

In []:

```
In [1]: from google.colab import drive  
drive.mount('/content/drive')
```

Mounted at /content/drive

```
In [2]: import numpy as np # linear algebra  
import pandas as pd # data processing, CSV file I/O (e.g. pd.read_csv)  
  
import os  
for dirname, _, filenames in os.walk('/content/drive/MyDrive/cityscapes_data'):  
    for filename in filenames:  
        print(os.path.join(dirname, filename))
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```

In []:

```
In [3]: import numpy as np # linear algebra
import pandas as pd # data processing, CSV file I/O (e.g. pd.read_csv)

import os
```

```
In [5]: import tensorflow as tf

train_folder = "/content/drive/MyDrive/cityscapes_data/train"
test_folder = "/content/drive/MyDrive/cityscapes_data/val"
```

```

train_onlyfiles = [f for f in os.listdir(train_folder) if os.path.isfile(os.path.join(test_folder, f))]
test_onlyfiles = [f for f in os.listdir(test_folder) if os.path.isfile(os.path.join(test_folder, f))]

print("Working with {} train images".format(len(train_onlyfiles)))
print("Working with {} test images".format(len(test_onlyfiles)))

```

Working with 1330 train images
Working with 500 test images

```

In [6]: from scipy import ndimage
        from keras.preprocessing.image import ImageDataGenerator, array_to_img, img_to_array, load_img

        train_files = []
        test_files = []
        train_img_arr = []
        test_img_arr = []

        i=0
        for _file in train_onlyfiles:
            train_files.append(_file)
        for _file in test_onlyfiles:
            test_files.append(_file)

        for _file in train_files:
            img = load_img(train_folder + "/" + _file) # this is a PIL image
            img.thumbnail((256, 512))
            # Convert to Numpy Array
            x = img_to_array(img)
            train_img_arr.append(x)
        for _file in test_files:
            img = load_img(test_folder + "/" + _file) # this is a PIL image
            img.thumbnail((256, 512))
            # Convert to Numpy Array
            x = img_to_array(img)
            test_img_arr.append(x)

```

```

In [7]: train_arr = np.array(train_img_arr)
        test_arr = np.array(test_img_arr)

```

```

In [8]: x_train = train_arr[:, :, 0:128, :]
        y_train = train_arr[:, :, 128:256, :]
        x_test = test_arr[:, :, 0:128, :]
        y_test = test_arr[:, :, 128:256, :]

```

```

In [9]: x_train = x_train/255
        y_train = y_train/255
        x_test = x_test/255
        y_test = y_test/255

```

```

In [10]: import matplotlib.pyplot as plt

        plt.figure(figsize=(10,10))
        for i in range(25):
            plt.subplot(5,5,i+1)
            plt.xticks([])
            plt.yticks([])

```



```
plt.grid(False)
plt.imshow(x_train[i])
plt.show()
```



```
In [11]: import tensorflow as tf
```

```
In [12]: def conv_block(inputs, conv_type, kernel, kernel_size, strides, padding='same', relu=True):
    if(conv_type == 'ds'):
        x = tf.keras.layers.SeparableConv2D(kernel, kernel_size, padding=padding, strides = strides)(inputs)
    else:
        x = tf.keras.layers.Conv2D(kernel, kernel_size, padding=padding, strides = strides)(inputs)
    x = tf.keras.layers.BatchNormalization()(x)
    if (relu):
        x = tf.keras.activations.relu(x)
    return x
```

```
In [13]: input_layer = tf.keras.layers.Input(shape=(128, 128, 3), name = 'input_layer')
```

```
In [14]: lds_layer = conv_block(input_layer, 'conv', 32, (3, 3), strides = (2, 2))
```

```
lds_layer = conv_block(lds_layer, 'ds', 48, (3, 3), strides = (2, 2))
lds_layer = conv_block(lds_layer, 'ds', 64, (3, 3), strides = (2, 2))
```

```
In [15]: def _res_bottleneck(inputs, filters, kernel, t, s, r=False):

    tchannel = tf.keras.backend.int_shape(inputs)[-1] * t

    x = conv_block(inputs, 'conv', tchannel, (1, 1), strides=(1, 1))

    x = tf.keras.layers.DepthwiseConv2D(kernel, strides=(s, s), depth_multiplier=1, padding='same')(x)
    x = tf.keras.layers.BatchNormalization()(x)
    x = tf.keras.activations.relu(x)

    x = conv_block(x, 'conv', filters, (1, 1), strides=(1, 1), padding='same', relu=False)

    if r:
        x = tf.keras.layers.add([x, inputs])
    return x
```

```
In [16]: def bottleneck_block(inputs, filters, kernel, t, strides, n):
    x = _res_bottleneck(inputs, filters, kernel, t, strides)

    for i in range(1, n):
        x = _res_bottleneck(x, filters, kernel, t, 1, True)

    return x
```

```
In [17]: def pyramid_pooling_block(input_tensor, bin_sizes):
    concat_list = [input_tensor]
    w = 64
    h = 32

    for bin_size in bin_sizes:
        x = tf.keras.layers.AveragePooling2D(pool_size=(w//bin_size, h//bin_size), strides=(1, 1))(x)
        x = tf.keras.layers.Conv2D(128, 3, 2, padding='same')(x)
        x = tf.keras.layers.Lambda(lambda x: tf.image.resize(x, (w, h)))(x)

        concat_list.append(x)

    return tf.keras.layers.concatenate(concat_list)
```

```
In [18]: gfe_layer = bottleneck_block(lds_layer, 64, (3, 3), t=6, strides=2, n=3)
gfe_layer = bottleneck_block(gfe_layer, 96, (3, 3), t=6, strides=2, n=3)
gfe_layer = bottleneck_block(gfe_layer, 128, (3, 3), t=6, strides=1, n=3)
```

