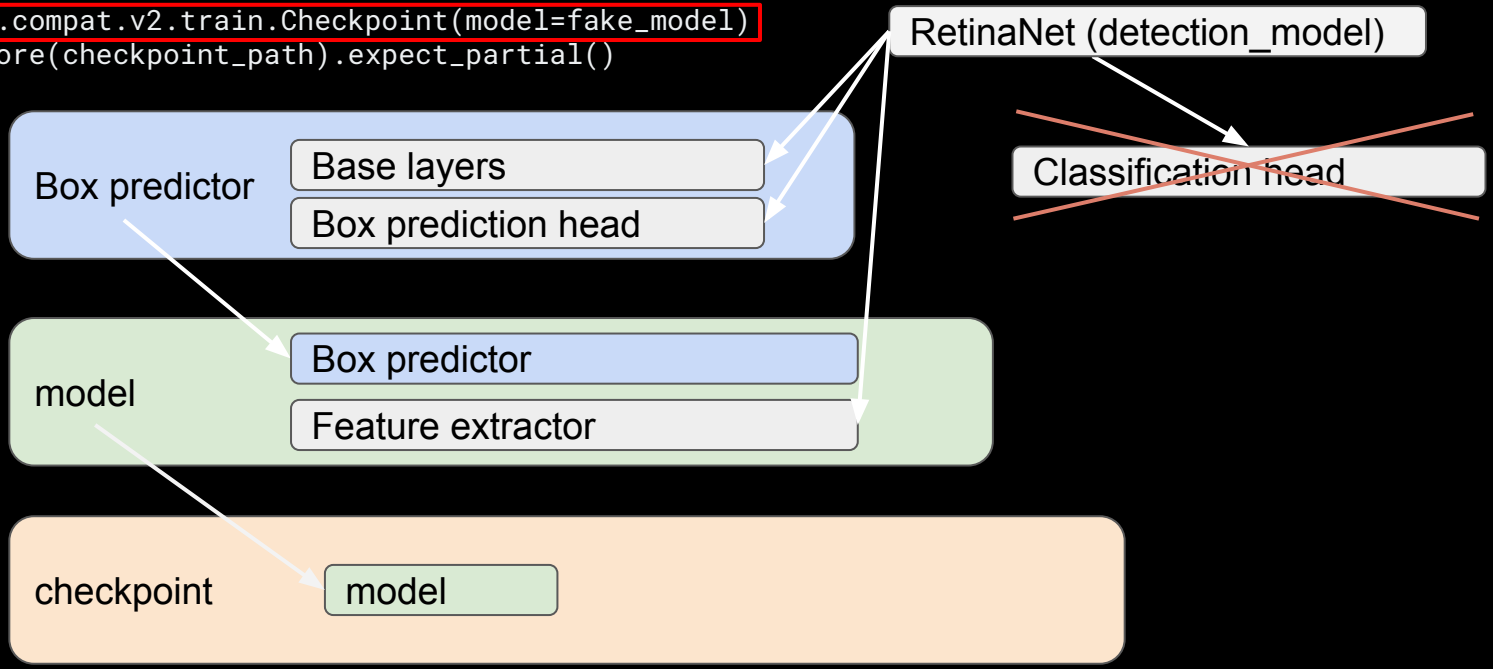

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    _base_tower_layers_for_heads=detection_model._box_predictor._base_tower_layers_for_heads,
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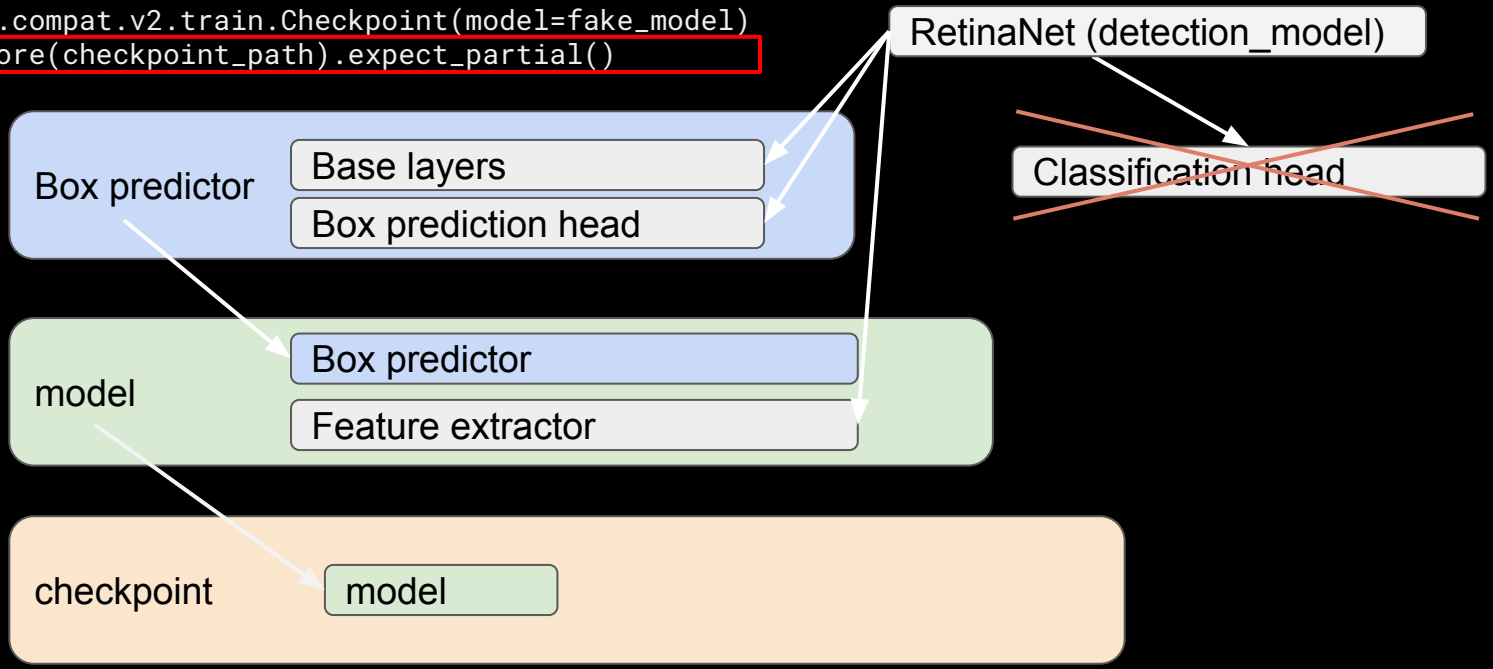

