Untitled3

July 27, 2024

[1]:
```
import os
import numpy as np
import cv2
from glob import glob
import tensorflow as tf
import matplotlib.pyplot as plt
from sklearn.model_selection import train_test_split

from tensorflow.keras.layers import Conv2D, Activation, BatchNormalization,␣
↪UpSampling2D, Input, Concatenate, Cropping2D
from tensorflow.keras.models import Model
from tensorflow.keras.applications import MobileNetV2
from tensorflow.keras.callbacks import EarlyStopping, ReduceLROnPlateau
from tensorflow.keras import backend as K

# Set NumPy random seed for reproducibility
np.random.seed(42)

# Set TensorFlow random seed for reproducibility
tf.random.set_seed(42)

# Define image size for resizing input images and masks
WIDTH = 256
HEIGHT = 192

# Define number of epochs for training
EPOCHS = 2

# Define batch size
BATCH = 16

# Define learning rate for the optimizer
LR = 1e-4

# Define output path for saving training results and model
PATH = "/root/61541v001/V-03"
```

```
# Define label colors
colors = [
    (0, 0, 0), (128, 0, 0), (0, 128, 0), (128, 128, 0), (0, 0, 128),
    (128, 0, 128), (0, 128, 128), (128, 128, 128), (64, 0, 0), (192, 0, 0),
    (64, 128, 0), (192, 128, 0), (64, 0, 128), (192, 0, 128), (64, 128, 128),
    (192, 128, 128), (0, 64, 0), (128, 64, 0), (0, 192, 0), (128, 192, 0),
    (0, 64, 128), (128, 64, 12)
]
NUM_CLASSES = len(colors)
```

```
2024-07-27 08:08:49.294043: I tensorflow/core/util/port.cc:153] oneDNN custom
operations are on. You may see slightly different numerical results due to
floating-point round-off errors from different computation orders. To turn them
off, set the environment variable `TF_ENABLE_ONEDNN_OPTS=0`.
2024-07-27 08:08:49.303022: E
external/local_xla/xla/stream_executor/cuda/cuda_fft.cc:485] Unable to register
cuFFT factory: Attempting to register factory for plugin cuFFT when one has
already been registered
2024-07-27 08:08:49.311686: E
external/local_xla/xla/stream_executor/cuda/cuda_dnn.cc:8454] Unable to register
cuDNN factory: Attempting to register factory for plugin cuDNN when one has
already been registered
2024-07-27 08:08:49.314299: E
external/local_xla/xla/stream_executor/cuda/cuda_blas.cc:1452] Unable to
register cuBLAS factory: Attempting to register factory for plugin cuBLAS when
one has already been registered
2024-07-27 08:08:49.321880: I tensorflow/core/platform/cpu_feature_guard.cc:210]
This TensorFlow binary is optimized to use available CPU instructions in
performance-critical operations.
To enable the following instructions: AVX2 AVX512F AVX512_VNNI AVX512_BF16 FMA,
in other operations, rebuild TensorFlow with the appropriate compiler flags.
2024-07-27 08:08:49.708004: W
tensorflow/compiler/tf2tensorrt/utils/py_utils.cc:38] TF-TRT Warning: Could not
find TensorRT
```

[2]:
```
# Load dataset
def load_data(path, split=0.1):
    images = sorted(glob(os.path.join(PATH, "image/*")))
    masks = sorted(glob(os.path.join(PATH, "label/*")))
    total_size = len(images)
    valid_size = int(split * total_size)
    test_size = int(split * total_size)

    train_x, valid_x = train_test_split(images, test_size=valid_size,␣
 ↪random_state=42)
    train_y, valid_y = train_test_split(masks, test_size=valid_size,␣
 ↪random_state=42)
```

```
    train_x, test_x = train_test_split(train_x, test_size=test_size,␣
 ↪random_state=42)
    train_y, test_y = train_test_split(train_y, test_size=test_size,␣
 ↪random_state=42)

    return (train_x, train_y), (valid_x, valid_y), (test_x, test_y)

# Read and preprocess image
def read_image(path):
    if isinstance(path, bytes):
        path = path.decode()
    x = cv2.imread(path, cv2.IMREAD_COLOR)
    x = cv2.cvtColor(x, cv2.COLOR_BGR2RGB)
    x = cv2.resize(x, (WIDTH, HEIGHT))
    x = x / 255.0
    return x.astype(np.float32)

# Read and preprocess mask
def read_mask(path):
    if isinstance(path, bytes):
        path = path.decode()
    x = cv2.imread(path, cv2.IMREAD_GRAYSCALE)
    x = cv2.resize(x, (WIDTH, HEIGHT))
    x = x / 255.0
    x = np.round(x * (NUM_CLASSES - 1)).astype(np.uint8)
    x = tf.keras.utils.to_categorical(x, num_classes=NUM_CLASSES)
    return x.astype(np.float32)

# Parse function for TensorFlow dataset
def tf_parse(x, y):
    def _parse(x, y):
        x = read_image(x)
        y = read_mask(y)
        return x, y

    x, y = tf.numpy_function(_parse, [x, y], [tf.float32, tf.float32])
    x.set_shape([HEIGHT, WIDTH, 3])
    y.set_shape([HEIGHT, WIDTH, NUM_CLASSES])
    return x, y

# Create TensorFlow dataset
def tf_dataset(x, y, batch=8):
    dataset = tf.data.Dataset.from_tensor_slices((x, y))
    dataset = dataset.map(tf_parse)
    dataset = dataset.batch(batch)
    dataset = dataset.repeat()
    return dataset
```

```
# Parse mask for visualization
def mask_parse(mask):
    mask = np.argmax(mask, axis=-1)  # Convert one-hot encoded mask to␣
 ↪single-channel class mask
    rgb_mask = np.zeros((mask.shape[0], mask.shape[1], 3), dtype=np.uint8)  #␣
 ↪Create an empty color mask
    for i, color in enumerate(colors):
        rgb_mask[mask == i] = color  # Map class values to predefined colors
    return rgb_mask

# Build the model
def build_model():
    inputs = Input(shape=(HEIGHT, WIDTH, 3), name="input_image")
    encoder = MobileNetV2(input_tensor=inputs, weights="imagenet",␣
 ↪include_top=False, alpha=0.35)
    skip_connection_names = ["input_image", "block_1_expand_relu",␣
 ↪"block_3_expand_relu", "block_6_expand_relu"]
    encoder_output = encoder.get_layer("block_13_expand_relu").output
    f = [16, 32, 48, 64]
    x = encoder_output

    for i in range(1, len(skip_connection_names) + 1, 1):
        x_skip = encoder.get_layer(skip_connection_names[-i]).output
        x = UpSampling2D((2, 2))(x)
        height_diff = K.int_shape(x)[1] - K.int_shape(x_skip)[1]
        width_diff = K.int_shape(x)[2] - K.int_shape(x_skip)[2]
        if height_diff != 0 or width_diff != 0:
            x = Cropping2D(((height_diff // 2, height_diff - height_diff // 2),
                            (width_diff // 2, width_diff - width_diff // 2)))(x)
        x = Concatenate()([x, x_skip])
        x = Conv2D(f[-i], (3, 3), padding="same")(x)
        x = BatchNormalization()(x)
        x = Activation("relu")(x)
        x = Conv2D(f[-i], (3, 3), padding="same")(x)
        x = BatchNormalization()(x)
        x = Activation("relu")(x)

    x = Conv2D(NUM_CLASSES, (1, 1), padding="same")(x)
    x = Activation("softmax")(x)
    model = Model(inputs, x)
    return model
```

