

image-segmentation-final

October 17, 2021

1 Image Segmentation

1.0.1 Author: Sanjay Juras

1.0.2 Bellevue University

1.1 Import Libraries

```
[ ]: #!pip install git+https://github.com/tensorflow/examples.git
import os
import tensorflow as tf
from tensorflow.examples.models.pix2pix import pix2pix
from tensorflow.keras.layers.experimental import preprocessing
from IPython.display import clear_output
import matplotlib.pyplot as plt
import PIL
from PIL import Image
import numpy as np
from tqdm import tqdm
import random
```

1.2 Load image file paths

```
[ ]: #voc_path = "../input/pascal-voc-2012/VOC2012/"
voc_path = "VOCtrainval_11-May-2012/VOCdevkit/VOC2012/"
train_text_file = os.path.join(voc_path, "ImageSets/Segmentation/train.txt")
val_text_file = os.path.join(voc_path, "ImageSets/Segmentation/val.txt")
image_folder = os.path.join(voc_path, "JPEGImages")
mask_folder = os.path.join(voc_path, "SegmentationClass")
```

```
[ ]: def read_paths_img_masks(text_file_path, image_path, mask_path):
    paths = []
    with open(text_file_path, "r") as file:
        file_names = file.readlines()
    for file_name in tqdm(file_names):
        image = os.path.join(image_path, file_name.strip() + ".jpg")
        mask = os.path.join(mask_path, file_name.strip() + ".png")
        paths.append((image, mask))
    return paths
```

1.3 Split files into Train, Test and Validation dataset

```
[ ]: train_paths = read_paths_img_masks(train_text_file, image_folder, mask_folder)
val_paths = read_paths_img_masks(val_text_file, image_folder, mask_folder)

# Adding 1000 paths from validation dataset to training dataset increase ↗
→ training dataset size
train_paths.extend(val_paths[0:700])
test_paths = val_paths[700:1000]
val_paths = val_paths[1000:]

#train_paths = tf.data.Dataset.from_tensors(train_paths)
#val_paths = tf.data.Dataset.from_tensors(val_paths)
```

```
100%| 1464/1464 [00:00<00:00, 566254.25it/s]
100%| 1449/1449 [00:00<00:00, 580583.35it/s]
```

1.4 Functions

- **normalize**: Normalize the image data and replace white color to last class
- **load_image_to_array**: Load image into array and resize it to 256*256 pixels
- **load_image_and_mask**: Load original image and masks

```
[ ]: dim = 224
img_size = (dim, dim)
input_shape = [dim, dim, 3]

def normalize(input_image, input_mask1):
    input_image = tf.cast(input_image, tf.float32) / 255.0
    input_mask = input_mask1.copy()
    input_mask[input_mask == 255] = 21
    return input_image, input_mask

def load_image_to_array(file_path):
    with open(file_path, "rb") as f:
        img = PIL.Image.open(f)
        img = img.resize(img_size)
        nparr = np.asarray(img)
        #print("nparr:", nparr.shape)
    return nparr

def load_image_and_mask(paths_tuple):
    input_image = load_image_to_array(paths_tuple[0])
    input_mask = load_image_to_array(paths_tuple[1])
    input_image, input_mask = normalize(input_image, input_mask)

    return input_image, input_mask
```

1.5 Functions

- **augmentImage**: Augment original Image by flipping horizontally or vertically
- **augmentMask**: Augment original Mask by flipping horizontally or vertically
- **load_dataset**: Load all datasets

```
[ ]: def augmentImage(img, left_right=True):
    aug_img = tf.image.flip_left_right(img)
    if left_right is True:
        aug_img = tf.image.flip_left_right(img)
    else:
        aug_img = tf.image.flip_up_down(img)
    return aug_img

def augmentMask(mask, left_right=True):
    mask = mask[..., np.newaxis]
    if left_right is True:
        aug_mask = tf.image.flip_left_right(mask)
    else:
        aug_mask = tf.image.flip_up_down(mask)
    aug_mask = aug_mask[:, :, 0]
    mask = mask[:, :, 0]
    return aug_mask

def load_dataset(paths, augment=False):
    imgs = []
    masks = []
    for path in tqdm(paths):
        #print("Processing: ", path)
        img, mask = load_image_and_mask(path)
        imgs.append(img)
        masks.append(mask)
        if augment is True:
            imgs.append(augmentImage(img))
            masks.append(augmentMask(mask))
            imgs.append(augmentImage(img, False))
            masks.append(augmentMask(mask, False))

    # break

    return np.array(imgs), np.array(masks)
```

1.6 Load images into lists

```
[ ]: print("Loading Training Dataset...")
train_images, train_masks = load_dataset(train_paths, True)
print("Loading Validation Dataset...")
val_images, val_masks = load_dataset(val_paths)
print("Loading Test Dataset...")
test_images, test_masks = load_dataset(test_paths)

TRAIN_LENGTH = len(train_images)
VAL_LENGTH = len(val_images)
print("Training dataset size:", len(train_images))
print("Test dataset size:", len(test_images))
print("Validation dataset size:", len(val_images))
```

Loading Training Dataset...

```
0%|          | 0/2164 [00:00<?, ?it/s] 2021-10-17 14:40:14.439463: I
tensorflow/compiler/jit/xla_cpu_device.cc:41] Not creating XLA devices,
tf_xla_enable_xla_devices not set
2021-10-17 14:40:14.439673: I tensorflow/core/platform/cpu_feature_guard.cc:142]
This TensorFlow binary is optimized with oneAPI Deep Neural Network Library
(oneDNN) to use the following CPU instructions in performance-critical
operations: SSE4.1 SSE4.2 AVX AVX2 FMA
To enable them in other operations, rebuild TensorFlow with the appropriate
compiler flags.
2021-10-17 14:40:14.440665: I
tensorflow/core/common_runtime/process_util.cc:146] Creating new thread pool
with default inter op setting: 2. Tune using inter_op_parallelism_threads for
best performance.
100%|      | 2164/2164 [00:15<00:00, 142.20it/s]
```

Loading Validation Dataset...

```
100%|      | 449/449 [00:02<00:00, 174.67it/s]
```

