

Untitled3

July 27, 2024

```
[56]: 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 = 672
HEIGHT = 504

# Define number of epochs for training
EPOCHS = 5

# Define batch size
BATCH = 3

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

# Define output path for saving training results and model
PATH = "/root/61541v001/V-01"
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# 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)

```

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[57]: # 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)

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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)

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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

```

```

[58]: # 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))

```

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Training data: 595
Validation data: 74
Testing data: 74

```

```

[59]: # 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

```

```

[60]: # Create and compile the model
model = build_model()
model.summary()

```

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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_5823/2080664991.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)

```

Model: "functional_5"

| Layer (type) | Output Shape | Param # | Connected to |
|--|----------------------|---------|---------------------|
| input_image (InputLayer) | (None, 504, 672, 3) | 0 | - |
| Conv1 (Conv2D) | (None, 252, 336, 16) | 432 | input_image[0][0] |
| bn_Conv1 (BatchNormalizatio... | (None, 252, 336, 16) | 64 | Conv1[0][0] |
| Conv1_relu (ReLU) | (None, 252, 336, 16) | 0 | bn_Conv1[0][0] |
| expanded_conv_dept... (DepthwiseConv2D) | (None, 252, 336, 16) | 144 | Conv1_relu[0][0] |
| expanded_conv_dept... (BatchNormalizatio... | (None, 252, 336, 16) | 64 | expanded_conv_de... |
| expanded_conv_dept... (ReLU) | (None, 252, 336, 16) | 0 | expanded_conv_de... |
| expanded_conv_proj... (Conv2D) | (None, 252, 336, 8) | 128 | expanded_conv_de... |
| expanded_conv_proj... (BatchNormalizatio... | (None, 252, 336, 8) | 32 | expanded_conv_pr... |
| block_1_expand (Conv2D) | (None, 252, 336, 48) | 384 | expanded_conv_pr... |

| | | | |
|--|----------------------|-----|---------------------|
| block_1_expand_BN (BatchNormalizatio... | (None, 252, 336, 48) | 192 | block_1_expand[0... |
| block_1_expand_relu (ReLU) | (None, 252, 336, 48) | 0 | block_1_expand_B... |
| block_1_pad (ZeroPadding2D) | (None, 253, 337, 48) | 0 | block_1_expand_r... |
| block_1_depthwise (DepthwiseConv2D) | (None, 126, 168, 48) | 432 | block_1_pad[0][0] |
| block_1_depthwise_... (BatchNormalizatio... | (None, 126, 168, 48) | 192 | block_1_depthwis... |
| block_1_depthwise_... (ReLU) | (None, 126, 168, 48) | 0 | block_1_depthwis... |
| block_1_project (Conv2D) | (None, 126, 168, 8) | 384 | block_1_depthwis... |
| block_1_project_BN (BatchNormalizatio... | (None, 126, 168, 8) | 32 | block_1_project[... |
| block_2_expand (Conv2D) | (None, 126, 168, 48) | 384 | block_1_project_... |
| block_2_expand_BN (BatchNormalizatio... | (None, 126, 168, 48) | 192 | block_2_expand[0... |
| block_2_expand_relu (ReLU) | (None, 126, 168, 48) | 0 | block_2_expand_B... |
| block_2_depthwise (DepthwiseConv2D) | (None, 126, 168, 48) | 432 | block_2_expand_r... |
| block_2_depthwise_... (BatchNormalizatio... | (None, 126, 168, 48) | 192 | block_2_depthwis... |
| block_2_depthwise_... (ReLU) | (None, 126, 168, 48) | 0 | block_2_depthwis... |
| block_2_project (Conv2D) | (None, 126, 168, 8) | 384 | block_2_depthwis... |
| block_2_project_BN (BatchNormalizatio... | (None, 126, 168, 8) | 32 | block_2_project[... |

| | | | |
|--|----------------------|-------|---|
| block_2_add (Add) | (None, 126, 168, 8) | 0 | block_1_project_ block_2_project_... |