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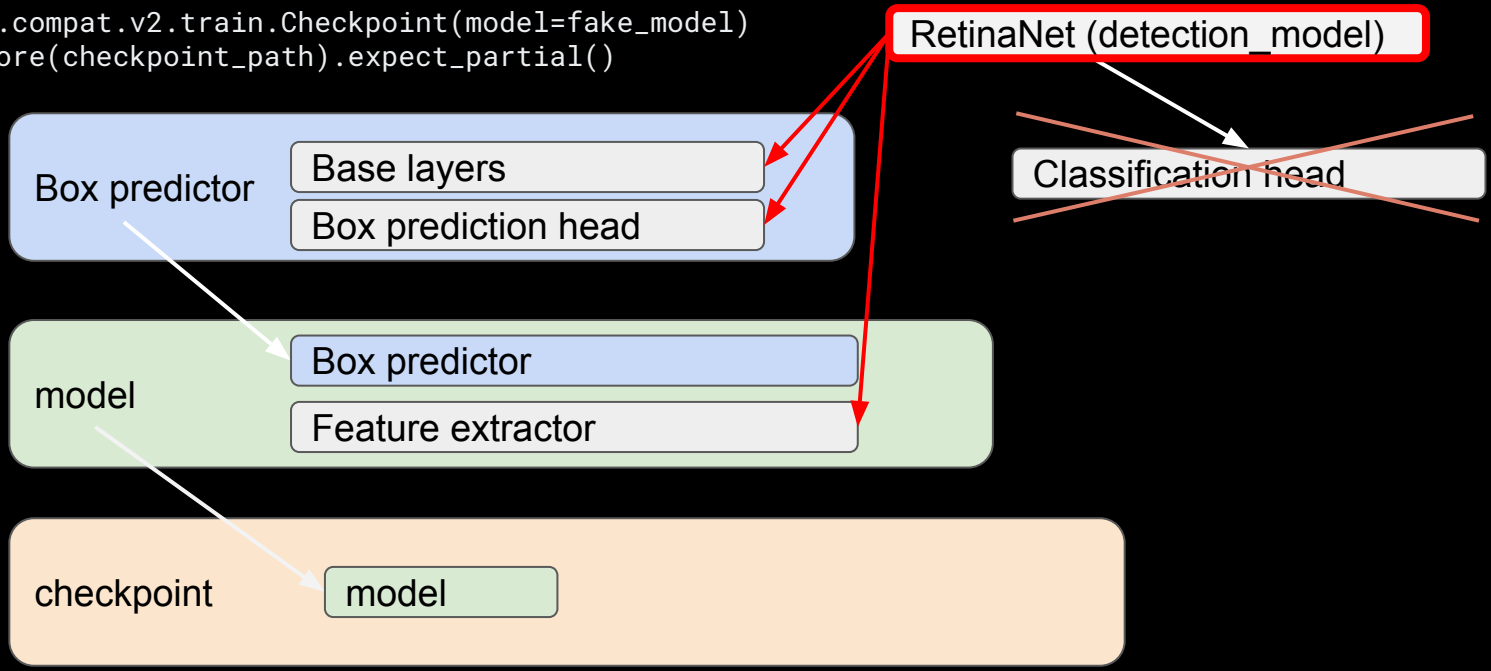
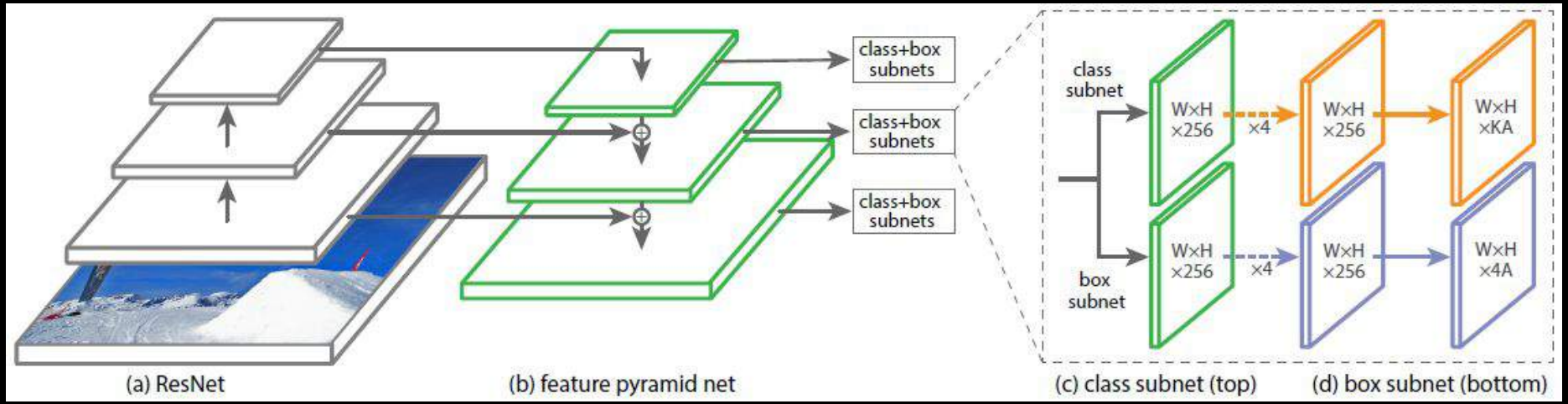


```
# Run dummy image through the model so that variables are created
image, shapes = detection_model.preprocess(tf.zeros([1, 640, 640, 3]))
prediction_dict = detection_model.predict(image, shapes)
_ = detection_model.postprocess(prediction_dict, shapes)
print('Weights restored!')
```



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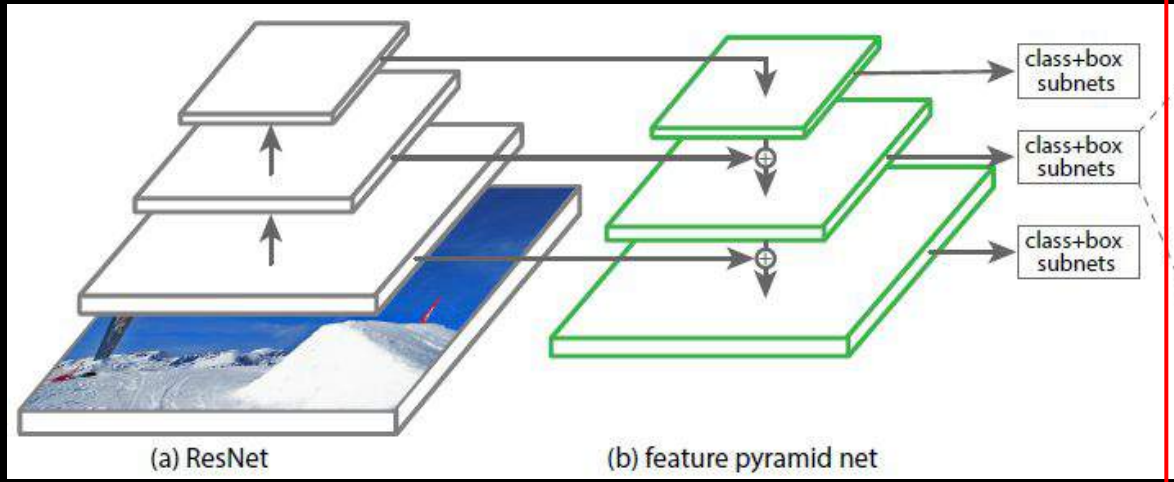

