CNN on CIFR Assignment:

1. Please visit this link to access the state-of-art DenseNet code for reference - DenseNet - cifar10 notebook link
2. You need to create a copy of this and "retrain" this model to achieve 90+ test accuracy.
3. You cannot use DropOut layers.
4. You MUST use Image Augmentation Techniques.
5. You cannot use an already trained model as a beginning points, you have to initilize as your own
6. You cannot run the program for more than 300 Epochs, and it should be clear from your log, that you have only used 300 Epochs
7. You cannot use test images for training the model.
8. You cannot change the general architecture of DenseNet (which means you must use Dense Block, Transition and Output blocks as mentioned in the code)
9. You are free to change Convolution types (e.g. from 3x3 normal convolution to Depthwise Separable, etc)
10. You cannot have more than 1 Million parameters in total
11. You are free to move the code from Keras to Tensorflow, Pytorch, MXNET etc.
12. You can use any optimization algorithm you need.
13. You can checkpoint your model and retrain the model from that checkpoint so that no need of training the model from first if you lost at any epoch while training. You can directly load that model and Train from that epoch.

In [1]:
```
#https://arxiv.org/pdf/1608.06993.pdf

from IPython.display import IFrame, YouTubeVideo
YouTubeVideo(id='-W6y8xnd--U', width=700)
```

Out[1]:

In [2]:
```
from datetime import datetime

import numpy as np
import seaborn as sns
import matplotlib.pyplot as plt
plt.style.use('fivethirtyeight')

import tensorflow
from tensorflow.keras import Model
from tensorflow.keras import Input
from tensorflow.keras.layers import Dense
from tensorflow.keras.layers import Conv2D
from tensorflow.keras.layers import Flatten
from tensorflow.keras.layers import Activation
from tensorflow.keras.layers import Concatenate
from tensorflow.keras.layers import AveragePooling2D
from tensorflow.keras.layers import BatchNormalization
from tensorflow.keras.layers import GlobalAveragePooling2D

from tensorflow.keras.callbacks import Callback
from tensorflow.keras.callbacks import TensorBoard
from tensorflow.keras.callbacks import EarlyStopping
from tensorflow.keras.callbacks import ModelCheckpoint
from tensorflow.keras.callbacks import ReduceLROnPlateau
from tensorflow.keras.callbacks import LearningRateScheduler

from tensorflow.keras.optimizers import SGD
from tensorflow.keras.datasets import cifar10
from tensorflow.keras.utils import to_categorical
from tensorflow.keras.preprocessing.image import ImageDataGenerator
```

In [3]:
```
# Load CIFAR10 Data

(x_train, y_train), (x_test, y_test) = cifar10.load_data()

print(f'Shape of train data : {x_train.shape}')
print(f'Shape of test data  : {x_test.shape}')
```

```
Downloading data from https://www.cs.toronto.edu/~kriz/cifar-10-python.tar.gz
170498071/170498071 [==============================] - 3s 0us/step
Shape of train data : (50000, 32, 32, 3)
Shape of test data  : (10000, 32, 32, 3)
```

In [4]:
```
img_height, img_width, channel_count = x_train.shape[1], x_train.shape[2], x_train.shape[3]
```

In [5]:
```
Epochs = 300
Num_classes = 10
Batch_size = 128
```

In [6]:
```
# Convert class vector to binary class matrix

print(f'Shape of class vector BEFORE converting into BINARY class matrix : {y_train.shape}')

y_train = to_categorical(y_train, Num_classes)
y_test = to_categorical(y_test, Num_classes)

print(f'Shape of class vector AFTER converting into BINARY class matrix  : {y_train.shape}')
```

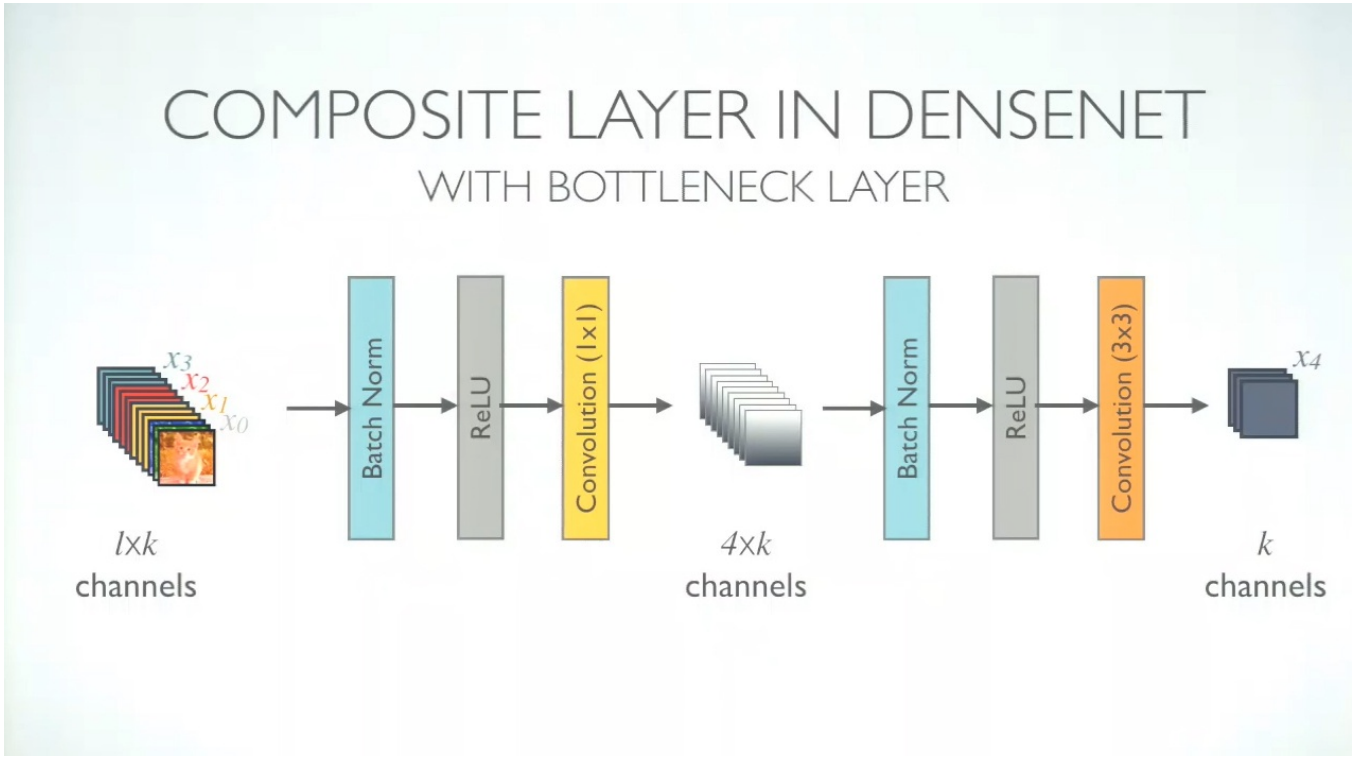
```
Shape of class vector BEFORE converting into BINARY class matrix : (50000, 1)
Shape of class vector AFTER converting into BINARY class matrix  : (50000, 10)
```

Image Augmentation

In [7]:
```
# https://www.tensorflow.org/api_docs/python/tf/keras/preprocessing/image/ImageDataGenerator

datagen = ImageDataGenerator(rotation_range = 10, shear_range = 0.4, zoom_range = 0.3,
                             horizontal_flip = True, vertical_flip = False, rescale = 1./255)
datagen.fit(x_train)
```

Bottleneck Layer :



Ref : https://youtu.be/-W6y8xnd--U

> *BN-ReLU-Conv(1×1)-BN-ReLU-Conv(3×3)*

In [8]:
```
def bottleneck(input_, num_filter = 12, loop = 16):

    temp = input_
    for _ in range(loop):

        BatchNorm = BatchNormalization()(temp)
        relu = Activation('relu')(BatchNorm)
        Conv2D_1_1 = Conv2D(4 * num_filter, (1, 1), use_bias = False, padding = 'same')(relu)

        BatchNorm = BatchNormalization()(Conv2D_1_1)
        relu = Activation('relu')(BatchNorm)
        Conv2D_3_3 = Conv2D(num_filter, (3, 3), use_bias = False, padding = 'same')(relu)

        concat = Concatenate(axis = -1)([temp, Conv2D_3_3])

        temp = concat

    return temp
```

Translation Layer :

> *The transition layers used in our experiments consist of a batch normalization layer and an 1×1 convolutional layer followed by a 2×2 average pooling layer.*

In [9]:
```
def transition(input_, num_filter = 12, compression = 0.5):

    num_filter = input_.shape.as_list()[-1]
    BatchNorm = BatchNormalization()(input_)
    relu = Activation('relu')(BatchNorm)
    Conv2D_transition = Conv2D(int(num_filter * compression), (1, 1),
                               use_bias = False, padding = 'same')(relu)
    avg = AveragePooling2D(pool_size = (2, 2))(Conv2D_transition)

    return avg
```

Output Layer :

