DETR – Detection Transformer

Reference: https://github.com/NielsRogge/Transformers-Tutorials/blob/master/DETR/Fine_tuning_DetrForObjectDetection_on_custom_dataset_(balloon).ipynb

Original DETR paper: https://arxiv.org/abs/2005.12872

Original DETR repo: https://github.com/facebookresearch/detr

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

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

```
!python --version
```

```
Python 3.10.12
```

```
!python -m pip install --upgrade pip
```

```
!pip install supervision==0.3.0
```

```
!pip install transformers
```

```
!pip install pytorch-lightning
```

```
!pip install timm
```

```
!pip install cython
```

```
!pip install pycocotools
```

```
!pip install scipy
```

```
Requirement already satisfied: pip in /usr/local/lib/python3.10/dist-
packages (23.1.2)
Collecting pip
  Downloading pip-23.3.2-py3-none-any.whl (2.1 MB)
──────────────────────────────────────── 2.1/2.1 MB 13.6 MB/s eta
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pting uninstall: pip
    Found existing installation: pip 23.1.2
    Uninstalling pip-23.1.2:
      Successfully uninstalled pip-23.1.2
Successfully installed pip-23.3.2
Collecting supervision==0.3.0
  Downloading supervision-0.3.0-py3-none-any.whl (21 kB)
Requirement already satisfied: numpy>=1.20.0 in
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/usr/local/lib/python3.10/dist-packages (from supervision==0.3.0)
(1.23.5)
Requirement already satisfied: opencv-python in
/usr/local/lib/python3.10/dist-packages (from supervision==0.3.0)
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/usr/local/lib/python3.10/dist-packages (from matplotlib-
>supervision==0.3.0) (2.8.2)
Requirement already satisfied: six>=1.5 in
/usr/local/lib/python3.10/dist-packages (from python-dateutil>=2.7-
>matplotlib->supervision==0.3.0) (1.16.0)
Installing collected packages: supervision
Successfully installed supervision-0.3.0
WARNING: Running pip as the 'root' user can result in broken
permissions and conflicting behaviour with the system package manager.
It is recommended to use a virtual environment instead:
https://pip.pypa.io/warnings/venv
Requirement already satisfied: transformers in
/usr/local/lib/python3.10/dist-packages (4.35.2)
Requirement already satisfied: filelock in
/usr/local/lib/python3.10/dist-packages (from transformers) (3.13.1)
Requirement already satisfied: huggingface-hub<1.0,>=0.16.4 in
/usr/local/lib/python3.10/dist-packages (from transformers) (0.20.2)
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Requirement already satisfied: pyyaml>=5.1 in
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Requirement already satisfied: requests in
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Requirement already satisfied: tokenizers<0.19,>=0.14 in
/usr/local/lib/python3.10/dist-packages (from transformers) (0.15.0)
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Requirement already satisfied: idna<4,>=2.5 in
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(2023.11.17)
WARNING: Running pip as the 'root' user can result in broken
permissions and conflicting behaviour with the system package manager.
It is recommended to use a virtual environment instead:
https://pip.pypa.io/warnings/venv
Collecting pytorch-lightning
  Downloading pytorch_lightning-2.1.3-py3-none-any.whl.metadata (21
kB)
Requirement already satisfied: numpy>=1.17.2 in
/usr/local/lib/python3.10/dist-packages (from pytorch-lightning)
(1.23.5)
Requirement already satisfied: torch>=1.12.0 in
/usr/local/lib/python3.10/dist-packages (from pytorch-lightning)
(2.1.0+cu121)
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/usr/local/lib/python3.10/dist-packages (from pytorch-lightning)
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Requirement already satisfied: PyYAML>=5.4 in
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Requirement already satisfied: fsspec>=2022.5.0 in
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Requirement already satisfied: setuptools in
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Requirement already satisfied: filelock in
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Requirement already satisfied: sympy in
/usr/local/lib/python3.10/dist-packages (from torch>=1.12.0->pytorch-
lightning) (1.12)
Requirement already satisfied: networkx in
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Requirement already satisfied: multidict<7.0,>=4.5 in
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Requirement already satisfied: yarl<2.0,>=1.0 in
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=4.0.0a1->fsspec[http]>=2022.5.0->pytorch-lightning) (1.9.4)
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Requirement already satisfied: frozenlist>=1.1.1 in
/usr/local/lib/python3.10/dist-packages (from aiohttp!=4.0.0a0,!
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Requirement already satisfied: aiosignal>=1.1.2 in
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Requirement already satisfied: async-timeout<5.0,>=4.0 in
/usr/local/lib/python3.10/dist-packages (from aiohttp!=4.0.0a0,!
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Requirement already satisfied: MarkupSafe>=2.0 in
/usr/local/lib/python3.10/dist-packages (from jinja2->torch>=1.12.0-
>pytorch-lightning) (2.1.3)