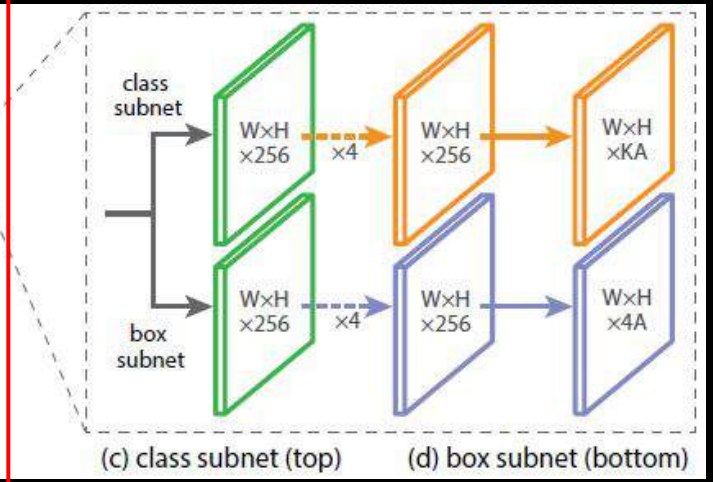

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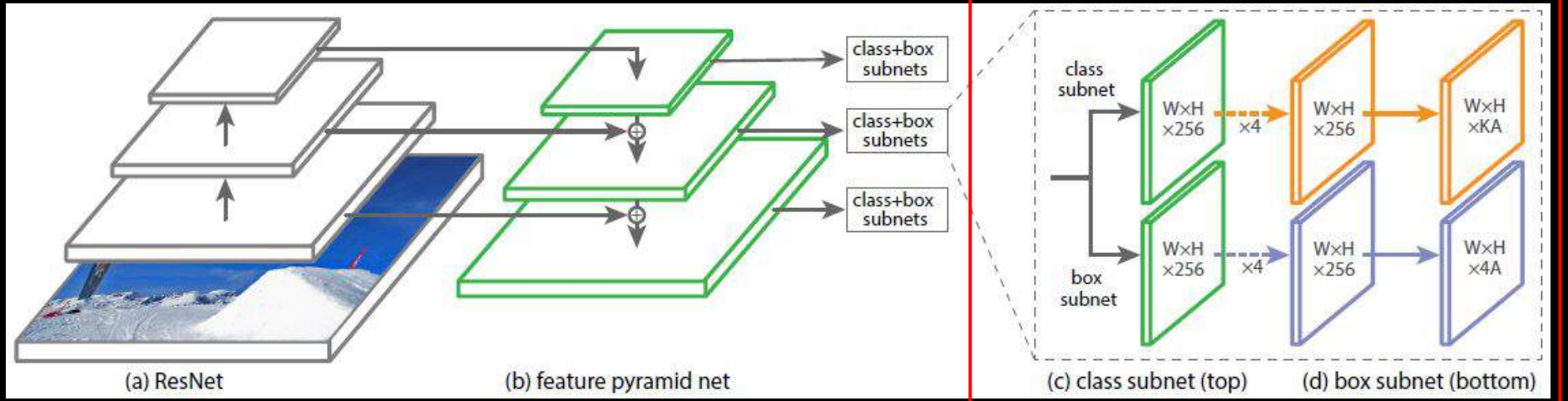

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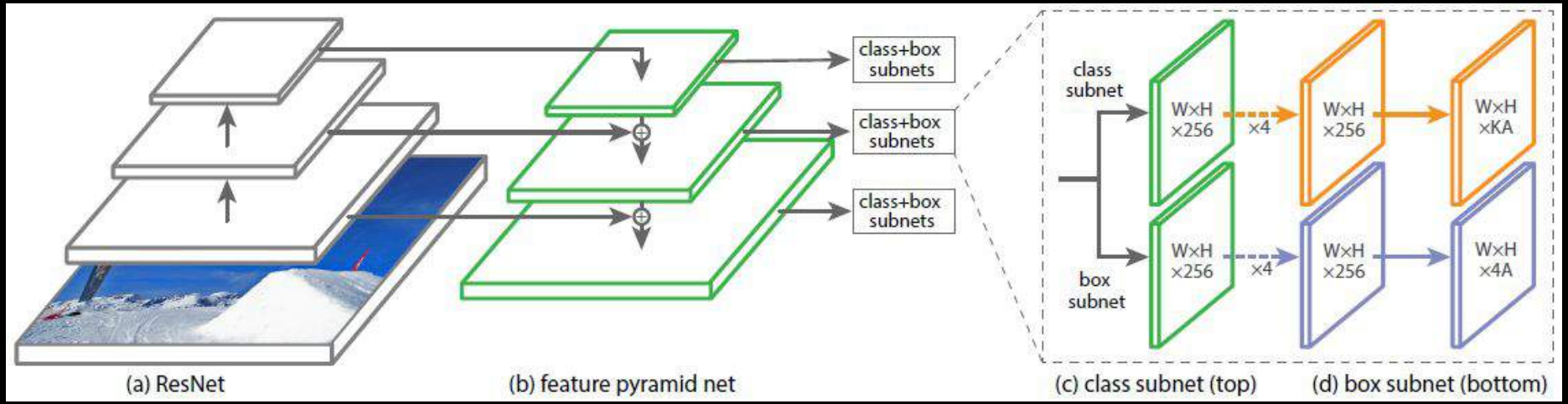

```
gt_boxes = []
colab_utils.annotate(train_images_np, box_storage_pointer=gt_boxes)
```

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```

prev image | next image | undo bbox | delete all

submit

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prev image | next image | undo bbox | delete all

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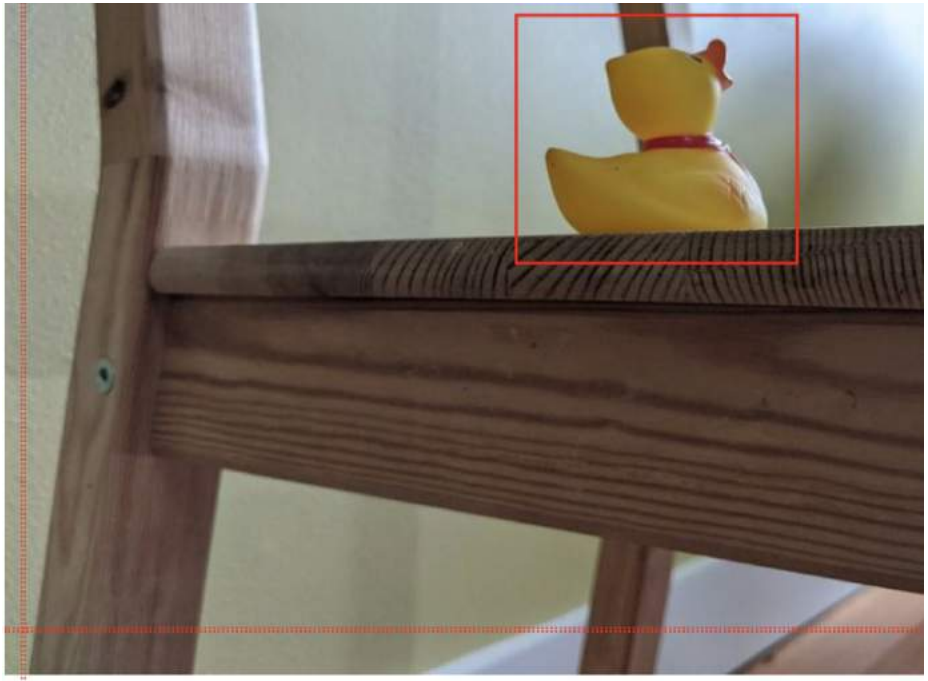