```
In [19]: ff_layer1 = conv_block(lds_layer, 'conv', 128, (1,1), padding='same', strides= (1,1), relu=False)
```

```
In [20]: ff_layer2 = tf.keras.layers.UpSampling2D((4, 4))(gfe_layer)
ff_layer2 = tf.keras.layers.DepthwiseConv2D((3,3), strides=(1, 1), depth_multiplier=1, padding='same')(ff_layer2)
ff_layer2 = tf.keras.layers.BatchNormalization()(ff_layer2)
ff_layer2 = tf.keras.activations.relu(ff_layer2)
ff_layer2 = tf.keras.layers.Conv2D(128, 1, 1, padding='same', activation=None)(ff_layer2)
```

```
In [21]: ff_final = tf.keras.layers.add([ff_layer1, ff_layer2])
ff_final = tf.keras.layers.BatchNormalization()(ff_final)
ff_final = tf.keras.activations.relu(ff_final)
```

```
In [22]: classifier = tf.keras.layers.SeparableConv2D(128, (3, 3), padding='same', strides = (1,
classifier = tf.keras.layers.BatchNormalization()(classifier)
classifier = tf.keras.activations.relu(classifier)

classifier = tf.keras.layers.SeparableConv2D(128, (3, 3), padding='same', strides = (1,
classifier = tf.keras.layers.BatchNormalization()(classifier)
classifier = tf.keras.activations.relu(classifier)

classifier = conv_block(classifier, 'conv', 3, (1, 1), strides=(1, 1), padding='same',
classifier = tf.keras.layers.Dropout(0.3)(classifier)

classifier = tf.keras.layers.UpSampling2D((8, 8))(classifier)
classifier = tf.keras.activations.softmax(classifier)
```

```
In [24]: fast_scnn = tf.keras.Model(inputs = input_layer , outputs = classifier, name = 'Fast_SC
optimizer = tf.keras.optimizers.SGD(momentum=0.9, lr=0.045)
fast_scnn.compile(loss='categorical_crossentropy', optimizer=optimizer, metrics=['accur
```

```
/usr/local/lib/python3.7/dist-packages/keras/optimizer_v2/gradient_descent.py:102: UserWarning: The `lr` argument is deprecated, use `learning_rate` instead.
super(SGD, self).__init__(name, **kwargs)
```