Requirement already satisfied: charset-normalizer<4,>=2 in
/usr/local/lib/python3.10/dist-packages (from requests-
>fsspec[http]>=2022.5.0->pytorch-lightning) (3.3.2)
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Requirement already satisfied: certifi>=2017.4.17 in
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>fsspec[http]>=2022.5.0->pytorch-lightning) (2023.11.17)
Requirement already satisfied: mpmath>=0.19 in
/usr/local/lib/python3.10/dist-packages (from sympy->torch>=1.12.0-
>pytorch-lightning) (1.3.0)
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Successfully installed lightning-utilities-0.10.0 pytorch-lightning-
2.1.3 torchmetrics-1.3.0
WARNING: Running pip as the 'root' user can result in broken
permissions and conflicting behaviour with the system package manager.
It is recommended to use a virtual environment instead:
https://pip.pypa.io/warnings/venv
Collecting timm
  Downloading timm-0.9.12-py3-none-any.whl.metadata (60 kB)
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packages (from timm) (2.1.0+cu121)
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/usr/local/lib/python3.10/dist-packages (from timm) (0.16.0+cu121)
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/usr/local/lib/python3.10/dist-packages (from huggingface-hub->timm)
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/usr/local/lib/python3.10/dist-packages (from huggingface-hub->timm)
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Requirement already satisfied: numpy in
/usr/local/lib/python3.10/dist-packages (from torchvision->timm)
(1.23.5)
Requirement already satisfied: pillow!=8.3.*,>=5.3.0 in
/usr/local/lib/python3.10/dist-packages (from torchvision->timm)
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/usr/local/lib/python3.10/dist-packages (from jinja2->torch>=1.7-
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/usr/local/lib/python3.10/dist-packages (from requests->huggingface-
hub->timm) (3.3.2)
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Requirement already satisfied: urllib3<3,>=1.21.1 in
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Requirement already satisfied: certifi>=2017.4.17 in
/usr/local/lib/python3.10/dist-packages (from requests->huggingface-
hub->timm) (2023.11.17)
Requirement already satisfied: mpmath>=0.19 in
/usr/local/lib/python3.10/dist-packages (from sympy->torch>=1.7->timm)
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Downloading timm-0.9.12-py3-none-any.whl (2.2 MB)
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m
Successfully installed timm-0.9.12
WARNING: Running pip as the 'root' user can result in broken
permissions and conflicting behaviour with the system package manager.
It is recommended to use a virtual environment instead:
https://pip.pypa.io/warnings/venv
Requirement already satisfied: cython in
/usr/local/lib/python3.10/dist-packages (3.0.7)
WARNING: Running pip as the 'root' user can result in broken
permissions and conflicting behaviour with the system package manager.
It is recommended to use a virtual environment instead:
https://pip.pypa.io/warnings/venv
Requirement already satisfied: pycocotools in
/usr/local/lib/python3.10/dist-packages (2.0.7)
Requirement already satisfied: matplotlib>=2.1.0 in
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/usr/local/lib/python3.10/dist-packages (from pycocotools) (1.23.5)
Requirement already satisfied: contourpy>=1.0.1 in
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>pycocotools) (4.47.0)
Requirement already satisfied: kiwisolver>=1.0.1 in
/usr/local/lib/python3.10/dist-packages (from matplotlib>=2.1.0-
>pycocotools) (1.4.5)
Requirement already satisfied: packaging>=20.0 in
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>pycocotools) (23.2)
Requirement already satisfied: pillow>=6.2.0 in
/usr/local/lib/python3.10/dist-packages (from matplotlib>=2.1.0-
>pycocotools) (9.4.0)
Requirement already satisfied: pyparsing>=2.3.1 in
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Requirement already satisfied: python-dateutil>=2.7 in
/usr/local/lib/python3.10/dist-packages (from matplotlib>=2.1.0-
>pycocotools) (2.8.2)
Requirement already satisfied: six>=1.5 in
/usr/local/lib/python3.10/dist-packages (from python-dateutil>=2.7-
>matplotlib>=2.1.0->pycocotools) (1.16.0)
WARNING: Running pip as the 'root' user can result in broken
permissions and conflicting behaviour with the system package manager.
It is recommended to use a virtual environment instead:
https://pip.pypa.io/warnings/venv
Requirement already satisfied: scipy in
/usr/local/lib/python3.10/dist-packages (1.11.4)
Requirement already satisfied: numpy<1.28.0,>=1.21.6 in
/usr/local/lib/python3.10/dist-packages (from scipy) (1.23.5)
WARNING: Running pip as the 'root' user can result in broken
permissions and conflicting behaviour with the system package manager.
It is recommended to use a virtual environment instead:
https://pip.pypa.io/warnings/venv
```

```python
!pip --version
```

```
pip 23.3.2 from /usr/local/lib/python3.10/dist-packages/pip (python
3.10)
```

```python
import torch
torch.__version__
```

```json
{"type":"string"}
```

```python
import supervision as sv
import transformers

# supervision.__version__ , transformers.__version__

import pytorch_lightning
print(pytorch_lightning.__version__)
```

```
2.1.3
```