[3]:
```
# Load dataset
(train_x, train_y), (valid_x, valid_y), (test_x, test_y) = load_data(PATH)
print("Training data: ", len(train_x))
print("Validation data: ", len(valid_x))
```

```
print("Testing data: ", len(test_x))
```

```
Training data:  1477
Validation data:  184
Testing data:  184
```

[4]:
```
# Define custom metrics
def dice_coefficient(y_true, y_pred):
    y_true_f = tf.keras.backend.flatten(y_true)
    y_pred_f = tf.keras.backend.flatten(y_pred)
    intersection = tf.keras.backend.sum(y_true_f * y_pred_f)
    return (2. * intersection) / (tf.keras.backend.sum(y_true_f) + tf.keras.
 ↪backend.sum(y_pred_f))

def iou(y_true, y_pred):
    y_true_f = tf.keras.backend.flatten(y_true)
    y_pred_f = tf.keras.backend.flatten(y_pred)
    intersection = tf.keras.backend.sum(y_true_f * y_pred_f)
    union = tf.keras.backend.sum(y_true_f) + tf.keras.backend.sum(y_pred_f) -␣
 ↪intersection
    return intersection / union
```

[5]:
```
# Create and compile the model
model = build_model()
model.summary()
loss = tf.keras.losses.CategoricalCrossentropy()
opt = tf.keras.optimizers.Nadam(LR)
metrics = ['accuracy']
model.compile(loss=loss, optimizer=opt, metrics=['accuracy', dice_coefficient,␣
 ↪iou])
```

```
/tmp/ipykernel_2005/2080664991.py:68: UserWarning: `input_shape` is undefined or
non-square, or `rows` is not in [96, 128, 160, 192, 224]. Weights for input
shape (224, 224) will be loaded as the default.
  encoder = MobileNetV2(input_tensor=inputs, weights="imagenet",
include_top=False, alpha=0.35)
WARNING: All log messages before absl::InitializeLog() is called are written to
STDERR
I0000 00:00:1722067733.677033    2005 cuda_executor.cc:1015] successful NUMA
node read from SysFS had negative value (-1), but there must be at least one
NUMA node, so returning NUMA node zero. See more at
https://github.com/torvalds/linux/blob/v6.0/Documentation/ABI/testing/sysfs-bus-
pci#L344-L355
I0000 00:00:1722067733.712509    2005 cuda_executor.cc:1015] successful NUMA
node read from SysFS had negative value (-1), but there must be at least one
NUMA node, so returning NUMA node zero. See more at
https://github.com/torvalds/linux/blob/v6.0/Documentation/ABI/testing/sysfs-bus-
```

```
pci#L344-L355
I0000 00:00:1722067733.712711    2005 cuda_executor.cc:1015] successful NUMA
node read from SysFS had negative value (-1), but there must be at least one
NUMA node, so returning NUMA node zero. See more at
https://github.com/torvalds/linux/blob/v6.0/Documentation/ABI/testing/sysfs-bus-
pci#L344-L355
I0000 00:00:1722067733.714678    2005 cuda_executor.cc:1015] successful NUMA
node read from SysFS had negative value (-1), but there must be at least one
NUMA node, so returning NUMA node zero. See more at
https://github.com/torvalds/linux/blob/v6.0/Documentation/ABI/testing/sysfs-bus-
pci#L344-L355
I0000 00:00:1722067733.714819    2005 cuda_executor.cc:1015] successful NUMA
node read from SysFS had negative value (-1), but there must be at least one
NUMA node, so returning NUMA node zero. See more at
https://github.com/torvalds/linux/blob/v6.0/Documentation/ABI/testing/sysfs-bus-
pci#L344-L355
I0000 00:00:1722067733.714936    2005 cuda_executor.cc:1015] successful NUMA
node read from SysFS had negative value (-1), but there must be at least one
NUMA node, so returning NUMA node zero. See more at
https://github.com/torvalds/linux/blob/v6.0/Documentation/ABI/testing/sysfs-bus-
pci#L344-L355
I0000 00:00:1722067733.781295    2005 cuda_executor.cc:1015] successful NUMA
node read from SysFS had negative value (-1), but there must be at least one
NUMA node, so returning NUMA node zero. See more at
https://github.com/torvalds/linux/blob/v6.0/Documentation/ABI/testing/sysfs-bus-
pci#L344-L355
I0000 00:00:1722067733.781460    2005 cuda_executor.cc:1015] successful NUMA
node read from SysFS had negative value (-1), but there must be at least one
NUMA node, so returning NUMA node zero. See more at
https://github.com/torvalds/linux/blob/v6.0/Documentation/ABI/testing/sysfs-bus-
pci#L344-L355
I0000 00:00:1722067733.781585    2005 cuda_executor.cc:1015] successful NUMA
node read from SysFS had negative value (-1), but there must be at least one
NUMA node, so returning NUMA node zero. See more at
https://github.com/torvalds/linux/blob/v6.0/Documentation/ABI/testing/sysfs-bus-
pci#L344-L355
2024-07-27 08:08:53.781690: I
tensorflow/core/common_runtime/gpu/gpu_device.cc:2021] Created device
/job:localhost/replica:0/task:0/device:GPU:0 with 22288 MB memory:  -> device:
0, name: NVIDIA GeForce RTX 4090, pci bus id: 0000:02:00.0, compute capability:
8.9
```

Model: "functional"