```
In [25]: fast_scnn.summary()
```

Model: "Fast_SCNN"

Layer (type)	Output Shape	Param #	Connected to
=====			
input_layer (InputLayer)	[(None, 128, 128, 3)]	0	[]
conv2d (Conv2D)	(None, 64, 64, 32)	896	['input_layer[0][0]']
batch_normalization (BatchNormalization)	(None, 64, 64, 32)	128	['conv2d[0][0]']
tf.nn.relu (TFOpLambda)	(None, 64, 64, 32)	0	['batch_normalization[0][0]']
separable_conv2d (SeparableConv2D)	(None, 32, 32, 48)	1872	['tf.nn.relu[0][0]']
batch_normalization_1 (BatchNormalization)	(None, 32, 32, 48)	192	['separable_conv2d[0][0]']
tf.nn.relu_1 (TFOpLambda)	(None, 32, 32, 48)	0	['batch_normalization_1[0][0]']
separable_conv2d_1 (SeparableConv2D)	(None, 16, 16, 64)	3568	['tf.nn.relu_1[0][0]']
batch_normalization_2 (BatchNormalization)	(None, 16, 16, 64)	256	['separable_conv2d_1[0][0]']

tf.nn.relu_2 (TFOpLambda)	(None, 16, 16, 64)	0	['batch_normalization_2[0][0]']
conv2d_1 (Conv2D)	(None, 16, 16, 384)	24960	['tf.nn.relu_2[0][0]']
batch_normalization_3 (Batch Normalization)	(None, 16, 16, 384)	1536	['conv2d_1[0][0]']
tf.nn.relu_3 (TFOpLambda)	(None, 16, 16, 384)	0	['batch_normalization_3[0][0]']
depthwise_conv2d (DepthwiseConv2D)	(None, 8, 8, 384)	3840	['tf.nn.relu_3[0][0]']
batch_normalization_4 (Batch Normalization)	(None, 8, 8, 384)	1536	['depthwise_conv2d[0][0]']
tf.nn.relu_4 (TFOpLambda)	(None, 8, 8, 384)	0	['batch_normalization_4[0][0]']
conv2d_2 (Conv2D)	(None, 8, 8, 64)	24640	['tf.nn.relu_4[0][0]']
batch_normalization_5 (Batch Normalization)	(None, 8, 8, 64)	256	['conv2d_2[0][0]']
conv2d_3 (Conv2D)	(None, 8, 8, 384)	24960	['batch_normalization_5[0][0]']
batch_normalization_6 (Batch Normalization)	(None, 8, 8, 384)	1536	['conv2d_3[0][0]']
tf.nn.relu_5 (TFOpLambda)	(None, 8, 8, 384)	0	['batch_normalization_6[0][0]']
depthwise_conv2d_1 (DepthwiseConv2D)	(None, 8, 8, 384)	3840	['tf.nn.relu_5[0][0]']
batch_normalization_7 (Batch Normalization)	(None, 8, 8, 384)	1536	['depthwise_conv2d_1[0][0]']
tf.nn.relu_6 (TFOpLambda)	(None, 8, 8, 384)	0	['batch_normalization_7[0][0]']
conv2d_4 (Conv2D)	(None, 8, 8, 64)	24640	['tf.nn.relu_6[0][0]']
batch_normalization_8 (Batch Normalization)	(None, 8, 8, 64)	256	['conv2d_4[0][0]']
add (Add)	(None, 8, 8, 64)	0	['batch_normalization_8[0][0]', 'batch_normalization_5[0][0]']
conv2d_5 (Conv2D)	(None, 8, 8, 384)	24960	['add[0][0]']
batch_normalization_9 (Batch Normalization)	(None, 8, 8, 384)	1536	['conv2d_5[0][0]']

tf.nn.relu_7 (TFOpLambda)	(None, 8, 8, 384)	0	['batch_normalization_9[0][0]']
depthwise_conv2d_2 (DepthwiseConv2D)	(None, 8, 8, 384)	3840	['tf.nn.relu_7[0][0]']
batch_normalization_10 (BatchNormalization)	(None, 8, 8, 384)	1536	['depthwise_conv2d_2[0][0]']
tf.nn.relu_8 (TFOpLambda)	(None, 8, 8, 384)	0	['batch_normalization_10[0][0]']
conv2d_6 (Conv2D)	(None, 8, 8, 64)	24640	['tf.nn.relu_8[0][0]']
batch_normalization_11 (BatchNormalization)	(None, 8, 8, 64)	256	['conv2d_6[0][0]']
add_1 (Add)	(None, 8, 8, 64)	0	['batch_normalization_11[0][0]', 'add[0][0]']
conv2d_7 (Conv2D)	(None, 8, 8, 384)	24960	['add_1[0][0]']
batch_normalization_12 (BatchNormalization)	(None, 8, 8, 384)	1536	['conv2d_7[0][0]']
tf.nn.relu_9 (TFOpLambda)	(None, 8, 8, 384)	0	['batch_normalization_12[0][0]']
depthwise_conv2d_3 (DepthwiseConv2D)	(None, 4, 4, 384)	3840	['tf.nn.relu_9[0][0]']
batch_normalization_13 (BatchNormalization)	(None, 4, 4, 384)	1536	['depthwise_conv2d_3[0][0]']
tf.nn.relu_10 (TFOpLambda)	(None, 4, 4, 384)	0	['batch_normalization_13[0][0]']
conv2d_8 (Conv2D)	(None, 4, 4, 96)	36960	['tf.nn.relu_10[0][0]']
batch_normalization_14 (BatchNormalization)	(None, 4, 4, 96)	384	['conv2d_8[0][0]']
conv2d_9 (Conv2D)	(None, 4, 4, 576)	55872	['batch_normalization_14[0][0]']
batch_normalization_15 (BatchNormalization)	(None, 4, 4, 576)	2304	['conv2d_9[0][0]']
tf.nn.relu_11 (TFOpLambda)	(None, 4, 4, 576)	0	['batch_normalization_15[0][0]']
depthwise_conv2d_4 (DepthwiseConv2D)	(None, 4, 4, 576)	5760	['tf.nn.relu_11[0][0]']
batch_normalization_16 (BatchNormalization)	(None, 4, 4, 576)	2304	['depthwise_conv2d_4[0][0]']

ormalization)			
tf.nn.relu_12 (TFOpLambda)	(None, 4, 4, 576)	0	['batch_normalization_16[0][0]']
conv2d_10 (Conv2D)	(None, 4, 4, 96)	55392	['tf.nn.relu_12[0][0]']
batch_normalization_17 (BatchNormal ormalization)	(None, 4, 4, 96)	384	['conv2d_10[0][0]']
add_2 (Add)	(None, 4, 4, 96)	0	['batch_normalization_17[0][0]', 4[0][0]']
conv2d_11 (Conv2D)	(None, 4, 4, 576)	55872	['add_2[0][0]']