| block_3_expand (Conv2D) | (None, 126, 168, 48) | 384 | block_2_add[0][0] |
| block_3_expand_BN (BatchNormalizatio... | (None, 126, 168, 48) | 192 | block_3_expand[0... |
| block_3_expand_relu (ReLU) | (None, 126, 168, 48) | 0 | block_3_expand_B... |
| block_3_pad (ZeroPadding2D) | (None, 127, 169, 48) | 0 | block_3_expand_r... |
| block_3_depthwise (DepthwiseConv2D) | (None, 63, 84, 48) | 432 | block_3_pad[0][0] |
| block_3_depthwise_... (BatchNormalizatio... | (None, 63, 84, 48) | 192 | block_3_depthwis... |
| block_3_depthwise_... (ReLU) | (None, 63, 84, 48) | 0 | block_3_depthwis... |
| block_3_project (Conv2D) | (None, 63, 84, 16) | 768 | block_3_depthwis... |
| block_3_project_BN (BatchNormalizatio... | (None, 63, 84, 16) | 64 | block_3_project[... |
| block_4_expand (Conv2D) | (None, 63, 84, 96) | 1,536 | block_3_project_... |
| block_4_expand_BN (BatchNormalizatio... | (None, 63, 84, 96) | 384 | block_4_expand[0... |
| block_4_expand_relu (ReLU) | (None, 63, 84, 96) | 0 | block_4_expand_B... |
| block_4_depthwise (DepthwiseConv2D) | (None, 63, 84, 96) | 864 | block_4_expand_r... |
| block_4_depthwise_... (BatchNormalizatio... | (None, 63, 84, 96) | 384 | block_4_depthwis... |
| block_4_depthwise_... (ReLU) | (None, 63, 84, 96) | 0 | block_4_depthwis... |

| | | | |
|--|-----------------------|-------|--|
| block_4_project (Conv2D) | (None, 63, 84, 16) | 1,536 | block_4_depthwis... |
| block_4_project_BN (BatchNormalizatio... | (None, 63, 84, 16) | 64 | block_4_project[... |
| block_4_add (Add) | (None, 63, 84, 16) | 0 | block_3_project_... block_4_project_... |
| block_5_expand (Conv2D) | (None, 63, 84, 96) | 1,536 | block_4_add[0][0] |
| block_5_expand_BN (BatchNormalizatio... | (None, 63, 84, 96) | 384 | block_5_expand[0... |
| block_5_expand_relu (ReLU) | (None, 63, 84, 96) | 0 | block_5_expand_B... |
| block_5_depthwise (DepthwiseConv2D) | (None, 63, 84, 96) | 864 | block_5_expand_r... |
| block_5_depthwise_... (BatchNormalizatio... | (None, 63, 84, 96) | 384 | block_5_depthwis... |
| block_5_depthwise_... (ReLU) | (None, 63, 84, 96) | 0 | block_5_depthwis... |
| block_5_project (Conv2D) | (None, 63, 84, 16) | 1,536 | block_5_depthwis... |
| block_5_project_BN (BatchNormalizatio... | (None, 63, 84, 16) | 64 | block_5_project[... |
| block_5_add (Add) | (None, 63, 84, 16) | 0 | block_4_add[0][0... block_5_project_... |
| block_6_expand (Conv2D) | (None, 63, 84, 96) | 1,536 | block_5_add[0][0] |
| block_6_expand_BN (BatchNormalizatio... | (None, 63, 84, 96) | 384 | block_6_expand[0... |
| block_6_expand_relu (ReLU) | (None, 63, 84, 96) | 0 | block_6_expand_B... |
| block_6_pad (ZeroPadding2D) | (None, 65, 85, 96) | 0 | block_6_expand_r... |

| | | | |
|---|--|-------|--|
| block_6_depthwise (DepthwiseConv2D) | (None, 32, 42, 96) | 864 | block_6_pad[0][0] |
| block_6_depthwise_... | (None, 32, 42, (BatchNormalizatio... 96) | 384 | block_6_depthwis... |
| block_6_depthwise_... | (None, 32, 42, (ReLU) 96) | 0 | block_6_depthwis... |
| block_6_project (Conv2D) | (None, 32, 42, 24) | 2,304 | block_6_depthwis... |
| block_6_project_BN (BatchNormalizatio... | (None, 32, 42, 24) | 96 | block_6_project[... |
| block_7_expand (Conv2D) | (None, 32, 42, 144) | 3,456 | block_6_project_... |
| block_7_expand_BN (BatchNormalizatio... | (None, 32, 42, 144) | 576 | block_7_expand[0... |
| block_7_expand_relu (ReLU) | (None, 32, 42, 144) | 0 | block_7_expand_B... |
| block_7_depthwise (DepthwiseConv2D) | (None, 32, 42, 144) | 1,296 | block_7_expand_r... |
| block_7_depthwise_... | (None, 32, 42, (BatchNormalizatio... 144) | 576 | block_7_depthwis... |
| block_7_depthwise_... | (None, 32, 42, (ReLU) 144) | 0 | block_7_depthwis... |
| block_7_project (Conv2D) | (None, 32, 42, 24) | 3,456 | block_7_depthwis... |