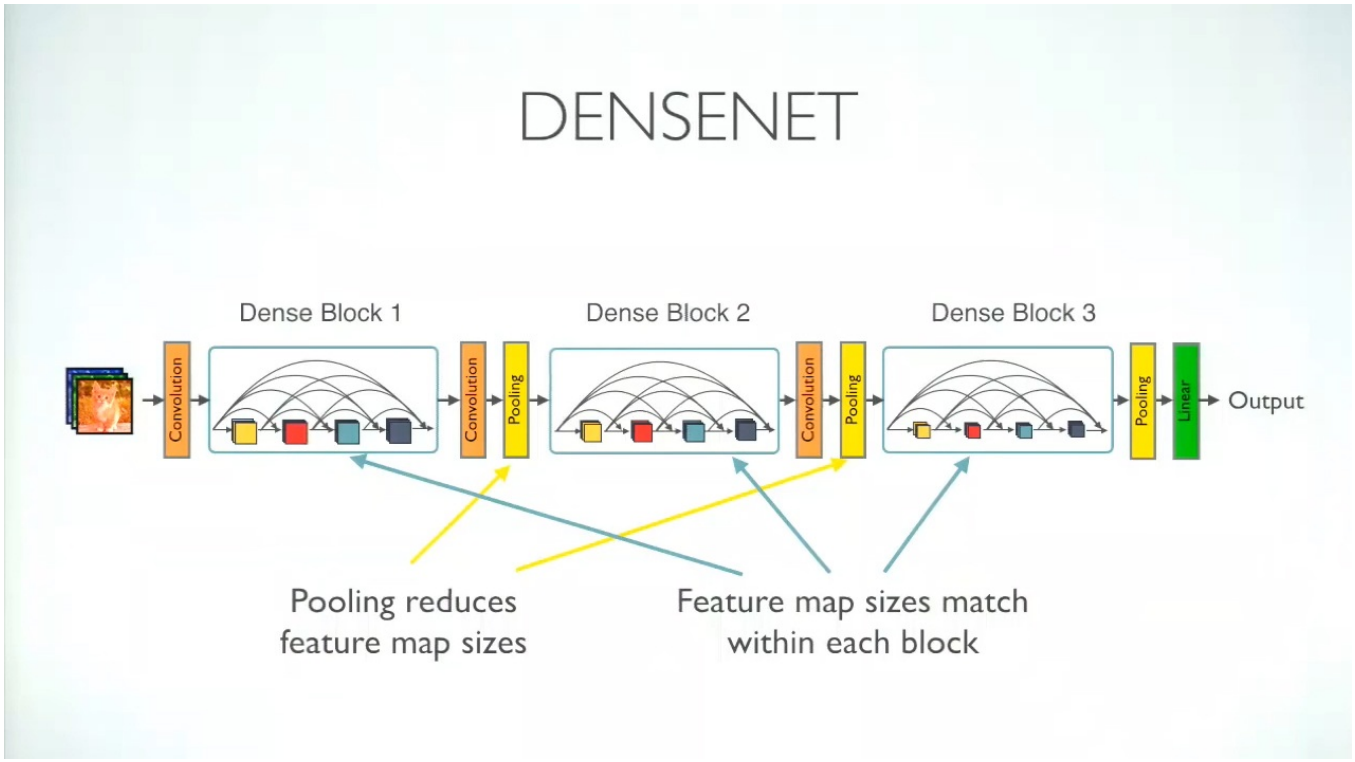
> *At the end of the last dense block, a global average pooling is performed and then a softmax classifier is attached.*

In [10]:
```
def output_layer(input_, num_classes = 10):

    BatchNorm = BatchNormalization()(input_)
    GlobalAP = GlobalAveragePooling2D()(BatchNorm)
    outP = Dense(num_classes, activation = 'softmax')(GlobalAP)

    return outP
```

Architecture



Ref : https://youtu.be/-W6y8xnd--U

Experimenting with the basic DenseNet structure with configurations L = 100 and k = 12.

```
Where L : Layers
      k : Growth Rate
```

> *In our experiments on ImageNet, we use a DenseNet-BC structure with 4 dense blocks on 224×224 input images. The initial convolution layer comprises 2k convolutions of size 7×7 with stride 2*

In [11]:

```
tensorflow.keras.backend.clear_session()
tensorflow.random.set_seed(45)
np.random.seed(48)

num_filter = 12

in_ = Input(shape = (img_height, img_width, channel_count))
First_Conv2D = Conv2D(2 * num_filter, (3,3), use_bias=False ,padding='same')(in_)

First_Block = bottleneck(First_Conv2D)
First_Transition = transition(First_Block)

Second_Block = bottleneck(First_Transition)
Second_Transition = transition(Second_Block)

Third_Block = bottleneck(Second_Transition)
Third_Transition = transition(Third_Block)


output = output_layer(Third_Transition)
```

In [12]:

```
tensorflow.keras.backend.clear_session()

model = Model(inputs=[in_], outputs=[output])
model.summary()
```

```
Model: "model"
```

