# Activity Recognition from Video

## Data:

Videos taken for 7 different activities (3-Similar, 4-Different) from UCF-101 Dataset:

1. Apply Eye Makeup (Similar)
2. Apply Lipstick (Similar)
3. Brushing Teeth (Similar)
4. Basketball (Different)
5. Diving (Different)
6. Nunchucks (Different)
7. Punch (Different)

### Train Data:

8 videos/activity ⇔ 500 frames/video => 4,000 frames/activity
Total frames in training dataset: ~ 28,000

### Cross-Validation Data:

10 videos/activity ⇔ 100 frames/video => 1,000 frames/activity
Total frames in CV dataset: ~ 7,000

### Test-Data Data:

10 videos/activity ⇔ 100 frames/video => 1,000 frames/activity
Total frames in CV dataset: ~ 7,000
Video resized to size: (224, 224, 3) (RGB images)

| Classification | Sequential |
|---|---|
| Train Shape: | Train Shape: |
| (29566, 224, 224, 3) | (14783, 16, 224, 224, 3) x 2 |
| (29566, 7) | (14783, 16, 7) x 2 |
| | |
| CV Shape: | CV Shape: |
| (7367, 224, 224, 3) | (7351, 16, 224, 224, 3) |
| (7367, 7) | (7351, 16, 7) |
| | |
| Test Shape: | Test Shape: |
| (7320, 224, 224, 3) | (7304, 16, 224, 224, 3) |
| (7320, 7) | (7304, 16, 7) |

Due to memory constraints on Henry Cluster, LSTM is trained in 2 batches each with ~14,000 frames.

## Approach 1:

### **Network**:

(https://github.com/LisaAnne/lisa-caffe-public/blob/lstm_video_deploy/examples/LRCN_activity_recognition/train_test_lstm_RGB.prototxt)

### Classification Model:

- 5 x Convolutional Layers
- 2 x Max Pooling Layers
- 2 x Batch Normalization
- 2 x Fully connected layers (1024 & 512)
- Activation: ReLU
- Classification: Softmax
- Loss: Categorical Cross Entropy
- Optimizer: Adam

- Total parameters: 48,327,303
- Total Trainable parameters: 48,326,343

Hyper-parameters:

- Regularization: Dropout (probability: 0.5)
- Batch size: 128
- Learning Rate: 1e-4
- Decay Rate: 1e-2