| block_7_project_BN (BatchNormalizatio... | (None, 32, 42, 24) | 96 | block_7_project[... |
| block_7_add (Add) | (None, 32, 42, 24) | 0 | block_6_project_... block_7_project_... |
| block_8_expand (Conv2D) | (None, 32, 42, 144) | 3,456 | block_7_add[0][0] |
| block_8_expand_BN (BatchNormalizatio... | (None, 32, 42, 144) | 576 | block_8_expand[0... |

| | | | |
|--|------------------------|-------|--|
| block_8_expand_relu (ReLU) | (None, 32, 42, 144) | 0 | block_8_expand_B... |
| block_8_depthwise (DepthwiseConv2D) | (None, 32, 42, 144) | 1,296 | block_8_expand_r... |
| block_8_depthwise_... (BatchNormalizatio... | (None, 32, 42, 144) | 576 | block_8_depthwis... |
| block_8_depthwise_... (ReLU) | (None, 32, 42, 144) | 0 | block_8_depthwis... |
| block_8_project (Conv2D) | (None, 32, 42, 24) | 3,456 | block_8_depthwis... |
| block_8_project_BN (BatchNormalizatio... | (None, 32, 42, 24) | 96 | block_8_project[... |
| block_8_add (Add) | (None, 32, 42, 24) | 0 | block_7_add[0][0... block_8_project_... |
| block_9_expand (Conv2D) | (None, 32, 42, 144) | 3,456 | block_8_add[0][0] |
| block_9_expand_BN (BatchNormalizatio... | (None, 32, 42, 144) | 576 | block_9_expand[0... |
| block_9_expand_relu (ReLU) | (None, 32, 42, 144) | 0 | block_9_expand_B... |
| block_9_depthwise (DepthwiseConv2D) | (None, 32, 42, 144) | 1,296 | block_9_expand_r... |
| block_9_depthwise_... (BatchNormalizatio... | (None, 32, 42, 144) | 576 | block_9_depthwis... |
| block_9_depthwise_... (ReLU) | (None, 32, 42, 144) | 0 | block_9_depthwis... |
| block_9_project (Conv2D) | (None, 32, 42, 24) | 3,456 | block_9_depthwis... |
| block_9_project_BN (BatchNormalizatio... | (None, 32, 42, 24) | 96 | block_9_project[... |
| block_9_add (Add) | (None, 32, 42, 24) | 0 | block_8_add[0][0... block_9_project_... |

| | | | |
|--|------------------------|-------|---------------------|
| block_10_expand (Conv2D) | (None, 32, 42, 144) | 3,456 | block_9_add[0][0] |
| block_10_expand_BN (BatchNormalizatio... | (None, 32, 42, 144) | 576 | block_10_expand[... |
| block_10_expand_re... (ReLU) | (None, 32, 42, 144) | 0 | block_10_expand_... |
| block_10_depthwise (DepthwiseConv2D) | (None, 32, 42, 144) | 1,296 | block_10_expand_... |
| block_10_depthwise... (BatchNormalizatio... | (None, 32, 42, 144) | 576 | block_10_depthwi... |
| block_10_depthwise... (ReLU) | (None, 32, 42, 144) | 0 | block_10_depthwi... |
| block_10_project (Conv2D) | (None, 32, 42, 32) | 4,608 | block_10_depthwi... |
| block_10_project_BN (BatchNormalizatio... | (None, 32, 42, 32) | 128 | block_10_project... |
| block_11_expand (Conv2D) | (None, 32, 42, 192) | 6,144 | block_10_project... |
| block_11_expand_BN (BatchNormalizatio... | (None, 32, 42, 192) | 768 | block_11_expand[... |
| block_11_expand_re... (ReLU) | (None, 32, 42, 192) | 0 | block_11_expand_... |
| block_11_depthwise (DepthwiseConv2D) | (None, 32, 42, 192) | 1,728 | block_11_expand_... |
| block_11_depthwise... (BatchNormalizatio... | (None, 32, 42, 192) | 768 | block_11_depthwi... |
| block_11_depthwise... (ReLU) | (None, 32, 42, 192) | 0 | block_11_depthwi... |
| block_11_project (Conv2D) | (None, 32, 42, 32) | 6,144 | block_11_depthwi... |
| block_11_project_BN (BatchNormalizatio... | (None, 32, 42, 32) | 128 | block_11_project... |

| | | | |
|---|---------------------|-------|--|
| block_11_add (Add) | (None, 32, 42, 32) | 0 | block_10_project... block_11_project... |
| block_12_expand (Conv2D) | (None, 32, 42, 192) | 6,144 | block_11_add[0] [...] |
| block_12_expand_BN (BatchNormalizatio... | (None, 32, 42, 192) | 768 | block_12_expand[...] |
| block_12_expand_re... (ReLU) | (None, 32, 42, 192) | 0 | block_12_expand_... |
| block_12_depthwise (DepthwiseConv2D) | (None, 32, 42, 192) | 1,728 | block_12_expand_... |
| block_12_depthwise... (BatchNormalizatio... | (None, 32, 42, 192) | 768 | block_12_depthwi... |