All images completed!!

prev image | next image | undo bbox | delete all

submit

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```

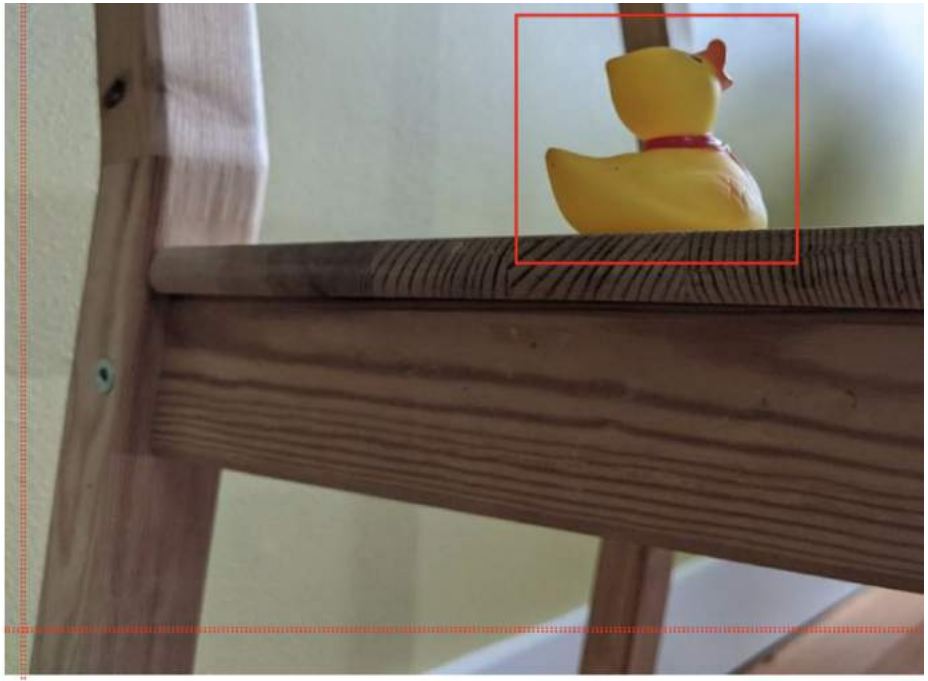

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submit

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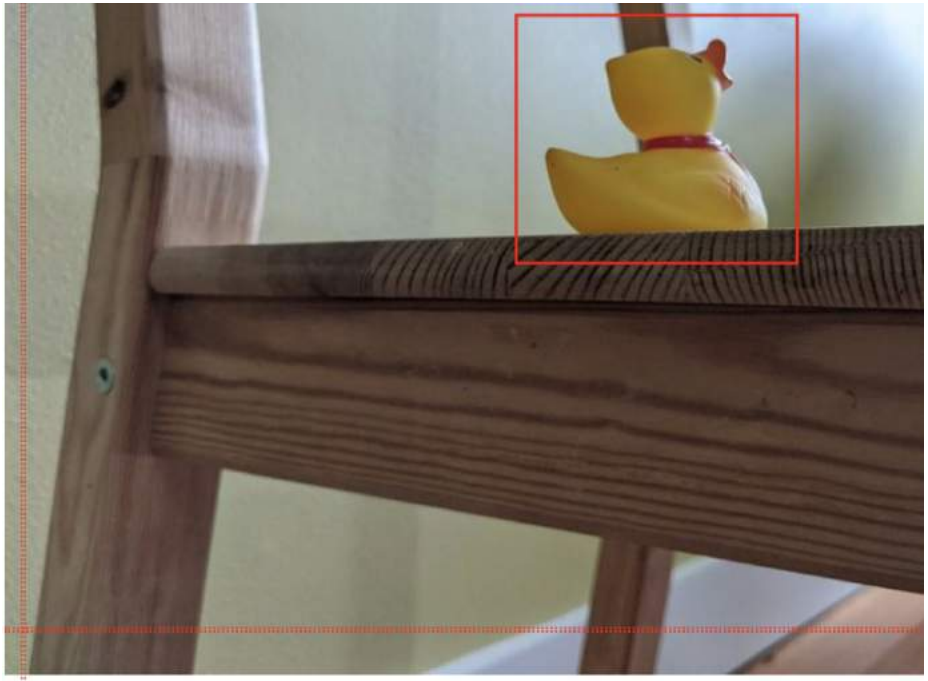
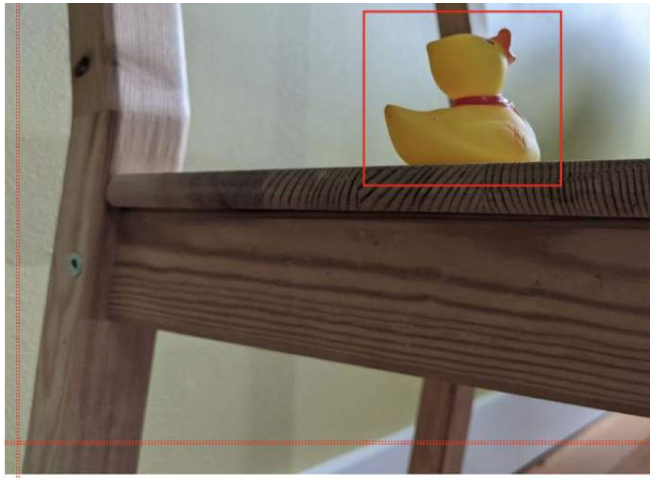


All images completed!!

prev image | next image | undo bbox | delete all

submit

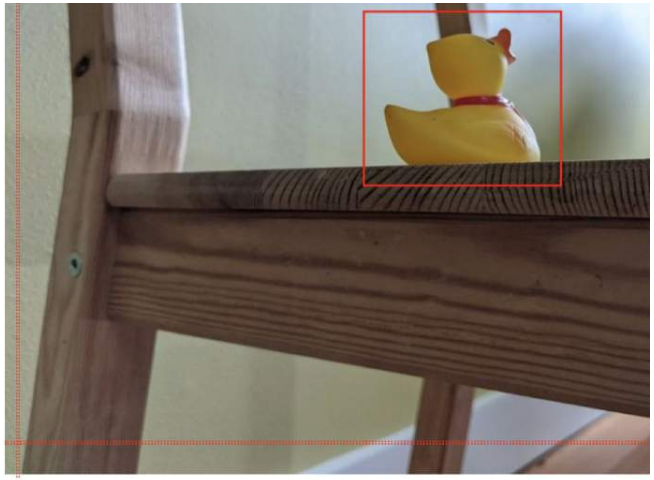


All images completed!!