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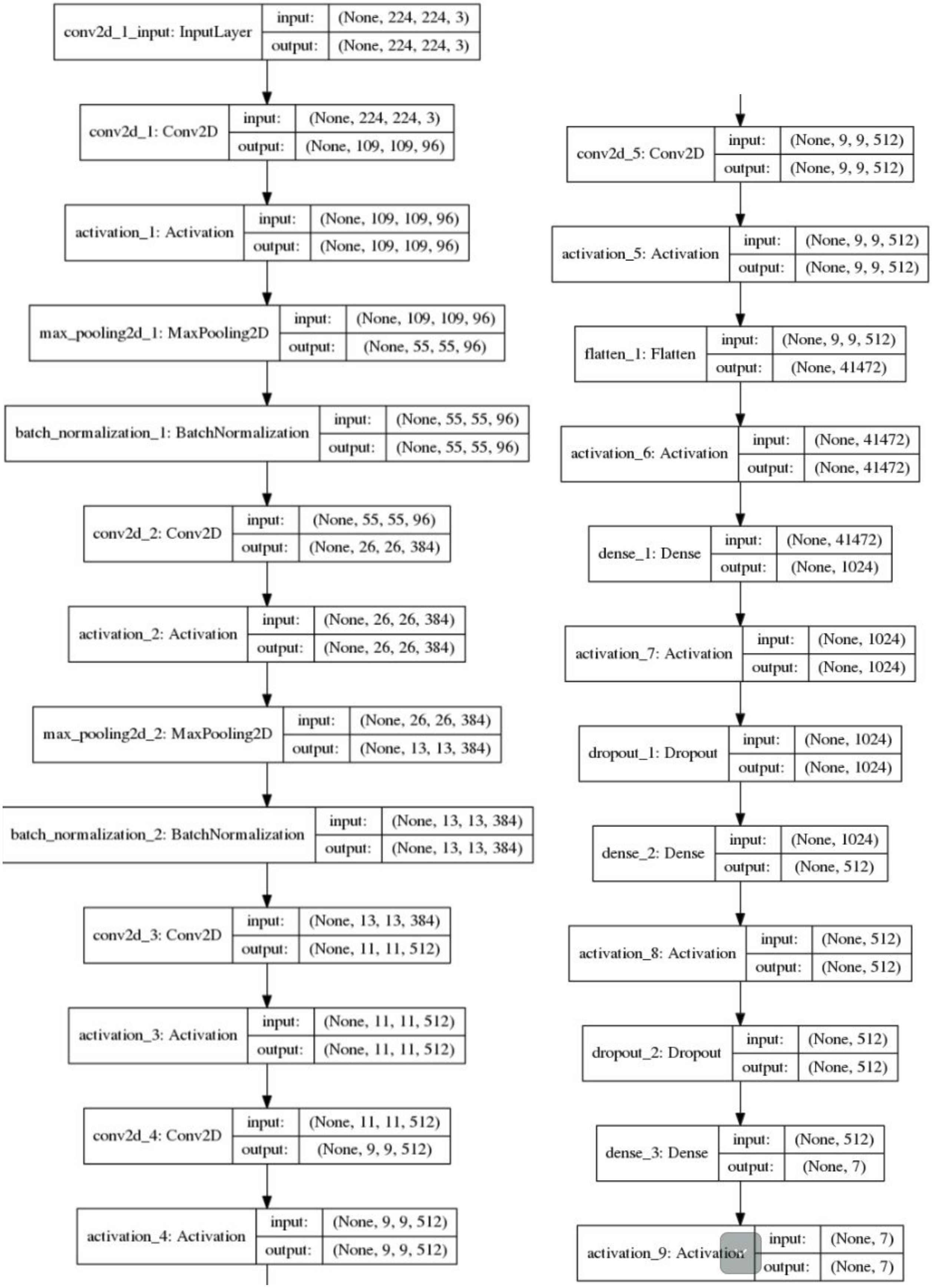
conv2d_1_input: InputLayer
input: (None, 224, 224, 3)
output: (None, 224, 224, 3)
conv2d_1: Conv2D
input: (None, 224, 224, 3)
output: (None, 109, 109, 96)
activation_1: Activation
input: (None, 109, 109, 96)
output: (None, 109, 109, 96)
max_pooling2d_1: MaxPooling2D
input: (None, 109, 109, 96)
output: (None, 55, 55, 96)
batch_normalization_1: BatchNormalization
input: (None, 55, 55, 96)
output: (None, 55, 55, 96)
conv2d_2: Conv2D
input: (None, 55, 55, 96)
output: (None, 26, 26, 384)
activation_2: Activation
input: (None, 26, 26, 384)
output: (None, 26, 26, 384)
max_pooling2d_2: MaxPooling2D
input: (None, 26, 26, 384)
output: (None, 13, 13, 384)
batch_normalization_2: BatchNormalization
input: (None, 13, 13, 384)
output: (None, 13, 13, 384)
conv2d_3: Conv2D
input: (None, 13, 13, 384)
output: (None, 11, 11, 512)
activation_3: Activation
input: (None, 11, 11, 512)
output: (None, 11, 11, 512)
conv2d_4: Conv2D
input: (None, 11, 11, 512)
output: (None, 9, 9, 512)
activation_4: Activation
input: (None, 9, 9, 512)
output: (None, 9, 9, 512)
conv2d_5: Conv2D
input: (None, 9, 9, 512)
output: (None, 9, 9, 512)
activation_5: Activation
input: (None, 9, 9, 512)
output: (None, 9, 9, 512)
flatten_1: Flatten
input: (None, 9, 9, 512)
output: (None, 41472)
activation_6: Activation
input: (None, 41472)
output: (None, 41472)
dense_1: Dense
input: (None, 41472)
output: (None, 1024)
activation_7: Activation
input: (None, 1024)
output: (None, 1024)
dropout_1: Dropout
input: (None, 1024)
output: (None, 1024)
dense_2: Dense
input: (None, 1024)
output: (None, 512)
activation_8: Activation
input: (None, 512)
output: (None, 512)
dropout_2: Dropout
input: (None, 512)
output: (None, 512)
dense_3: Dense
input: (None, 512)
output: (None, 7)
activation_9: Activation
input: (None, 7)
output: (None, 7)

Sequential Model:

- 5 x Convolutional Layers
- 2 x Max Pooling Layers
- 2 x Batch Normalization
- 2 x Fully connected layers (1024 & 512)
- 2 x LSTM layers
- Activation: ReLU
- Classification: Softmax
- Loss: Categorical Cross Entropy
- Optimizer: Adam

- Total parameters: 48,504,903
- Total Trainable parameters: 43,174,343

Hyper-parameters:

- Sequence Length: 16
- Regularization: Dropout (probability: 0.5)
- Batch size: 64
- Learning Rate: 1e-4
- Decay Rate: 1e-2
- LSTM cells: 64 cells x 2 layers

- Due to memory constraints on Henry cluster, batch size is reduced to 64.
- Since the model design is same as classification, we use the classification pretrained weights for initialization.
- Here the **convolutional part is frozen** whereas the **fully-connected layers and the LSTM layers are made trainable**. (i.e. until **Flatten** layer, all layers are **non-trainable**)