| block_12_depthwise... (ReLU) | (None, 32, 42, 192) | 0 | block_12_depthwi... |
| block_12_project (Conv2D) | (None, 32, 42, 32) | 6,144 | block_12_depthwi... |
| block_12_project_BN (BatchNormalizatio... | (None, 32, 42, 32) | 128 | block_12_project... |
| block_12_add (Add) | (None, 32, 42, 32) | 0 | block_11_add[0] [...] block_12_project... |
| block_13_expand (Conv2D) | (None, 32, 42, 192) | 6,144 | block_12_add[0] [...] |
| block_13_expand_BN (BatchNormalizatio... | (None, 32, 42, 192) | 768 | block_13_expand[...] |
| block_13_expand_re... (ReLU) | (None, 32, 42, 192) | 0 | block_13_expand_... |
| up_sampling2d_20 (UpSampling2D) | (None, 64, 84, 192) | 0 | block_13_expand_... |
| cropping2d_5 (Cropping2D) | (None, 63, 84, 192) | 0 | up_sampling2d_20... |
| concatenate_20 (Concatenate) | (None, 63, 84, 288) | 0 | cropping2d_5[0] [...] block_6_expand_r... |

| | | | |
|--|---|---------|--|
| conv2d_45 (Conv2D) | (None , 63, 84, 64) | 165,952 | concatenate_20[0... |
| batch_normalizatio... (BatchNormalizatio...) | (None , 63, 84, 64) | 256 | conv2d_45[0][0] |
| activation_45 (Activation) | (None , 63, 84, 64) | 0 | batch_normalizati... |
| conv2d_46 (Conv2D) | (None , 63, 84, 64) | 36,928 | activation_45[0]... |
| batch_normalizatio... (BatchNormalizatio...) | (None , 63, 84, 64) | 256 | conv2d_46[0][0] |
| activation_46 (Activation) | (None , 63, 84, 64) | 0 | batch_normalizati... |
| up_sampling2d_21 (UpSampling2D) | (None , 126, 168, 64) | 0 | activation_46[0]... |
| concatenate_21 (Concatenate) | (None , 126, 168, 112) | 0 | up_sampling2d_21... block_3_expand_r... |
| conv2d_47 (Conv2D) | (None , 126, 168, 48) | 48,432 | concatenate_21[0... |
| batch_normalizatio... (BatchNormalizatio...) | (None , 126, 168, 48) | 192 | conv2d_47[0][0] |
| activation_47 (Activation) | (None , 126, 168, 48) | 0 | batch_normalizati... |
| conv2d_48 (Conv2D) | (None , 126, 168, 48) | 20,784 | activation_47[0]... |
| batch_normalizatio... (BatchNormalizatio...) | (None , 126, 168, 48) | 192 | conv2d_48[0][0] |
| activation_48 (Activation) | (None , 126, 168, 48) | 0 | batch_normalizati... |
| up_sampling2d_22 (UpSampling2D) | (None , 252, 336, 48) | 0 | activation_48[0]... |
| concatenate_22 (Concatenate) | (None , 252, 336, 96) | 0 | up_sampling2d_22... block_1_expand_r... |

| | | | |
|--|----------------------|--------|--|
| conv2d_49 (Conv2D) | (None, 252, 336, 32) | 27,680 | concatenate_22[0]... |
| batch_normalizatio... (BatchNormalizatio... | (None, 252, 336, 32) | 128 | conv2d_49[0][0] |
| activation_49 (Activation) | (None, 252, 336, 32) | 0 | batch_normalizat... |
| conv2d_50 (Conv2D) | (None, 252, 336, 32) | 9,248 | activation_49[0]... |
| batch_normalizatio... (BatchNormalizatio... | (None, 252, 336, 32) | 128 | conv2d_50[0][0] |
| activation_50 (Activation) | (None, 252, 336, 32) | 0 | batch_normalizat... |
| up_sampling2d_23 (UpSampling2D) | (None, 504, 672, 32) | 0 | activation_50[0]... |
| concatenate_23 (Concatenate) | (None, 504, 672, 35) | 0 | up_sampling2d_23... input_image[0][0] |
| conv2d_51 (Conv2D) | (None, 504, 672, 16) | 5,056 | concatenate_23[0]... |
| batch_normalizatio... (BatchNormalizatio... | (None, 504, 672, 16) | 64 | conv2d_51[0][0] |
| activation_51 (Activation) | (None, 504, 672, 16) | 0 | batch_normalizat... |
| conv2d_52 (Conv2D) | (None, 504, 672, 16) | 2,320 | activation_51[0]... |
| batch_normalizatio... (BatchNormalizatio... | (None, 504, 672, 16) | 64 | conv2d_52[0][0] |
| activation_52 (Activation) | (None, 504, 672, 16) | 0 | batch_normalizat... |
| conv2d_53 (Conv2D) | (None, 504, 672, 22) | 374 | activation_52[0]... |
| activation_53 (Activation) | (None, 504, 672, 22) | 0 | conv2d_53[0][0] |

Total params: 416,566 (1.59 MB)

Trainable params: 409,382 (1.56 MB)

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