Layer (type)	Output Shape	Param #	Connected to
input_image	(None, 192, 256,	0	-

(InputLayer)	3)		
Conv1 (Conv2D)	(None, 96, 128, 16)	432	input_image[0][0]
bn_Conv1 (BatchNormalizatio…	(None, 96, 128, 16)	64	Conv1[0][0]
Conv1_relu (ReLU)	(None, 96, 128, 16)	0	bn_Conv1[0][0]
expanded_conv_dept… (DepthwiseConv2D)	(None, 96, 128, 16)	144	Conv1_relu[0][0]
expanded_conv_dept… (BatchNormalizatio…	(None, 96, 128, 16)	64	expanded_conv_de…
expanded_conv_dept… (ReLU)	(None, 96, 128, 16)	0	expanded_conv_de…
expanded_conv_proj… (Conv2D)	(None, 96, 128, 8)	128	expanded_conv_de…
expanded_conv_proj… (BatchNormalizatio…	(None, 96, 128, 8)	32	expanded_conv_pr…
block_1_expand (Conv2D)	(None, 96, 128, 48)	384	expanded_conv_pr…
block_1_expand_BN (BatchNormalizatio…	(None, 96, 128, 48)	192	block_1_expand[0…
block_1_expand_relu (ReLU)	(None, 96, 128, 48)	0	block_1_expand_B…
block_1_pad (ZeroPadding2D)	(None, 97, 129, 48)	0	block_1_expand_r…
block_1_depthwise (DepthwiseConv2D)	(None, 48, 64, 48)	432	block_1_pad[0][0]
block_1_depthwise_… (BatchNormalizatio…	(None, 48, 64, 48)	192	block_1_depthwis…
block_1_depthwise_… (ReLU)	(None, 48, 64, 48)	0	block_1_depthwis…
block_1_project	(None, 48, 64, 8)	384	block_1_depthwis…

```
(Conv2D)

block_1_project_BN    (None, 48, 64, 8)          32   block_1_project[…
(BatchNormalizatio…

block_2_expand        (None, 48, 64,             384  block_1_project_…
(Conv2D)              48)

block_2_expand_BN     (None, 48, 64,             192  block_2_expand[0…
(BatchNormalizatio…   48)

block_2_expand_relu   (None, 48, 64,             0    block_2_expand_B…
(ReLU)                48)

block_2_depthwise     (None, 48, 64,             432  block_2_expand_r…
(DepthwiseConv2D)     48)

block_2_depthwise_…   (None, 48, 64,             192  block_2_depthwis…
(BatchNormalizatio…   48)

block_2_depthwise_…   (None, 48, 64,             0    block_2_depthwis…
(ReLU)                48)

block_2_project       (None, 48, 64, 8)          384  block_2_depthwis…
(Conv2D)

block_2_project_BN    (None, 48, 64, 8)          32   block_2_project[…
(BatchNormalizatio…

block_2_add (Add)     (None, 48, 64, 8)          0    block_1_project_…
                                                      block_2_project_…

block_3_expand        (None, 48, 64,             384  block_2_add[0][0]
(Conv2D)              48)

block_3_expand_BN     (None, 48, 64,             192  block_3_expand[0…
(BatchNormalizatio…   48)

block_3_expand_relu   (None, 48, 64,             0    block_3_expand_B…
(ReLU)                48)

block_3_pad           (None, 49, 65,             0    block_3_expand_r…
(ZeroPadding2D)       48)

block_3_depthwise     (None, 24, 32,             432  block_3_pad[0][0]
(DepthwiseConv2D)     48)

block_3_depthwise_…   (None, 24, 32,             192  block_3_depthwis…
```

```
(BatchNormalizatio…  48)

block_3_depthwise_…  (None, 24, 32,              0  block_3_depthwis…
(ReLU)               48)

block_3_project      (None, 24, 32,            768  block_3_depthwis…
(Conv2D)             16)

block_3_project_BN   (None, 24, 32,             64  block_3_project[…
(BatchNormalizatio…  16)

block_4_expand       (None, 24, 32,          1,536  block_3_project_…
(Conv2D)             96)

block_4_expand_BN    (None, 24, 32,            384  block_4_expand[0…
(BatchNormalizatio…  96)

block_4_expand_relu  (None, 24, 32,              0  block_4_expand_B…
(ReLU)               96)

block_4_depthwise    (None, 24, 32,            864  block_4_expand_r…
(DepthwiseConv2D)    96)

block_4_depthwise_…  (None, 24, 32,            384  block_4_depthwis…
(BatchNormalizatio…  96)

block_4_depthwise_…  (None, 24, 32,              0  block_4_depthwis…
(ReLU)               96)

block_4_project      (None, 24, 32,          1,536  block_4_depthwis…
(Conv2D)             16)

block_4_project_BN   (None, 24, 32,             64  block_4_project[…
(BatchNormalizatio…  16)

block_4_add (Add)    (None, 24, 32,              0  block_3_project_…
                     16)                            block_4_project_…

block_5_expand       (None, 24, 32,          1,536  block_4_add[0][0]
(Conv2D)             96)

block_5_expand_BN    (None, 24, 32,            384  block_5_expand[0…
(BatchNormalizatio…  96)

block_5_expand_relu  (None, 24, 32,              0  block_5_expand_B…
(ReLU)               96)

block_5_depthwise    (None, 24, 32,            864  block_5_expand_r…
```

(DepthwiseConv2D)	96)		
block_5_depthwise_… (BatchNormalizatio…	(None, 24, 32, 96)	384	block_5_depthwis…
block_5_depthwise_… (ReLU)	(None, 24, 32, 96)	0	block_5_depthwis…
block_5_project (Conv2D)	(None, 24, 32, 16)	1,536	block_5_depthwis…
block_5_project_BN (BatchNormalizatio…	(None, 24, 32, 16)	64	block_5_project[…
block_5_add (Add)	(None, 24, 32, 16)	0	block_4_add[0][0… block_5_project_…
block_6_expand (Conv2D)	(None, 24, 32, 96)	1,536	block_5_add[0][0]
block_6_expand_BN (BatchNormalizatio…	(None, 24, 32, 96)	384	block_6_expand[0…
block_6_expand_relu (ReLU)	(None, 24, 32, 96)	0	block_6_expand_B…
block_6_pad (ZeroPadding2D)	(None, 25, 33, 96)	0	block_6_expand_r…
block_6_depthwise (DepthwiseConv2D)	(None, 12, 16, 96)	864	block_6_pad[0][0]
block_6_depthwise_… (BatchNormalizatio…	(None, 12, 16, 96)	384	block_6_depthwis…
block_6_depthwise_… (ReLU)	(None, 12, 16, 96)	0	block_6_depthwis…
block_6_project (Conv2D)	(None, 12, 16, 24)	2,304	block_6_depthwis…
block_6_project_BN (BatchNormalizatio…	(None, 12, 16, 24)	96	block_6_project[…
block_7_expand (Conv2D)	(None, 12, 16, 144)	3,456	block_6_project_…
block_7_expand_BN	(None, 12, 16,	576	block_7_expand[0…

```
(BatchNormalizatio…  144)

block_7_expand_relu  (None, 12, 16,              0  block_7_expand_B…
(ReLU)               144)

block_7_depthwise    (None, 12, 16,          1,296  block_7_expand_r…
(DepthwiseConv2D)    144)

block_7_depthwise_…  (None, 12, 16,            576  block_7_depthwis…
(BatchNormalizatio…  144)

block_7_depthwise_…  (None, 12, 16,              0  block_7_depthwis…
(ReLU)               144)

block_7_project      (None, 12, 16,          3,456  block_7_depthwis…
(Conv2D)             24)

block_7_project_BN   (None, 12, 16,             96  block_7_project[…
(BatchNormalizatio…  24)

block_7_add (Add)    (None, 12, 16,              0  block_6_project_…
                     24)                         block_7_project_…

block_8_expand       (None, 12, 16,          3,456  block_7_add[0][0]
(Conv2D)             144)

block_8_expand_BN    (None, 12, 16,            576  block_8_expand[0…
(BatchNormalizatio…  144)

block_8_expand_relu  (None, 12, 16,              0  block_8_expand_B…
(ReLU)               144)

block_8_depthwise    (None, 12, 16,          1,296  block_8_expand_r…
(DepthwiseConv2D)    144)

block_8_depthwise_…  (None, 12, 16,            576  block_8_depthwis…
(BatchNormalizatio…  144)

block_8_depthwise_…  (None, 12, 16,              0  block_8_depthwis…
(ReLU)               144)

block_8_project      (None, 12, 16,          3,456  block_8_depthwis…
(Conv2D)             24)

block_8_project_BN   (None, 12, 16,             96  block_8_project[…
(BatchNormalizatio…  24)

block_8_add (Add)    (None, 12, 16,              0  block_7_add[0][0…
```