Create COCO data loaders

```python
import os
import torch
import torchvision.transforms as T
import torchvision

dataset = '/content/drive/MyDrive/Detect'

ANNOTATION_FILE_NAME = "annotations.json"
```

```python
TRAIN_DIRECTORY = os.path.join(dataset, "train")
VAL_DIRECTORY = os.path.join(dataset, "valid")
TEST_DIRECTORY = os.path.join(dataset, "test")

# Instantiate the image processor
from transformers import DetrImageProcessor
image_processor = DetrImageProcessor.from_pretrained("facebook/detr-
resnet-50")

class CocoDetection(torchvision.datasets.CocoDetection):
    def __init__(
        self,
        image_directory_path: str,
        image_processor,
        train: bool = True
    ):
        annotation_file_path = os.path.join(image_directory_path,
ANNOTATION_FILE_NAME)
        if not os.path.exists(annotation_file_path):
            raise FileNotFoundError(f"Annotation file not found:
{annotation_file_path}")

        super(CocoDetection, self).__init__(image_directory_path,
annotation_file_path)
        self.image_processor = image_processor

    def __getitem__(self, idx):
        images, annotations = super(CocoDetection,
self).__getitem__(idx)
        image_id = self.ids[idx]
        annotations = {'image_id': image_id, 'annotations':
annotations}
        encoding = self.image_processor(images=images,
annotations=annotations, return_tensors="pt")
        pixel_values = encoding["pixel_values"].squeeze()
        target = encoding["labels"][0]

        return pixel_values, target

# Now you can use the image_processor
try:
    TRAIN_DATASET =
CocoDetection(image_directory_path=TRAIN_DIRECTORY,
image_processor=image_processor, train=True)
    VAL_DATASET = CocoDetection(image_directory_path=VAL_DIRECTORY,
image_processor=image_processor, train=False)
    TEST_DATASET = CocoDetection(image_directory_path=TEST_DIRECTORY,
image_processor=image_processor, train=False)

    print("Number of training examples:", len(TRAIN_DATASET))
```

```
    print("Number of validation examples:", len(VAL_DATASET))
    print("Number of test examples:", len(TEST_DATASET))

except FileNotFoundError as e:
    print(f"Error: {e}")
except Exception as e:
    print(f"An unexpected error occurred: {e}")
```