batch_normalization_18 (BatchNormal ormalization)	(None, 4, 4, 576)	2304	['conv2d_11[0][0]']
tf.nn.relu_13 (TFOpLambda)	(None, 4, 4, 576)	0	['batch_normalization_18[0][0]']
depthwise_conv2d_5 (DepthwiseConv onv2D)	(None, 4, 4, 576)	5760	['tf.nn.relu_13[0][0]']
batch_normalization_19 (BatchNormal ormalization)	(None, 4, 4, 576)	2304	['depthwise_conv2d_5[0][0]']
tf.nn.relu_14 (TFOpLambda)	(None, 4, 4, 576)	0	['batch_normalization_19[0][0]']
conv2d_12 (Conv2D)	(None, 4, 4, 96)	55392	['tf.nn.relu_14[0][0]']
batch_normalization_20 (BatchNormal ormalization)	(None, 4, 4, 96)	384	['conv2d_12[0][0]']
add_3 (Add)	(None, 4, 4, 96)	0	['batch_normalization_20[0][0]', 'add_2[0][0]']
conv2d_13 (Conv2D)	(None, 4, 4, 576)	55872	['add_3[0][0]']
batch_normalization_21 (BatchNormal ormalization)	(None, 4, 4, 576)	2304	['conv2d_13[0][0]']
tf.nn.relu_15 (TFOpLambda)	(None, 4, 4, 576)	0	['batch_normalization_21[0][0]']
depthwise_conv2d_6 (DepthwiseConv onv2D)	(None, 4, 4, 576)	5760	['tf.nn.relu_15[0][0]']
batch_normalization_22 (BatchNormal ormalization)	(None, 4, 4, 576)	2304	['depthwise_conv2d_6[0][0]']
tf.nn.relu_16 (TFOpLambda)	(None, 4, 4, 576)	0	['batch_normalization_22[0][0]']

conv2d_14 (Conv2D)	(None, 4, 4, 128)	73856	['tf.nn.relu_16[0][0]']
batch_normalization_23 (Batch Normalization)	(None, 4, 4, 128)	512	['conv2d_14[0][0]']
conv2d_15 (Conv2D)	(None, 4, 4, 768)	99072	['batch_normalization_23[0][0]']
batch_normalization_24 (Batch Normalization)	(None, 4, 4, 768)	3072	['conv2d_15[0][0]']
tf.nn.relu_17 (TFOpLambda)	(None, 4, 4, 768)	0	['batch_normalization_24[0][0]']
depthwise_conv2d_7 (Depthwise Conv2D)	(None, 4, 4, 768)	7680	['tf.nn.relu_17[0][0]']
batch_normalization_25 (Batch Normalization)	(None, 4, 4, 768)	3072	['depthwise_conv2d_7[0][0]']
tf.nn.relu_18 (TFOpLambda)	(None, 4, 4, 768)	0	['batch_normalization_25[0][0]']
conv2d_16 (Conv2D)	(None, 4, 4, 128)	98432	['tf.nn.relu_18[0][0]']
batch_normalization_26 (Batch Normalization)	(None, 4, 4, 128)	512	['conv2d_16[0][0]']
add_4 (Add)	(None, 4, 4, 128)	0	['batch_normalization_26[0][0]', 'batch_normalization_23[0][0]']
conv2d_17 (Conv2D)	(None, 4, 4, 768)	99072	['add_4[0][0]']
batch_normalization_27 (Batch Normalization)	(None, 4, 4, 768)	3072	['conv2d_17[0][0]']
tf.nn.relu_19 (TFOpLambda)	(None, 4, 4, 768)	0	['batch_normalization_27[0][0]']
depthwise_conv2d_8 (Depthwise Conv2D)	(None, 4, 4, 768)	7680	['tf.nn.relu_19[0][0]']
batch_normalization_28 (Batch Normalization)	(None, 4, 4, 768)	3072	['depthwise_conv2d_8[0][0]']
tf.nn.relu_20 (TFOpLambda)	(None, 4, 4, 768)	0	['batch_normalization_28[0][0]']
conv2d_18 (Conv2D)	(None, 4, 4, 128)	98432	['tf.nn.relu_20[0][0]']
batch_normalization_29 (Batch Normalization)	(None, 4, 4, 128)	512	['conv2d_18[0][0]']
add_5 (Add)	(None, 4, 4, 128)	0	['batch_normalization_29[0][0]', 'add_4[0][0]']

up_sampling2d (UpSampling2D)	(None, 16, 16, 128)	0	['add_5[0][0]']
depthwise_conv2d_9 (DepthwiseConv2D)	(None, 16, 16, 128)	1280	['up_sampling2d[0][0]']
batch_normalization_31 (BatchNormalization)	(None, 16, 16, 128)	512	['depthwise_conv2d_9[0][0]']
conv2d_19 (Conv2D)	(None, 16, 16, 128)	8320	['tf.nn.relu_2[0][0]']
tf.nn.relu_21 (TFOpLambda)	(None, 16, 16, 128)	0	['batch_normalization_31[0][0]']
batch_normalization_30 (BatchNormalization)	(None, 16, 16, 128)	512	['conv2d_19[0][0]']
conv2d_20 (Conv2D)	(None, 16, 16, 128)	16512	['tf.nn.relu_21[0][0]']
add_6 (Add)	(None, 16, 16, 128)	0	['batch_normalization_30[0][0]', 'conv2d_20[0][0]']
batch_normalization_32 (BatchNormalization)	(None, 16, 16, 128)	512	['add_6[0][0]']
tf.nn.relu_22 (TFOpLambda)	(None, 16, 16, 128)	0	['batch_normalization_32[0][0]']
DSConv1_classifier (SeparableConv2D)	(None, 16, 16, 128)	17664	['tf.nn.relu_22[0][0]']
batch_normalization_33 (BatchNormalization)	(None, 16, 16, 128)	512	['DSConv1_classifier[0][0]']
tf.nn.relu_23 (TFOpLambda)	(None, 16, 16, 128)	0	['batch_normalization_33[0][0]']
DSConv2_classifier (SeparableConv2D)	(None, 16, 16, 128)	17664	['tf.nn.relu_23[0][0]']
batch_normalization_34 (BatchNormalization)	(None, 16, 16, 128)	512	['DSConv2_classifier[0][0]']
tf.nn.relu_24 (TFOpLambda)	(None, 16, 16, 128)	0	['batch_normalization_34[0][0]']
conv2d_21 (Conv2D)	(None, 16, 16, 3)	387	['tf.nn.relu_24[0][0]']
batch_normalization_35 (BatchNormalization)	(None, 16, 16, 3)	12	['conv2d_21[0][0]']
dropout (Dropout)	(None, 16, 16, 3)	0	['batch_normalization_35[0][0]']
up_sampling2d_1 (UpSampling2D)	(None, 128, 128, 3)	0	['dropout[0][0]']