	24)		block_8_project_…
block_9_expand (Conv2D)	(None, 12, 16, 144)	3,456	block_8_add[0][0]
block_9_expand_BN (BatchNormalizatio…	(None, 12, 16, 144)	576	block_9_expand[0…
block_9_expand_relu (ReLU)	(None, 12, 16, 144)	0	block_9_expand_B…
block_9_depthwise (DepthwiseConv2D)	(None, 12, 16, 144)	1,296	block_9_expand_r…
block_9_depthwise_… (BatchNormalizatio…	(None, 12, 16, 144)	576	block_9_depthwis…
block_9_depthwise_… (ReLU)	(None, 12, 16, 144)	0	block_9_depthwis…
block_9_project (Conv2D)	(None, 12, 16, 24)	3,456	block_9_depthwis…
block_9_project_BN (BatchNormalizatio…	(None, 12, 16, 24)	96	block_9_project[…
block_9_add (Add)	(None, 12, 16, 24)	0	block_8_add[0][0… block_9_project_…
block_10_expand (Conv2D)	(None, 12, 16, 144)	3,456	block_9_add[0][0]
block_10_expand_BN (BatchNormalizatio…	(None, 12, 16, 144)	576	block_10_expand[…
block_10_expand_re… (ReLU)	(None, 12, 16, 144)	0	block_10_expand_…
block_10_depthwise (DepthwiseConv2D)	(None, 12, 16, 144)	1,296	block_10_expand_…
block_10_depthwise… (BatchNormalizatio…	(None, 12, 16, 144)	576	block_10_depthwi…
block_10_depthwise… (ReLU)	(None, 12, 16, 144)	0	block_10_depthwi…
block_10_project	(None, 12, 16,	4,608	block_10_depthwi…

```
(Conv2D)                 32)

block_10_project_BN      (None, 12, 16,            128   block_10_project…
(BatchNormalizatio…      32)

block_11_expand          (None, 12, 16,          6,144   block_10_project…
(Conv2D)                 192)

block_11_expand_BN       (None, 12, 16,            768   block_11_expand[…
(BatchNormalizatio…      192)

block_11_expand_re…      (None, 12, 16,              0   block_11_expand_…
(ReLU)                   192)

block_11_depthwise       (None, 12, 16,          1,728   block_11_expand_…
(DepthwiseConv2D)        192)

block_11_depthwise…      (None, 12, 16,            768   block_11_depthwi…
(BatchNormalizatio…      192)

block_11_depthwise…      (None, 12, 16,              0   block_11_depthwi…
(ReLU)                   192)

block_11_project         (None, 12, 16,          6,144   block_11_depthwi…
(Conv2D)                 32)

block_11_project_BN      (None, 12, 16,            128   block_11_project…
(BatchNormalizatio…      32)

block_11_add (Add)       (None, 12, 16,              0   block_10_project…
                         32)                           block_11_project…

block_12_expand          (None, 12, 16,          6,144   block_11_add[0][…
(Conv2D)                 192)

block_12_expand_BN       (None, 12, 16,            768   block_12_expand[…
(BatchNormalizatio…      192)

block_12_expand_re…      (None, 12, 16,              0   block_12_expand_…
(ReLU)                   192)

block_12_depthwise       (None, 12, 16,          1,728   block_12_expand_…
(DepthwiseConv2D)        192)

block_12_depthwise…      (None, 12, 16,            768   block_12_depthwi…
(BatchNormalizatio…      192)

block_12_depthwise…      (None, 12, 16,              0   block_12_depthwi…
```

(ReLU)	192)		
block_12_project (Conv2D)	(None, 12, 16, 32)	6,144	block_12_depthwi…
block_12_project_BN (BatchNormalizatio…	(None, 12, 16, 32)	128	block_12_project…
block_12_add (Add)	(None, 12, 16, 32)	0	block_11_add[0][… block_12_project…
block_13_expand (Conv2D)	(None, 12, 16, 192)	6,144	block_12_add[0][…
block_13_expand_BN (BatchNormalizatio…	(None, 12, 16, 192)	768	block_13_expand[…
block_13_expand_re… (ReLU)	(None, 12, 16, 192)	0	block_13_expand_…
up_sampling2d (UpSampling2D)	(None, 24, 32, 192)	0	block_13_expand_…
concatenate (Concatenate)	(None, 24, 32, 288)	0	up_sampling2d[0]… block_6_expand_r…
conv2d (Conv2D)	(None, 24, 32, 64)	165,952	concatenate[0][0]
batch_normalization (BatchNormalizatio…	(None, 24, 32, 64)	256	conv2d[0][0]
activation (Activation)	(None, 24, 32, 64)	0	batch_normalizat…
conv2d_1 (Conv2D)	(None, 24, 32, 64)	36,928	activation[0][0]
batch_normalizatio… (BatchNormalizatio…	(None, 24, 32, 64)	256	conv2d_1[0][0]
activation_1 (Activation)	(None, 24, 32, 64)	0	batch_normalizat…
up_sampling2d_1 (UpSampling2D)	(None, 48, 64, 64)	0	activation_1[0][…
concatenate_1	(None, 48, 64,	0	up_sampling2d_1[…

(Concatenate)	112)		block_3_expand_r…
conv2d_2 (Conv2D)	(None, 48, 64, 48)	48,432	concatenate_1[0]…
batch_normalizatio… (BatchNormalizatio…	(None, 48, 64, 48)	192	conv2d_2[0][0]
activation_2 (Activation)	(None, 48, 64, 48)	0	batch_normalizat…
conv2d_3 (Conv2D)	(None, 48, 64, 48)	20,784	activation_2[0][…
batch_normalizatio… (BatchNormalizatio…	(None, 48, 64, 48)	192	conv2d_3[0][0]
activation_3 (Activation)	(None, 48, 64, 48)	0	batch_normalizat…
up_sampling2d_2 (UpSampling2D)	(None, 96, 128, 48)	0	activation_3[0][…
concatenate_2 (Concatenate)	(None, 96, 128, 96)	0	up_sampling2d_2[… block_1_expand_r…
conv2d_4 (Conv2D)	(None, 96, 128, 32)	27,680	concatenate_2[0]…
batch_normalizatio… (BatchNormalizatio…	(None, 96, 128, 32)	128	conv2d_4[0][0]
activation_4 (Activation)	(None, 96, 128, 32)	0	batch_normalizat…
conv2d_5 (Conv2D)	(None, 96, 128, 32)	9,248	activation_4[0][…
batch_normalizatio… (BatchNormalizatio…	(None, 96, 128, 32)	128	conv2d_5[0][0]
activation_5 (Activation)	(None, 96, 128, 32)	0	batch_normalizat…
up_sampling2d_3 (UpSampling2D)	(None, 192, 256, 32)	0	activation_5[0][…
concatenate_3	(None, 192, 256,	0	up_sampling2d_3[…