/usr/local/lib/python3.10/dist-packages/huggingface_hub/utils/
_token.py:88: UserWarning:
The secret `HF_TOKEN` does not exist in your Colab secrets.
To authenticate with the Hugging Face Hub, create a token in your
settings tab (https://huggingface.co/settings/tokens), set it as
secret in your Google Colab and restart your session.
You will be able to reuse this secret in all of your notebooks.
Please note that authentication is recommended but still optional to
access public models or datasets.
  warnings.warn(

{"model_id":"4b25c6effa7d4083bc241c15556af414","version_major":2,"version_minor":0}

The `max_size` parameter is deprecated and will be removed in v4.26.
Please specify in `size['longest_edge'] instead`.

loading annotations into memory...
Done (t=0.66s)
creating index...
index created!
loading annotations into memory...
Done (t=0.39s)
creating index...
index created!
loading annotations into memory...
Done (t=0.63s)
creating index...
index created!
Number of training examples: 267
Number of validation examples: 10
Number of test examples: 5

```
# Visualize if dataset is loaded properly

import random
import cv2
import numpy as np


# select random image
image_ids = TRAIN_DATASET.coco.getImgIds()
image_id = random.choice(image_ids)
```

```python
print('Image #{}'.format(image_id))

# load image and annotatons
image = TRAIN_DATASET.coco.loadImgs(image_id)[0]
annotations = TRAIN_DATASET.coco.imgToAnns[image_id]
image_path = os.path.join(TRAIN_DATASET.root, image['file_name'])
image = cv2.imread(image_path)

# annotate
detections = \
sv.Detections.from_coco_annotations(coco_annotation=annotations)

# we will use id2label function for training
categories = TRAIN_DATASET.coco.cats
id2label = {k: v['name'] for k,v in categories.items()}

labels = [
    f"{id2label[class_id]}"
    for _, _, class_id, _
    in detections
]

box_annotator = sv.BoxAnnotator()
frame = box_annotator.annotate(scene=image, detections=detections,
labels=labels)

%matplotlib inline
sv.show_frame_in_notebook(image, (8, 8))
```

Image #186

```python
from torch.utils.data import DataLoader

def collate_fn(batch):
    pixel_values = [item[0] for item in batch]
    encoding = image_processor.pad(pixel_values, return_tensors="pt")
    labels = [item[1] for item in batch]
    return {
        'pixel_values': encoding['pixel_values'],
        'pixel_mask': encoding['pixel_mask'],
        'labels': labels
    }

TRAIN_DATALOADER = DataLoader(dataset=TRAIN_DATASET,
```

```
collate_fn=collate_fn, batch_size=4, shuffle=True)
VAL_DATALOADER = DataLoader(dataset=VAL_DATASET,
collate_fn=collate_fn, batch_size=4)
TEST_DATALOADER = DataLoader(dataset=TEST_DATASET,
collate_fn=collate_fn, batch_size=4)
```