Layer (type)	Output Shape	Param #	Connected to
input_1 (InputLayer)	[(None, 32, 32, 3)]	0	[]
conv2d (Conv2D)	(None, 32, 32, 24)	648	['input_1[0][0]']
batch_normalization (BatchNormalization)	(None, 32, 32, 24)	96	['conv2d[0][0]']
activation (Activation)	(None, 32, 32, 24)	0	['batch_normalization[0][0]']
conv2d_1 (Conv2D)	(None, 32, 32, 48)	1152	['activation[0][0]']

```
batch_normalization_1 (BatchNo  (None, 32, 32, 48)  192         ['conv2d_1[0][0]']
rmalization)

activation_1 (Activation)      (None, 32, 32, 48)   0           ['batch_normalization_1[0][0]']

conv2d_2 (Conv2D)              (None, 32, 32, 12)   5184        ['activation_1[0][0]']

concatenate (Concatenate)      (None, 32, 32, 36)   0           ['conv2d[0][0]',
                                                                 'conv2d_2[0][0]']

batch_normalization_2 (BatchNo  (None, 32, 32, 36)  144         ['concatenate[0][0]']
rmalization)

activation_2 (Activation)      (None, 32, 32, 36)   0           ['batch_normalization_2[0][0]']

conv2d_3 (Conv2D)              (None, 32, 32, 48)   1728        ['activation_2[0][0]']

batch_normalization_3 (BatchNo  (None, 32, 32, 48)  192         ['conv2d_3[0][0]']
rmalization)

activation_3 (Activation)      (None, 32, 32, 48)   0           ['batch_normalization_3[0][0]']

conv2d_4 (Conv2D)              (None, 32, 32, 12)   5184        ['activation_3[0][0]']

concatenate_1 (Concatenate)    (None, 32, 32, 48)   0           ['concatenate[0][0]',
                                                                 'conv2d_4[0][0]']

batch_normalization_4 (BatchNo  (None, 32, 32, 48)  192         ['concatenate_1[0][0]']
rmalization)

activation_4 (Activation)      (None, 32, 32, 48)   0           ['batch_normalization_4[0][0]']

conv2d_5 (Conv2D)              (None, 32, 32, 48)   2304        ['activation_4[0][0]']

batch_normalization_5 (BatchNo  (None, 32, 32, 48)  192         ['conv2d_5[0][0]']
rmalization)

activation_5 (Activation)      (None, 32, 32, 48)   0           ['batch_normalization_5[0][0]']

conv2d_6 (Conv2D)              (None, 32, 32, 12)   5184        ['activation_5[0][0]']

concatenate_2 (Concatenate)    (None, 32, 32, 60)   0           ['concatenate_1[0][0]',
                                                                 'conv2d_6[0][0]']

batch_normalization_6 (BatchNo  (None, 32, 32, 60)  240         ['concatenate_2[0][0]']
rmalization)

activation_6 (Activation)      (None, 32, 32, 60)   0           ['batch_normalization_6[0][0]']

conv2d_7 (Conv2D)              (None, 32, 32, 48)   2880        ['activation_6[0][0]']

batch_normalization_7 (BatchNo  (None, 32, 32, 48)  192         ['conv2d_7[0][0]']
rmalization)

activation_7 (Activation)      (None, 32, 32, 48)   0           ['batch_normalization_7[0][0]']

conv2d_8 (Conv2D)              (None, 32, 32, 12)   5184        ['activation_7[0][0]']

concatenate_3 (Concatenate)    (None, 32, 32, 72)   0           ['concatenate_2[0][0]',
                                                                 'conv2d_8[0][0]']

batch_normalization_8 (BatchNo  (None, 32, 32, 72)  288         ['concatenate_3[0][0]']
rmalization)

activation_8 (Activation)      (None, 32, 32, 72)   0           ['batch_normalization_8[0][0]']

conv2d_9 (Conv2D)              (None, 32, 32, 48)   3456        ['activation_8[0][0]']

batch_normalization_9 (BatchNo  (None, 32, 32, 48)  192         ['conv2d_9[0][0]']
rmalization)

activation_9 (Activation)      (None, 32, 32, 48)   0           ['batch_normalization_9[0][0]']

conv2d_10 (Conv2D)             (None, 32, 32, 12)   5184        ['activation_9[0][0]']

concatenate_4 (Concatenate)    (None, 32, 32, 84)   0           ['concatenate_3[0][0]',
                                                                 'conv2d_10[0][0]']

batch_normalization_10 (BatchN  (None, 32, 32, 84)  336         ['concatenate_4[0][0]']
ormalization)

activation_10 (Activation)     (None, 32, 32, 84)   0           ['batch_normalization_10[0][0]']

conv2d_11 (Conv2D)             (None, 32, 32, 48)   4032        ['activation_10[0][0]']

batch_normalization_11 (BatchN  (None, 32, 32, 48)  192         ['conv2d_11[0][0]']
ormalization)

activation_11 (Activation)     (None, 32, 32, 48)   0           ['batch_normalization_11[0][0]']
```

```
conv2d_12 (Conv2D)             (None, 32, 32, 12)   5184        ['activation_11[0][0]']

concatenate_5 (Concatenate)    (None, 32, 32, 96)   0           ['concatenate_4[0][0]',
                                                                 'conv2d_12[0][0]']

batch_normalization_12 (BatchN  (None, 32, 32, 96)  384         ['concatenate_5[0][0]']
ormalization)

activation_12 (Activation)     (None, 32, 32, 96)   0           ['batch_normalization_12[0][0]']

conv2d_13 (Conv2D)             (None, 32, 32, 48)   4608        ['activation_12[0][0]']

batch_normalization_13 (BatchN  (None, 32, 32, 48)  192         ['conv2d_13[0][0]']
ormalization)

activation_13 (Activation)     (None, 32, 32, 48)   0           ['batch_normalization_13[0][0]']

conv2d_14 (Conv2D)             (None, 32, 32, 12)   5184        ['activation_13[0][0]']

concatenate_6 (Concatenate)    (None, 32, 32, 108)  0           ['concatenate_5[0][0]',
                                                                 'conv2d_14[0][0]']

batch_normalization_14 (BatchN  (None, 32, 32, 108)  432        ['concatenate_6[0][0]']
ormalization)

activation_14 (Activation)     (None, 32, 32, 108)  0           ['batch_normalization_14[0][0]']

conv2d_15 (Conv2D)             (None, 32, 32, 48)   5184        ['activation_14[0][0]']

batch_normalization_15 (BatchN  (None, 32, 32, 48)  192         ['conv2d_15[0][0]']
ormalization)

activation_15 (Activation)     (None, 32, 32, 48)   0           ['batch_normalization_15[0][0]']

conv2d_16 (Conv2D)             (None, 32, 32, 12)   5184        ['activation_15[0][0]']

concatenate_7 (Concatenate)    (None, 32, 32, 120)  0           ['concatenate_6[0][0]',
                                                                 'conv2d_16[0][0]']

batch_normalization_16 (BatchN  (None, 32, 32, 120)  480        ['concatenate_7[0][0]']
ormalization)

activation_16 (Activation)     (None, 32, 32, 120)  0           ['batch_normalization_16[0][0]']

conv2d_17 (Conv2D)             (None, 32, 32, 48)   5760        ['activation_16[0][0]']

batch_normalization_17 (BatchN  (None, 32, 32, 48)  192         ['conv2d_17[0][0]']
ormalization)

activation_17 (Activation)     (None, 32, 32, 48)   0           ['batch_normalization_17[0][0]']

conv2d_18 (Conv2D)             (None, 32, 32, 12)   5184        ['activation_17[0][0]']

concatenate_8 (Concatenate)    (None, 32, 32, 132)  0           ['concatenate_7[0][0]',
                                                                 'conv2d_18[0][0]']

batch_normalization_18 (BatchN  (None, 32, 32, 132)  528        ['concatenate_8[0][0]']
ormalization)

activation_18 (Activation)     (None, 32, 32, 132)  0           ['batch_normalization_18[0][0]']

conv2d_19 (Conv2D)             (None, 32, 32, 48)   6336        ['activation_18[0][0]']

batch_normalization_19 (BatchN  (None, 32, 32, 48)  192         ['conv2d_19[0][0]']
ormalization)

activation_19 (Activation)     (None, 32, 32, 48)   0           ['batch_normalization_19[0][0]']

conv2d_20 (Conv2D)             (None, 32, 32, 12)   5184        ['activation_19[0][0]']

concatenate_9 (Concatenate)    (None, 32, 32, 144)  0           ['concatenate_8[0][0]',
                                                                 'conv2d_20[0][0]']

batch_normalization_20 (BatchN  (None, 32, 32, 144)  576        ['concatenate_9[0][0]']
ormalization)

activation_20 (Activation)     (None, 32, 32, 144)  0           ['batch_normalization_20[0][0]']

conv2d_21 (Conv2D)             (None, 32, 32, 48)   6912        ['activation_20[0][0]']

batch_normalization_21 (BatchN  (None, 32, 32, 48)  192         ['conv2d_21[0][0]']
ormalization)

activation_21 (Activation)     (None, 32, 32, 48)   0           ['batch_normalization_21[0][0]']

conv2d_22 (Conv2D)             (None, 32, 32, 12)   5184        ['activation_21[0][0]']

concatenate_10 (Concatenate)   (None, 32, 32, 156)  0           ['concatenate_9[0][0]',
```

```
                                                                  'conv2d_22[0][0]']

batch_normalization_22 (BatchN  (None, 32, 32, 156)  624        ['concatenate_10[0][0]']
ormalization)

activation_22 (Activation)     (None, 32, 32, 156)  0           ['batch_normalization_22[0][0]']

conv2d_23 (Conv2D)             (None, 32, 32, 48)   7488        ['activation_22[0][0]']

batch_normalization_23 (BatchN  (None, 32, 32, 48)  192         ['conv2d_23[0][0]']
ormalization)

activation_23 (Activation)     (None, 32, 32, 48)   0           ['batch_normalization_23[0][0]']

conv2d_24 (Conv2D)             (None, 32, 32, 12)   5184        ['activation_23[0][0]']

concatenate_11 (Concatenate)   (None, 32, 32, 168)  0           ['concatenate_10[0][0]',
                                                                 'conv2d_24[0][0]']

batch_normalization_24 (BatchN  (None, 32, 32, 168)  672        ['concatenate_11[0][0]']
ormalization)

activation_24 (Activation)     (None, 32, 32, 168)  0           ['batch_normalization_24[0][0]']

conv2d_25 (Conv2D)             (None, 32, 32, 48)   8064        ['activation_24[0][0]']

batch_normalization_25 (BatchN  (None, 32, 32, 48)  192         ['conv2d_25[0][0]']
ormalization)

activation_25 (Activation)     (None, 32, 32, 48)   0           ['batch_normalization_25[0][0]']

conv2d_26 (Conv2D)             (None, 32, 32, 12)   5184        ['activation_25[0][0]']

concatenate_12 (Concatenate)   (None, 32, 32, 180)  0           ['concatenate_11[0][0]',
                                                                 'conv2d_26[0][0]']

batch_normalization_26 (BatchN  (None, 32, 32, 180)  720        ['concatenate_12[0][0]']
ormalization)

activation_26 (Activation)     (None, 32, 32, 180)  0           ['batch_normalization_26[0][0]']

conv2d_27 (Conv2D)             (None, 32, 32, 48)   8640        ['activation_26[0][0]']

batch_normalization_27 (BatchN  (None, 32, 32, 48)  192         ['conv2d_27[0][0]']
ormalization)

activation_27 (Activation)     (None, 32, 32, 48)   0           ['batch_normalization_27[0][0]']

conv2d_28 (Conv2D)             (None, 32, 32, 12)   5184        ['activation_27[0][0]']

concatenate_13 (Concatenate)   (None, 32, 32, 192)  0           ['concatenate_12[0][0]',
                                                                 'conv2d_28[0][0]']

batch_normalization_28 (BatchN  (None, 32, 32, 192)  768        ['concatenate_13[0][0]']
ormalization)

activation_28 (Activation)     (None, 32, 32, 192)  0           ['batch_normalization_28[0][0]']

conv2d_29 (Conv2D)             (None, 32, 32, 48)   9216        ['activation_28[0][0]']

batch_normalization_29 (BatchN  (None, 32, 32, 48)  192         ['conv2d_29[0][0]']
ormalization)

activation_29 (Activation)     (None, 32, 32, 48)   0           ['batch_normalization_29[0][0]']

conv2d_30 (Conv2D)             (None, 32, 32, 12)   5184        ['activation_29[0][0]']

concatenate_14 (Concatenate)   (None, 32, 32, 204)  0           ['concatenate_13[0][0]',
                                                                 'conv2d_30[0][0]']

batch_normalization_30 (BatchN  (None, 32, 32, 204)  816        ['concatenate_14[0][0]']
ormalization)

activation_30 (Activation)     (None, 32, 32, 204)  0           ['batch_normalization_30[0][0]']

conv2d_31 (Conv2D)             (None, 32, 32, 48)   9792        ['activation_30[0][0]']

batch_normalization_31 (BatchN  (None, 32, 32, 48)  192         ['conv2d_31[0][0]']
ormalization)

activation_31 (Activation)     (None, 32, 32, 48)   0           ['batch_normalization_31[0][0]']

conv2d_32 (Conv2D)             (None, 32, 32, 12)   5184        ['activation_31[0][0]']

concatenate_15 (Concatenate)   (None, 32, 32, 216)  0           ['concatenate_14[0][0]',
                                                                 'conv2d_32[0][0]']

batch_normalization_32 (BatchN  (None, 32, 32, 216)  864        ['concatenate_15[0][0]']
ormalization)
```

```
activation_32 (Activation)     (None, 32, 32, 216)  0           ['batch_normalization_32[0][0]']

conv2d_33 (Conv2D)             (None, 32, 32, 108)  23328       ['activation_32[0][0]']

average_pooling2d (AveragePool  (None, 16, 16, 108)  0          ['conv2d_33[0][0]']
ing2D)

batch_normalization_33 (BatchN  (None, 16, 16, 108)  432        ['average_pooling2d[0][0]']
ormalization)

activation_33 (Activation)     (None, 16, 16, 108)  0           ['batch_normalization_33[0][0]']

conv2d_34 (Conv2D)             (None, 16, 16, 48)   5184        ['activation_33[0][0]']