(Concatenate)	35)		input_image[0][0]
conv2d_6 (Conv2D)	(None, 192, 256, 16)	5,056	concatenate_3[0]…
batch_normalizatio… (BatchNormalizatio…	(None, 192, 256, 16)	64	conv2d_6[0][0]
activation_6 (Activation)	(None, 192, 256, 16)	0	batch_normalizat…
conv2d_7 (Conv2D)	(None, 192, 256, 16)	2,320	activation_6[0][…
batch_normalizatio… (BatchNormalizatio…	(None, 192, 256, 16)	64	conv2d_7[0][0]
activation_7 (Activation)	(None, 192, 256, 16)	0	batch_normalizat…
conv2d_8 (Conv2D)	(None, 192, 256, 22)	374	activation_7[0][…
activation_8 (Activation)	(None, 192, 256, 22)	0	conv2d_8[0][0]

Total params: 416,566 (1.59 MB)

Trainable params: 409,382 (1.56 MB)

Non-trainable params: 7,184 (28.06 KB)

[6]:
```
# Define callbacks
callbacks = [
    ReduceLROnPlateau(monitor='val_loss', factor=0.1, patience=4),
    EarlyStopping(monitor='val_loss', patience=10, restore_best_weights=False)
]

train_steps = len(train_x) // BATCH
valid_steps = len(valid_x) // BATCH
if len(train_x) % BATCH != 0:
    train_steps += 1
if len(valid_x) % BATCH != 0:
    valid_steps += 1
```

```
train_dataset = tf_dataset(train_x, train_y, batch=BATCH)
valid_dataset = tf_dataset(valid_x, valid_y, batch=BATCH)

# Train the model and record history
history = model.fit(
    train_dataset,
    validation_data=valid_dataset,
    epochs=EPOCHS,
    steps_per_epoch=train_steps,
    validation_steps=valid_steps,
    callbacks=callbacks
)
```

```
Epoch 1/2
```

```
WARNING: All log messages before absl::InitializeLog() is called are written to
STDERR
I0000 00:00:1722067751.371010    2452 service.cc:146] XLA service 0x7f890c015350
initialized for platform CUDA (this does not guarantee that XLA will be used).
Devices:
I0000 00:00:1722067751.371038    2452 service.cc:154]   StreamExecutor device
(0): NVIDIA GeForce RTX 4090, Compute Capability 8.9
2024-07-27 08:09:11.716538: I
tensorflow/compiler/mlir/tensorflow/utils/dump_mlir_util.cc:268] disabling MLIR
crash reproducer, set env var `MLIR_CRASH_REPRODUCER_DIRECTORY` to enable.
2024-07-27 08:09:12.771766: I
external/local_xla/xla/stream_executor/cuda/cuda_dnn.cc:531] Loaded cuDNN
version 8900
```

```
 1/93              31:38 21s/step - accuracy:
0.0321 - dice_coefficient: 0.0453 - iou: 0.0232 - loss: 3.2806
```

```
I0000 00:00:1722067762.916668    2452 device_compiler.h:188] Compiled cluster
using XLA!  This line is logged at most once for the lifetime of the process.
```

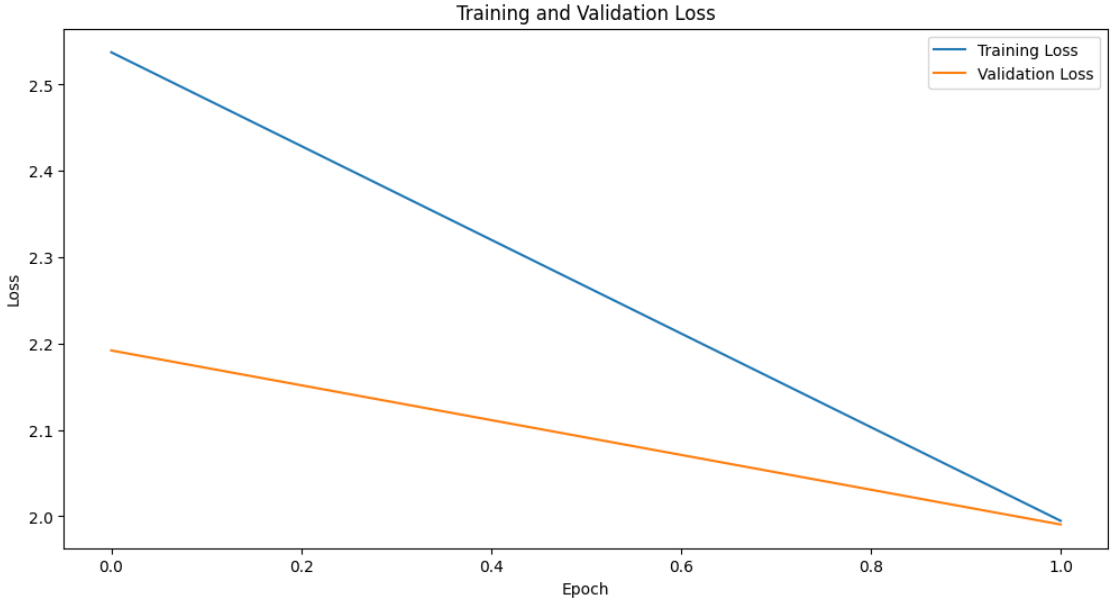
```
93/93             116s 1s/step -
accuracy: 0.1365 - dice_coefficient: 0.0752 - iou: 0.0393 - loss: 2.8452 -
val_accuracy: 0.6141 - val_dice_coefficient: 0.1498 - val_iou: 0.0810 -
val_loss: 2.1921 - learning_rate: 1.0000e-04
Epoch 2/2
93/93             82s 896ms/step -
accuracy: 0.6402 - dice_coefficient: 0.1607 - iou: 0.0874 - loss: 2.0575 -
val_accuracy: 0.7394 - val_dice_coefficient: 0.1690 - val_iou: 0.0923 -
val_loss: 1.9906 - learning_rate: 1.0000e-04
```

[7]:
```
# Evaluate the model
test_dataset = tf_dataset(test_x, test_y, batch=BATCH)
test_steps = (len(test_x) // BATCH)
```