```
[61]: # 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 1/5

199/199 82s 299ms/step -

accuracy: 0.1283 - dice_coefficient: 0.0547 - iou: 0.0283 - loss: 3.1495 -
val_accuracy: 0.6074 - val_dice_coefficient: 0.0904 - val_iou: 0.0473 -
val_loss: 2.5448 - learning_rate: 1.0000e-04

Epoch 2/5

199/199 49s 249ms/step -

accuracy: 0.7108 - dice_coefficient: 0.1231 - iou: 0.0656 - loss: 2.2310 -
val_accuracy: 0.7648 - val_dice_coefficient: 0.1594 - val_iou: 0.0866 -
val_loss: 1.9771 - learning_rate: 1.0000e-04

Epoch 3/5

199/199 49s 246ms/step -

accuracy: 0.7700 - dice_coefficient: 0.1647 - iou: 0.0898 - loss: 1.9512 -
val_accuracy: 0.8545 - val_dice_coefficient: 0.2170 - val_iou: 0.1217 -
val_loss: 1.6800 - learning_rate: 1.0000e-04

Epoch 4/5

199/199 47s 239ms/step -

accuracy: 0.8479 - dice_coefficient: 0.2160 - iou: 0.1212 - loss: 1.6990 -
val_accuracy: 0.8636 - val_dice_coefficient: 0.2672 - val_iou: 0.1542 -
val_loss: 1.4825 - learning_rate: 1.0000e-04