prev image | next image | undo bbox | delete all

submit

```
gt_boxes = [
            np.array([[0.436, 0.591, 0.629, 0.712]], dtype=np.float32),
            np.array([[0.539, 0.583, 0.73, 0.71]], dtype=np.float32),
            np.array([[0.464, 0.414, 0.626, 0.548]], dtype=np.float32),
            np.array([[0.313, 0.308, 0.648, 0.526]], dtype=np.float32),
            np.array([[0.256, 0.444, 0.484, 0.629]], dtype=np.float32)
]
```



All images completed!!

prev image | next image | undo bbox | delete all

submit

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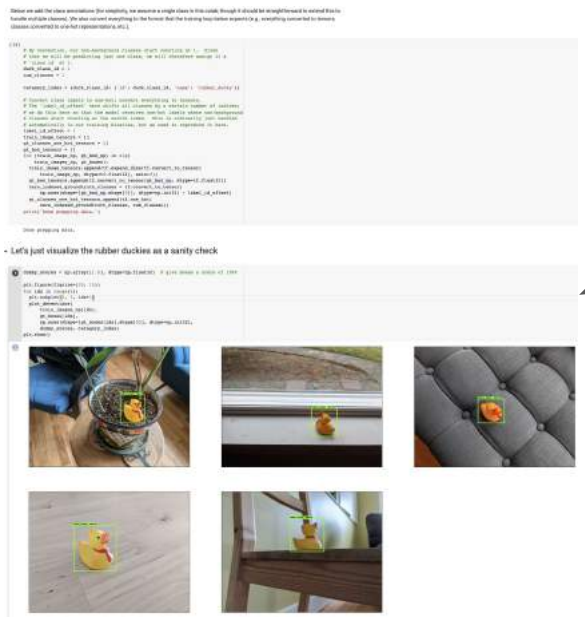
            np.array([[0.313, 0.308, 0.648, 0.526]], dtype=np.float32),
            np.array([[0.256, 0.444, 0.484, 0.629]], dtype=np.float32)
]
```

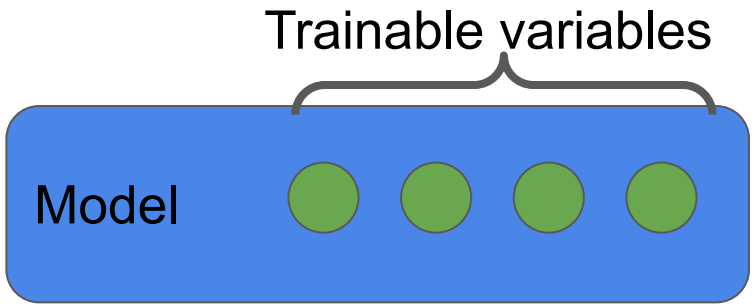
Prepare data for training



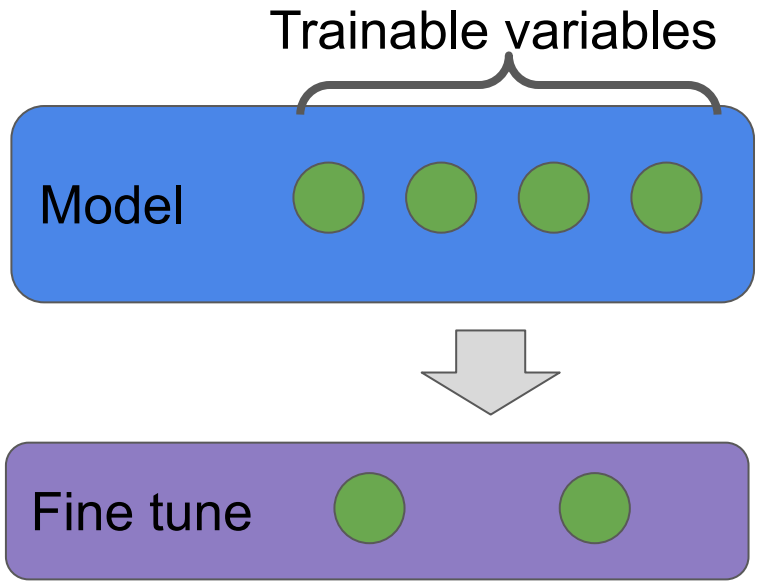