```
tf.nn.softmax (TFOpLambda)      (None, 128, 128, 3)  0      ['up_sampling2d_1[0]
[0]']
```

```
=====
=====
Total params: 1,119,151
Trainable params: 1,096,649
Non-trainable params: 22,502
```



```
In [ ]: tf.keras.utils.plot_model(fast_scnn, show_layer_names=True, show_shapes=True)

('Failed to import pydot. You must `pip install pydot` and install graphviz (https://graphviz.gitlab.io/download/), ', 'for `pydotprint` to work.')
```

```
In [26]: history = fast_scnn.fit(x_train, y_train, epochs=100, validation_data=(x_test, y_test))
```

```
Epoch 1/100
42/42 [=====] - 45s 958ms/step - loss: 1.2222 - accuracy: 0.428
4 - val_loss: 1.1287 - val_accuracy: 0.5798
Epoch 2/100
42/42 [=====] - 40s 944ms/step - loss: 1.2367 - accuracy: 0.461
3 - val_loss: 1.1295 - val_accuracy: 0.5798
Epoch 3/100
42/42 [=====] - 40s 947ms/step - loss: 1.3092 - accuracy: 0.469
8 - val_loss: 1.1291 - val_accuracy: 0.5798
Epoch 4/100
42/42 [=====] - 40s 948ms/step - loss: 1.3677 - accuracy: 0.471
7 - val_loss: 1.1275 - val_accuracy: 0.5470
Epoch 5/100
42/42 [=====] - 40s 946ms/step - loss: 1.4471 - accuracy: 0.472
6 - val_loss: 1.1254 - val_accuracy: 0.5319
Epoch 6/100
42/42 [=====] - 40s 948ms/step - loss: 1.5217 - accuracy: 0.476
5 - val_loss: 1.1235 - val_accuracy: 0.5684
Epoch 7/100
42/42 [=====] - 40s 957ms/step - loss: 1.5774 - accuracy: 0.468
8 - val_loss: 1.1323 - val_accuracy: 0.5593
Epoch 8/100
42/42 [=====] - 40s 955ms/step - loss: 1.6704 - accuracy: 0.478
7 - val_loss: 1.1293 - val_accuracy: 0.5806
Epoch 9/100
42/42 [=====] - 40s 952ms/step - loss: 1.7410 - accuracy: 0.475
7 - val_loss: 1.1138 - val_accuracy: 0.6233
Epoch 10/100
42/42 [=====] - 40s 951ms/step - loss: 1.8520 - accuracy: 0.475
5 - val_loss: 1.1105 - val_accuracy: 0.6010
Epoch 11/100
42/42 [=====] - 40s 957ms/step - loss: 1.9178 - accuracy: 0.474
1 - val_loss: 1.1136 - val_accuracy: 0.3903
Epoch 12/100
42/42 [=====] - 40s 953ms/step - loss: 2.0293 - accuracy: 0.477
8 - val_loss: 1.1006 - val_accuracy: 0.5165
Epoch 13/100
42/42 [=====] - 40s 956ms/step - loss: 2.1223 - accuracy: 0.479
2 - val_loss: 1.1073 - val_accuracy: 0.5836
Epoch 14/100
42/42 [=====] - 40s 955ms/step - loss: 2.2315 - accuracy: 0.478
```

4 - val_loss: 1.1340 - val_accuracy: 0.3197
Epoch 15/100
42/42 [=====] - 40s 955ms/step - loss: 2.3425 - accuracy: 0.477
0 - val_loss: 1.2913 - val_accuracy: 0.2884
Epoch 16/100
42/42 [=====] - 40s 956ms/step - loss: 2.4609 - accuracy: 0.479
2 - val_loss: 1.1372 - val_accuracy: 0.3463
Epoch 17/100
42/42 [=====] - 40s 960ms/step - loss: 2.6074 - accuracy: 0.479
4 - val_loss: 1.2021 - val_accuracy: 0.4644
Epoch 18/100
42/42 [=====] - 40s 954ms/step - loss: 2.7443 - accuracy: 0.473
3 - val_loss: 1.1454 - val_accuracy: 0.4763
Epoch 19/100
42/42 [=====] - 40s 956ms/step - loss: 2.8588 - accuracy: 0.475
2 - val_loss: 1.1193 - val_accuracy: 0.4495
Epoch 20/100
42/42 [=====] - 40s 964ms/step - loss: 2.9965 - accuracy: 0.472
3 - val_loss: 1.4753 - val_accuracy: 0.2896
Epoch 21/100
42/42 [=====] - 41s 967ms/step - loss: 3.1236 - accuracy: 0.470
6 - val_loss: 1.1747 - val_accuracy: 0.5173
Epoch 22/100
42/42 [=====] - 40s 956ms/step - loss: 3.2682 - accuracy: 0.477
2 - val_loss: 1.1360 - val_accuracy: 0.4759
Epoch 23/100
42/42 [=====] - 40s 957ms/step - loss: 3.4500 - accuracy: 0.470
4 - val_loss: 1.1621 - val_accuracy: 0.4808
Epoch 24/100
42/42 [=====] - 40s 952ms/step - loss: 3.6178 - accuracy: 0.476
8 - val_loss: 1.1366 - val_accuracy: 0.5948
Epoch 25/100
42/42 [=====] - 40s 953ms/step - loss: 3.6920 - accuracy: 0.468
5 - val_loss: 1.2239 - val_accuracy: 0.4132
Epoch 26/100
42/42 [=====] - 40s 955ms/step - loss: 3.8327 - accuracy: 0.469
2 - val_loss: 1.3123 - val_accuracy: 0.4158
Epoch 27/100
42/42 [=====] - 40s 959ms/step - loss: 3.9712 - accuracy: 0.465
4 - val_loss: 1.1345 - val_accuracy: 0.4384
Epoch 28/100
42/42 [=====] - 40s 952ms/step - loss: 4.0847 - accuracy: 0.468
5 - val_loss: 1.1379 - val_accuracy: 0.4628
Epoch 29/100
42/42 [=====] - 40s 957ms/step - loss: 4.2951 - accuracy: 0.478
7 - val_loss: 1.1900 - val_accuracy: 0.3706
Epoch 30/100
42/42 [=====] - 40s 951ms/step - loss: 4.4092 - accuracy: 0.463
9 - val_loss: 1.4169 - val_accuracy: 0.3258
Epoch 31/100
42/42 [=====] - 40s 956ms/step - loss: 4.5706 - accuracy: 0.467
1 - val_loss: 1.2108 - val_accuracy: 0.3823
Epoch 32/100
42/42 [=====] - 40s 954ms/step - loss: 4.7414 - accuracy: 0.465
5 - val_loss: 1.2437 - val_accuracy: 0.4844
Epoch 33/100
42/42 [=====] - 40s 957ms/step - loss: 4.8895 - accuracy: 0.467
6 - val_loss: 1.1495 - val_accuracy: 0.5249
Epoch 34/100
42/42 [=====] - 40s 955ms/step - loss: 5.0754 - accuracy: 0.469

7 - val_loss: 1.2861 - val_accuracy: 0.5985
Epoch 35/100
42/42 [=====] - 40s 952ms/step - loss: 5.2464 - accuracy: 0.468