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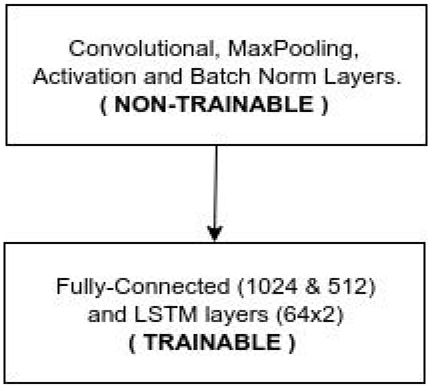
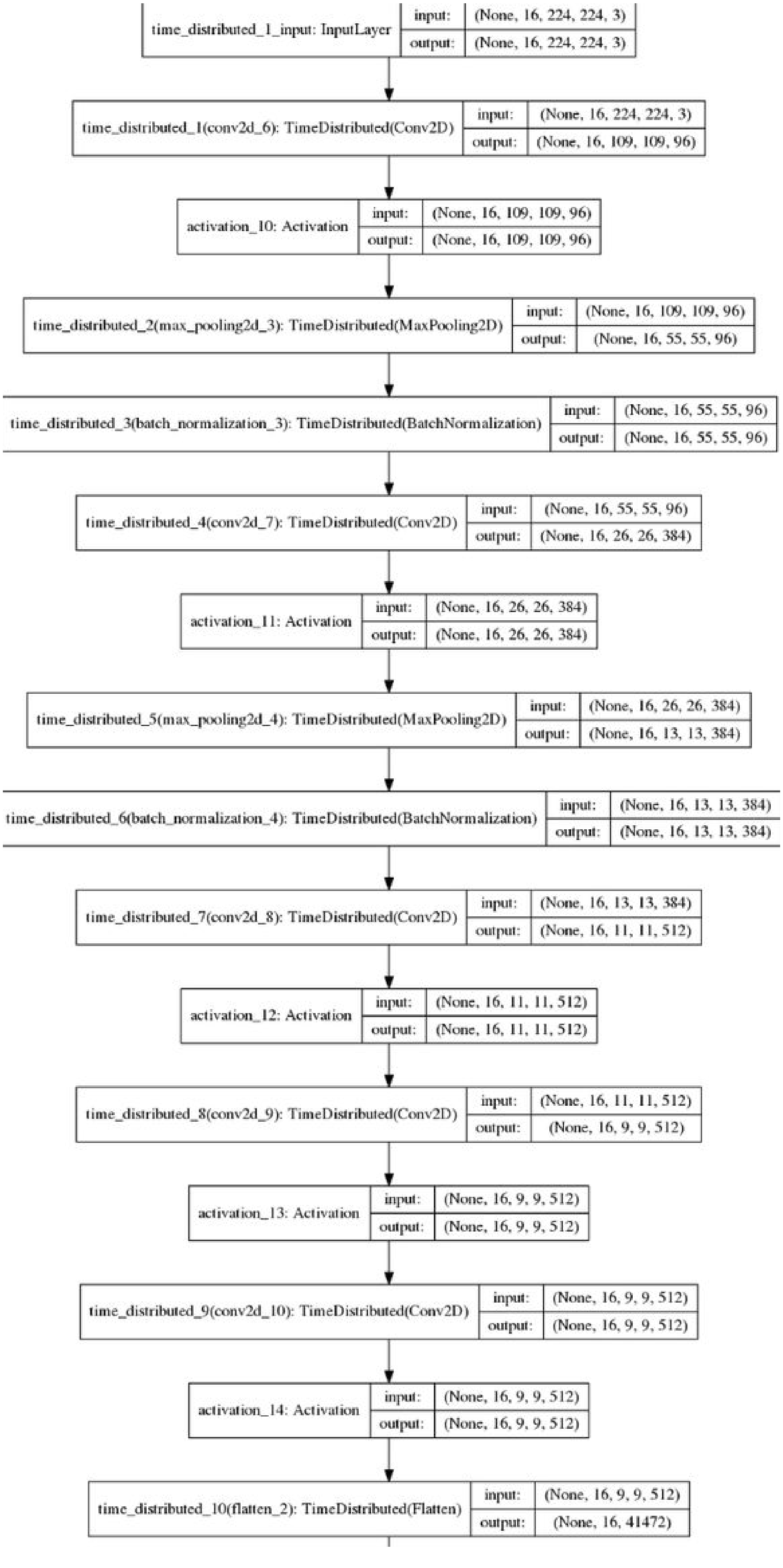
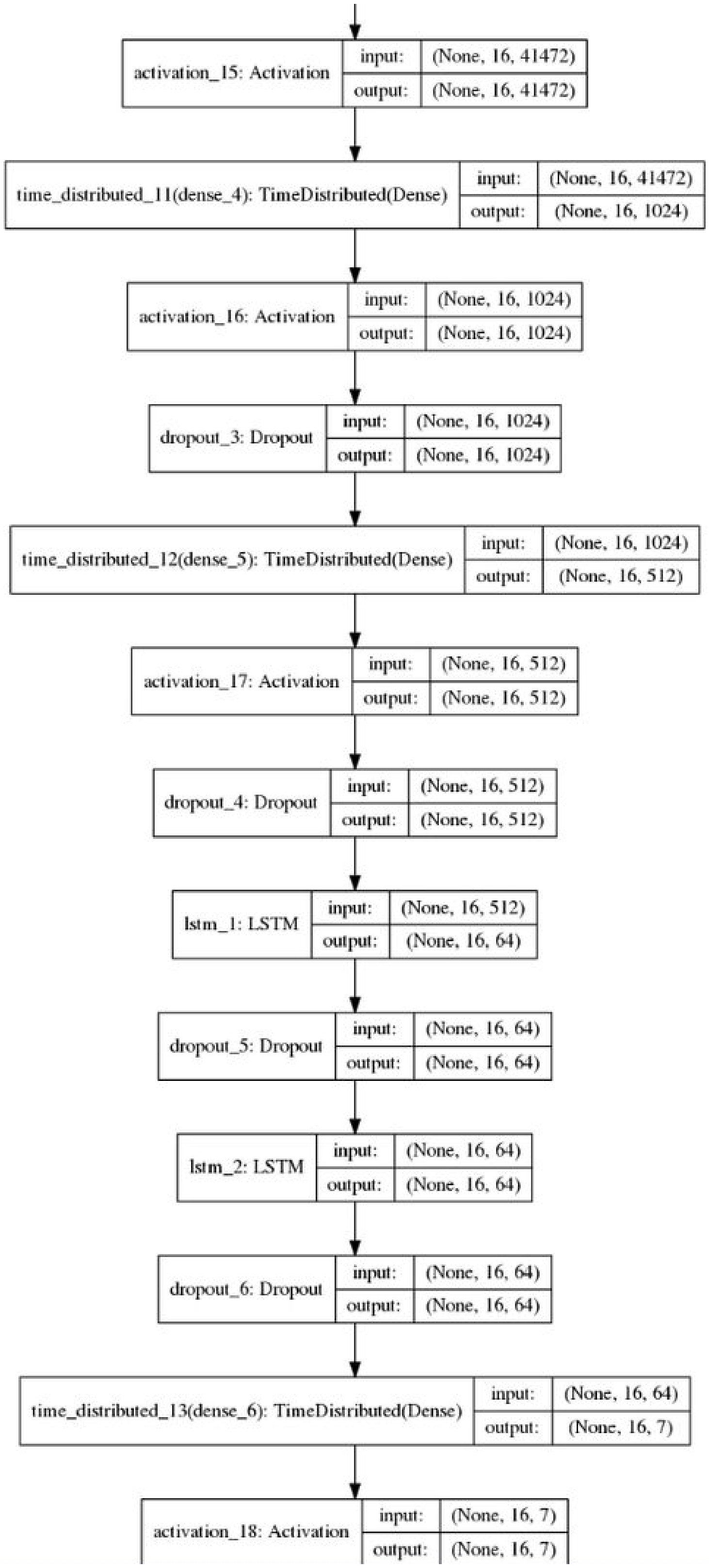