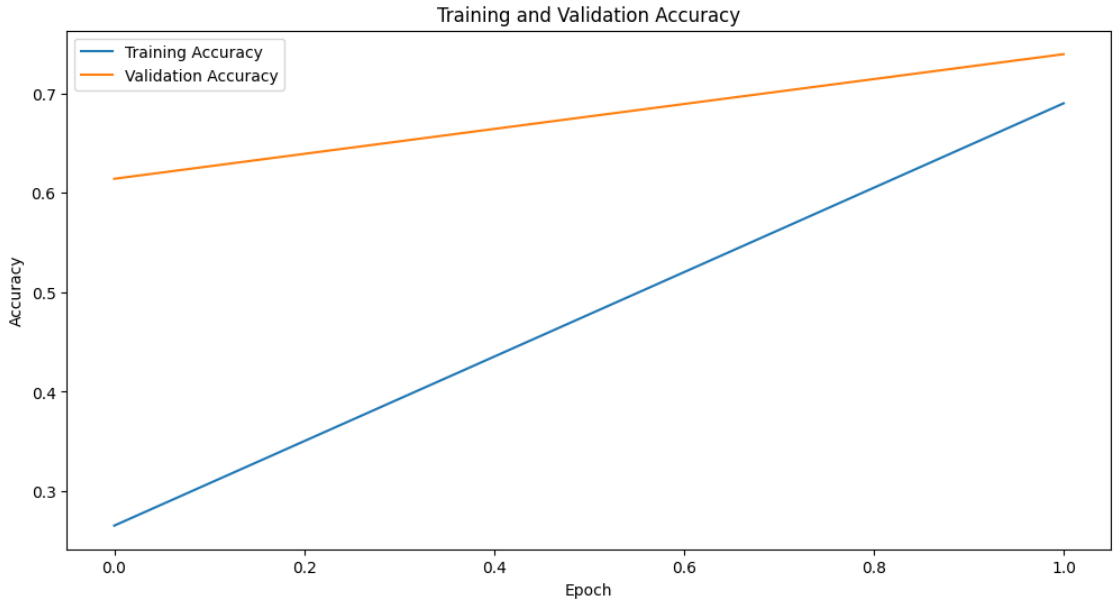
```
if len(test_x) % BATCH != 0:
    test_steps += 1
results = model.evaluate(test_dataset, steps=test_steps)

# Get metric names
metrics_names = model.metrics_names

# Print evaluation results
for name, value in zip(metrics_names, results):
    print(f"{name}: {value:.4f}")
```

```
12/12            10s 787ms/step -
accuracy: 0.7197 - dice_coefficient: 0.1651 - iou: 0.0900 - loss: 2.0211
loss: 2.0243
compile_metrics: 0.7207
```

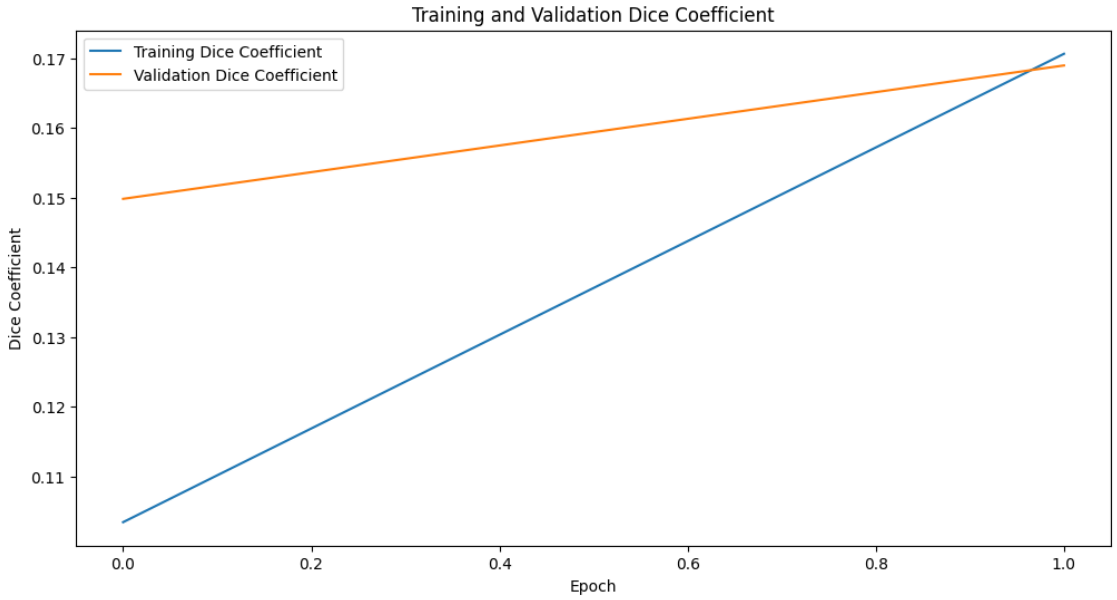
[8]:
```
# Plot training and validation loss
plt.figure(figsize=(12, 6))
plt.plot(history.history['loss'], label='Training Loss')
plt.plot(history.history['val_loss'], label='Validation Loss')
plt.legend()
plt.title('Training and Validation Loss')
plt.xlabel('Epoch')
plt.ylabel('Loss')
plt.show()
```



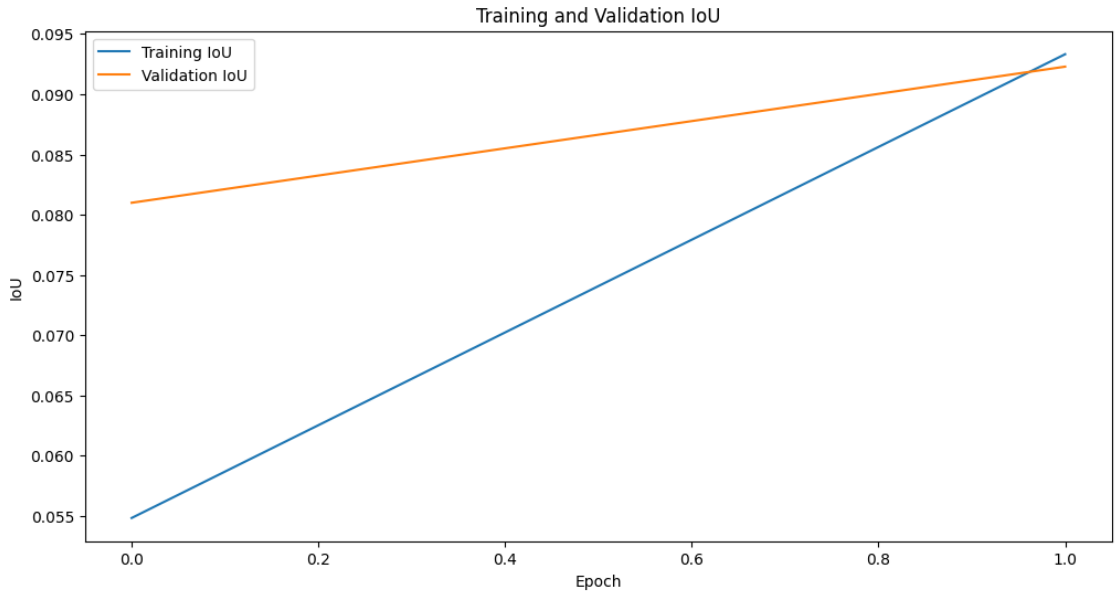
[9]:
```
# Plot training and validation accuracy
plt.figure(figsize=(12, 6))
plt.plot(history.history['accuracy'], label='Training Accuracy')
plt.plot(history.history['val_accuracy'], label='Validation Accuracy')
plt.legend()
plt.title('Training and Validation Accuracy')
plt.xlabel('Epoch')
plt.ylabel('Accuracy')
plt.show()
```