See the colab later!

Custom Training Loop

Custom Training Loop

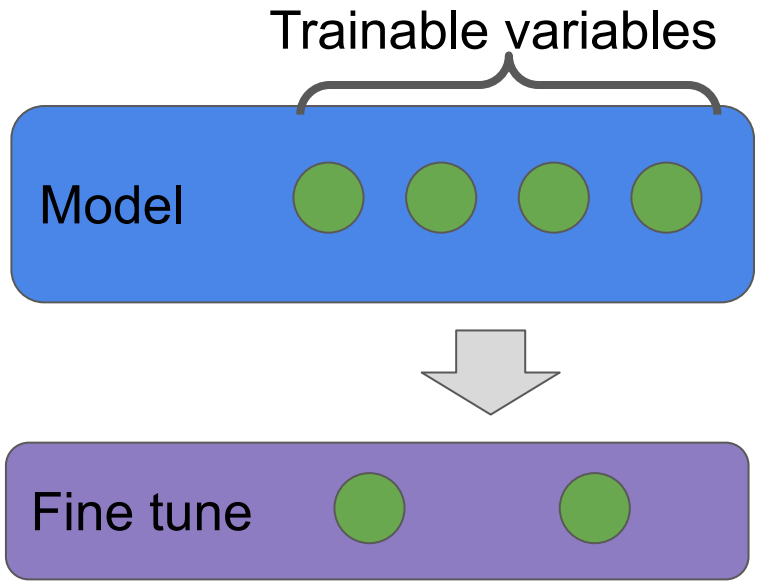


Custom Training Loop

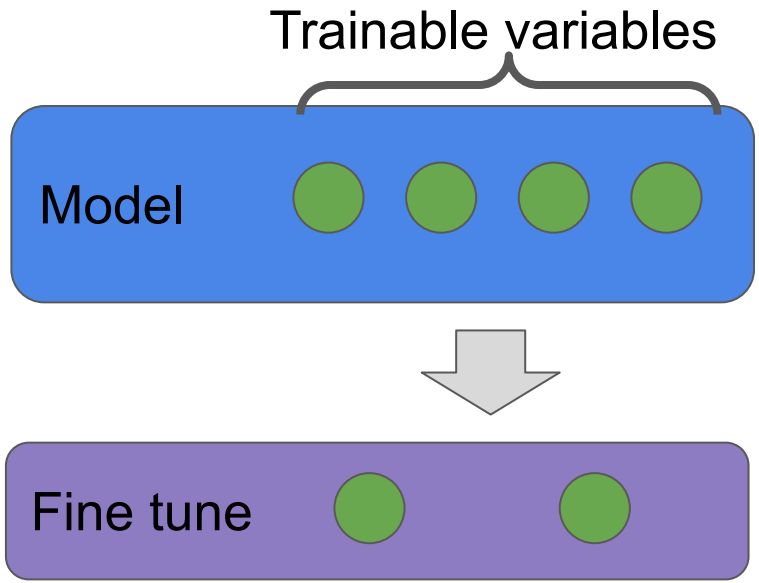


Custom Training Loop

For all training images:



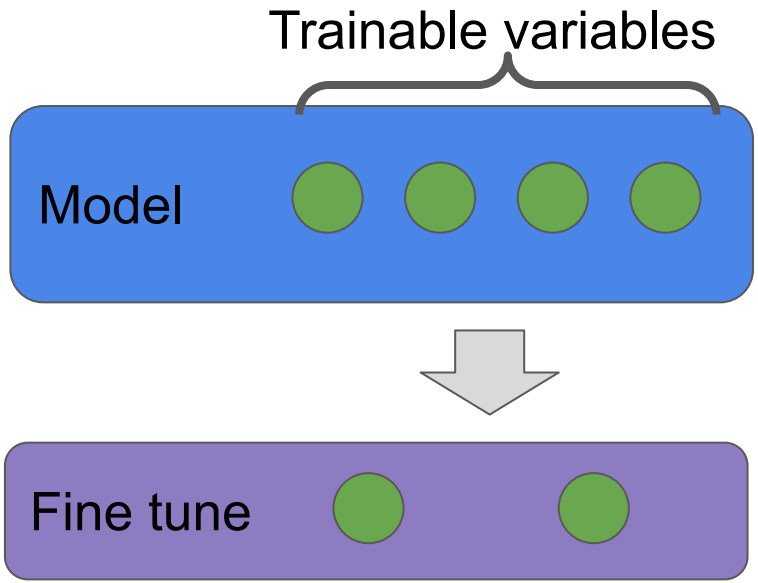
Custom Training Loop



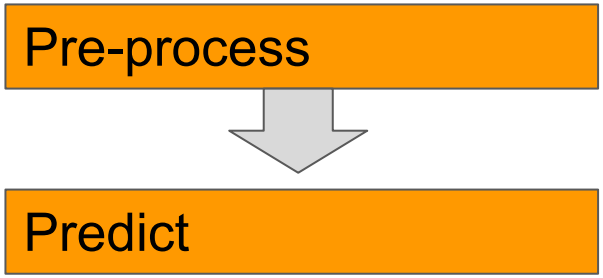
For all training images:

Pre-process

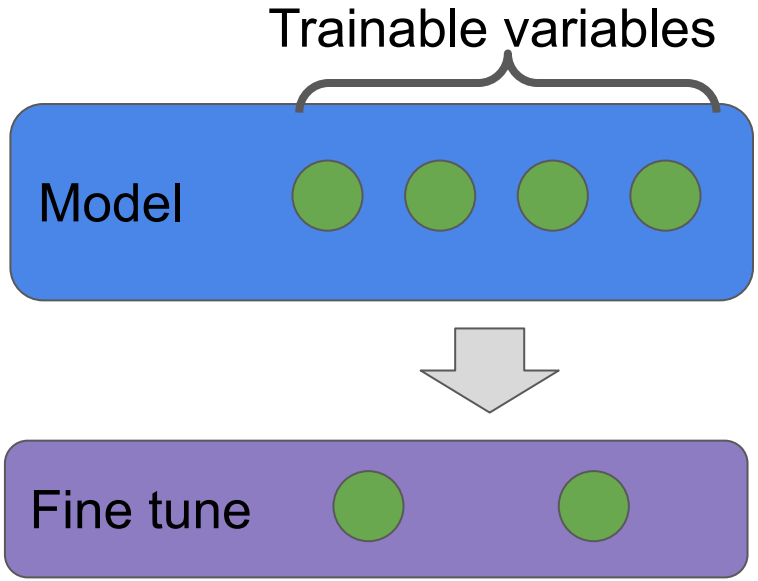
Custom Training Loop



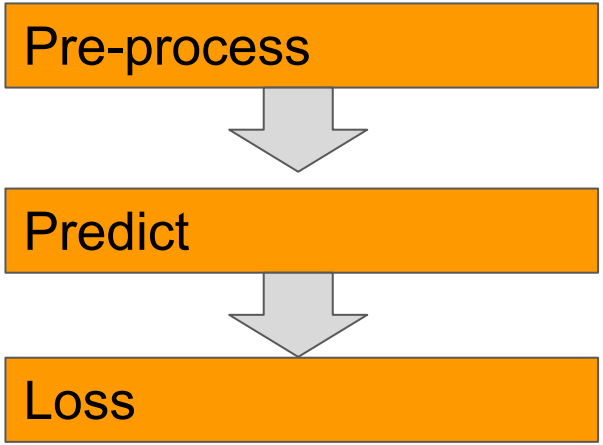
For all training images:



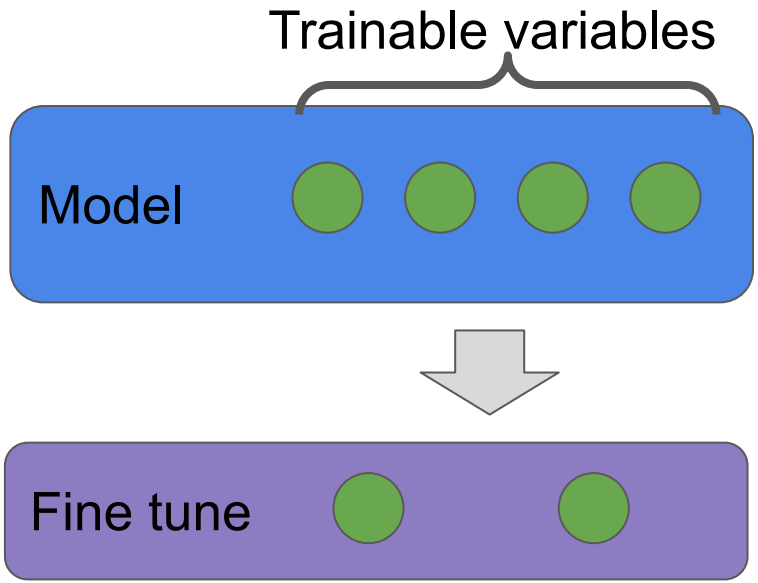
Custom Training Loop



For all training images:



Custom Training Loop



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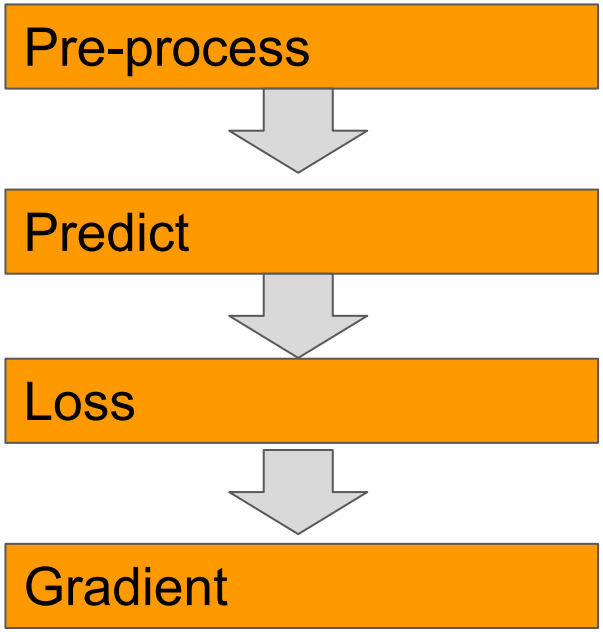
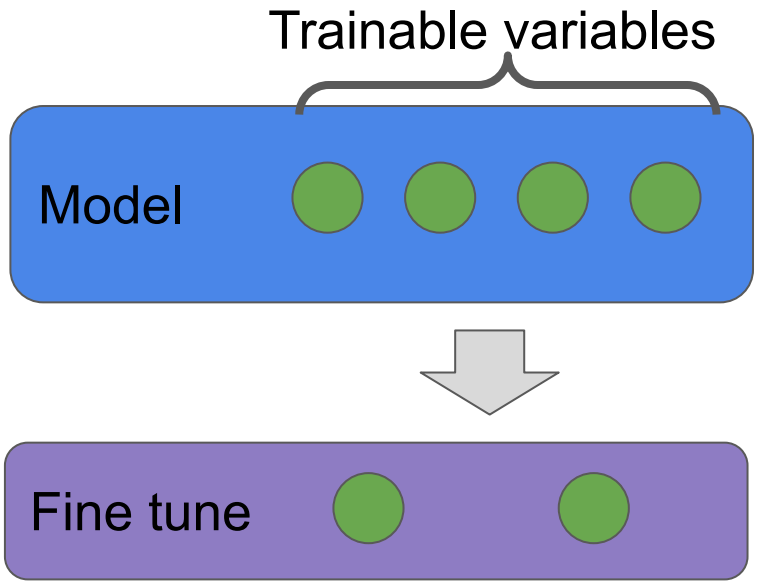


Custom Training Loop



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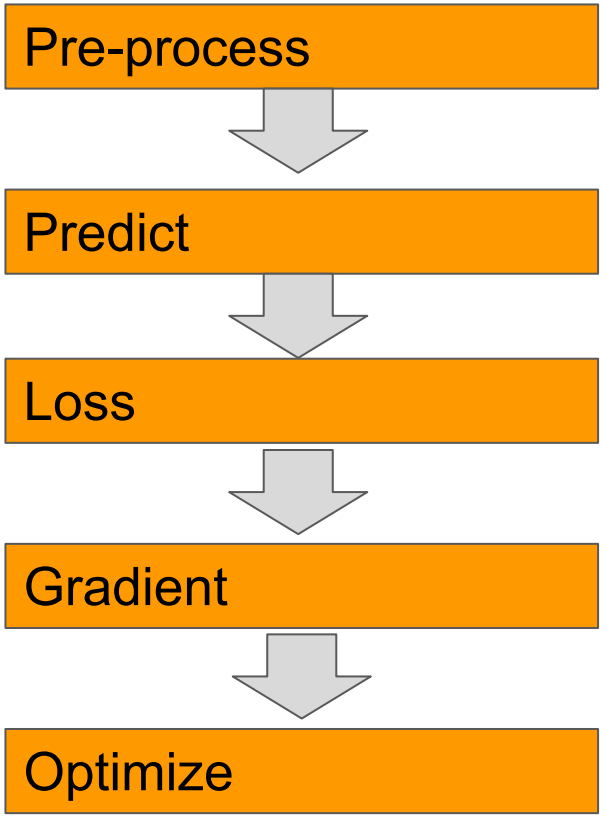