batch_normalization_34 (BatchN  (None, 16, 16, 48)  192         ['conv2d_34[0][0]']
ormalization)

activation_34 (Activation)     (None, 16, 16, 48)   0           ['batch_normalization_34[0][0]']

conv2d_35 (Conv2D)             (None, 16, 16, 12)   5184        ['activation_34[0][0]']

concatenate_16 (Concatenate)   (None, 16, 16, 120)  0           ['average_pooling2d[0][0]',
                                                                 'conv2d_35[0][0]']

batch_normalization_35 (BatchN  (None, 16, 16, 120)  480        ['concatenate_16[0][0]']
ormalization)

activation_35 (Activation)     (None, 16, 16, 120)  0           ['batch_normalization_35[0][0]']

conv2d_36 (Conv2D)             (None, 16, 16, 48)   5760        ['activation_35[0][0]']

batch_normalization_36 (BatchN  (None, 16, 16, 48)  192         ['conv2d_36[0][0]']
ormalization)

activation_36 (Activation)     (None, 16, 16, 48)   0           ['batch_normalization_36[0][0]']

conv2d_37 (Conv2D)             (None, 16, 16, 12)   5184        ['activation_36[0][0]']

concatenate_17 (Concatenate)   (None, 16, 16, 132)  0           ['concatenate_16[0][0]',
                                                                 'conv2d_37[0][0]']

batch_normalization_37 (BatchN  (None, 16, 16, 132)  528        ['concatenate_17[0][0]']
ormalization)

activation_37 (Activation)     (None, 16, 16, 132)  0           ['batch_normalization_37[0][0]']

conv2d_38 (Conv2D)             (None, 16, 16, 48)   6336        ['activation_37[0][0]']

batch_normalization_38 (BatchN  (None, 16, 16, 48)  192         ['conv2d_38[0][0]']
ormalization)

activation_38 (Activation)     (None, 16, 16, 48)   0           ['batch_normalization_38[0][0]']

conv2d_39 (Conv2D)             (None, 16, 16, 12)   5184        ['activation_38[0][0]']

concatenate_18 (Concatenate)   (None, 16, 16, 144)  0           ['concatenate_17[0][0]',
                                                                 'conv2d_39[0][0]']

batch_normalization_39 (BatchN  (None, 16, 16, 144)  576        ['concatenate_18[0][0]']
ormalization)

activation_39 (Activation)     (None, 16, 16, 144)  0           ['batch_normalization_39[0][0]']

conv2d_40 (Conv2D)             (None, 16, 16, 48)   6912        ['activation_39[0][0]']

batch_normalization_40 (BatchN  (None, 16, 16, 48)  192         ['conv2d_40[0][0]']
ormalization)

activation_40 (Activation)     (None, 16, 16, 48)   0           ['batch_normalization_40[0][0]']

conv2d_41 (Conv2D)             (None, 16, 16, 12)   5184        ['activation_40[0][0]']

concatenate_19 (Concatenate)   (None, 16, 16, 156)  0           ['concatenate_18[0][0]',
                                                                 'conv2d_41[0][0]']

batch_normalization_41 (BatchN  (None, 16, 16, 156)  624        ['concatenate_19[0][0]']
ormalization)

activation_41 (Activation)     (None, 16, 16, 156)  0           ['batch_normalization_41[0][0]']

conv2d_42 (Conv2D)             (None, 16, 16, 48)   7488        ['activation_41[0][0]']

batch_normalization_42 (BatchN  (None, 16, 16, 48)  192         ['conv2d_42[0][0]']
ormalization)

activation_42 (Activation)     (None, 16, 16, 48)   0           ['batch_normalization_42[0][0]']

conv2d_43 (Conv2D)             (None, 16, 16, 12)   5184        ['activation_42[0][0]']
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concatenate_20 (Concatenate)   (None, 16, 16, 168)  0           ['concatenate_19[0][0]',
                                                                 'conv2d_43[0][0]']

batch_normalization_43 (BatchN  (None, 16, 16, 168)  672        ['concatenate_20[0][0]']
ormalization)

activation_43 (Activation)     (None, 16, 16, 168)  0           ['batch_normalization_43[0][0]']

conv2d_44 (Conv2D)             (None, 16, 16, 48)   8064        ['activation_43[0][0]']

batch_normalization_44 (BatchN  (None, 16, 16, 48)  192         ['conv2d_44[0][0]']
ormalization)

activation_44 (Activation)     (None, 16, 16, 48)   0           ['batch_normalization_44[0][0]']

conv2d_45 (Conv2D)             (None, 16, 16, 12)   5184        ['activation_44[0][0]']

concatenate_21 (Concatenate)   (None, 16, 16, 180)  0           ['concatenate_20[0][0]',
                                                                 'conv2d_45[0][0]']

batch_normalization_45 (BatchN  (None, 16, 16, 180)  720        ['concatenate_21[0][0]']
ormalization)

activation_45 (Activation)     (None, 16, 16, 180)  0           ['batch_normalization_45[0][0]']

conv2d_46 (Conv2D)             (None, 16, 16, 48)   8640        ['activation_45[0][0]']

batch_normalization_46 (BatchN  (None, 16, 16, 48)  192         ['conv2d_46[0][0]']
ormalization)

activation_46 (Activation)     (None, 16, 16, 48)   0           ['batch_normalization_46[0][0]']

conv2d_47 (Conv2D)             (None, 16, 16, 12)   5184        ['activation_46[0][0]']

concatenate_22 (Concatenate)   (None, 16, 16, 192)  0           ['concatenate_21[0][0]',
                                                                 'conv2d_47[0][0]']

batch_normalization_47 (BatchN  (None, 16, 16, 192)  768        ['concatenate_22[0][0]']
ormalization)

activation_47 (Activation)     (None, 16, 16, 192)  0           ['batch_normalization_47[0][0]']

conv2d_48 (Conv2D)             (None, 16, 16, 48)   9216        ['activation_47[0][0]']

batch_normalization_48 (BatchN  (None, 16, 16, 48)  192         ['conv2d_48[0][0]']
ormalization)

activation_48 (Activation)     (None, 16, 16, 48)   0           ['batch_normalization_48[0][0]']

conv2d_49 (Conv2D)             (None, 16, 16, 12)   5184        ['activation_48[0][0]']

concatenate_23 (Concatenate)   (None, 16, 16, 204)  0           ['concatenate_22[0][0]',
                                                                 'conv2d_49[0][0]']

batch_normalization_49 (BatchN  (None, 16, 16, 204)  816        ['concatenate_23[0][0]']
ormalization)

activation_49 (Activation)     (None, 16, 16, 204)  0           ['batch_normalization_49[0][0]']

conv2d_50 (Conv2D)             (None, 16, 16, 48)   9792        ['activation_49[0][0]']

batch_normalization_50 (BatchN  (None, 16, 16, 48)  192         ['conv2d_50[0][0]']
ormalization)

activation_50 (Activation)     (None, 16, 16, 48)   0           ['batch_normalization_50[0][0]']

conv2d_51 (Conv2D)             (None, 16, 16, 12)   5184        ['activation_50[0][0]']

concatenate_24 (Concatenate)   (None, 16, 16, 216)  0           ['concatenate_23[0][0]',
                                                                 'conv2d_51[0][0]']

batch_normalization_51 (BatchN  (None, 16, 16, 216)  864        ['concatenate_24[0][0]']
ormalization)

activation_51 (Activation)     (None, 16, 16, 216)  0           ['batch_normalization_51[0][0]']

conv2d_52 (Conv2D)             (None, 16, 16, 48)   10368       ['activation_51[0][0]']

batch_normalization_52 (BatchN  (None, 16, 16, 48)  192         ['conv2d_52[0][0]']
ormalization)

activation_52 (Activation)     (None, 16, 16, 48)   0           ['batch_normalization_52[0][0]']

conv2d_53 (Conv2D)             (None, 16, 16, 12)   5184        ['activation_52[0][0]']

concatenate_25 (Concatenate)   (None, 16, 16, 228)  0           ['concatenate_24[0][0]',
                                                                 'conv2d_53[0][0]']
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batch_normalization_53 (BatchN  (None, 16, 16, 228)  912        ['concatenate_25[0][0]']
ormalization)

activation_53 (Activation)     (None, 16, 16, 228)  0          ['batch_normalization_53[0][0]']

conv2d_54 (Conv2D)             (None, 16, 16, 48)   10944      ['activation_53[0][0]']

batch_normalization_54 (BatchN  (None, 16, 16, 48)  192        ['conv2d_54[0][0]']
ormalization)

activation_54 (Activation)     (None, 16, 16, 48)   0          ['batch_normalization_54[0][0]']

conv2d_55 (Conv2D)             (None, 16, 16, 12)   5184       ['activation_54[0][0]']

concatenate_26 (Concatenate)   (None, 16, 16, 240)  0          ['concatenate_25[0][0]',
                                                                'conv2d_55[0][0]']

batch_normalization_55 (BatchN  (None, 16, 16, 240)  960       ['concatenate_26[0][0]']
ormalization)

activation_55 (Activation)     (None, 16, 16, 240)  0          ['batch_normalization_55[0][0]']

conv2d_56 (Conv2D)             (None, 16, 16, 48)   11520      ['activation_55[0][0]']

batch_normalization_56 (BatchN  (None, 16, 16, 48)  192        ['conv2d_56[0][0]']
ormalization)

activation_56 (Activation)     (None, 16, 16, 48)   0          ['batch_normalization_56[0][0]']

conv2d_57 (Conv2D)             (None, 16, 16, 12)   5184       ['activation_56[0][0]']

concatenate_27 (Concatenate)   (None, 16, 16, 252)  0          ['concatenate_26[0][0]',
                                                                'conv2d_57[0][0]']

batch_normalization_57 (BatchN  (None, 16, 16, 252)  1008      ['concatenate_27[0][0]']
ormalization)

activation_57 (Activation)     (None, 16, 16, 252)  0          ['batch_normalization_57[0][0]']

conv2d_58 (Conv2D)             (None, 16, 16, 48)   12096      ['activation_57[0][0]']

batch_normalization_58 (BatchN  (None, 16, 16, 48)  192        ['conv2d_58[0][0]']
ormalization)

activation_58 (Activation)     (None, 16, 16, 48)   0          ['batch_normalization_58[0][0]']

conv2d_59 (Conv2D)             (None, 16, 16, 12)   5184       ['activation_58[0][0]']

concatenate_28 (Concatenate)   (None, 16, 16, 264)  0          ['concatenate_27[0][0]',
                                                                'conv2d_59[0][0]']

batch_normalization_59 (BatchN  (None, 16, 16, 264)  1056      ['concatenate_28[0][0]']
ormalization)

activation_59 (Activation)     (None, 16, 16, 264)  0          ['batch_normalization_59[0][0]']

conv2d_60 (Conv2D)             (None, 16, 16, 48)   12672      ['activation_59[0][0]']

batch_normalization_60 (BatchN  (None, 16, 16, 48)  192        ['conv2d_60[0][0]']
ormalization)

activation_60 (Activation)     (None, 16, 16, 48)   0          ['batch_normalization_60[0][0]']

conv2d_61 (Conv2D)             (None, 16, 16, 12)   5184       ['activation_60[0][0]']

concatenate_29 (Concatenate)   (None, 16, 16, 276)  0          ['concatenate_28[0][0]',
                                                                'conv2d_61[0][0]']

batch_normalization_61 (BatchN  (None, 16, 16, 276)  1104      ['concatenate_29[0][0]']
ormalization)

activation_61 (Activation)     (None, 16, 16, 276)  0          ['batch_normalization_61[0][0]']

conv2d_62 (Conv2D)             (None, 16, 16, 48)   13248      ['activation_61[0][0]']

batch_normalization_62 (BatchN  (None, 16, 16, 48)  192        ['conv2d_62[0][0]']
ormalization)

activation_62 (Activation)     (None, 16, 16, 48)   0          ['batch_normalization_62[0][0]']

conv2d_63 (Conv2D)             (None, 16, 16, 12)   5184       ['activation_62[0][0]']

concatenate_30 (Concatenate)   (None, 16, 16, 288)  0          ['concatenate_29[0][0]',
                                                                'conv2d_63[0][0]']

batch_normalization_63 (BatchN  (None, 16, 16, 288)  1152      ['concatenate_30[0][0]']
ormalization)

activation_63 (Activation)     (None, 16, 16, 288)  0          ['batch_normalization_63[0][0]']
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conv2d_64 (Conv2D)             (None, 16, 16, 48)   13824       ['activation_63[0][0]']

batch_normalization_64 (BatchN  (None, 16, 16, 48)  192         ['conv2d_64[0][0]']
ormalization)

activation_64 (Activation)     (None, 16, 16, 48)   0           ['batch_normalization_64[0][0]']

conv2d_65 (Conv2D)             (None, 16, 16, 12)   5184        ['activation_64[0][0]']

concatenate_31 (Concatenate)   (None, 16, 16, 300)  0           ['concatenate_30[0][0]',
                                                                 'conv2d_65[0][0]']

batch_normalization_65 (BatchN  (None, 16, 16, 300)  1200       ['concatenate_31[0][0]']
ormalization)

activation_65 (Activation)     (None, 16, 16, 300)  0           ['batch_normalization_65[0][0]']

conv2d_66 (Conv2D)             (None, 16, 16, 150)  45000       ['activation_65[0][0]']

average_pooling2d_1 (AveragePo  (None, 8, 8, 150)   0           ['conv2d_66[0][0]']
oling2D)

batch_normalization_66 (BatchN  (None, 8, 8, 150)   600         ['average_pooling2d_1[0][0]']
ormalization)

activation_66 (Activation)     (None, 8, 8, 150)    0           ['batch_normalization_66[0][0]']

conv2d_67 (Conv2D)             (None, 8, 8, 48)     7200        ['activation_66[0][0]']

batch_normalization_67 (BatchN  (None, 8, 8, 48)    192         ['conv2d_67[0][0]']
ormalization)

activation_67 (Activation)     (None, 8, 8, 48)     0           ['batch_normalization_67[0][0]']