9 - val_loss: 1.2109 - val_accuracy: 0.5146
Epoch 36/100
42/42 [=====] - 40s 956ms/step - loss: 5.4385 - accuracy: 0.463
1 - val_loss: 1.2563 - val_accuracy: 0.5658
Epoch 37/100
42/42 [=====] - 40s 957ms/step - loss: 5.6210 - accuracy: 0.469
1 - val_loss: 1.4160 - val_accuracy: 0.4756
Epoch 38/100
42/42 [=====] - 40s 961ms/step - loss: 5.7530 - accuracy: 0.464
0 - val_loss: 1.4869 - val_accuracy: 0.3959
Epoch 39/100
42/42 [=====] - 40s 956ms/step - loss: 5.9106 - accuracy: 0.459
8 - val_loss: 1.2811 - val_accuracy: 0.3999
Epoch 40/100
42/42 [=====] - 40s 950ms/step - loss: 6.2097 - accuracy: 0.463
5 - val_loss: 1.2519 - val_accuracy: 0.5730
Epoch 41/100
42/42 [=====] - 40s 949ms/step - loss: 6.3143 - accuracy: 0.455
7 - val_loss: 1.3079 - val_accuracy: 0.4707
Epoch 42/100
42/42 [=====] - 40s 950ms/step - loss: 6.4517 - accuracy: 0.464
9 - val_loss: 1.3669 - val_accuracy: 0.3175
Epoch 43/100
42/42 [=====] - 40s 947ms/step - loss: 6.6293 - accuracy: 0.462
9 - val_loss: 1.3008 - val_accuracy: 0.4191
Epoch 44/100
42/42 [=====] - 40s 953ms/step - loss: 6.8097 - accuracy: 0.466
4 - val_loss: 1.2494 - val_accuracy: 0.4968
Epoch 45/100
42/42 [=====] - 40s 954ms/step - loss: 7.0452 - accuracy: 0.455
8 - val_loss: 1.5442 - val_accuracy: 0.5563
Epoch 46/100
42/42 [=====] - 40s 956ms/step - loss: 7.1922 - accuracy: 0.459
3 - val_loss: 1.2237 - val_accuracy: 0.4199
Epoch 47/100
42/42 [=====] - 40s 944ms/step - loss: 7.3448 - accuracy: 0.462
5 - val_loss: 1.1687 - val_accuracy: 0.4824
Epoch 48/100
42/42 [=====] - 40s 949ms/step - loss: 7.5265 - accuracy: 0.467
9 - val_loss: 1.1943 - val_accuracy: 0.4145
Epoch 49/100
42/42 [=====] - 40s 947ms/step - loss: 7.6797 - accuracy: 0.469
9 - val_loss: 1.7447 - val_accuracy: 0.5731
Epoch 50/100
42/42 [=====] - 40s 948ms/step - loss: 7.8902 - accuracy: 0.458
9 - val_loss: 1.3037 - val_accuracy: 0.5803
Epoch 51/100
42/42 [=====] - 40s 952ms/step - loss: 8.0942 - accuracy: 0.450
4 - val_loss: 1.5614 - val_accuracy: 0.3898
Epoch 52/100
42/42 [=====] - 40s 948ms/step - loss: 8.3256 - accuracy: 0.457
6 - val_loss: 1.1447 - val_accuracy: 0.4428
Epoch 53/100
42/42 [=====] - 40s 950ms/step - loss: 8.4793 - accuracy: 0.463
3 - val_loss: 1.1258 - val_accuracy: 0.4842
Epoch 54/100
42/42 [=====] - 40s 956ms/step - loss: 8.7146 - accuracy: 0.450

6 - val_loss: 1.4696 - val_accuracy: 0.3986
Epoch 55/100
42/42 [=====] - 40s 948ms/step - loss: 8.9542 - accuracy: 0.460
4 - val_loss: 1.2940 - val_accuracy: 0.3397
Epoch 56/100
42/42 [=====] - 40s 947ms/step - loss: 9.0245 - accuracy: 0.454
2 - val_loss: 1.2534 - val_accuracy: 0.4006
Epoch 57/100
42/42 [=====] - 40s 953ms/step - loss: 9.2626 - accuracy: 0.454
8 - val_loss: 1.3344 - val_accuracy: 0.5700
Epoch 58/100
42/42 [=====] - 40s 946ms/step - loss: 9.3301 - accuracy: 0.452
9 - val_loss: 1.2222 - val_accuracy: 0.5129
Epoch 59/100
42/42 [=====] - 40s 947ms/step - loss: 9.6112 - accuracy: 0.461
5 - val_loss: 1.4054 - val_accuracy: 0.5410
Epoch 60/100
42/42 [=====] - 40s 948ms/step - loss: 9.7488 - accuracy: 0.460
5 - val_loss: 1.2670 - val_accuracy: 0.4598
Epoch 61/100
42/42 [=====] - 40s 948ms/step - loss: 9.9894 - accuracy: 0.442
1 - val_loss: 1.4941 - val_accuracy: 0.5238
Epoch 62/100
42/42 [=====] - 40s 950ms/step - loss: 10.1111 - accuracy: 0.45
66 - val_loss: 1.4818 - val_accuracy: 0.5540
Epoch 63/100
42/42 [=====] - 40s 951ms/step - loss: 10.3633 - accuracy: 0.45
18 - val_loss: 1.4092 - val_accuracy: 0.4875
Epoch 64/100
42/42 [=====] - 40s 947ms/step - loss: 10.4926 - accuracy: 0.44
91 - val_loss: 1.2194 - val_accuracy: 0.5457
Epoch 65/100
42/42 [=====] - 40s 945ms/step - loss: 10.6170 - accuracy: 0.45
77 - val_loss: 1.2386 - val_accuracy: 0.4791
Epoch 66/100
42/42 [=====] - 39s 943ms/step - loss: 10.8665 - accuracy: 0.45
10 - val_loss: 1.2062 - val_accuracy: 0.5041
Epoch 67/100
42/42 [=====] - 40s 943ms/step - loss: 11.0237 - accuracy: 0.45
32 - val_loss: 2.1177 - val_accuracy: 0.3935
Epoch 68/100
42/42 [=====] - 40s 950ms/step - loss: 11.1830 - accuracy: 0.44
71 - val_loss: 1.7661 - val_accuracy: 0.4363
Epoch 69/100
42/42 [=====] - 40s 953ms/step - loss: 11.3996 - accuracy: 0.45
07 - val_loss: 1.5338 - val_accuracy: 0.3629
Epoch 70/100
42/42 [=====] - 40s 950ms/step - loss: 11.4415 - accuracy: 0.45
18 - val_loss: 1.2681 - val_accuracy: 0.5000
Epoch 71/100
42/42 [=====] - 40s 951ms/step - loss: 11.8035 - accuracy: 0.45
06 - val_loss: 1.3852 - val_accuracy: 0.5721
Epoch 72/100
42/42 [=====] - 40s 951ms/step - loss: 11.8992 - accuracy: 0.44
76 - val_loss: 1.3040 - val_accuracy: 0.3944
Epoch 73/100
42/42 [=====] - 40s 950ms/step - loss: 12.2661 - accuracy: 0.44
96 - val_loss: 1.3717 - val_accuracy: 0.5977
Epoch 74/100
42/42 [=====] - 40s 957ms/step - loss: 12.3231 - accuracy: 0.43