Loading Test Dataset...

```
100%|      | 300/300 [00:01<00:00, 166.24it/s]
```

Training dataset size: 6492

Test dataset size: 300

Validation dataset size: 449

1.7 Utility function to display Input image, mask and predicted mask side by side.

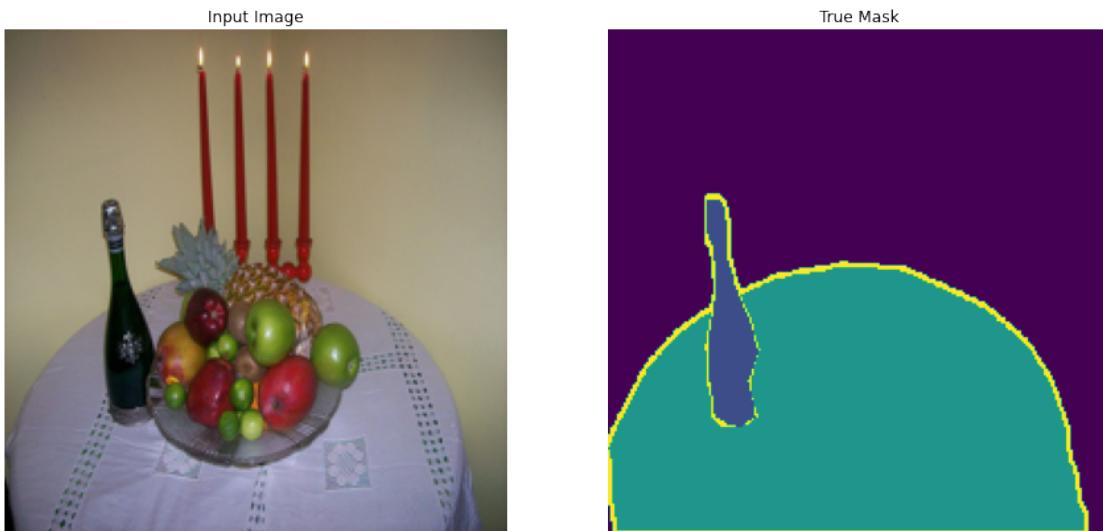
```
[ ]: def display_images(display_list):
    plt.figure(figsize=(15, 15))

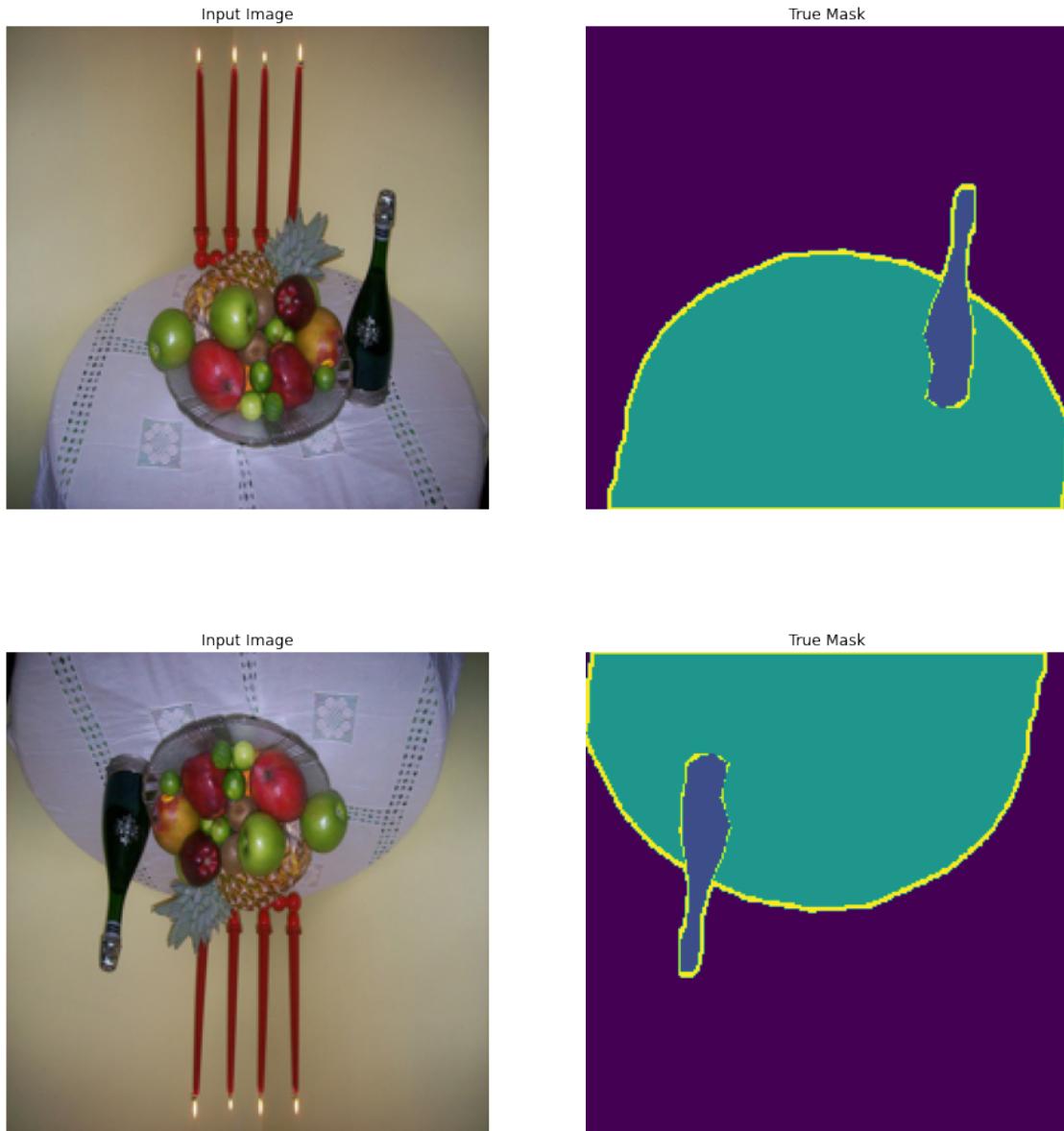
    title = ['Input Image', 'True Mask', 'Predicted Mask']

    for i in range(len(display_list)):
        plt.subplot(1, len(display_list), i+1)
        plt.title(title[i])
        plt.imshow(display_list[i])
        plt.axis('off')
    plt.show()
```

1.8 Augmented images and masks

```
[ ]: for i in range(24,27):
    display_images([train_images[i], train_masks[i]])
```





1.9 Load datasets into TensorSliceDataset

```
[ ]: train_images_ds = tf.data.Dataset.from_tensor_slices((train_images, ▾
    ↪train_masks))
del train_images, train_masks
test_images_ds = tf.data.Dataset.from_tensor_slices((test_images, test_masks))
del test_images, test_masks
val_images_ds = tf.data.Dataset.from_tensor_slices((val_images, val_masks))
del val_images, val_masks
```

1.10 Define Batch size

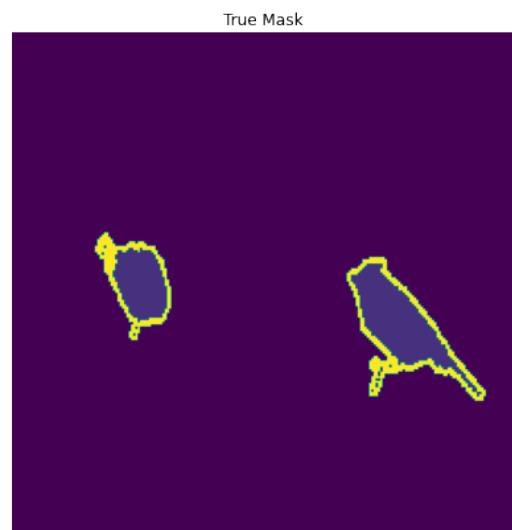
```
[ ]: BUFFER_SIZE = TRAIN_LENGTH  
      BATCH_SIZE = 32
```

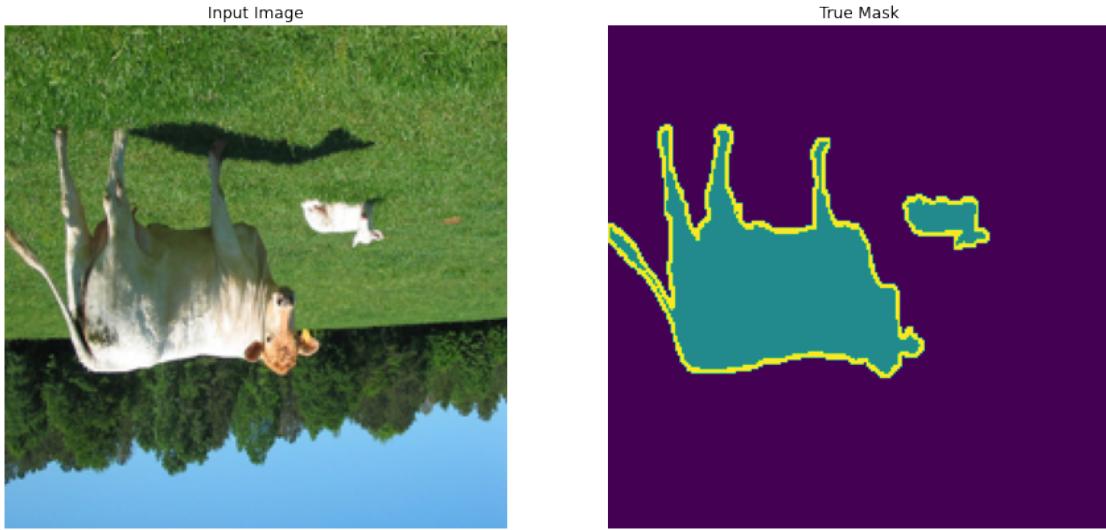
1.11 Create Batches for all 3 dataset

```
[ ]: train_batches = (  
      train_images_ds  
      .cache()  
      .shuffle(BUFFER_SIZE)  
      .batch(BATCH_SIZE)  
      .repeat()  
      #.map(Augment())  
      .prefetch(buffer_size=tf.data.experimental.AUTOTUNE))  
      #tf.data.AUTOTUNE  
  
test_batches = test_images_ds.batch(BATCH_SIZE)  
val_batches = val_images_ds.batch(BATCH_SIZE)
```

1.12 Sample images and masks

```
[ ]: for images, masks in train_batches.take(2).cache():  
      sample_image, sample_mask = images[0], masks[0]  
      display_images([sample_image, sample_mask])
```