Convolutional, MaxPooling, Activation and Batch Norm Layers.
( NON-TRAINABLE )
Fully-Connected (1024 & 512) and LSTM layers (64x2)
( TRAINABLE )

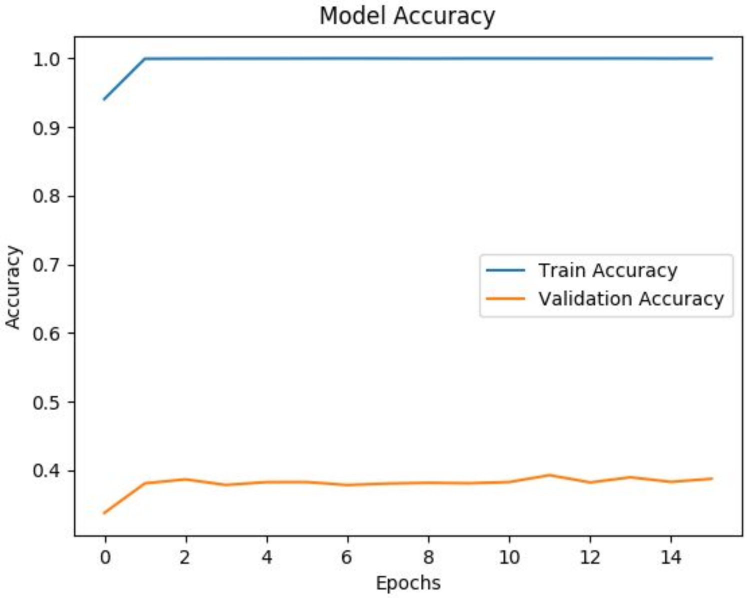

time_distributed_1_input: InputLayer
input: (None, 16, 224, 224, 3)
output: (None, 16, 224, 224, 3)
time_distributed_1(conv2d_6): TimeDistributed(Conv2D)
input: (None, 16, 224, 224, 3)
output: (None, 16, 109, 109, 96)
activation_10: Activation
input: (None, 16, 109, 109, 96)
output: (None, 16, 109, 109, 96)
time_distributed_2(max_pooling2d_3): TimeDistributed(MaxPooling2D)
input: (None, 16, 109, 109, 96)
output: (None, 16, 55, 55, 96)
time_distributed_3(batch_normalization_3): TimeDistributed(BatchNormalization)
input: (None, 16, 55, 55, 96)
output: (None, 16, 55, 55, 96)
time_distributed_4(conv2d_7): TimeDistributed(Conv2D)
input: (None, 16, 55, 55, 96)
output: (None, 16, 26, 26, 384)
activation_11: Activation
input: (None, 16, 26, 26, 384)
output: (None, 16, 26, 26, 384)
time_distributed_5(max_pooling2d_4): TimeDistributed(MaxPooling2D)
input: (None, 16, 26, 26, 384)
output: (None, 16, 13, 13, 384)
time_distributed_6(batch_normalization_4): TimeDistributed(BatchNormalization)
input: (None, 16, 13, 13, 384)
output: (None, 16, 13, 13, 384)
time_distributed_7(conv2d_8): TimeDistributed(Conv2D)
input: (None, 16, 13, 13, 384)
output: (None, 16, 11, 11, 512)
activation_12: Activation
input: (None, 16, 11, 11, 512)
output: (None, 16, 11, 11, 512)
time_distributed_8(conv2d_9): TimeDistributed(Conv2D)
input: (None, 16, 11, 11, 512)
output: (None, 16, 9, 9, 512)
activation_13: Activation
input: (None, 16, 9, 9, 512)
output: (None, 16, 9, 9, 512)
time_distributed_9(conv2d_10): TimeDistributed(Conv2D)
input: (None, 16, 9, 9, 512)
output: (None, 16, 9, 9, 512)
activation_14: Activation
input: (None, 16, 9, 9, 512)
output: (None, 16, 9, 9, 512)
time_distributed_10(flatten_2): TimeDistributed(Flatten)
input: (None, 16, 9, 9, 512)
output: (None, 16, 41472)

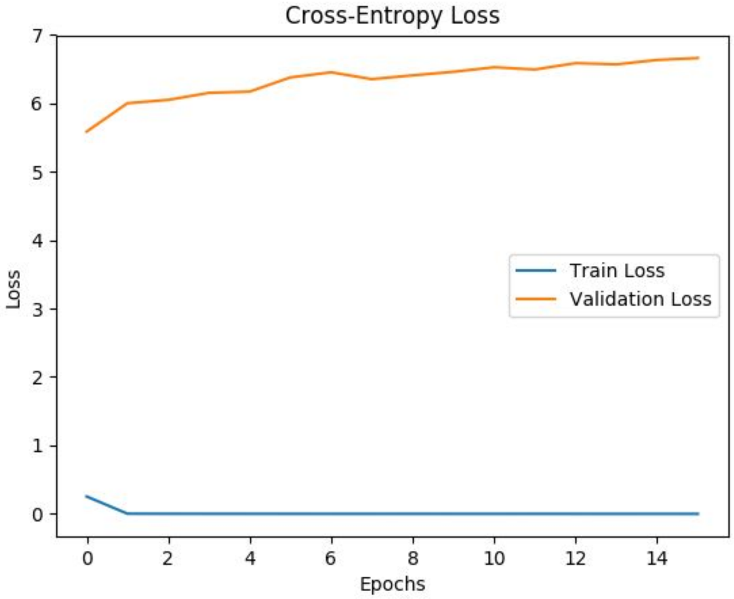

activation_15: Activation | input: | (None, 16, 41472) | output: | (None, 16, 41472)
time_distributed_11(dense_4): TimeDistributed(Dense) | input: | (None, 16, 41472) | output: | (None, 16, 1024)
activation_16: Activation | input: | (None, 16, 1024) | output: | (None, 16, 1024)
dropout_3: Dropout | input: | (None, 16, 1024) | output: | (None, 16, 1024)
time_distributed_12(dense_5): TimeDistributed(Dense) | input: | (None, 16, 1024) | output: | (None, 16, 512)
activation_17: Activation | input: | (None, 16, 512) | output: | (None, 16, 512)
dropout_4: Dropout | input: | (None, 16, 512) | output: | (None, 16, 512)
lstm_1: LSTM | input: | (None, 16, 512) | output: | (None, 16, 64)
dropout_5: Dropout | input: | (None, 16, 64) | output: | (None, 16, 64)
lstm_2: LSTM | input: | (None, 16, 64) | output: | (None, 16, 64)
dropout_6: Dropout | input: | (None, 16, 64) | output: | (None, 16, 64)
time_distributed_13(dense_6): TimeDistributed(Dense) | input: | (None, 16, 64) | output: | (None, 16, 7)
activation_18: Activation | input: | (None, 16, 7) | output: | (None, 16, 7)