conv2d_68 (Conv2D)             (None, 8, 8, 12)     5184        ['activation_67[0][0]']

concatenate_32 (Concatenate)   (None, 8, 8, 162)    0           ['average_pooling2d_1[0][0]',
                                                                 'conv2d_68[0][0]']

batch_normalization_68 (BatchN  (None, 8, 8, 162)   648         ['concatenate_32[0][0]']
ormalization)

activation_68 (Activation)     (None, 8, 8, 162)    0           ['batch_normalization_68[0][0]']

conv2d_69 (Conv2D)             (None, 8, 8, 48)     7776        ['activation_68[0][0]']

batch_normalization_69 (BatchN  (None, 8, 8, 48)    192         ['conv2d_69[0][0]']
ormalization)

activation_69 (Activation)     (None, 8, 8, 48)     0           ['batch_normalization_69[0][0]']

conv2d_70 (Conv2D)             (None, 8, 8, 12)     5184        ['activation_69[0][0]']

concatenate_33 (Concatenate)   (None, 8, 8, 174)    0           ['concatenate_32[0][0]',
                                                                 'conv2d_70[0][0]']

batch_normalization_70 (BatchN  (None, 8, 8, 174)   696         ['concatenate_33[0][0]']
ormalization)

activation_70 (Activation)     (None, 8, 8, 174)    0           ['batch_normalization_70[0][0]']

conv2d_71 (Conv2D)             (None, 8, 8, 48)     8352        ['activation_70[0][0]']

batch_normalization_71 (BatchN  (None, 8, 8, 48)    192         ['conv2d_71[0][0]']
ormalization)

activation_71 (Activation)     (None, 8, 8, 48)     0           ['batch_normalization_71[0][0]']

conv2d_72 (Conv2D)             (None, 8, 8, 12)     5184        ['activation_71[0][0]']

concatenate_34 (Concatenate)   (None, 8, 8, 186)    0           ['concatenate_33[0][0]',
                                                                 'conv2d_72[0][0]']

batch_normalization_72 (BatchN  (None, 8, 8, 186)   744         ['concatenate_34[0][0]']
ormalization)

activation_72 (Activation)     (None, 8, 8, 186)    0           ['batch_normalization_72[0][0]']

conv2d_73 (Conv2D)             (None, 8, 8, 48)     8928        ['activation_72[0][0]']

batch_normalization_73 (BatchN  (None, 8, 8, 48)    192         ['conv2d_73[0][0]']
ormalization)

activation_73 (Activation)     (None, 8, 8, 48)     0           ['batch_normalization_73[0][0]']

conv2d_74 (Conv2D)             (None, 8, 8, 12)     5184        ['activation_73[0][0]']

concatenate_35 (Concatenate)   (None, 8, 8, 198)    0           ['concatenate_34[0][0]',
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                                                                  'conv2d_74[0][0]']

batch_normalization_74 (BatchN  (None, 8, 8, 198)   792         ['concatenate_35[0][0]']
ormalization)

activation_74 (Activation)     (None, 8, 8, 198)    0           ['batch_normalization_74[0][0]']

conv2d_75 (Conv2D)             (None, 8, 8, 48)     9504        ['activation_74[0][0]']

batch_normalization_75 (BatchN  (None, 8, 8, 48)    192         ['conv2d_75[0][0]']
ormalization)

activation_75 (Activation)     (None, 8, 8, 48)     0           ['batch_normalization_75[0][0]']

conv2d_76 (Conv2D)             (None, 8, 8, 12)     5184        ['activation_75[0][0]']

concatenate_36 (Concatenate)   (None, 8, 8, 210)    0           ['concatenate_35[0][0]',
                                                                 'conv2d_76[0][0]']

batch_normalization_76 (BatchN  (None, 8, 8, 210)   840         ['concatenate_36[0][0]']
ormalization)

activation_76 (Activation)     (None, 8, 8, 210)    0           ['batch_normalization_76[0][0]']

conv2d_77 (Conv2D)             (None, 8, 8, 48)     10080       ['activation_76[0][0]']

batch_normalization_77 (BatchN  (None, 8, 8, 48)    192         ['conv2d_77[0][0]']
ormalization)

activation_77 (Activation)     (None, 8, 8, 48)     0           ['batch_normalization_77[0][0]']

conv2d_78 (Conv2D)             (None, 8, 8, 12)     5184        ['activation_77[0][0]']

concatenate_37 (Concatenate)   (None, 8, 8, 222)    0           ['concatenate_36[0][0]',
                                                                 'conv2d_78[0][0]']

batch_normalization_78 (BatchN  (None, 8, 8, 222)   888         ['concatenate_37[0][0]']
ormalization)

activation_78 (Activation)     (None, 8, 8, 222)    0           ['batch_normalization_78[0][0]']

conv2d_79 (Conv2D)             (None, 8, 8, 48)     10656       ['activation_78[0][0]']

batch_normalization_79 (BatchN  (None, 8, 8, 48)    192         ['conv2d_79[0][0]']
ormalization)

activation_79 (Activation)     (None, 8, 8, 48)     0           ['batch_normalization_79[0][0]']

conv2d_80 (Conv2D)             (None, 8, 8, 12)     5184        ['activation_79[0][0]']

concatenate_38 (Concatenate)   (None, 8, 8, 234)    0           ['concatenate_37[0][0]',
                                                                 'conv2d_80[0][0]']

batch_normalization_80 (BatchN  (None, 8, 8, 234)   936         ['concatenate_38[0][0]']
ormalization)

activation_80 (Activation)     (None, 8, 8, 234)    0           ['batch_normalization_80[0][0]']

conv2d_81 (Conv2D)             (None, 8, 8, 48)     11232       ['activation_80[0][0]']

batch_normalization_81 (BatchN  (None, 8, 8, 48)    192         ['conv2d_81[0][0]']
ormalization)

activation_81 (Activation)     (None, 8, 8, 48)     0           ['batch_normalization_81[0][0]']

conv2d_82 (Conv2D)             (None, 8, 8, 12)     5184        ['activation_81[0][0]']

concatenate_39 (Concatenate)   (None, 8, 8, 246)    0           ['concatenate_38[0][0]',
                                                                 'conv2d_82[0][0]']

batch_normalization_82 (BatchN  (None, 8, 8, 246)   984         ['concatenate_39[0][0]']
ormalization)

activation_82 (Activation)     (None, 8, 8, 246)    0           ['batch_normalization_82[0][0]']

conv2d_83 (Conv2D)             (None, 8, 8, 48)     11808       ['activation_82[0][0]']

batch_normalization_83 (BatchN  (None, 8, 8, 48)    192         ['conv2d_83[0][0]']
ormalization)

activation_83 (Activation)     (None, 8, 8, 48)     0           ['batch_normalization_83[0][0]']

conv2d_84 (Conv2D)             (None, 8, 8, 12)     5184        ['activation_83[0][0]']

concatenate_40 (Concatenate)   (None, 8, 8, 258)    0           ['concatenate_39[0][0]',
                                                                 'conv2d_84[0][0]']

batch_normalization_84 (BatchN  (None, 8, 8, 258)   1032        ['concatenate_40[0][0]']
ormalization)
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activation_84 (Activation)     (None, 8, 8, 258)    0           ['batch_normalization_84[0][0]']

conv2d_85 (Conv2D)             (None, 8, 8, 48)     12384       ['activation_84[0][0]']

batch_normalization_85 (BatchN  (None, 8, 8, 48)    192         ['conv2d_85[0][0]']
ormalization)

activation_85 (Activation)     (None, 8, 8, 48)     0           ['batch_normalization_85[0][0]']

conv2d_86 (Conv2D)             (None, 8, 8, 12)     5184        ['activation_85[0][0]']

concatenate_41 (Concatenate)   (None, 8, 8, 270)    0           ['concatenate_40[0][0]',
                                                                 'conv2d_86[0][0]']

batch_normalization_86 (BatchN  (None, 8, 8, 270)   1080        ['concatenate_41[0][0]']
ormalization)

activation_86 (Activation)     (None, 8, 8, 270)    0           ['batch_normalization_86[0][0]']

conv2d_87 (Conv2D)             (None, 8, 8, 48)     12960       ['activation_86[0][0]']

batch_normalization_87 (BatchN  (None, 8, 8, 48)    192         ['conv2d_87[0][0]']
ormalization)

activation_87 (Activation)     (None, 8, 8, 48)     0           ['batch_normalization_87[0][0]']

conv2d_88 (Conv2D)             (None, 8, 8, 12)     5184        ['activation_87[0][0]']

concatenate_42 (Concatenate)   (None, 8, 8, 282)    0           ['concatenate_41[0][0]',
                                                                 'conv2d_88[0][0]']

batch_normalization_88 (BatchN  (None, 8, 8, 282)   1128        ['concatenate_42[0][0]']
ormalization)

activation_88 (Activation)     (None, 8, 8, 282)    0           ['batch_normalization_88[0][0]']

conv2d_89 (Conv2D)             (None, 8, 8, 48)     13536       ['activation_88[0][0]']

batch_normalization_89 (BatchN  (None, 8, 8, 48)    192         ['conv2d_89[0][0]']
ormalization)

activation_89 (Activation)     (None, 8, 8, 48)     0           ['batch_normalization_89[0][0]']

conv2d_90 (Conv2D)             (None, 8, 8, 12)     5184        ['activation_89[0][0]']

concatenate_43 (Concatenate)   (None, 8, 8, 294)    0           ['concatenate_42[0][0]',
                                                                 'conv2d_90[0][0]']

batch_normalization_90 (BatchN  (None, 8, 8, 294)   1176        ['concatenate_43[0][0]']
ormalization)

activation_90 (Activation)     (None, 8, 8, 294)    0           ['batch_normalization_90[0][0]']

conv2d_91 (Conv2D)             (None, 8, 8, 48)     14112       ['activation_90[0][0]']

batch_normalization_91 (BatchN  (None, 8, 8, 48)    192         ['conv2d_91[0][0]']
ormalization)

activation_91 (Activation)     (None, 8, 8, 48)     0           ['batch_normalization_91[0][0]']

conv2d_92 (Conv2D)             (None, 8, 8, 12)     5184        ['activation_91[0][0]']

concatenate_44 (Concatenate)   (None, 8, 8, 306)    0           ['concatenate_43[0][0]',
                                                                 'conv2d_92[0][0]']

batch_normalization_92 (BatchN  (None, 8, 8, 306)   1224        ['concatenate_44[0][0]']
ormalization)

activation_92 (Activation)     (None, 8, 8, 306)    0           ['batch_normalization_92[0][0]']

conv2d_93 (Conv2D)             (None, 8, 8, 48)     14688       ['activation_92[0][0]']

batch_normalization_93 (BatchN  (None, 8, 8, 48)    192         ['conv2d_93[0][0]']
ormalization)

activation_93 (Activation)     (None, 8, 8, 48)     0           ['batch_normalization_93[0][0]']

conv2d_94 (Conv2D)             (None, 8, 8, 12)     5184        ['activation_93[0][0]']

concatenate_45 (Concatenate)   (None, 8, 8, 318)    0           ['concatenate_44[0][0]',
                                                                 'conv2d_94[0][0]']

batch_normalization_94 (BatchN  (None, 8, 8, 318)   1272        ['concatenate_45[0][0]']
ormalization)

activation_94 (Activation)     (None, 8, 8, 318)    0           ['batch_normalization_94[0][0]']

conv2d_95 (Conv2D)             (None, 8, 8, 48)     15264       ['activation_94[0][0]']
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batch_normalization_95 (BatchN  (None, 8, 8, 48)    192         ['conv2d_95[0][0]']
ormalization)

activation_95 (Activation)     (None, 8, 8, 48)     0           ['batch_normalization_95[0][0]']

conv2d_96 (Conv2D)             (None, 8, 8, 12)     5184        ['activation_95[0][0]']

concatenate_46 (Concatenate)   (None, 8, 8, 330)    0           ['concatenate_45[0][0]',
                                                                 'conv2d_96[0][0]']

batch_normalization_96 (BatchN  (None, 8, 8, 330)   1320        ['concatenate_46[0][0]']
ormalization)

activation_96 (Activation)     (None, 8, 8, 330)    0           ['batch_normalization_96[0][0]']

conv2d_97 (Conv2D)             (None, 8, 8, 48)     15840       ['activation_96[0][0]']

batch_normalization_97 (BatchN  (None, 8, 8, 48)    192         ['conv2d_97[0][0]']
ormalization)

activation_97 (Activation)     (None, 8, 8, 48)     0           ['batch_normalization_97[0][0]']

conv2d_98 (Conv2D)             (None, 8, 8, 12)     5184        ['activation_97[0][0]']

concatenate_47 (Concatenate)   (None, 8, 8, 342)    0           ['concatenate_46[0][0]',
                                                                 'conv2d_98[0][0]']

batch_normalization_98 (BatchN  (None, 8, 8, 342)   1368        ['concatenate_47[0][0]']
ormalization)

activation_98 (Activation)     (None, 8, 8, 342)    0           ['batch_normalization_98[0][0]']

conv2d_99 (Conv2D)             (None, 8, 8, 171)    58482       ['activation_98[0][0]']

average_pooling2d_2 (AveragePo  (None, 4, 4, 171)   0           ['conv2d_99[0][0]']
oling2D)

batch_normalization_99 (BatchN  (None, 4, 4, 171)   684         ['average_pooling2d_2[0][0]']
ormalization)

global_average_pooling2d (Glob  (None, 171)         0           ['batch_normalization_99[0][0]']
alAveragePooling2D)

dense (Dense)                  (None, 10)           1720        ['global_average_pooling2d[0][0]'
                                                                ]

==================================================================================================
Total params: 850,606
Trainable params: 826,276
Non-trainable params: 24,330
__________________________________________________________________________________________________
```