```
for var in detection_model.trainable_variables:
  print(var.name)
```

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```
WeightSharedConvolutionalBoxPredictor/WeightSharedConvolutionalBoxHead/BoxPredictor/kernel:0
WeightSharedConvolutionalBoxPredictor/WeightSharedConvolutionalBoxHead/BoxPredictor/bias:0
WeightSharedConvolutionalBoxPredictor/WeightSharedConvolutionalClassHead/ClassPredictor/kernel:0
WeightSharedConvolutionalBoxPredictor/WeightSharedConvolutionalClassHead/ClassPredictor/bias:0
WeightSharedConvolutionalBoxPredictor/BoxPredictionTower/conv2d_0/kernel:0
WeightSharedConvolutionalBoxPredictor/BoxPredictionTower/conv2d_0/BatchNorm/feature_0/gamma:0
WeightSharedConvolutionalBoxPredictor/BoxPredictionTower/conv2d_0/BatchNorm/feature_0/beta:0
WeightSharedConvolutionalBoxPredictor/BoxPredictionTower/conv2d_1/kernel:0
```

```
prefixes_to_train = [
  'WeightSharedConvolutionalBoxPredictor/WeightSharedConvolutionalBoxHead',
  'WeightSharedConvolutionalBoxPredictor/WeightSharedConvolutionalClassHead']

for var in trainable_variables:
  if any([var.name.startswith(prefix) for prefix in prefixes_to_train]):
    to_fine_tune.append(var)
```

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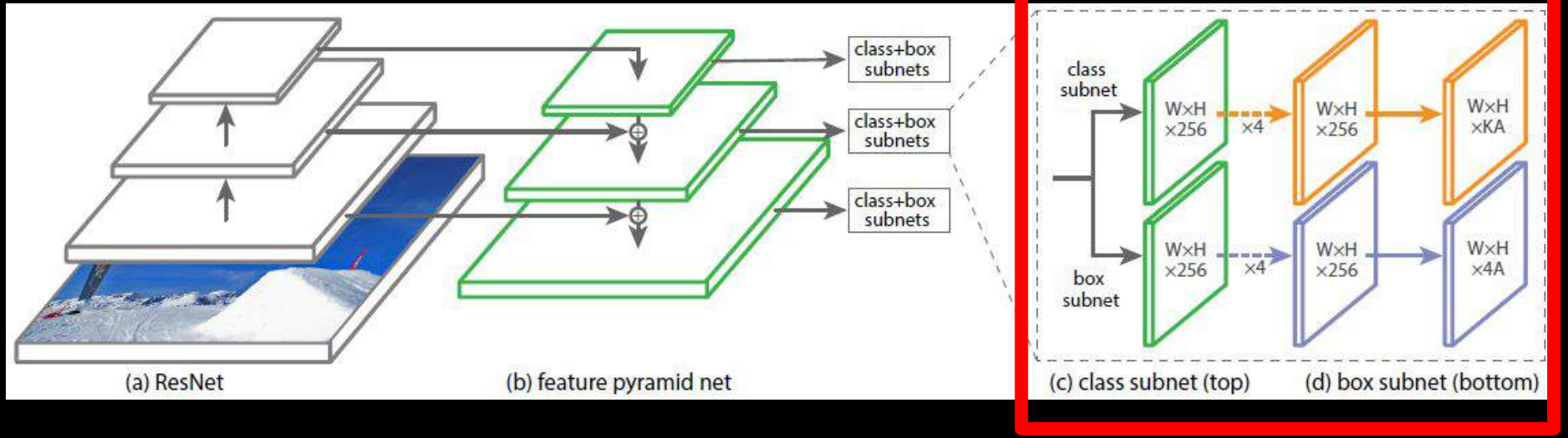

```
with tf.GradientTape() as tape:
  preprocessed_images = tf.concat(
      [detection_model.preprocess(image_tensor)[0]
       for image_tensor in image_tensors], axis=0)
  prediction_dict = model.predict(preprocessed_images, shapes)
  losses_dict = model.loss(prediction_dict, shapes)
  total_loss = losses_dict['Loss/localization_loss'] +
               losses_dict['Loss/classification_loss']
  gradients = tape.gradient(total_loss, vars_to_fine_tune)
  optimizer.apply_gradients(zip(gradients, vars_to_fine_tune))
return total_loss
```