## Result:

Classification:

| | | |
|---|---|---|
| Train Loss | : | 0.00029122 |
| Cross Validation Loss | : | 6.6589 |
| Test Loss | : | 5.7841 |
| | | |
| Train Accuracy | : | 100.00 % |
| Cross Validation Accuracy | : | 38.75 % |
| Test Accuracy | : | 44.71 % |

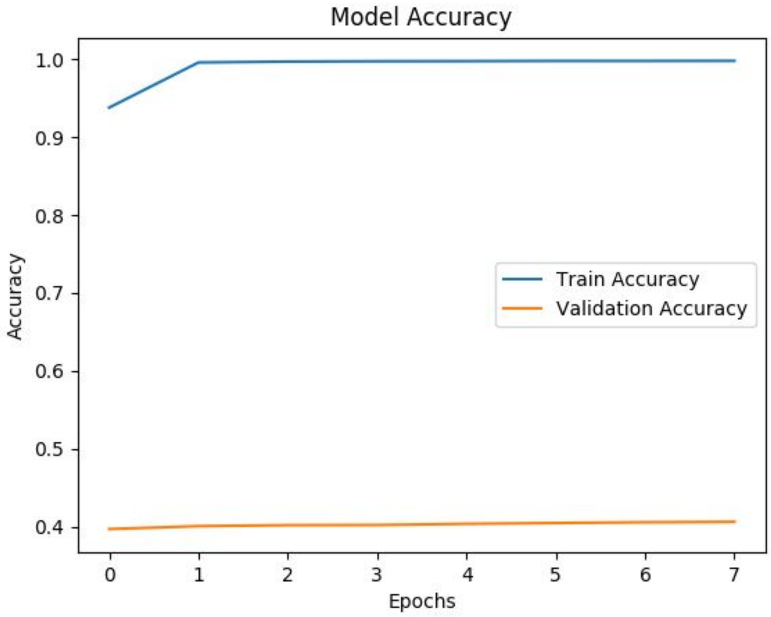


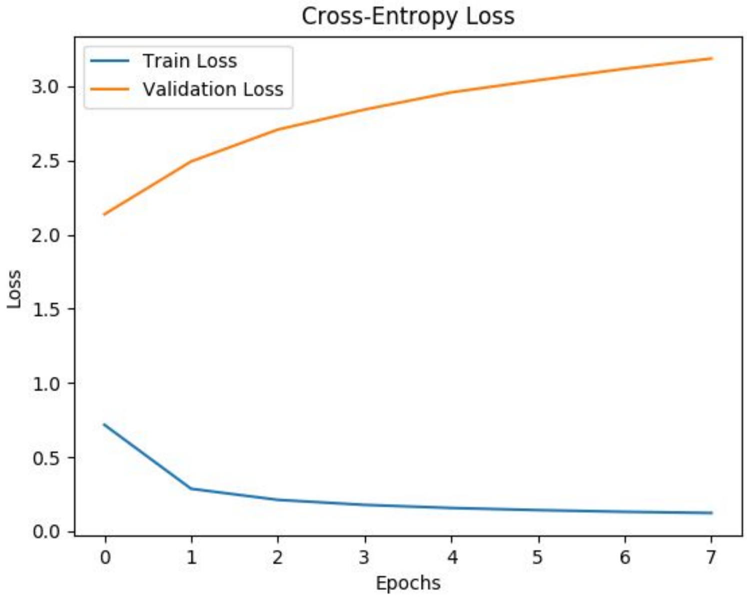


Sequential:

Train Loss : 0.1233
Cross Validation Loss : 3.1875
Test Loss : 2.7415

Train Accuracy : 99.79 %
Cross Validation Accuracy : **40.62** % (Improvement over classification: 38.75 %)
Test Accuracy : **44.84** % (Improvement over classification: 46.95%)



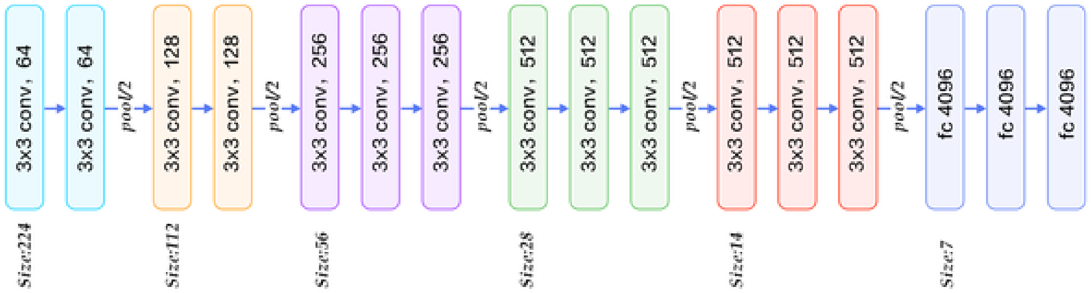


Observation:

- The training accuracy is very high compared to test accuracy. This shows that the network overfits the data.
- This is probably because the network weights are randomly initialized.
- The original paper uses the same network pre-trained on ImageNet dataset.
- Since it is not possible to train the current network on the ImageNet dataset, we opt for different architecture(VGG-16) which is available pre-trained on ImageNet.