1.13 Define Model using MobileNetV2

Use pretrained model MobileNetV2 and pick the layers for downsampling

```
[ ]: base_model = tf.keras.applications.MobileNetV2(input_shape=input_shape, ↴
    ↪include_top=False)

# Use the activations of these layers
layer_names = [
    'block_1_expand_relu',      # 64x64
    'block_3_expand_relu',      # 32x32
    'block_6_expand_relu',      # 16x16
    'block_13_expand_relu',     # 8x8
    'block_16_project',        # 4x4
]
base_model_outputs = [base_model.get_layer(name).output for name in layer_names]

# Create the feature extraction model
down_stack = tf.keras.Model(inputs=base_model.input, outputs=base_model_outputs)

down_stack.trainable = False
```

1.14 Pick the layers for upsampling

```
[ ]: up_stack = [
    pix2pix.upsample(512, 3),   # 4x4 -> 8x8
    pix2pix.upsample(256, 3),   # 8x8 -> 16x16
    pix2pix.upsample(128, 3),   # 16x16 -> 32x32
    pix2pix.upsample(64, 3),    # 32x32 -> 64x64
```

```
]
```

1.15 Combine above steps to create UNET model

```
[ ]: def unet_model(output_channels:int):
    inputs = tf.keras.layers.Input(shape=input_shape)

    # Downsampling through the model
    skips = down_stack(inputs)
    x = skips[-1]
    skips = reversed(skips[:-1])

    # Upsampling and establishing the skip connections
    for up, skip in zip(up_stack, skips):
        x = up(x)
        concat = tf.keras.layers.concatenate([x, skip])

    # This is the last layer of the model
    last = tf.keras.layers.Conv2DTranspose(
        filters=output_channels, kernel_size=2, strides=2,
        activation="sigmoid",
        padding='same')  #64x64 -> 128x128

    x = last(x)

    return tf.keras.Model(inputs=inputs, outputs=x)
```

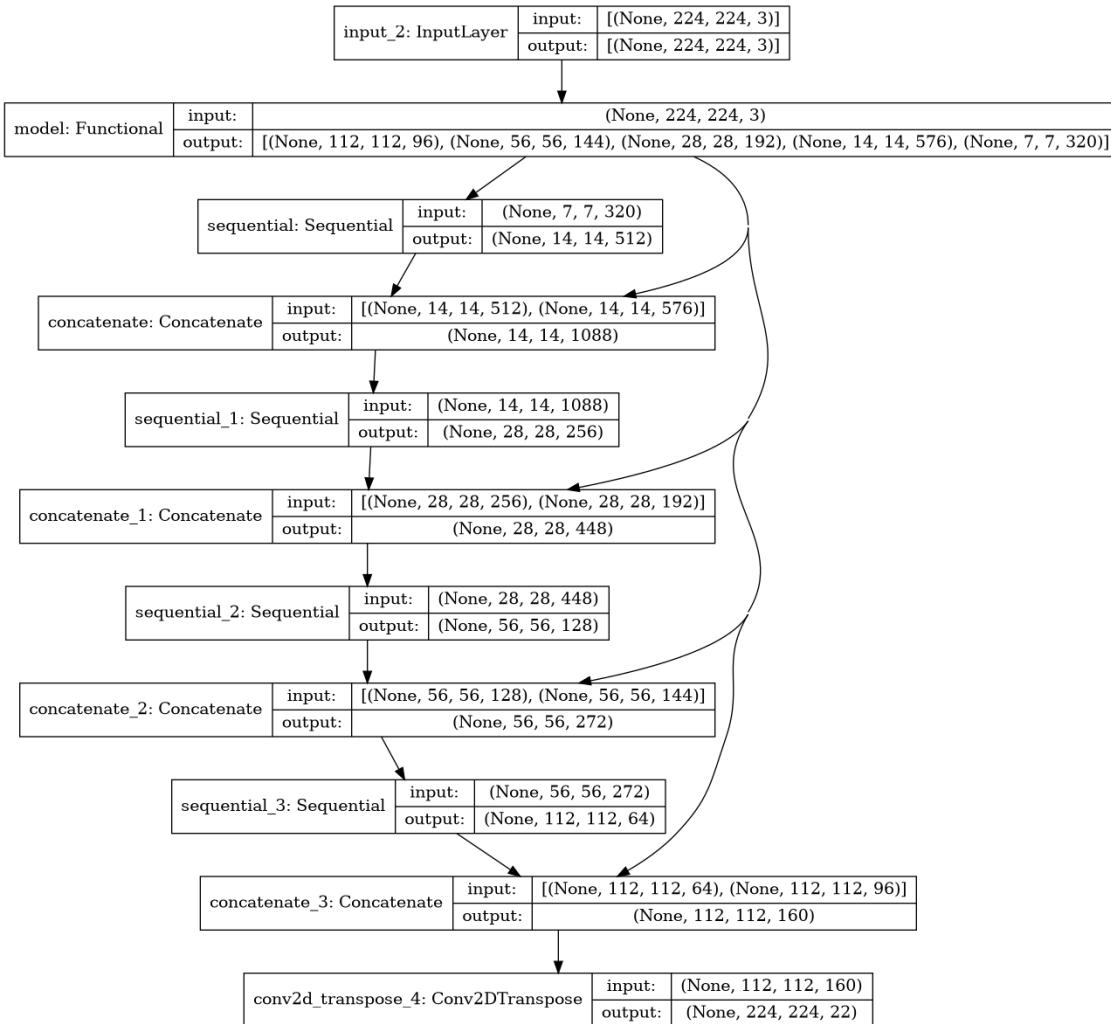
1.16 Compile unet model

```
[ ]: OUTPUT_CLASSES = 22

model = unet_model(output_channels=OUTPUT_CLASSES)
model.compile(optimizer='adam',
              loss=tf.keras.losses.
              →SparseCategoricalCrossentropy(from_logits=True),
              metrics=['accuracy'])
```

```
[ ]: tf.keras.utils.plot_model(model, show_shapes=True)
```

```
[ ]:
```



1.17 Functions to create mask

```
[ ]: def create_mask(pred_mask):
    pred_mask = tf.argmax(pred_mask, axis=-1)
    pred_mask = pred_mask[..., tf.newaxis]
    return pred_mask[0]
```

1.18 Functions to show detected classes, predictions alongside true mask and image

```
[ ]: classes = {0:"background", 1:"aeroplane", 2:"bicycle", 3:"bird", 4:"boat", 5:
    "bottle", 6:"bus", 7:"car",
    8:"cat", 9:"chair", 10:"cow", 11:"diningtable", 12:"dog", 13:
    "horse", 14:"motorbike", 15:"person",}
```

```

    16:"potted plant", 17:"sheep", 18:"sofa", 19:"train", 20:"tv/
→monitor",21:"Unknown"}}

def print_classes(class_arr):
    print("\nClasses detected:")
    for cls in class_arr:
        print(cls, classes[cls])

def show_predictions(dataset=None, num=1):
    if dataset:
        for image, mask in dataset.take(num):
            pred_mask = create_mask(model.predict(image))
            print_classes(np.unique(pred_mask))
            display_images([image[0], mask[0], pred_mask])
    else:
        pred_mask = create_mask(model.predict(sample_image[tf.newaxis, ...]))
        print_classes(np.unique(pred_mask))
        display_images([sample_image, sample_mask,pred_mask])

```

1.19 Predictions before training the model

[]: show_predictions()

```

2021-10-17 14:40:41.038622: I
tensorflow/compiler/mlir/mlir_graph_optimization_pass.cc:116] None of the MLIR
optimization passes are enabled (registered 2)
2021-10-17 14:40:41.055915: I
tensorflow/core/platform/profile_utils/cpu_utils.cc:112] CPU Frequency:
3601435000 Hz