In [13]:

```python
# https://stackoverflow.com/a/59564740

class AccThreshold(Callback):

    def __init__(self, threshold):
        self.threshold = threshold + 0.01

    def on_epoch_end(self, epoch, logs = {}):
        val_acc = logs.get('val_accuracy')
        if val_acc >= self.threshold:
            print(f'\n\n\tTerminating training at epoch {epoch+1} with a \
            minimum validation accuracy of {self.threshold} %\n')
            self.model.stop_training = True
```

In [14]:

```python
logdir = 'logs/' + datetime.now().strftime('%Y%m%d_%H%M%S')
tensorBoard = TensorBoard(log_dir = logdir, histogram_freq = 1)

filepath = 'modelCheck/epo_{epoch:02d}-accu_{val_accuracy:.4f}.hdf5'
checkPoint = ModelCheckpoint(filepath, monitor = 'val_accuracy', verbose = 0)

reduceLr = ReduceLROnPlateau(monitor = 'val_accuracy', factor = 0.5, patience = 2, verbose = 1)

my_callback = AccThreshold(threshold = 0.9)

callBack_List = [tensorBoard, checkPoint, reduceLr, my_callback]
```

In [15]:

```python
test_datagen = ImageDataGenerator(rescale = 1./255)
test_datagen.fit(x_test)
```

In [16]:
```
sgd = SGD(learning_rate = 0.1, momentum = 0.9, nesterov = True)
model.compile(optimizer = sgd, loss = 'categorical_crossentropy', metrics = ['accuracy'])
```

In [17]:
```
!nvidia-smi
```

```
Fri Aug 19 06:59:07 2022
+-----------------------------------------------------------------------------+
| NVIDIA-SMI 470.82.01    Driver Version: 470.82.01    CUDA Version: 11.7     |
|-------------------------------+----------------------+----------------------+
| GPU  Name        Persistence-M| Bus-Id        Disp.A | Volatile Uncorr. ECC |
| Fan  Temp  Perf  Pwr:Usage/Cap|         Memory-Usage | GPU-Util  Compute M. |
|                               |                      |               MIG M. |
|===============================+======================+======================|
|   0  NVIDIA A10G         On   | 00000000:00:1E.0 Off |                    0 |
|  0%   29C    P0    58W / 300W |  20933MiB / 22731MiB |      0%      Default |
|                               |                      |                  N/A |
+-------------------------------+----------------------+----------------------+

+-----------------------------------------------------------------------------+
| Processes:                                                                  |
|  GPU   GI   CI        PID   Type   Process name                  GPU Memory |
|        ID   ID                                                   Usage      |
|=============================================================================|
+-----------------------------------------------------------------------------+
```