Epoch 5/5

199/199 46s 231ms/step -

accuracy: 0.8579 - dice_coefficient: 0.2766 - iou: 0.1606 - loss: 1.4672 -
val_accuracy: 0.8680 - val_dice_coefficient: 0.3288 - val_iou: 0.1968 -
val_loss: 1.2891 - learning_rate: 1.0000e-04

```
[62]: # 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)

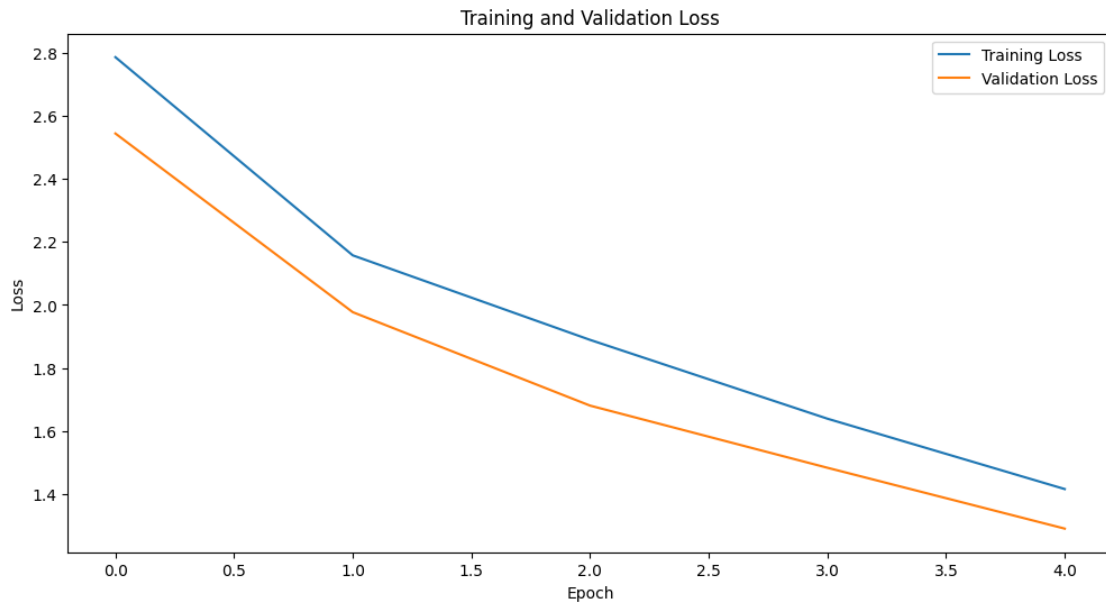
# Get metric names
metrics_names = model.metrics_names

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

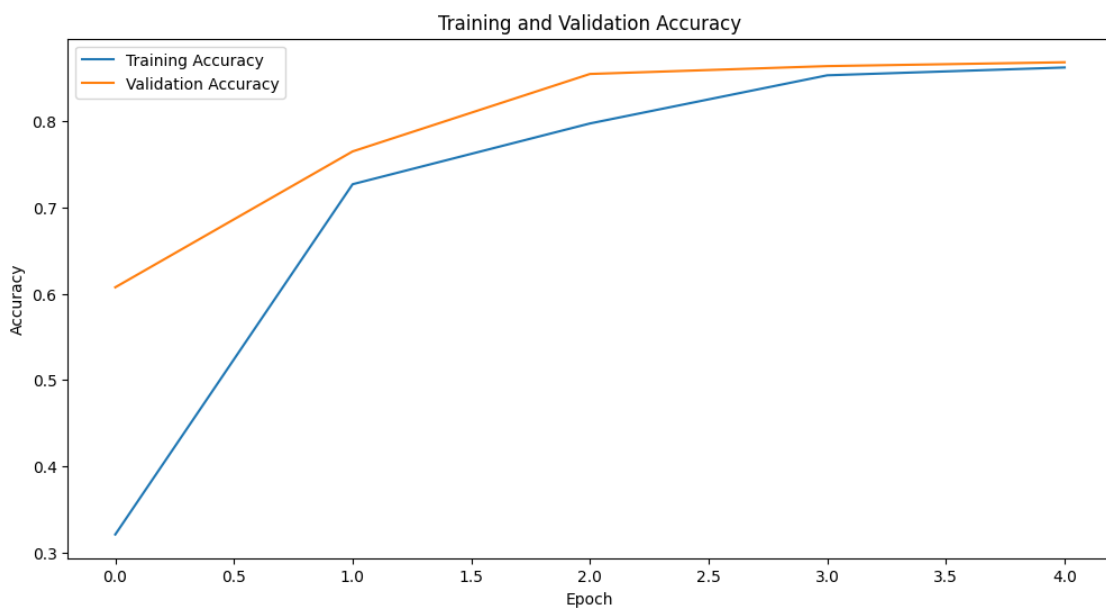
25/25 6s 234ms/step -

accuracy: 0.8685 - dice_coefficient: 0.3311 - iou: 0.1985 - loss: 1.2845
loss: 1.2866
compile_metrics: 0.8691

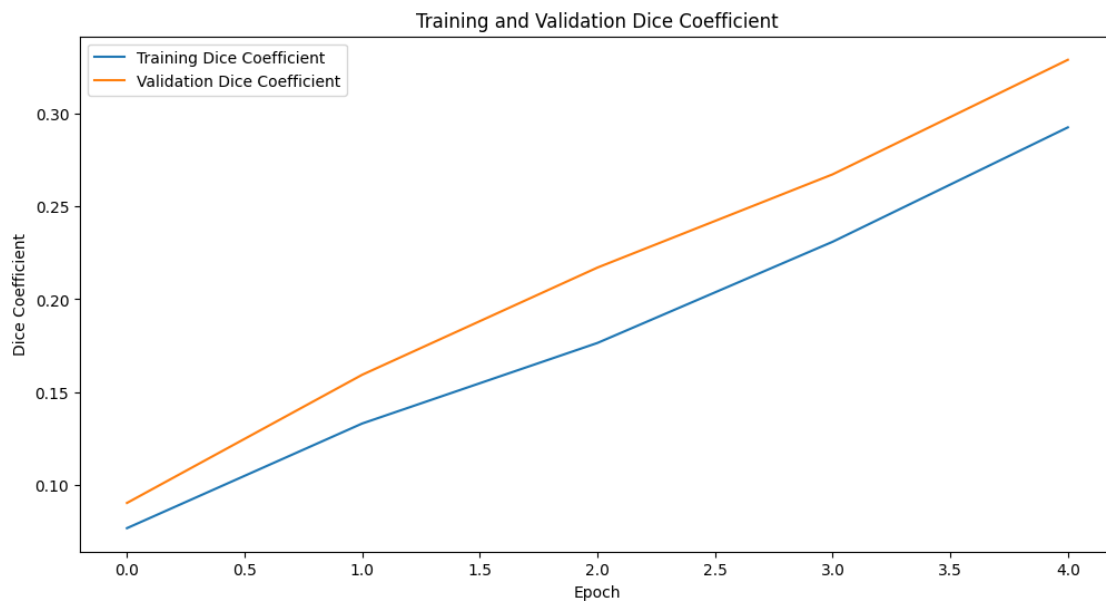
```
[63]: # Plot training and validation loss
plt.figure(figsize=(12, 6))
plt.plot(history.history['loss'], label='Training Loss')
plt.plot(history.history['val_loss'], label='Validation Loss')
plt.legend()
plt.title('Training and Validation Loss')
plt.xlabel('Epoch')
plt.ylabel('Loss')
plt.show()