```

Classes detected:

```

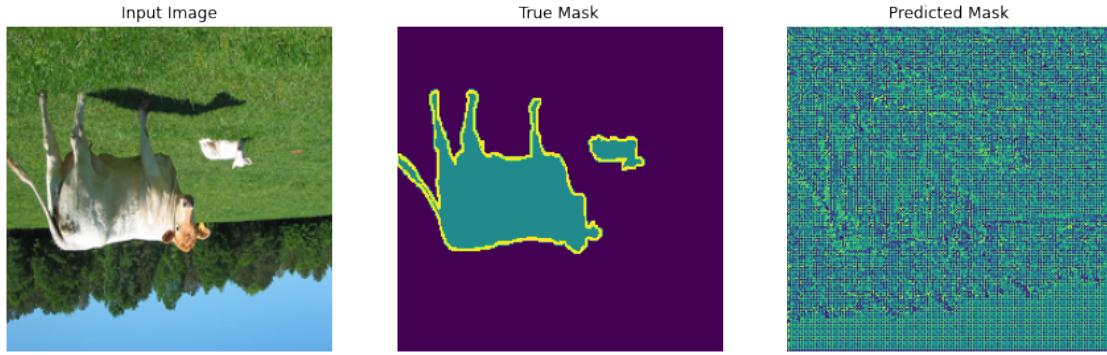
0 background
1 aeroplane
2 bicycle
3 bird
4 boat
5 bottle
6 bus
7 car
8 cat
9 chair
10 cow
11 diningtable
12 dog
13 horse
14 motorbike

```

```

16 potted plant
17 sheep
18 sofa
19 train
20 tv/monitor
21 Unknown

```



1.20 Callback functions for early stopping and Displaying information

```

[ ]: earlyStopCallback = tf.keras.callbacks.EarlyStopping(monitor='val_loss',
    ↪patience=3, min_delta=0.005, restore_best_weights=True)

class DisplayCallback(tf.keras.callbacks.Callback):
    def on_epoch_end(self, epoch, logs=None):
        #clear_output(wait=True)
        print('\nSample Prediction after epoch {} \n'.format(epoch+1))
        show_predictions()
        #for key in logs.keys():
        #    print("epoch {}, the {} is {:.2f}.".format(
        #        (epoch+1), key, logs[key]))
        #print(logs.keys())

```

1.21 Train the model

```

[ ]: EPOCHS = 30
VAL_SUBSPLITS = 5
VALIDATION_STEPS = VAL_LENGTH//BATCH_SIZE//VAL_SUBSPLITS #10
STEPS_PER_EPOCH = TRAIN_LENGTH // BATCH_SIZE
model_history = model.fit(train_batches, epochs=EPOCHS,
                           steps_per_epoch=STEPS_PER_EPOCH,
                           validation_steps=VALIDATION_STEPS,
                           validation_data=val_batches,
                           callbacks=[DisplayCallback(), earlyStopCallback])

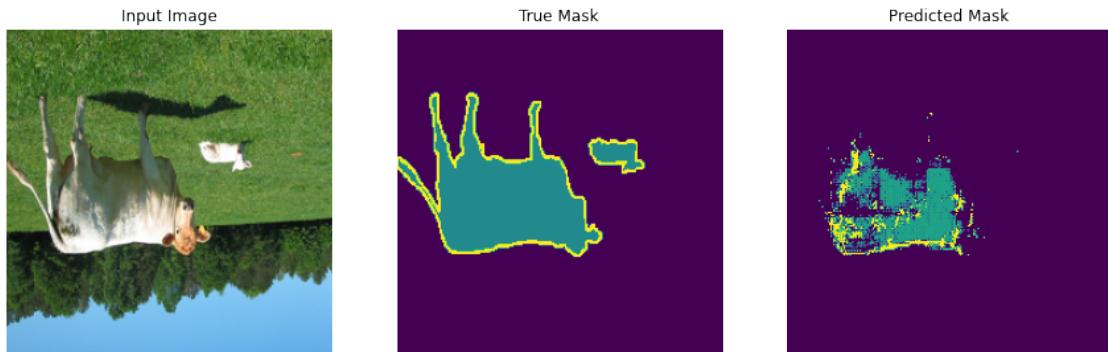
```

```
Epoch 1/30  
202/202 [=====] - 543s 3s/step - loss: 1.5218 -  
accuracy: 0.6297 - val_loss: 1.0282 - val_accuracy: 0.7113
```

Sample Prediction after epoch 1

Classes detected:

- 0 background
- 1 aeroplane
- 3 bird
- 8 cat
- 10 cow
- 12 dog
- 13 horse
- 14 motorbike
- 17 sheep
- 21 Unknown

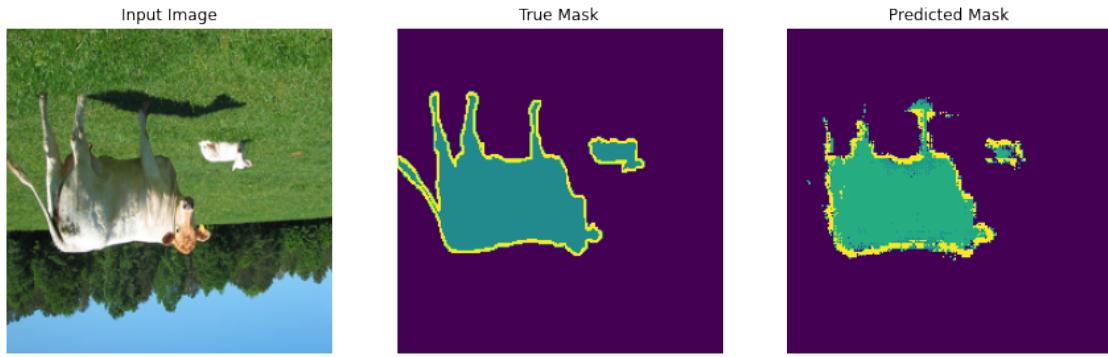


```
Epoch 2/30  
202/202 [=====] - 529s 3s/step - loss: 0.8427 -  
accuracy: 0.7600 - val_loss: 0.7738 - val_accuracy: 0.7516
```

Sample Prediction after epoch 2

Classes detected:

- 0 background
- 1 aeroplane
- 8 cat
- 10 cow
- 12 dog
- 13 horse
- 21 Unknown



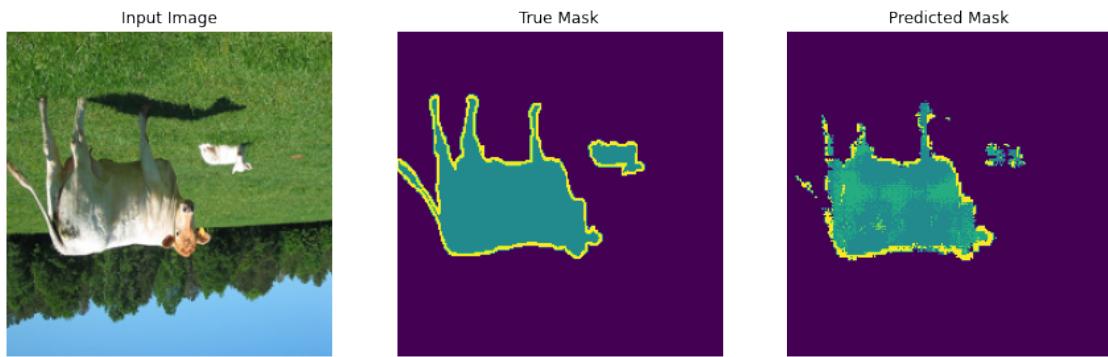
Epoch 3/30

```
202/202 [=====] - 524s 3s/step - loss: 0.6837 -
accuracy: 0.7953 - val_loss: 0.7434 - val_accuracy: 0.7809
```

Sample Prediction after epoch 3

Classes detected:

- 0 background
- 3 bird
- 10 cow
- 12 dog
- 13 horse
- 17 sheep
- 21 Unknown



Epoch 4/30

```
202/202 [=====] - 522s 3s/step - loss: 0.6355 -
accuracy: 0.8073 - val_loss: 0.6696 - val_accuracy: 0.7951
```

Sample Prediction after epoch 4

Classes detected:

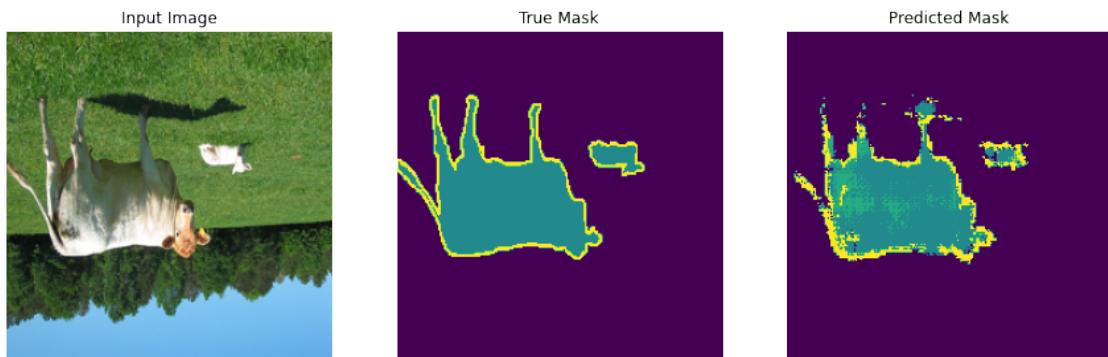
0 background

10 cow

13 horse

17 sheep

21 Unknown



Epoch 5/30

202/202 [=====] - 527s 3s/step - loss: 0.5672 -

accuracy: 0.8259 - val_loss: 0.6601 - val_accuracy: 0.7981

Sample Prediction after epoch 5

Classes detected:

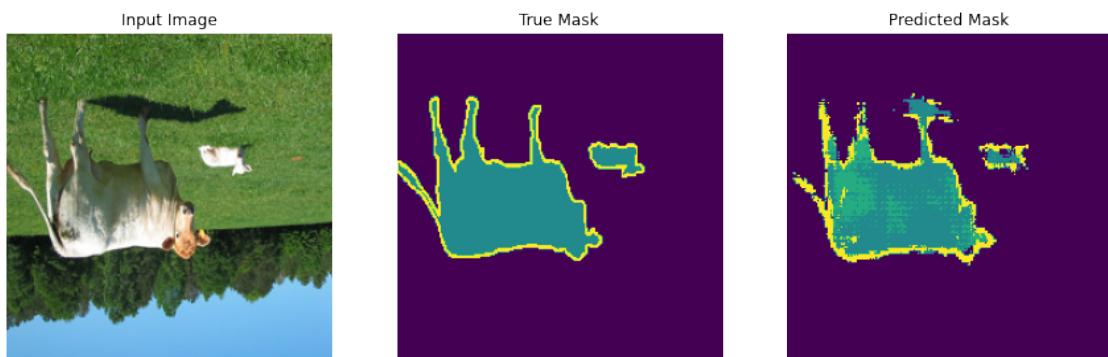
0 background

10 cow

13 horse

17 sheep

21 Unknown



Epoch 6/30

202/202 [=====] - 526s 3s/step - loss: 0.5450 -
accuracy: 0.8315 - val_loss: 0.6641 - val_accuracy: 0.7938

Sample Prediction after epoch 6

Classes detected:

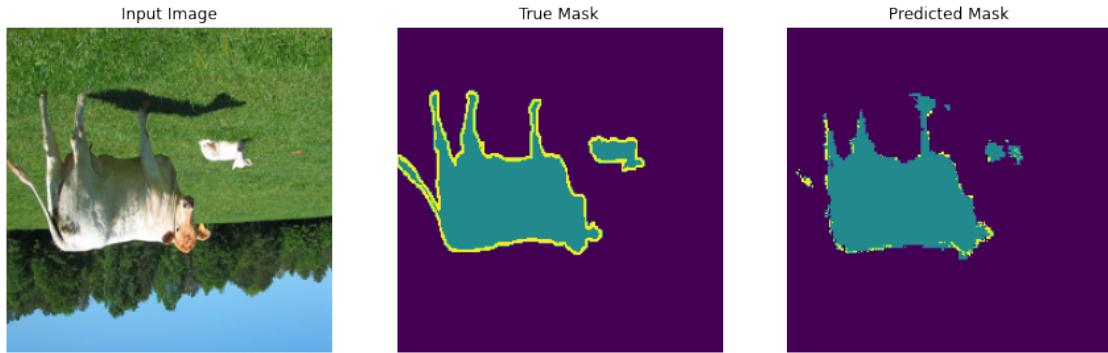
0 background

3 bird

10 cow

17 sheep

21 Unknown



Epoch 7/30

202/202 [=====] - 525s 3s/step - loss: 0.5268 -
accuracy: 0.8349 - val_loss: 0.6487 - val_accuracy: 0.8053

Sample Prediction after epoch 7

Classes detected:

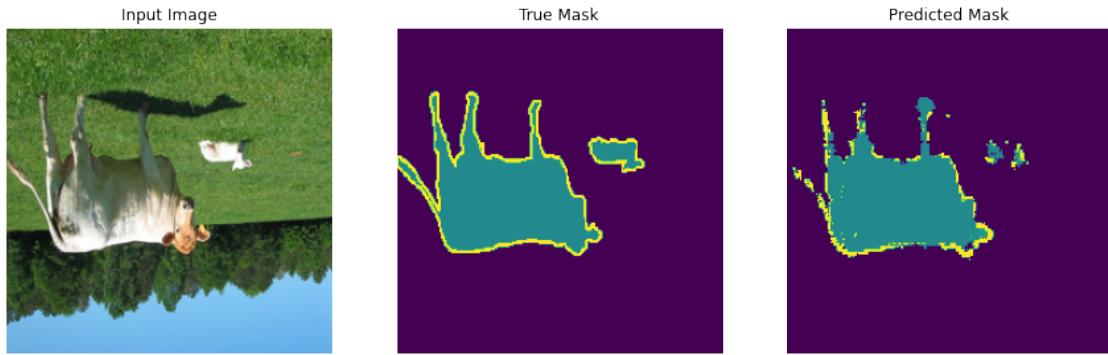
0 background

10 cow

13 horse

17 sheep

21 Unknown



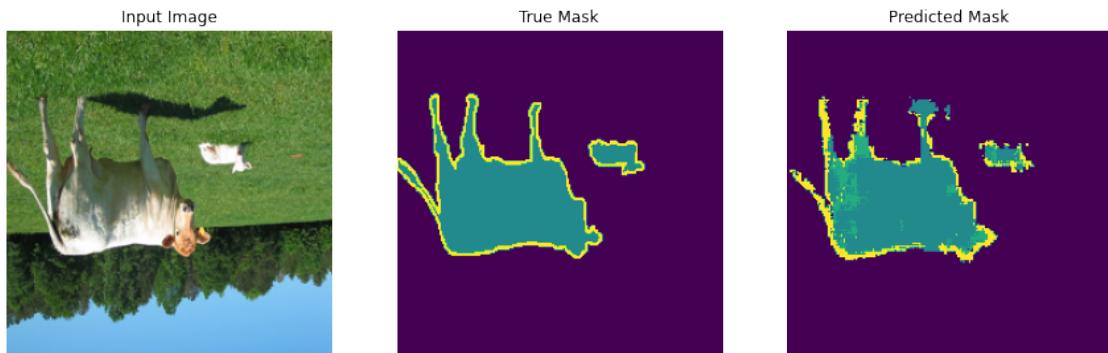
Epoch 8/30

```
202/202 [=====] - 526s 3s/step - loss: 0.4875 -
accuracy: 0.8469 - val_loss: 0.6432 - val_accuracy: 0.8014
```

Sample Prediction after epoch 8

Classes detected:

- 0 background
- 10 cow
- 13 horse
- 17 sheep
- 21 Unknown



Epoch 9/30

```
202/202 [=====] - 527s 3s/step - loss: 0.4845 -
accuracy: 0.8460 - val_loss: 0.6948 - val_accuracy: 0.7930
```

Sample Prediction after epoch 9

Classes detected:

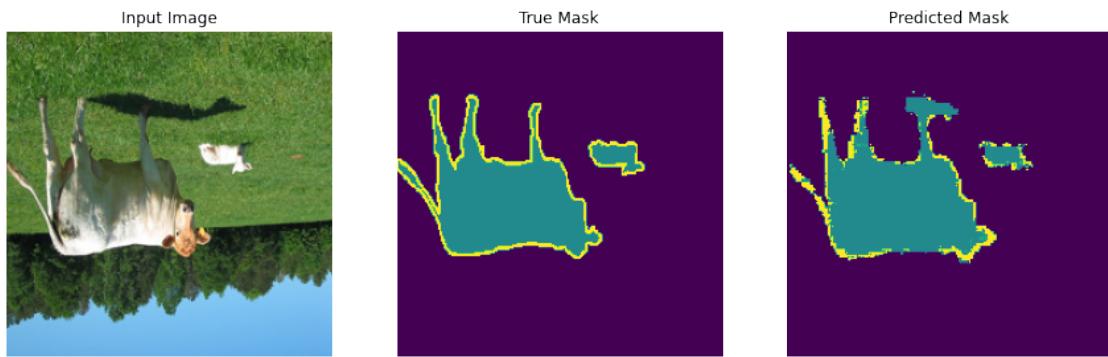
0 background

10 cow

13 horse

17 sheep

21 Unknown



Epoch 10/30

202/202 [=====] - 526s 3s/step - loss: 0.4576 -

accuracy: 0.8538 - val_loss: 0.6520 - val_accuracy: 0.8028

Sample Prediction after epoch 10

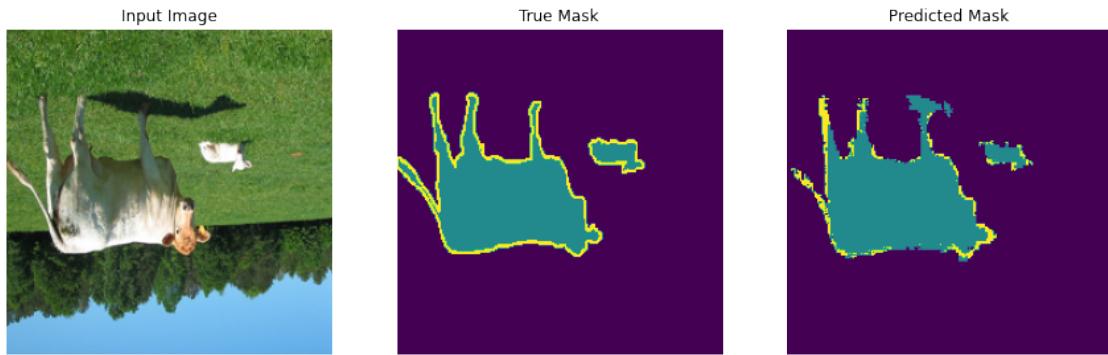
Classes detected:

0 background

10 cow

13 horse

21 Unknown



Epoch 11/30

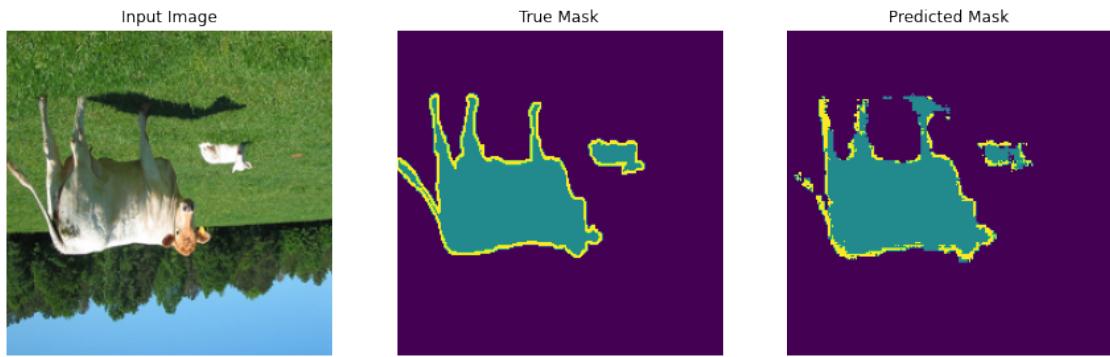
202/202 [=====] - 530s 3s/step - loss: 0.4346 -

```
accuracy: 0.8596 - val_loss: 0.6413 - val_accuracy: 0.8068
```

```
Sample Prediction after epoch 11
```

```
Classes detected:
```

```
0 background  
10 cow  
13 horse  
17 sheep  
21 Unknown
```

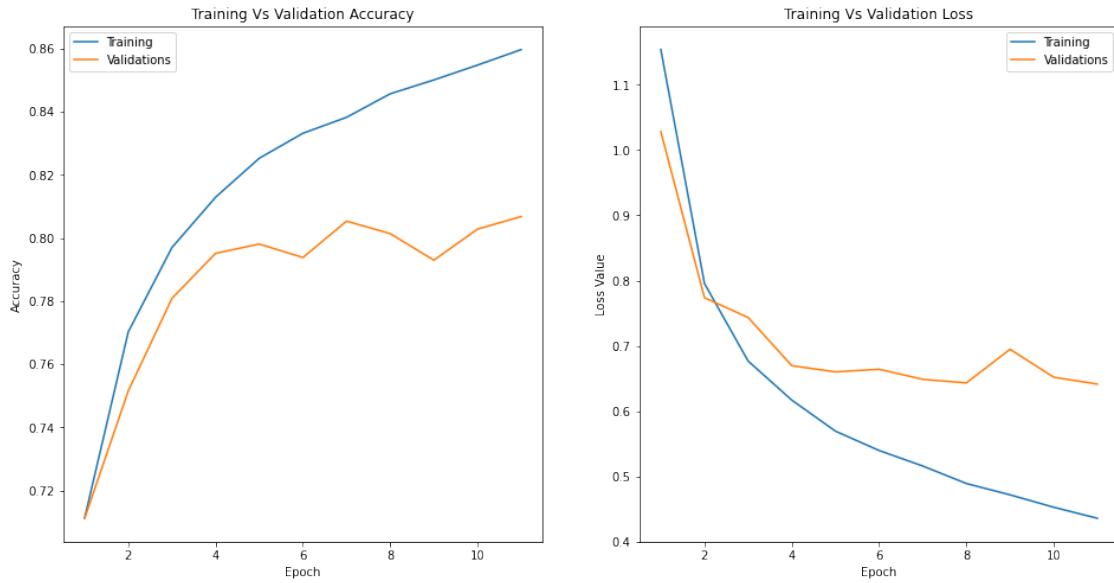


1.22 Plot accuracy and loss for training and validations

```
[ ]: length = len(model_history.history["accuracy"])+1

fig, ax = plt.subplots(nrows=1, ncols=2, figsize=(16, 8))
titles = ['Training Vs Validation Accuracy', 'Training Vs Validation Loss']
ax[0].set_title(titles[0])
ax[0].plot(range(1, length), model_history.history["accuracy"])
ax[0].plot(range(1, length), model_history.history["val_accuracy"])
ax[0].set_xlabel('Epoch')
ax[0].set_ylabel('Accuracy')
ax[0].legend(["Training", "Validations"])

ax[1].set_title(titles[1])
ax[1].plot(range(1, length), model_history.history["loss"])
ax[1].plot(range(1, length), model_history.history["val_loss"])
ax[1].set_xlabel('Epoch')
ax[1].set_ylabel('Loss Value')
ax[1].legend(["Training", "Validations"])
plt.show()
```



1.23 Evaluate model against test dataset

```
[ ]: model.evaluate(test_batches)
```

```
10/10 [=====] - 6s 631ms/step - loss: 0.4815 -
accuracy: 0.8518
```

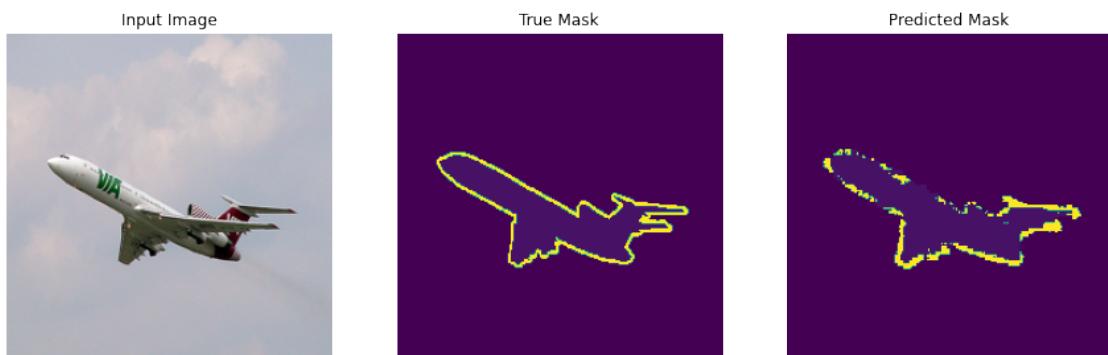
```
[ ]: [0.48146042227745056, 0.8518447875976562]
```

1.24 Sample predictions from validation dataset

```
[ ]: show_predictions(val_batches.shuffle(buffer_size=64), num =5)
```