[10]:
```
# Plot training and validation Dice coefficient
plt.figure(figsize=(12, 6))
plt.plot(history.history['dice_coefficient'], label='Training Dice Coefficient')
plt.plot(history.history['val_dice_coefficient'], label='Validation Dice␣
 ↪Coefficient')
plt.legend()
plt.title('Training and Validation Dice Coefficient')
plt.xlabel('Epoch')
plt.ylabel('Dice Coefficient')
plt.show()
```

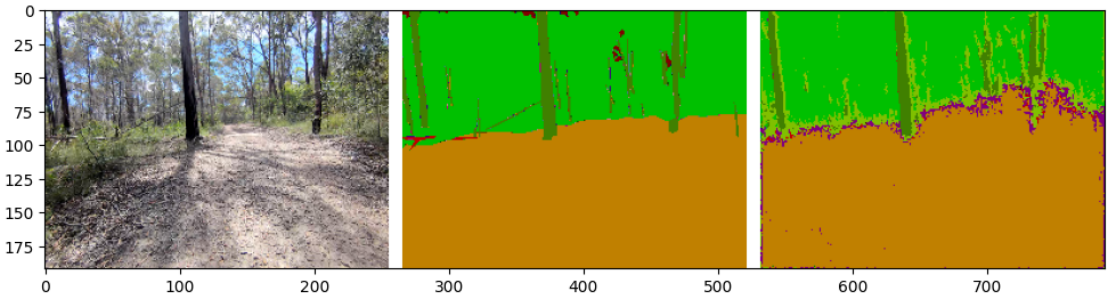


[11]:
```
# Plot training and validation IoU
plt.figure(figsize=(12, 6))
plt.plot(history.history['iou'], label='Training IoU')
plt.plot(history.history['val_iou'], label='Validation IoU')
plt.legend()
plt.title('Training and Validation IoU')
plt.xlabel('Epoch')
plt.ylabel('IoU')
plt.show()
```

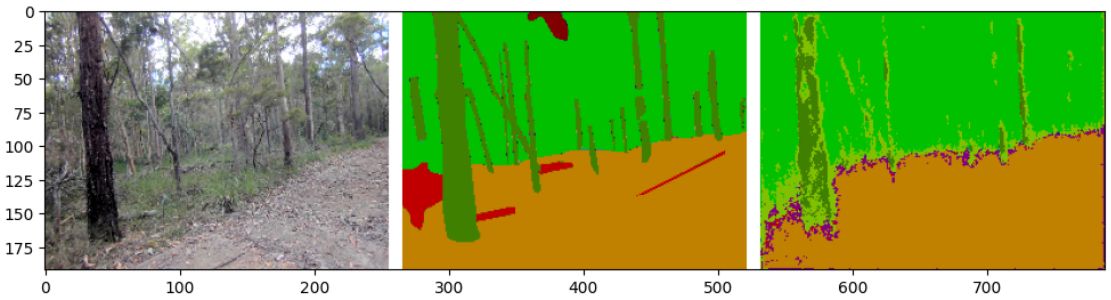


[12]:
```
# Visualize prediction results
for i, (x_path, y_path) in enumerate(zip(test_x[:10], test_y[:10])):
    x = read_image(x_path)
    y_pred = model.predict(np.expand_dims(x, axis=0))[0]
    y_original = read_mask(y_path)  # Directly read the mask

    h, w, _ = x.shape
    white_line = np.ones((h, 10, 3)) * 255

    all_images = [
        x * 255, white_line,
        mask_parse(y_original), white_line,  # Parse and display the original mask
        mask_parse(y_pred)
    ]
    image = np.concatenate(all_images, axis=1).astype(np.uint8)

    fig = plt.figure(figsize=(12, 12))
    a = fig.add_subplot(1, 1, 1)
    imgplot = plt.imshow(image)
    plt.show()
```