```

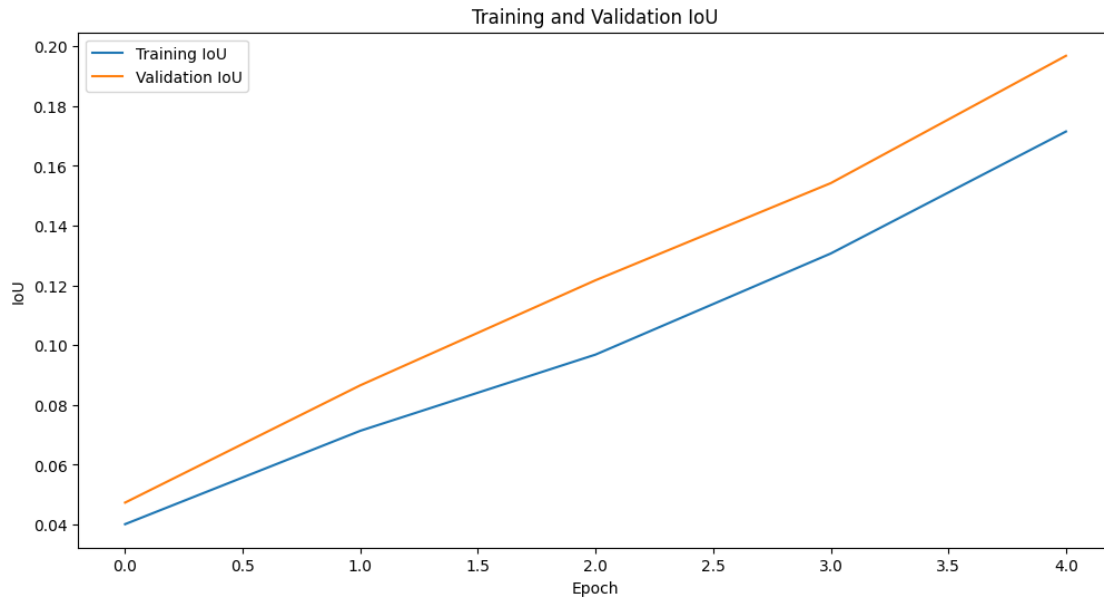
```
[64]: # Plot training and validation accuracy
plt.figure(figsize=(12, 6))
plt.plot(history.history['accuracy'], label='Training Accuracy')
plt.plot(history.history['val_accuracy'], label='Validation Accuracy')
plt.legend()
plt.title('Training and Validation Accuracy')
plt.xlabel('Epoch')
plt.ylabel('Accuracy')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



```
[65]: # 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()
```



```
[66]: # 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()
```



```
[67]: # 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

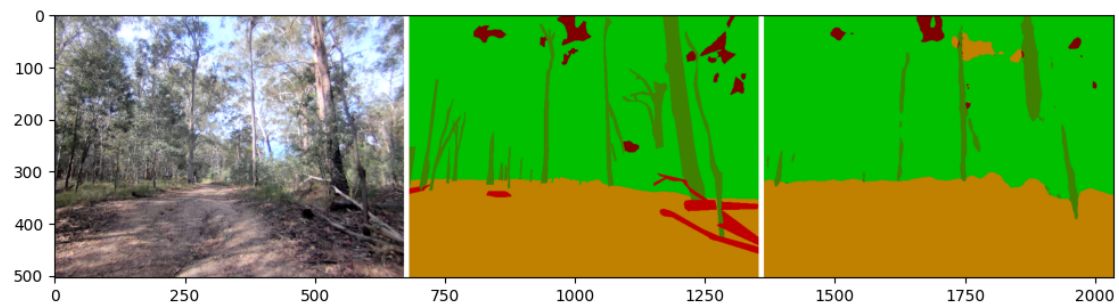
    h, w, _ = x.shape
    white_line = np.ones((h, 10, 3)) * 255

    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)

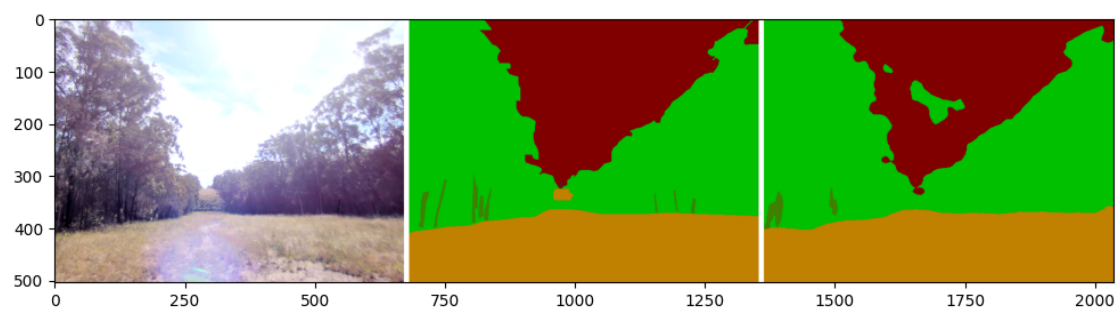
    fig = plt.figure(figsize=(12, 12))
    a = fig.add_subplot(1, 1, 1)
    imgplot = plt.imshow(image)
    plt.show()
```