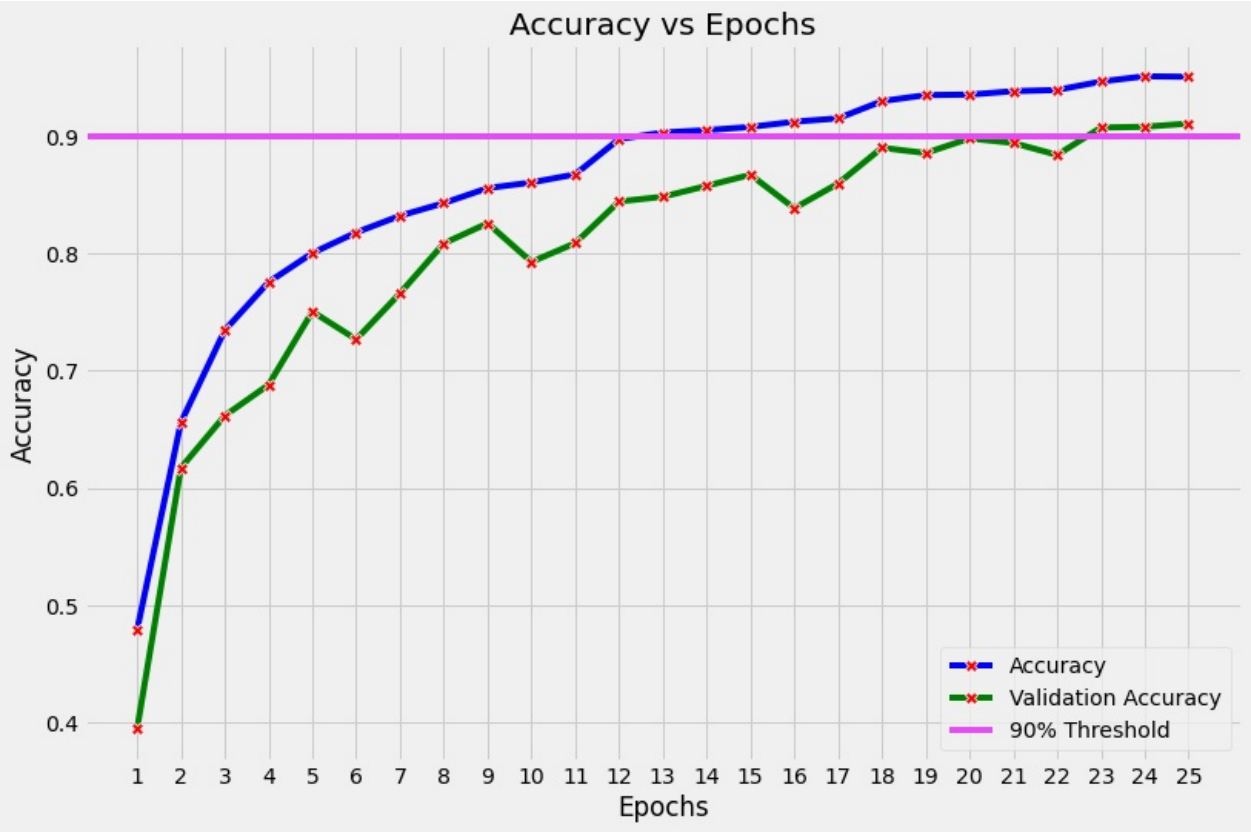
In [18]:
```
steps = len(x_train) // Batch_size
val_steps = len(x_test)//Batch_size

mod = model.fit(datagen.flow(x_train, y_train, batch_size = Batch_size), epochs = Epochs, verbose = 1,
                validation_data = test_datagen.flow(x_test, y_test, batch_size = Batch_size),
                steps_per_epoch = steps, validation_steps = val_steps, callbacks = callBack_List)
```

```
Epoch 1/300
390/390 [==============================] - 96s 220ms/step - loss: 1.4434 - accuracy: 0.4786 - val_loss: 1.8177 -
val_accuracy: 0.3941 - lr: 0.0010
Epoch 2/300
390/390 [==============================] - 84s 216ms/step - loss: 0.9688 - accuracy: 0.6559 - val_loss: 1.1896 -
val_accuracy: 0.6171 - lr: 0.0010
Epoch 3/300
390/390 [==============================] - 84s 216ms/step - loss: 0.7614 - accuracy: 0.7346 - val_loss: 1.0901 -
val_accuracy: 0.6616 - lr: 0.0010
Epoch 4/300
390/390 [==============================] - 85s 217ms/step - loss: 0.6459 - accuracy: 0.7757 - val_loss: 0.9804 -
val_accuracy: 0.6880 - lr: 0.0010
Epoch 5/300
390/390 [==============================] - 84s 216ms/step - loss: 0.5762 - accuracy: 0.8006 - val_loss: 0.7682 -
val_accuracy: 0.7506 - lr: 0.0010
Epoch 6/300
390/390 [==============================] - 84s 216ms/step - loss: 0.5205 - accuracy: 0.8182 - val_loss: 0.8841 -
val_accuracy: 0.7269 - lr: 0.0010
Epoch 7/300
390/390 [==============================] - 84s 216ms/step - loss: 0.4815 - accuracy: 0.8325 - val_loss: 0.7490 -
val_accuracy: 0.7662 - lr: 0.0010
Epoch 8/300
390/390 [==============================] - 84s 217ms/step - loss: 0.4508 - accuracy: 0.8433 - val_loss: 0.5817 -
val_accuracy: 0.8089 - lr: 0.0010
Epoch 9/300
390/390 [==============================] - 84s 216ms/step - loss: 0.4171 - accuracy: 0.8562 - val_loss: 0.5303 -
val_accuracy: 0.8261 - lr: 0.0010
Epoch 10/300
390/390 [==============================] - 85s 217ms/step - loss: 0.3970 - accuracy: 0.8610 - val_loss: 0.6382 -
val_accuracy: 0.7931 - lr: 0.0010
Epoch 11/300
390/390 [==============================] - ETA: 0s - loss: 0.3761 - accuracy: 0.8679
Epoch 11: ReduceLROnPlateau reducing learning rate to 0.0005000000237487257.
390/390 [==============================] - 84s 217ms/step - loss: 0.3761 - accuracy: 0.8679 - val_loss: 0.6110 -
val_accuracy: 0.8091 - lr: 0.0010
Epoch 12/300
390/390 [==============================] - 85s 217ms/step - loss: 0.2971 - accuracy: 0.8981 - val_loss: 0.4938 -
val_accuracy: 0.8448 - lr: 5.0000e-04
Epoch 13/300
390/390 [==============================] - 85s 217ms/step - loss: 0.2780 - accuracy: 0.9037 - val_loss: 0.4874 -
val_accuracy: 0.8488 - lr: 5.0000e-04
Epoch 14/300
390/390 [==============================] - 85s 217ms/step - loss: 0.2699 - accuracy: 0.9057 - val_loss: 0.4526 -
val_accuracy: 0.8581 - lr: 5.0000e-04
Epoch 15/300
390/390 [==============================] - 84s 216ms/step - loss: 0.2571 - accuracy: 0.9084 - val_loss: 0.4069 -
val_accuracy: 0.8676 - lr: 5.0000e-04
Epoch 16/300
390/390 [==============================] - 84s 216ms/step - loss: 0.2466 - accuracy: 0.9129 - val_loss: 0.5304 -
val_accuracy: 0.8389 - lr: 5.0000e-04
Epoch 17/300
390/390 [==============================] - ETA: 0s - loss: 0.2383 - accuracy: 0.9158
```

```
Epoch 17: ReduceLROnPlateau reducing learning rate to 0.0002500000118743628.
390/390 [==============================] - 84s 216ms/step - loss: 0.2383 - accuracy: 0.9158 - val_loss: 0.4556 -
val_accuracy: 0.8601 - lr: 5.0000e-04
Epoch 18/300
390/390 [==============================] - 84s 216ms/step - loss: 0.2004 - accuracy: 0.9305 - val_loss: 0.3422 -
val_accuracy: 0.8906 - lr: 2.5000e-04
Epoch 19/300
390/390 [==============================] - 84s 216ms/step - loss: 0.1858 - accuracy: 0.9357 - val_loss: 0.3732 -
val_accuracy: 0.8861 - lr: 2.5000e-04
Epoch 20/300
390/390 [==============================] - 85s 217ms/step - loss: 0.1812 - accuracy: 0.9361 - val_loss: 0.3209 -
val_accuracy: 0.8986 - lr: 2.5000e-04
Epoch 21/300
390/390 [==============================] - 84s 216ms/step - loss: 0.1742 - accuracy: 0.9390 - val_loss: 0.3523 -
val_accuracy: 0.8947 - lr: 2.5000e-04
Epoch 22/300
390/390 [==============================] - ETA: 0s - loss: 0.1717 - accuracy: 0.9400
Epoch 22: ReduceLROnPlateau reducing learning rate to 0.0001250000059371814.
390/390 [==============================] - 84s 216ms/step - loss: 0.1717 - accuracy: 0.9400 - val_loss: 0.3851 -
val_accuracy: 0.8845 - lr: 2.5000e-04
Epoch 23/300
390/390 [==============================] - 84s 217ms/step - loss: 0.1518 - accuracy: 0.9473 - val_loss: 0.2989 -
val_accuracy: 0.9080 - lr: 1.2500e-04
Epoch 24/300
390/390 [==============================] - 84s 216ms/step - loss: 0.1388 - accuracy: 0.9518 - val_loss: 0.3026 -
val_accuracy: 0.9086 - lr: 1.2500e-04
Epoch 25/300
390/390 [==============================] - ETA: 0s - loss: 0.1385 - accuracy: 0.9513

        Terminating training at epoch 25 with a             minimum validation accuracy of 0.91 %

390/390 [==============================] - 84s 217ms/step - loss: 0.1385 - accuracy: 0.9513 - val_loss: 0.3025 -
val_accuracy: 0.9114 - lr: 1.2500e-04
```

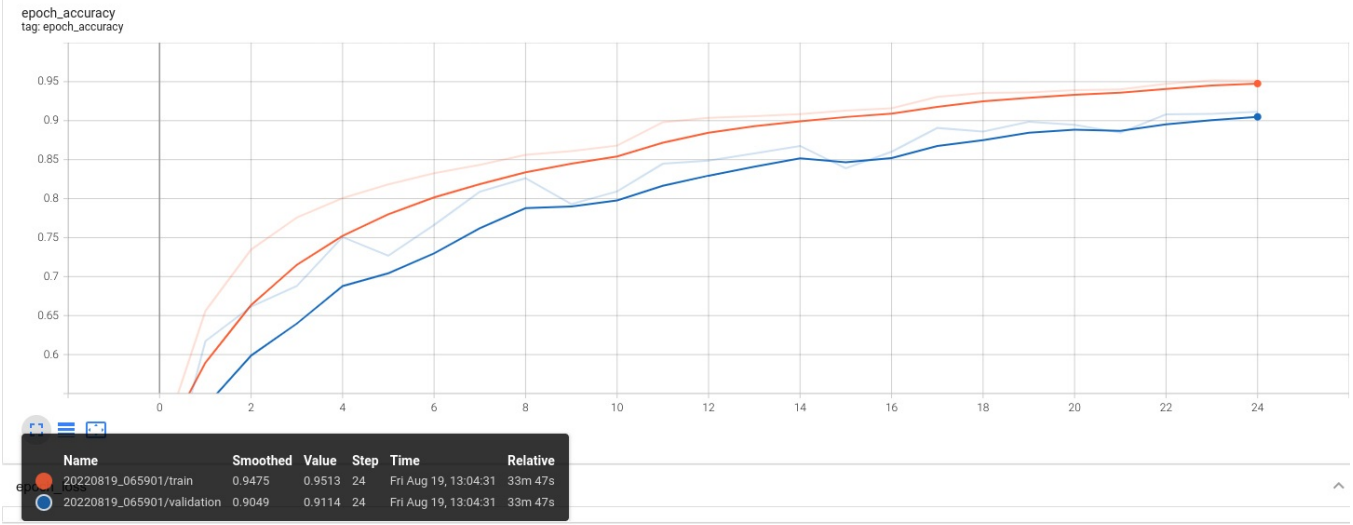
In [19]:

```
# https://seaborn.pydata.org/generated/seaborn.lineplot.html

epochs_ = list(range(1, len(mod.history['accuracy']) + 1))

plt.figure(figsize = (12, 8))
sns.lineplot(y = 'accuracy', data = mod.history , x = epochs_,
             label = 'Accuracy', color = 'b', marker = 'X', mfc = 'red', ms = 8)
sns.lineplot(y = 'val_accuracy', data = mod.history , x = epochs_,
             label = 'Validation Accuracy', color = 'g', marker = 'X', mfc = 'red', ms = 8)
plt.axhline(0.9, color = '#E44CF6', label = '90% Threshold')
plt.title('Accuracy vs Epochs')
plt.legend(loc = 4) ; plt.xticks(epochs_)
plt.xlabel('Epochs') ; plt.ylabel('Accuracy')
plt.show()
```