Train model with PyTorch Lightning

The DETR model is loaded using the Hugging Face Transformers library

```python
import pytorch_lightning as pl
from transformers import DetrForObjectDetection
import torch


class Detr(pl.LightningModule):

    def __init__(self, lr, lr_backbone, weight_decay):
        super().__init__()
        self.model = DetrForObjectDetection.from_pretrained(
            pretrained_model_name_or_path="facebook/detr-resnet-50",
            revision="no_timm",
            num_labels=len(id2label),
            ignore_mismatched_sizes=True
        )

        self.lr = lr
        self.lr_backbone = lr_backbone
        self.weight_decay = weight_decay

    def forward(self, pixel_values, pixel_mask):
        return self.model(pixel_values=pixel_values,
pixel_mask=pixel_mask)

    def common_step(self, batch, batch_idx):
        pixel_values = batch["pixel_values"]
        pixel_mask = batch["pixel_mask"]
        labels = [{k: v.to(self.device) for k, v in t.items()} for t
in batch["labels"]]

        outputs = self.model(pixel_values=pixel_values,
pixel_mask=pixel_mask, labels=labels)

        loss = outputs.loss
        loss_dict = outputs.loss_dict

        return loss, loss_dict
```

```python
    def training_step(self, batch, batch_idx):
        loss, loss_dict = self.common_step(batch, batch_idx)
        # logs metrics for each training_step, and the average across
the epoch
        self.log("training_loss", loss)
        for k,v in loss_dict.items():
            self.log("train_" + k, v.item())

        return loss

    def validation_step(self, batch, batch_idx):
        loss, loss_dict = self.common_step(batch, batch_idx)
        self.log("validation/loss", loss)
        for k, v in loss_dict.items():
            self.log("validation_" + k, v.item())

        return loss

    def configure_optimizers(self):
        param_dicts = [
            {
                "params": [p for n, p in self.named_parameters() if
"backbone" not in n and p.requires_grad]},
            {
                "params": [p for n, p in self.named_parameters() if
"backbone" in n and p.requires_grad],
                "lr": self.lr_backbone,
            },
        ]
        return torch.optim.AdamW(param_dicts, lr=self.lr,
weight_decay=self.weight_decay)

    def train_dataloader(self):
        return TRAIN_DATALOADER

    def val_dataloader(self):
        return VAL_DATALOADER

model = Detr(lr=1e-4, lr_backbone=1e-5, weight_decay=1e-4)

batch = next(iter(TRAIN_DATALOADER))
outputs = model(pixel_values=batch['pixel_values'],
pixel_mask=batch['pixel_mask'])

Some weights of DetrForObjectDetection were not initialized from the
model checkpoint at facebook/detr-resnet-50 and are newly initialized
because the shapes did not match:
- class_labels_classifier.weight: found shape torch.Size([92, 256]) in
the checkpoint and torch.Size([101, 256]) in the model instantiated
- class_labels_classifier.bias: found shape torch.Size([92]) in the
```

checkpoint and torch.Size([101]) in the model instantiated
You should probably TRAIN this model on a down-stream task to be able
to use it for predictions and inference.

```python
from pytorch_lightning import Trainer

# settings
MAX_EPOCHS = "250" # @param [2, 5,10,15,50,75,100,150,200,250,300]

trainer = Trainer(devices=1, accelerator="gpu",
max_epochs=int(MAX_EPOCHS), gradient_clip_val=0.1,
accumulate_grad_batches=6, log_every_n_steps=5)

trainer.fit(model)
```

```
INFO:pytorch_lightning.utilities.rank_zero:GPU available: True (cuda),
used: True
INFO:pytorch_lightning.utilities.rank_zero:TPU available: False,
using: 0 TPU cores
INFO:pytorch_lightning.utilities.rank_zero:IPU available: False,
using: 0 IPUs
INFO:pytorch_lightning.utilities.rank_zero:HPU available: False,
using: 0 HPUs
INFO:pytorch_lightning.accelerators.cuda:LOCAL_RANK: 0 -
CUDA_VISIBLE_DEVICES: [0]
INFO:pytorch_lightning.callbacks.model_summary:
  | Name  | Type                  | Params
---------------------------------------------------
0 | model | DetrForObjectDetection | 41.5 M
---------------------------------------------------
18.1 M    Trainable params
23.5 M    Non-trainable params
41.5 M    Total params
166.108   Total estimated model params size (MB)
```