1/1

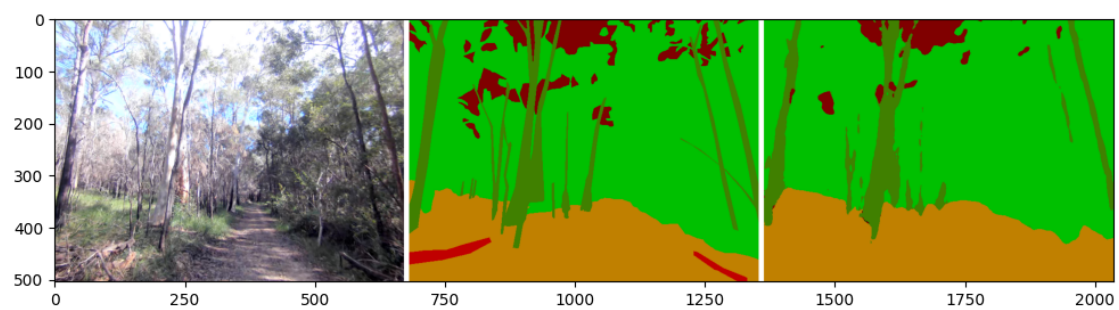
1s 792ms/step



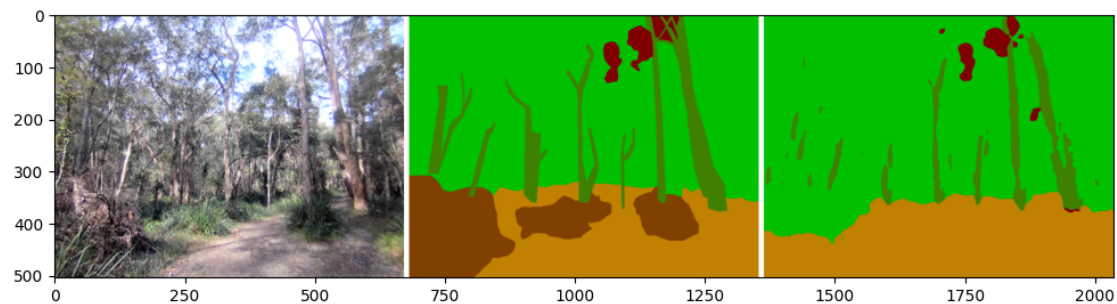
1/1 0s 10ms/step



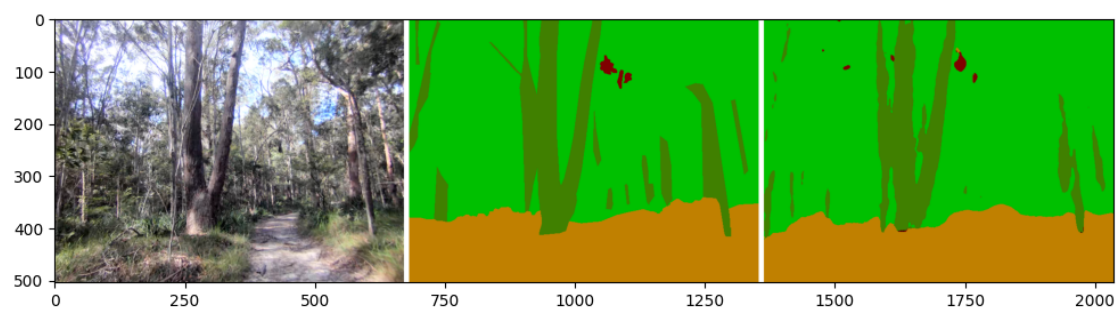
1/1 0s 11ms/step



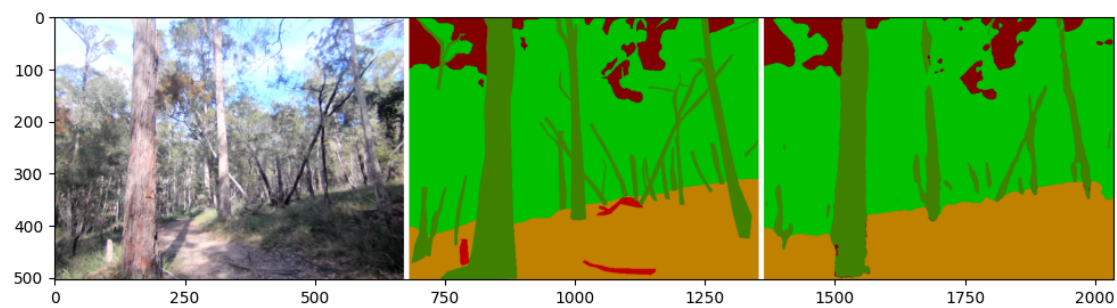
1/1 0s 11ms/step



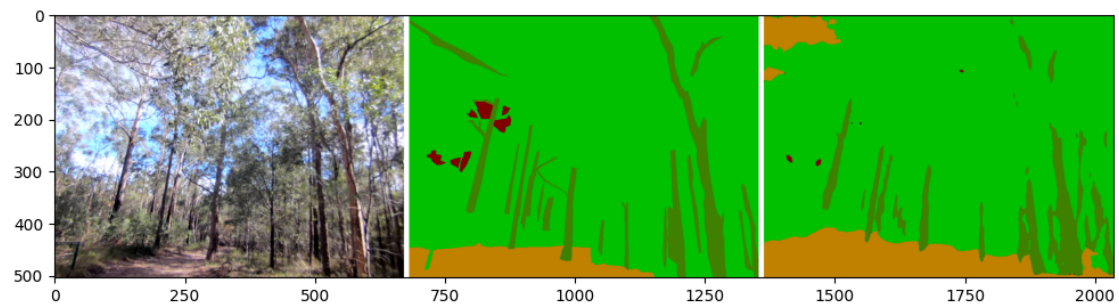
1/1 0s 10ms/step



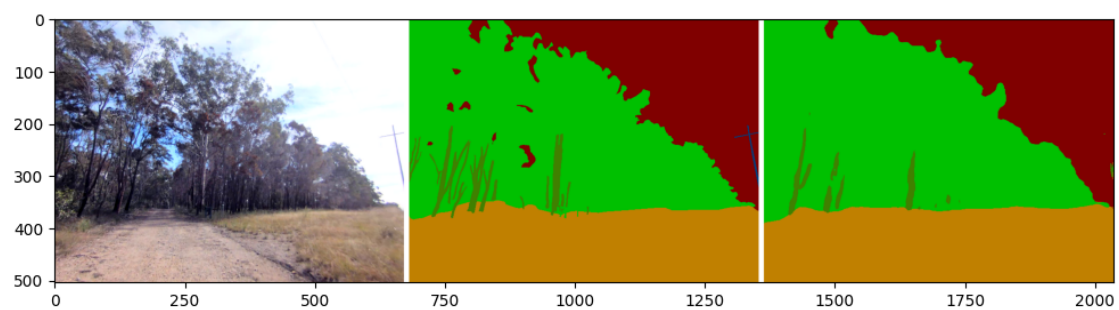
1/1 0s 11ms/step



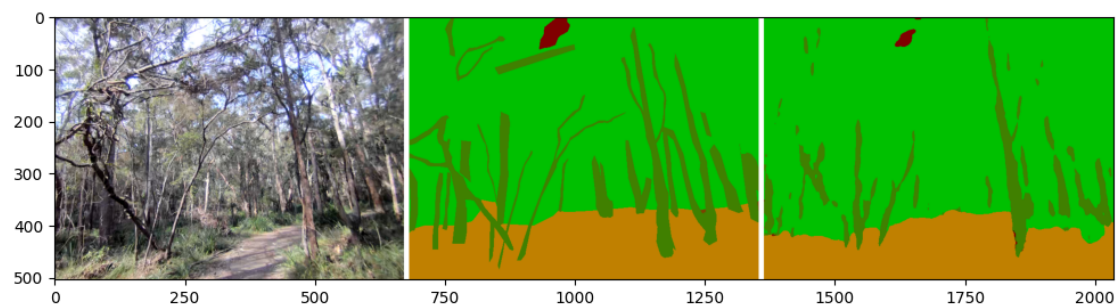
1/1 0s 10ms/step



1/1 0s 10ms/step



1/1 0s 10ms/step



1/1 0s 10ms/step