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  gradients = tape.gradient(total_loss, vars_to_fine_tune)
  optimizer.apply_gradients(zip(gradients, vars_to_fine_tune))
return total_loss
```

```
with tf.GradientTape() as tape:
  preprocessed_images = tf.concat(
      [detection_model.preprocess(image_tensor)[0]
       for image_tensor in image_tensors], axis=0)
  prediction_dict = model.predict(preprocessed_images, shapes)
  losses_dict = model.loss(prediction_dict, shapes)
  total_loss = losses_dict['Loss/localization_loss'] +
               losses_dict['Loss/classification_loss']
  gradients = tape.gradient(total_loss, vars_to_fine_tune)
  optimizer.apply_gradients(zip(gradients, vars_to_fine_tune))
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  gradients = tape.gradient(total_loss, vars_to_fine_tune)
  optimizer.apply_gradients(zip(gradients, vars_to_fine_tune))
return total_loss
```

```
Start fine-tuning!
epoch 0 of 100, loss=1.1637363
epoch 10 of 100, loss=1.2570567
epoch 20 of 100, loss=0.054274812
epoch 30 of 100, loss=0.015053727
epoch 40 of 100, loss=0.0052895746
epoch 50 of 100, loss=0.014283805
epoch 60 of 100, loss=0.003811138
epoch 70 of 100, loss=0.0035868755
epoch 80 of 100, loss=0.003034658
epoch 90 of 100, loss=0.002482821
Done fine-tuning!
```

```
input_tensor = tf.convert_to_tensor(test_images_np[i], dtype=tf.float32)
...
preprocessed_image, shapes = detection_model.preprocess(input_tensor)
prediction_dict = detection_model.predict(preprocessed_image, shapes)
return detection_model.postprocess(prediction_dict, shapes)
```

```
input_tensor = tf.convert_to_tensor(test_images_np[i], dtype=tf.float32)
...
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```

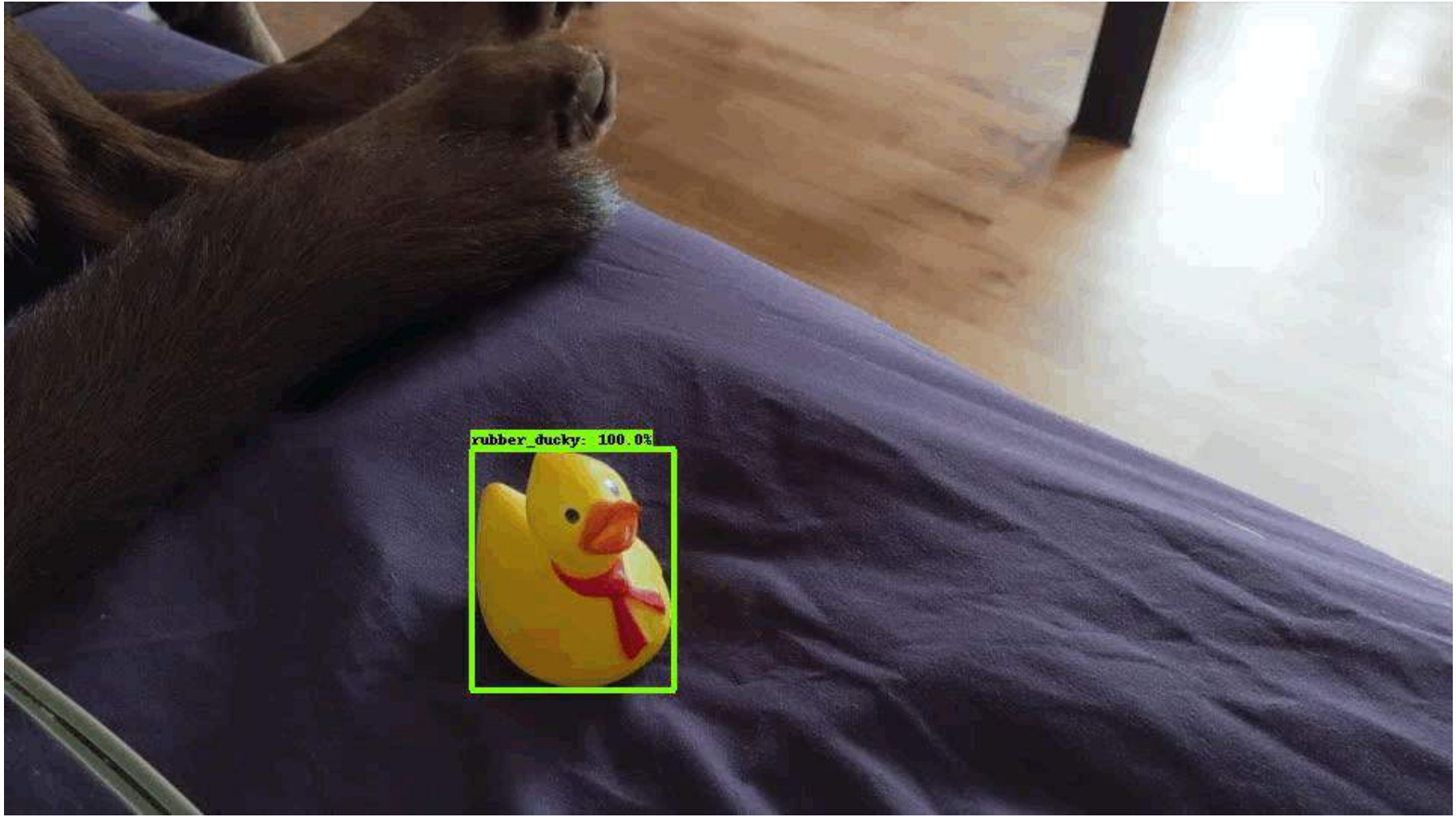
rubber_ducky: 100.0%