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```
/usr/local/lib/python3.10/dist-packages/pytorch_lightning/trainer/
connectors/data_connector.py:441: The 'val_dataloader' does not have
many workers which may be a bottleneck. Consider increasing the value
of the `num_workers` argument` to `num_workers=1` in the `DataLoader`
to improve performance.
/usr/local/lib/python3.10/dist-packages/pytorch_lightning/utilities/
data.py:77: Trying to infer the `batch_size` from an ambiguous
collection. The batch size we found is 4. To avoid any
miscalculations, use `self.log(..., batch_size=batch_size)`.
/usr/local/lib/python3.10/dist-packages/pytorch_lightning/trainer/
connectors/data_connector.py:441: The 'train_dataloader' does not have
many workers which may be a bottleneck. Consider increasing the value
```

of the `num_workers` argument` to `num_workers=1` in the `DataLoader`
to improve performance.

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data.py:77: Trying to infer the `batch_size` from an ambiguous
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```

```
INFO:pytorch_lightning.utilities.rank_zero:`Trainer.fit` stopped: `max_epochs=250` reached.
```

Save and load model

```python
MODEL_PATH = '/content/drive/MyDrive/Detect/custom-model'
model.model.save_pretrained(MODEL_PATH)
```

Inference on test dataset

Let's visualize the predictions of DETR on the first image of the validation set.

```python
import random
import cv2
import numpy as np
import matplotlib.pyplot as plt
from transformers import DetrForObjectDetection
import torch
import supervision as sv
import transformers

# loading model
model =
DetrForObjectDetection.from_pretrained("/content/drive/MyDrive/Detect/custom-model")
# model.to(DEVICE)

# utils
categories = TEST_DATASET.coco.cats
id2label = {k: v['name'] for k,v in categories.items()}
box_annotator = sv.BoxAnnotator()

# select random image
image_ids = TEST_DATASET.coco.getImgIds()
image_id = random.choice(image_ids)
print('Image #{}'.format(image_id))

# load image and annotatons
image = TEST_DATASET.coco.loadImgs(image_id)[0]
```

```python
annotations = TEST_DATASET.coco.imgToAnns[image_id]
image_path = os.path.join(TEST_DATASET.root, image['file_name'])
image = cv2.imread(image_path)

# Annotate ground truth
detections =
sv.Detections.from_coco_annotations(coco_annotation=annotations)
labels = [f"{id2label[class_id]}" for _, _, class_id, _ in detections]
frame_ground_truth = box_annotator.annotate(scene=image.copy(),
detections=detections, labels=labels)




# Annotate detections
with torch.no_grad():

    # load image and predict
    inputs = image_processor(images=image, return_tensors='pt')
    outputs = model(**inputs)

    # post-process
    target_sizes = torch.tensor([image.shape[:2]])
    results = image_processor.post_process_object_detection(
        outputs=outputs,
        threshold=0.20,
        target_sizes=target_sizes
    )[0]


    detections =
sv.Detections.from_transformers(transformers_results=results)
    labels = [f"{id2label[class_id]} {confidence:.2f}" for _,
confidence, class_id, _ in detections]
    frame_detections = box_annotator.annotate(scene=image.copy(),
detections=detections, labels=labels)


# %matplotlib inline # Remove this line, we won't use it anymore

# Combine both images side by side and display
fig, axs = plt.subplots(1, 2, figsize=(20, 10))
axs[0].imshow(cv2.cvtColor(frame_ground_truth, cv2.COLOR_BGR2RGB))
axs[0].axis('off')
axs[0].set_title('Ground Truth')

axs[1].imshow(cv2.cvtColor(frame_detections, cv2.COLOR_BGR2RGB))
axs[1].axis('off')
axs[1].set_title('Detections')

plt.show()
```

Ground Truth

Detections