```
84 - val_loss: 1.5617 - val_accuracy: 0.4944
Epoch 75/100
42/42 [=====] - 40s 960ms/step - loss: 12.6251 - accuracy: 0.44
53 - val_loss: 1.4625 - val_accuracy: 0.5502
Epoch 76/100
42/42 [=====] - 40s 957ms/step - loss: 12.8746 - accuracy: 0.43
80 - val_loss: 1.7837 - val_accuracy: 0.6247
Epoch 77/100
42/42 [=====] - 40s 961ms/step - loss: 12.8906 - accuracy: 0.45
31 - val_loss: 1.4608 - val_accuracy: 0.4888
Epoch 78/100
42/42 [=====] - 40s 956ms/step - loss: 13.1918 - accuracy: 0.45
45 - val_loss: 1.3218 - val_accuracy: 0.4832
Epoch 79/100
42/42 [=====] - 40s 958ms/step - loss: 13.4346 - accuracy: 0.44
39 - val_loss: 1.3290 - val_accuracy: 0.4908
Epoch 80/100
42/42 [=====] - 40s 959ms/step - loss: 13.6007 - accuracy: 0.44
14 - val_loss: 1.6991 - val_accuracy: 0.5017
Epoch 81/100
42/42 [=====] - 40s 959ms/step - loss: 13.8179 - accuracy: 0.42
67 - val_loss: 1.6166 - val_accuracy: 0.4411
Epoch 82/100
42/42 [=====] - 40s 952ms/step - loss: 14.0078 - accuracy: 0.44
81 - val_loss: 1.4367 - val_accuracy: 0.5269
Epoch 83/100
42/42 [=====] - 40s 954ms/step - loss: 14.0435 - accuracy: 0.43
89 - val_loss: 1.2934 - val_accuracy: 0.5079
Epoch 84/100
42/42 [=====] - 40s 957ms/step - loss: 14.2495 - accuracy: 0.44
61 - val_loss: 2.0623 - val_accuracy: 0.6203
Epoch 85/100
42/42 [=====] - 40s 956ms/step - loss: 14.3404 - accuracy: 0.44
71 - val_loss: 1.5163 - val_accuracy: 0.4374
Epoch 86/100
42/42 [=====] - 40s 961ms/step - loss: 14.6419 - accuracy: 0.44
77 - val_loss: 1.6755 - val_accuracy: 0.4259
Epoch 87/100
42/42 [=====] - 40s 963ms/step - loss: 15.0077 - accuracy: 0.44
42 - val_loss: 1.2144 - val_accuracy: 0.5625
Epoch 88/100
42/42 [=====] - 40s 958ms/step - loss: 15.2630 - accuracy: 0.44
80 - val_loss: 1.2525 - val_accuracy: 0.4968
Epoch 89/100
42/42 [=====] - 40s 959ms/step - loss: 15.4971 - accuracy: 0.45
59 - val_loss: 1.2195 - val_accuracy: 0.6961
Epoch 90/100
42/42 [=====] - 40s 955ms/step - loss: 15.5717 - accuracy: 0.44
23 - val_loss: 1.4387 - val_accuracy: 0.4713
Epoch 91/100
42/42 [=====] - 40s 956ms/step - loss: 15.6730 - accuracy: 0.43
95 - val_loss: 1.5805 - val_accuracy: 0.5869
Epoch 92/100
42/42 [=====] - 40s 950ms/step - loss: 15.9259 - accuracy: 0.44
51 - val_loss: 2.1752 - val_accuracy: 0.3946
Epoch 93/100
42/42 [=====] - 40s 951ms/step - loss: 16.2030 - accuracy: 0.45
08 - val_loss: 1.3985 - val_accuracy: 0.3975
Epoch 94/100
42/42 [=====] - 40s 951ms/step - loss: 16.1736 - accuracy: 0.43
```