## Approach 2: Transfer Learning (VGG-16 pretrained model)

The VGG-16 network is shown below:



https://goo.gl/images/1kAGbi

- The network is pretrained on ImageNet Dataset for 1000 classes
- **Only the convolutional part of the network is taken**

## Classification Model:

- The **Convolutional part** is made **non-trainable** so it acts as feature extractor
- A fully connected layer is added after flattening with 256 neurons (which is **trainable**)

- Classification: Softmax
- Loss: Categorical Cross Entropy
- Optimizer: Adam

- Total parameters: 21,139,271
- Total Trainable parameters: 6,424,583

### Hyper-parameters:

- Regularization: Dropout (probability: 0.5)
- Batch size: 128
- Learning Rate: 1e-4
- Decay Rate: 1e-2

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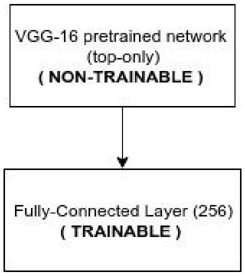
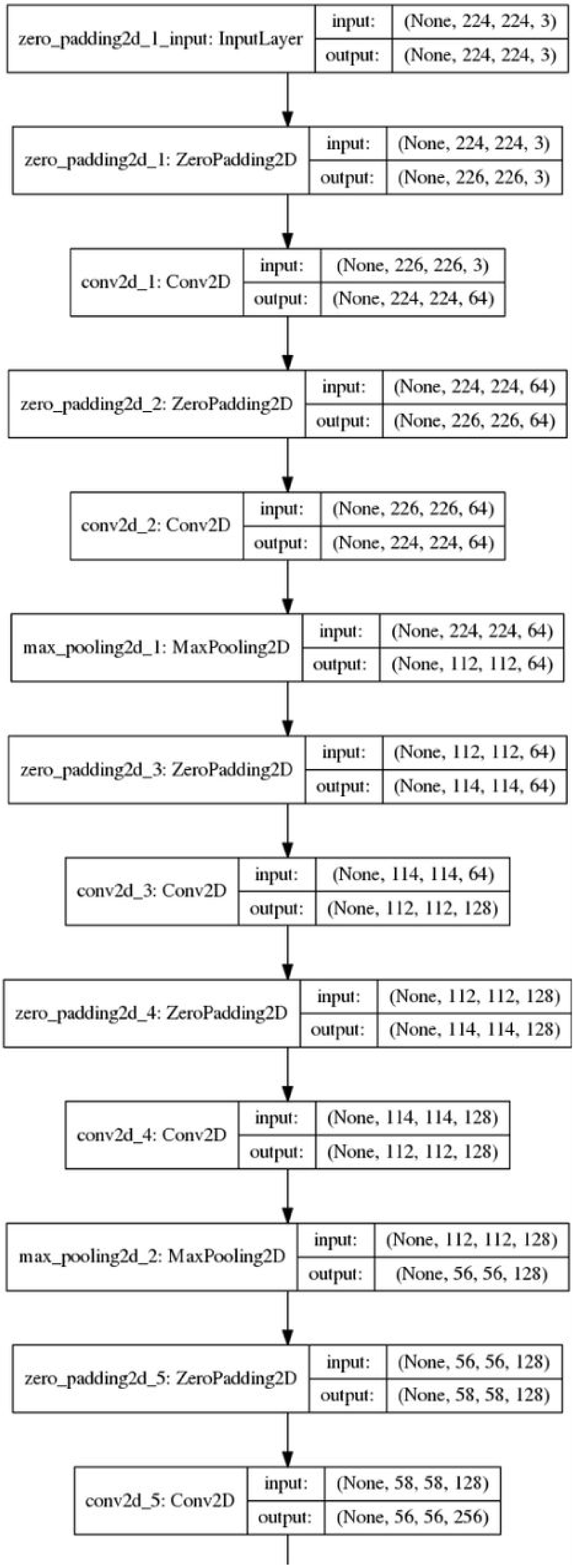
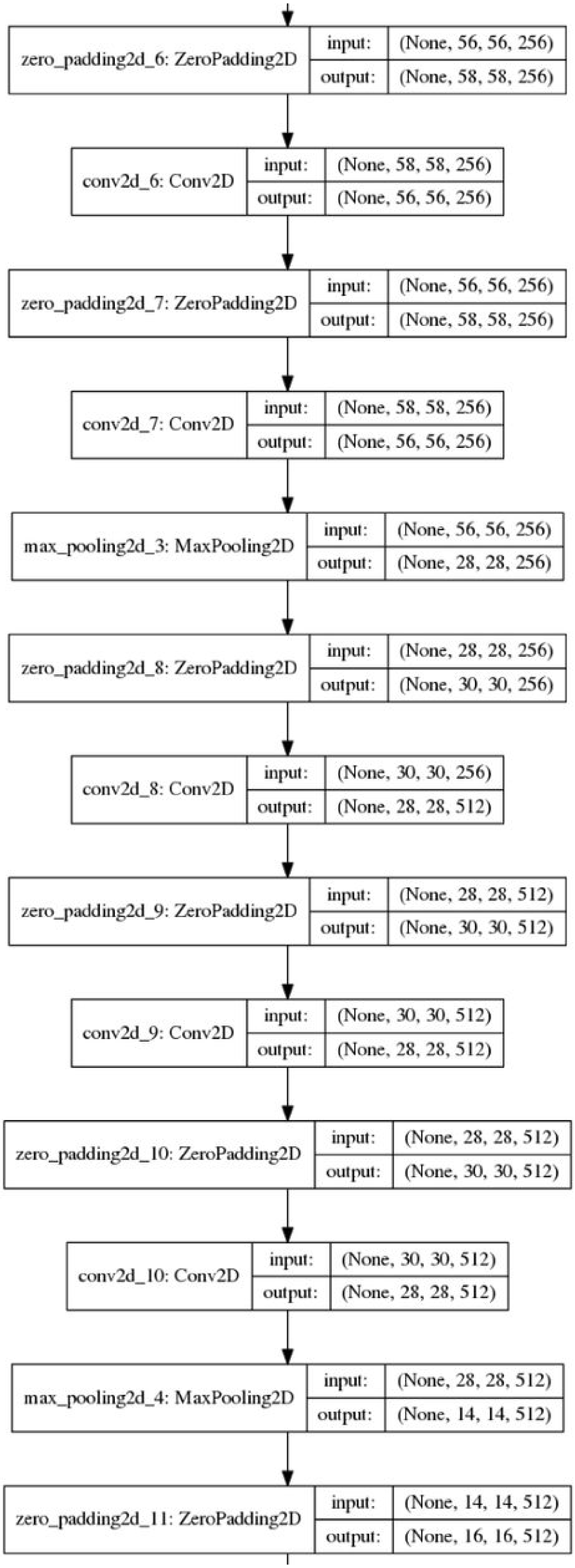