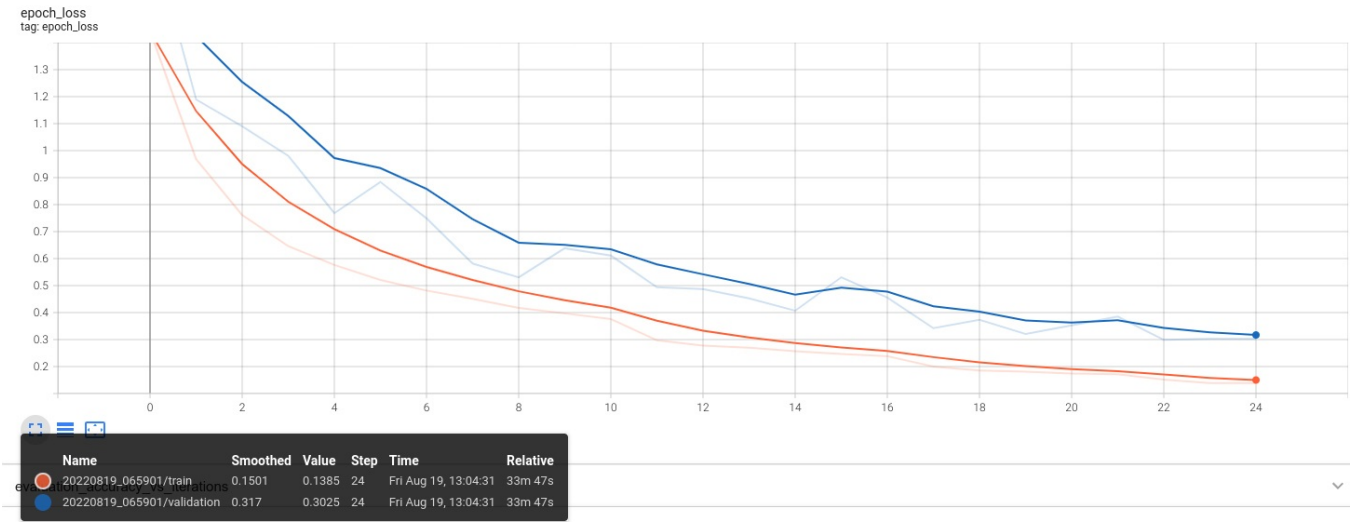
TensorBoard

epoch_accuracy



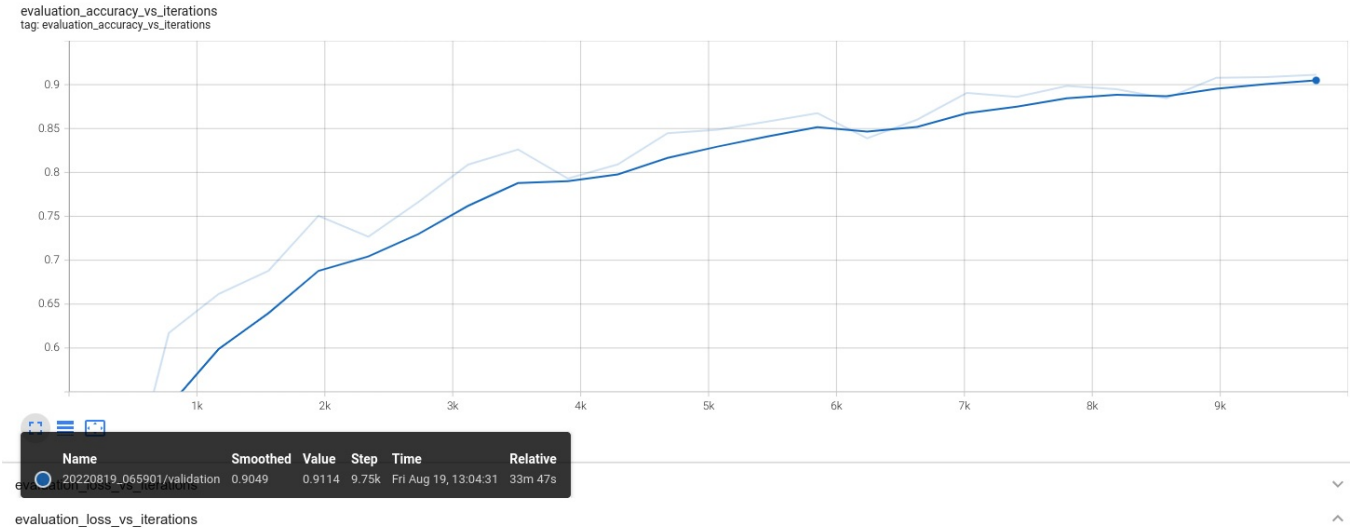
Name	Smoothed	Value	Step	Time	Relative
20220819_065901/train	0.9475	0.9513	24	Fri Aug 19, 13:04:31	33m 47s
20220819_065901/validation	0.9049	0.9114	24	Fri Aug 19, 13:04:31	33m 47s

epoch_loss



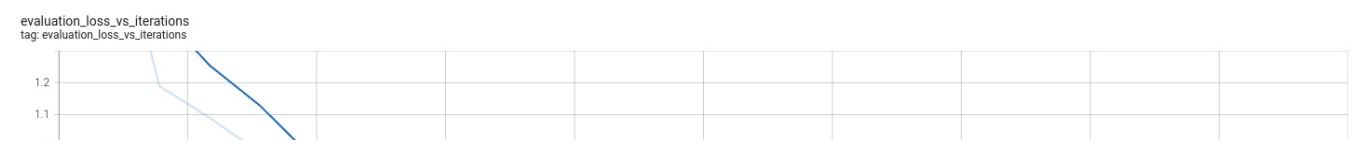
Name	Smoothed	Value	Step	Time	Relative
20220819_065901/train	0.1501	0.1385	24	Fri Aug 19, 13:04:31	33m 47s
20220819_065901/validation	0.317	0.3025	24	Fri Aug 19, 13:04:31	33m 47s

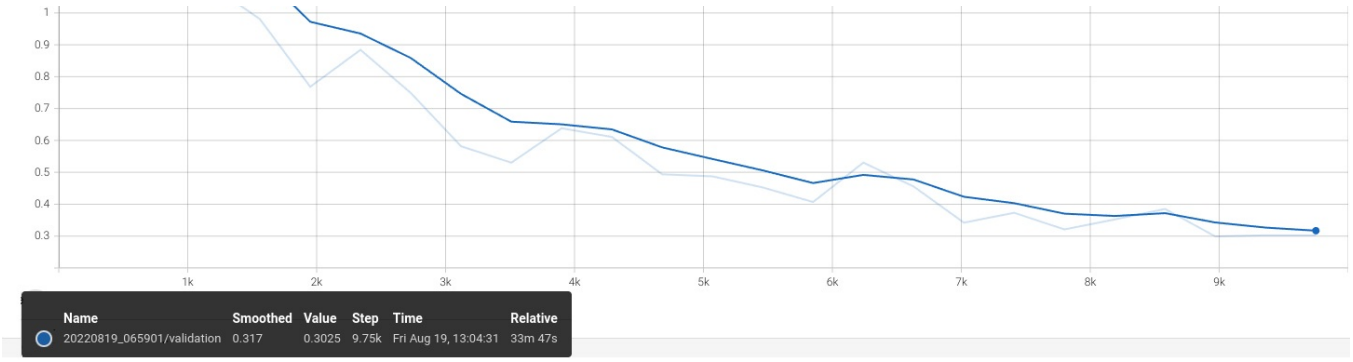
evaluation_accuracy_vs_iterations

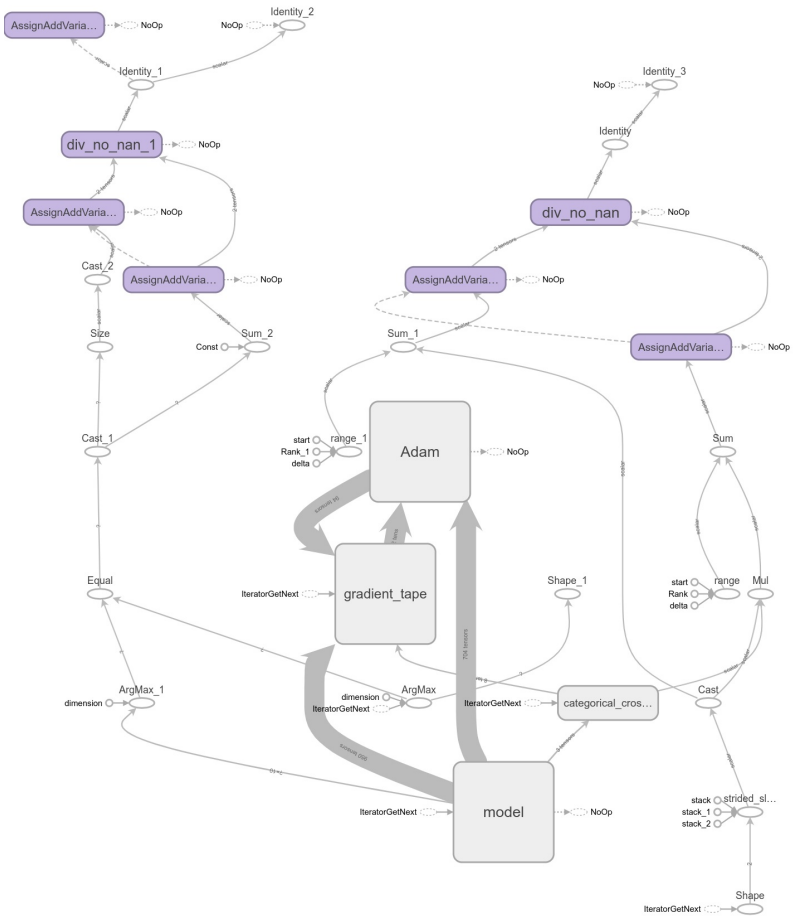


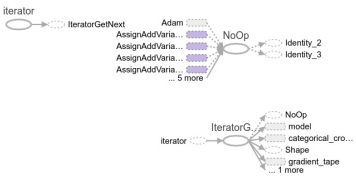
Name	Smoothed	Value	Step	Time	Relative
20220819_065901/validation	0.9049	0.9114	9.75k	Fri Aug 19, 13:04:31	33m 47s

evaluation_loss_vs_iterations




1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
1k
2k
3k
4k
5k
6k
7k
8k
9k
Name
Smoothed
Value
Step
Time
Relative
20220819_065901/validation
0.317
0.3025
9.75k
Fri Aug 19, 13:04:31
33m 47s


AssignAddVaria…
NoOp
Identity_2
Identity_1
div_no_nan_1
Cast_2
Size
Sum_2
Const
Cast_1
Identity_3
Identity
div_no_nan
Sum_1
Adam
start
Rank_1
delta
range_1
Sum
Equal
IteratorGetNext
gradient_tape
Shape_1
range
Mul
ArgMax_1
dimension
ArgMax
categorical_cros…
Cast
model
stack
stack_1
stack_2
strided_sl…
Shape


iterator
IteratorGetNext
Adam
AssignAddVaria…
NoOp
Identity_2
Identity_3
… 5 more
IteratorG…
model
categorical_cro…
Shape
gradient_tape
… 1 more