```

30 - val_loss: 1.5278 - val_accuracy: 0.3781
Epoch 95/100
42/42 [=====] - 40s 949ms/step - loss: 16.4876 - accuracy: 0.43
36 - val_loss: 1.6291 - val_accuracy: 0.5294
Epoch 96/100
42/42 [=====] - 40s 954ms/step - loss: 16.6073 - accuracy: 0.44
78 - val_loss: 1.6121 - val_accuracy: 0.5942
Epoch 97/100
42/42 [=====] - 40s 950ms/step - loss: 16.8593 - accuracy: 0.44
93 - val_loss: 1.7802 - val_accuracy: 0.5230
Epoch 98/100
42/42 [=====] - 40s 954ms/step - loss: 17.2980 - accuracy: 0.43
90 - val_loss: 1.5681 - val_accuracy: 0.4704
Epoch 99/100
42/42 [=====] - 40s 955ms/step - loss: 17.2812 - accuracy: 0.43
01 - val_loss: 1.5431 - val_accuracy: 0.4792
Epoch 100/100
42/42 [=====] - 40s 954ms/step - loss: 17.5480 - accuracy: 0.44
68 - val_loss: 1.9537 - val_accuracy: 0.5028

```

```
In [42]: df = pd.DataFrame(history.history)
df
```

```
Out[42]:
```

	loss	accuracy	val_loss	val_accuracy
0	1.222212	0.428408	1.128715	0.579831
1	1.236721	0.461335	1.129452	0.579831
2	1.309248	0.469792	1.129057	0.579831
3	1.367674	0.471684	1.127452	0.547034
4	1.447054	0.472633	1.125405	0.531910
...
95	16.607347	0.447823	1.612057	0.594153
96	16.859287	0.449316	1.780201	0.522970
97	17.297951	0.439048	1.568107	0.470356
98	17.281244	0.430145	1.543139	0.479230
99	17.548027	0.446827	1.953747	0.502815

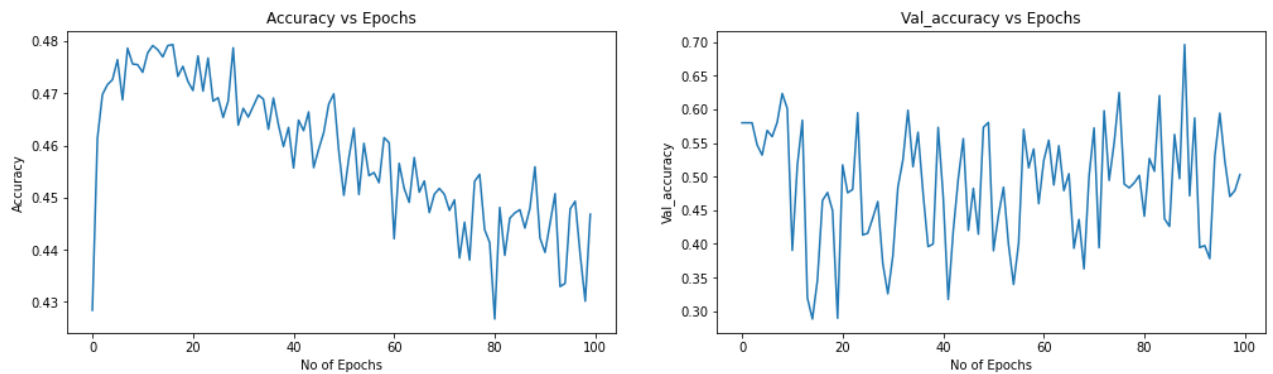
100 rows × 4 columns

```
In [28]: import matplotlib.pyplot as plt
fig, axes = plt.subplots(1,2, figsize=(15, 5))
fig.tight_layout(pad=5.0)

axes[0].plot(df.accuracy)
axes[0].set_xlabel('No of Epochs')
axes[0].set_ylabel('Accuracy')
axes[0].set_title('Accuracy vs Epochs')

axes[1].plot(df.val_accuracy)
axes[1].set_xlabel('No of Epochs')
axes[1].set_ylabel('Val_accuracy')
```

```
axes[1].set_title('Val_accuracy vs Epochs')
plt.show()
```

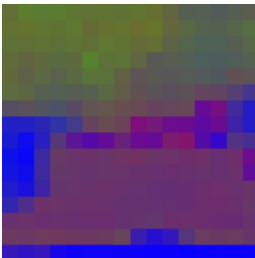


```
In [44]: probability_model = tf.keras.Sequential([fast_scnn,
                                                tf.keras.layers.Softmax()])
        predictions = probability_model.predict(x_test)
        predictions[0].shape
```

```
Out[44]: (128, 128, 3)
```

```
In [45]: tf.keras.preprocessing.image.array_to_img(
        predictions[0])
```

```
Out[45]:
```



```
In [39]: tf.keras.preprocessing.image.array_to_img(
        y_test[0])
```

```
Out[39]:
```



```
In [40]: from keras import backend as K
        def iou_coef(y_true, y_pred, smooth=1):
            intersection = K.sum(K.abs(y_true * y_pred), axis=[1,2,3])
            union = K.sum(y_true,[1,2,3])+K.sum(y_pred,[1,2,3])-intersection
            iou = K.mean((intersection + smooth) / (union + smooth), axis=0)
            return iou
```

```
In [41]: print(iou_coef(y_test, predictions))

tf.Tensor(0.31252956, shape=(), dtype=float32)
```

```
In [51]: from statistics import mean  
  
         avg = mean(df['accuracy'])  
  
         print("The average is ", avg)  
  
The average is  0.45836203008890153
```

```
In [52]: from statistics import mean  
  
         avg = mean(df['val_accuracy'])  
  
         print("The average is ", avg)  
  
The average is  0.4858311793208122
```