Classes detected:

- 0 background
- 1 aeroplane
- 21 Unknown



Classes detected:

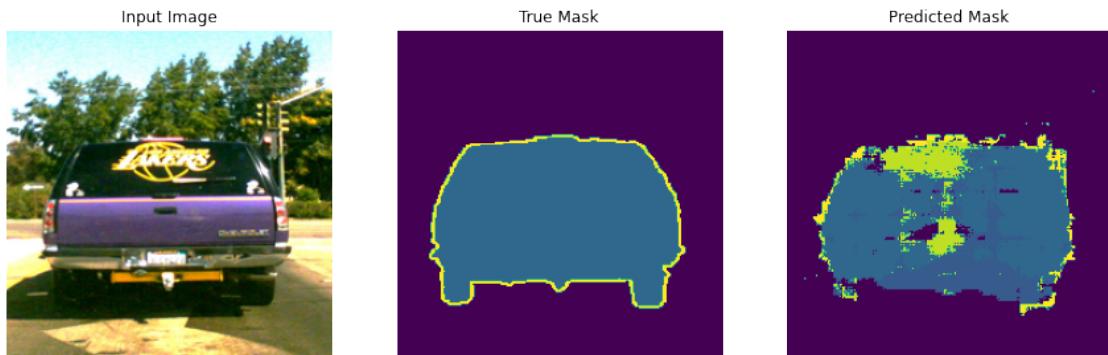
0 background

6 bus

7 car

19 train

21 Unknown

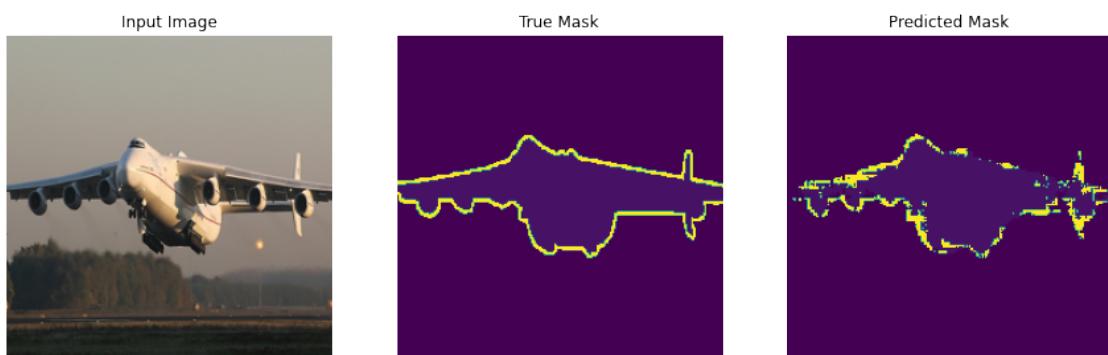


Classes detected:

0 background

1 aeroplane

21 Unknown



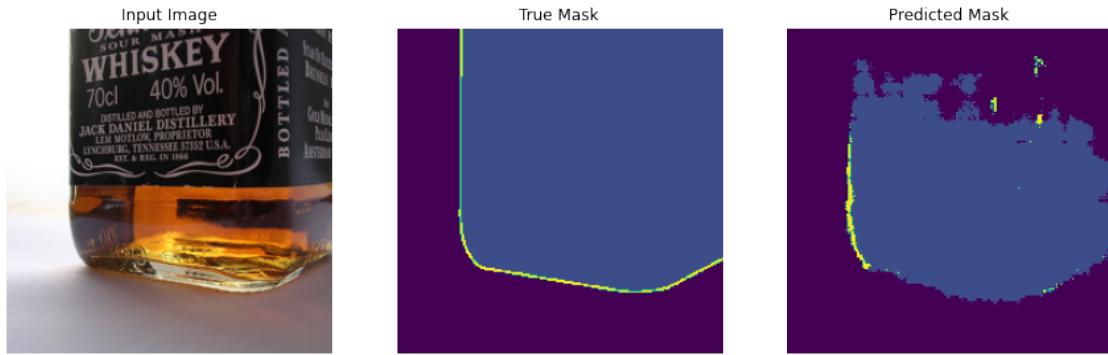
Classes detected:

0 background

4 boat

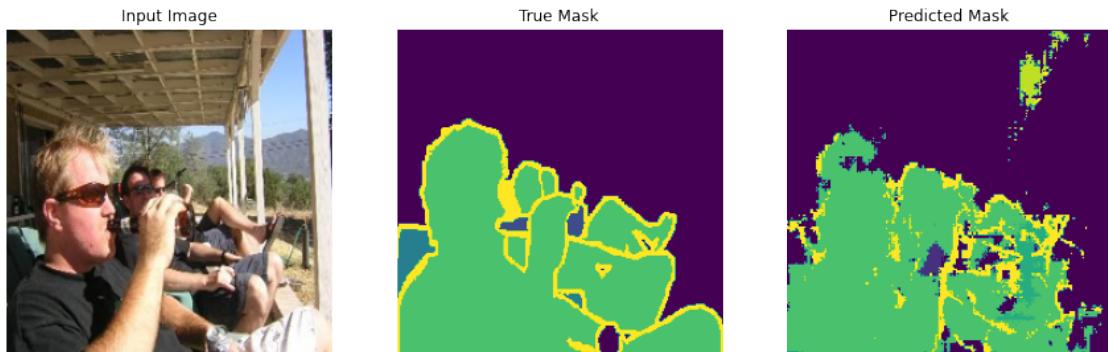
5 bottle

```
6 bus  
7 car  
20 tv/monitor  
21 Unknown
```



Classes detected:

```
0 background  
3 bird  
13 horse  
15 person  
19 train  
21 Unknown
```



1.25 Extract Images from original image using predicted mask from Test dataset

```
[ ]: def display_results(display_list):  
    plt.figure(figsize=(20, 15))  
  
    title = ['Input Image', 'True Mask', 'Predicted Mask', 'Segmented Image']
```

```

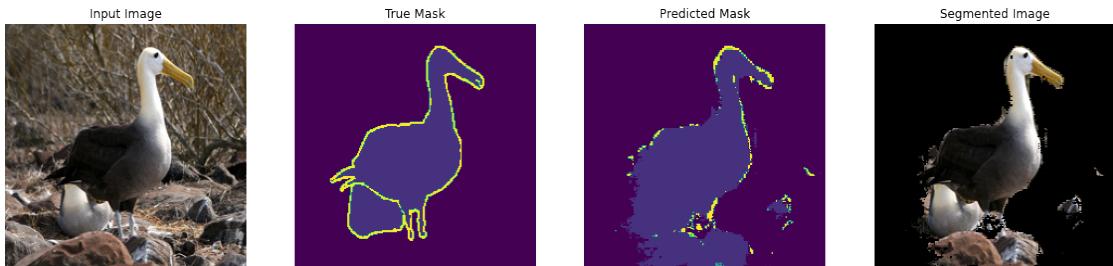
for i in range(len(display_list)):
    plt.subplot(1, len(display_list), i+1)
    plt.title(title[i])
    plt.imshow(display_list[i])
    plt.axis('off')
plt.show()

cnt = 0
for image, mask in test_batches.take(10):
    pred_mask_1 = model.predict(image)
    pred_mask_1 = create_mask(pred_mask_1)
    print_classes(np.unique(pred_mask_1))
    pred_mask = (np.array(pred_mask_1) !=0).astype(int)
    display_results([image[0], mask[0], pred_mask_1[:, :, 0], image[0] * pred_mask])
    cnt += 1

```

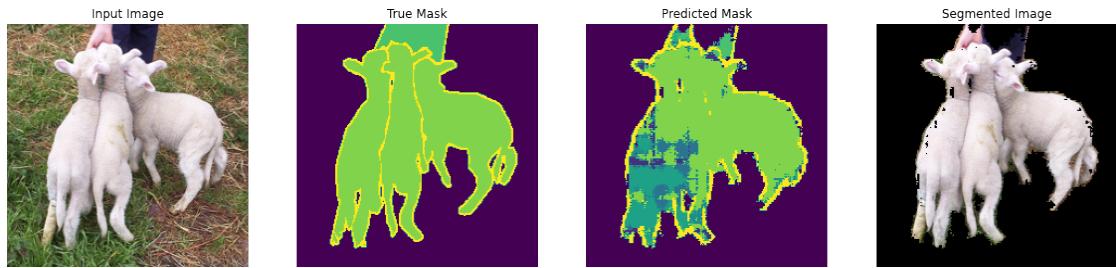
Classes detected:

0 background
 3 bird
 13 horse
 17 sheep
 21 Unknown



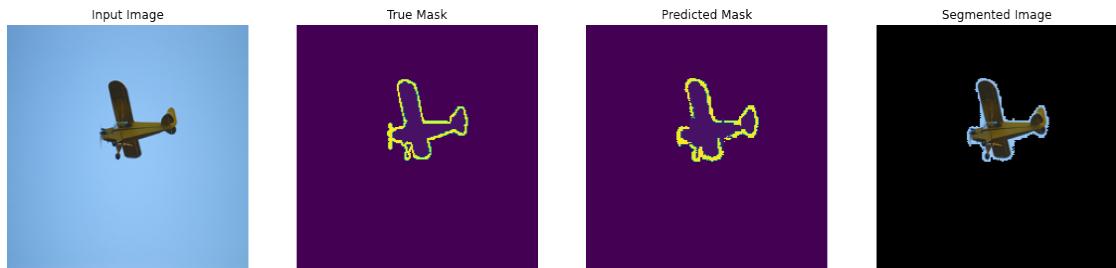
Classes detected:

0 background
 3 bird
 8 cat
 10 cow
 12 dog
 13 horse
 15 person
 17 sheep
 21 Unknown



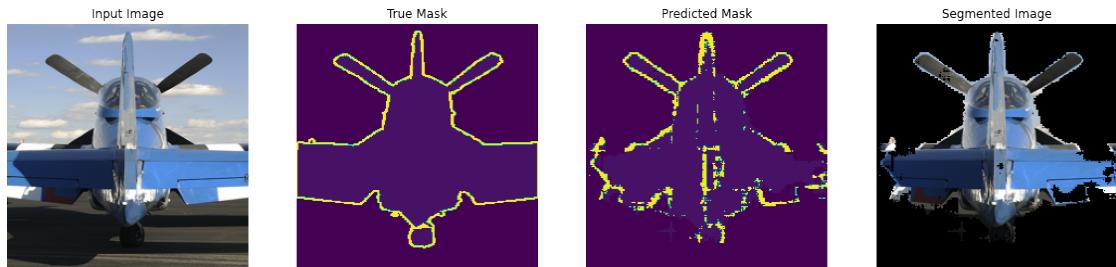
Classes detected:

- 0 background
- 1 aeroplane
- 21 Unknown



Classes detected:

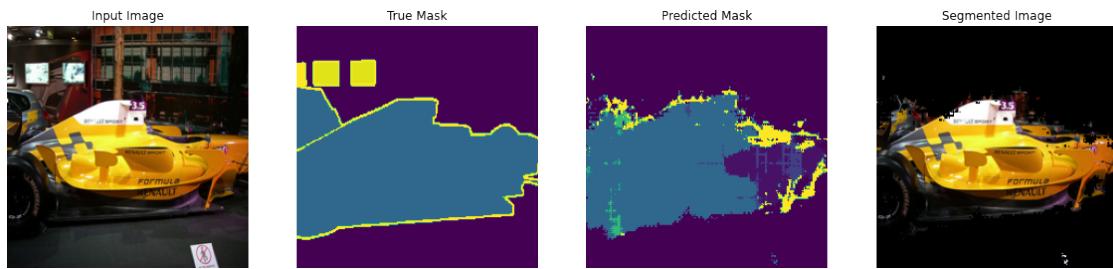
- 0 background
- 1 aeroplane
- 21 Unknown



Classes detected:

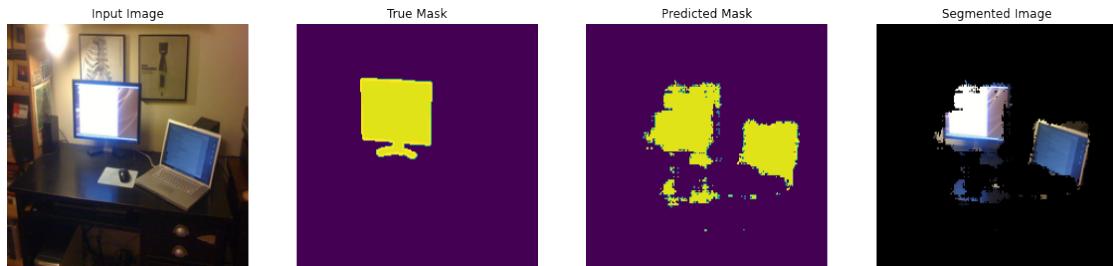
- 0 background
- 1 aeroplane

4 boat
5 bottle
7 car
14 motorbike
15 person
21 Unknown



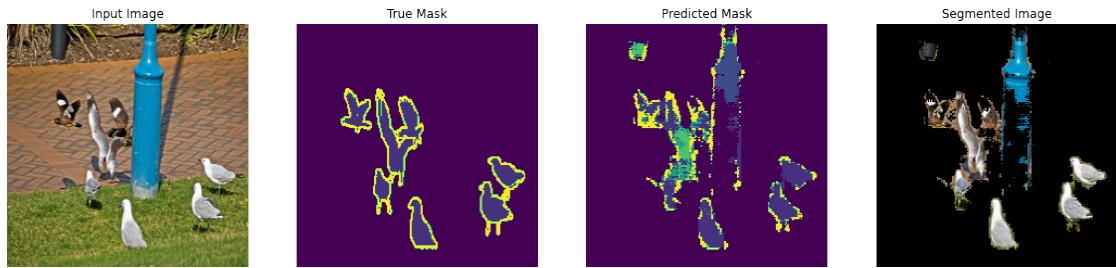
Classes detected:

0 background
20 tv/monitor
21 Unknown



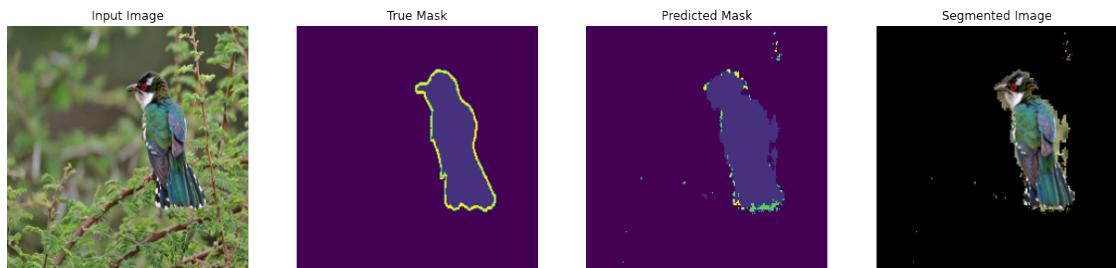
Classes detected:

0 background
3 bird
5 bottle
8 cat
12 dog
13 horse
15 person
21 Unknown



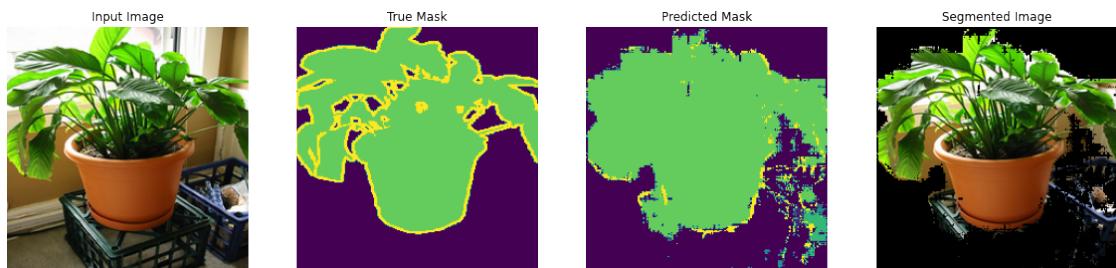
Classes detected:

- 0 background
- 3 bird
- 16 potted plant
- 21 Unknown



Classes detected:

- 0 background
- 2 bicycle
- 11 diningtable
- 14 motorbike
- 16 potted plant
- 21 Unknown



Classes detected:

0 background

3 bird

8 cat

10 cow

12 dog

13 horse

15 person

17 sheep

18 sofa

21 Unknown