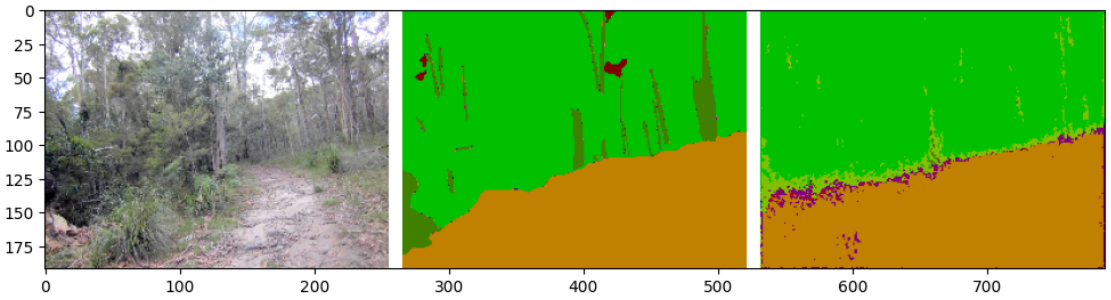
```
1/1             1s 1s/step
```



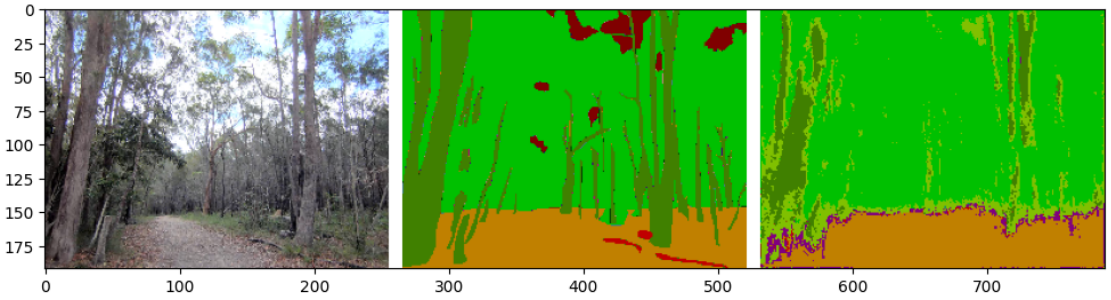

```
1/1             0s 10ms/step
```



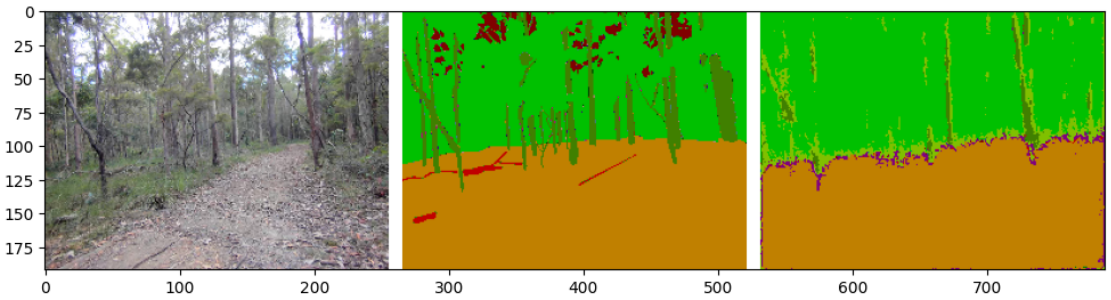

```
1/1             0s 10ms/step
```



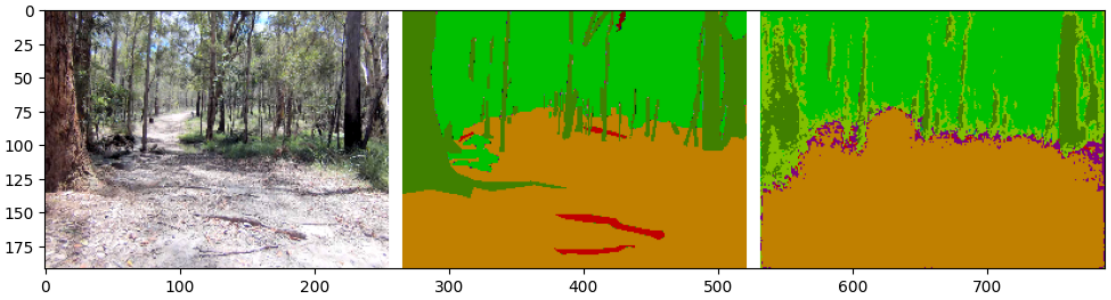

```
1/1             0s 10ms/step
```



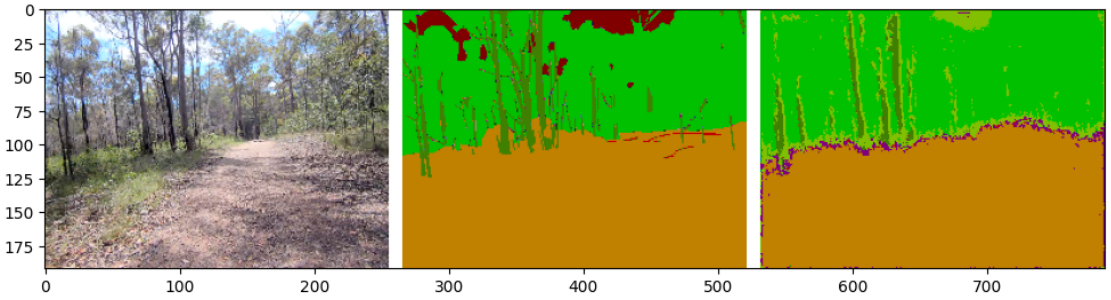

```
1/1             0s 10ms/step
```



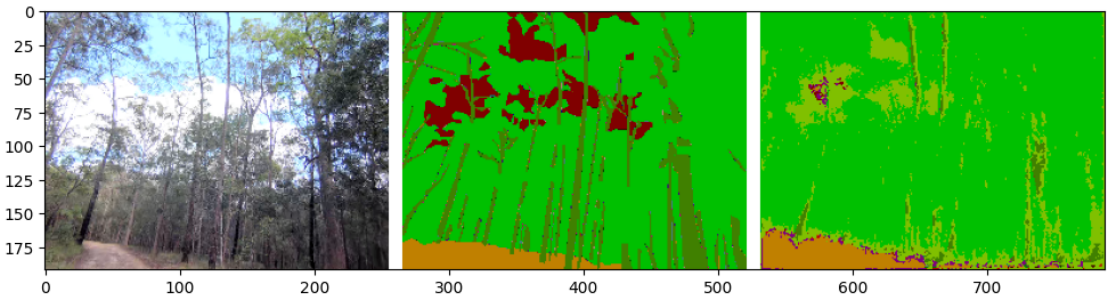

```
1/1             0s 10ms/step
```



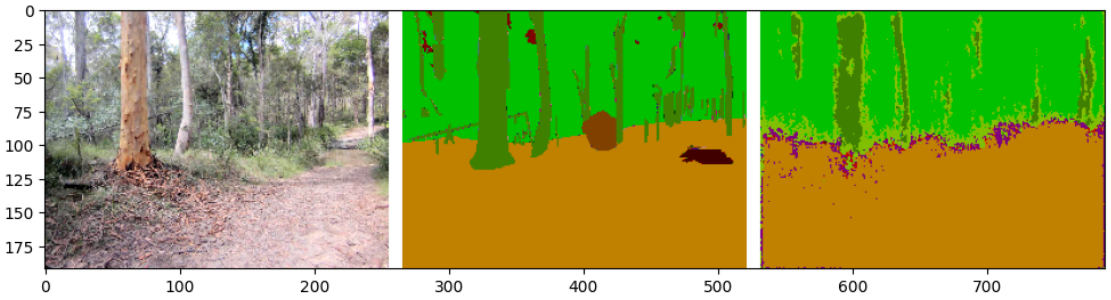

```
1/1             0s 10ms/step
```



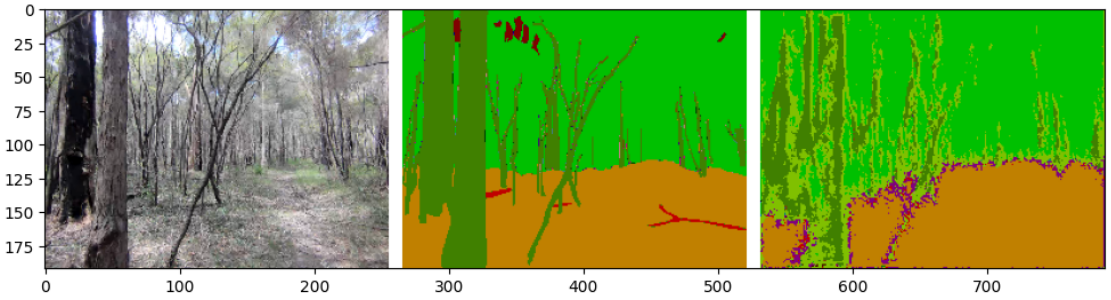

```
1/1             0s 10ms/step
```




```
1/1                 0s 10ms/step
```




```
1/1                 0s 9ms/step
```




```
[ ]:
```