zero_padding2d_1_input: InputLayer
input: (None, 224, 224, 3)
output: (None, 224, 224, 3)
zero_padding2d_1: ZeroPadding2D
input: (None, 224, 224, 3)
output: (None, 226, 226, 3)
conv2d_1: Conv2D
input: (None, 226, 226, 3)
output: (None, 224, 224, 64)
zero_padding2d_2: ZeroPadding2D
input: (None, 224, 224, 64)
output: (None, 226, 226, 64)
conv2d_2: Conv2D
input: (None, 226, 226, 64)
output: (None, 224, 224, 64)
max_pooling2d_1: MaxPooling2D
input: (None, 224, 224, 64)
output: (None, 112, 112, 64)
zero_padding2d_3: ZeroPadding2D
input: (None, 112, 112, 64)
output: (None, 114, 114, 64)
conv2d_3: Conv2D
input: (None, 114, 114, 64)
output: (None, 112, 112, 128)
zero_padding2d_4: ZeroPadding2D
input: (None, 112, 112, 128)
output: (None, 114, 114, 128)
conv2d_4: Conv2D
input: (None, 114, 114, 128)
output: (None, 112, 112, 128)
max_pooling2d_2: MaxPooling2D
input: (None, 112, 112, 128)
output: (None, 56, 56, 128)
zero_padding2d_5: ZeroPadding2D
input: (None, 56, 56, 128)
output: (None, 58, 58, 128)
conv2d_5: Conv2D
input: (None, 58, 58, 128)
output: (None, 56, 56, 256)



zero_padding2d_6: ZeroPadding2D — input: (None, 56, 56, 256) — output: (None, 58, 58, 256)

conv2d_6: Conv2D — input: (None, 58, 58, 256) — output: (None, 56, 56, 256)

zero_padding2d_7: ZeroPadding2D — input: (None, 56, 56, 256) — output: (None, 58, 58, 256)

conv2d_7: Conv2D — input: (None, 58, 58, 256) — output: (None, 56, 56, 256)

max_pooling2d_3: MaxPooling2D — input: (None, 56, 56, 256) — output: (None, 28, 28, 256)

zero_padding2d_8: ZeroPadding2D — input: (None, 28, 28, 256) — output: (None, 30, 30, 256)

conv2d_8: Conv2D — input: (None, 30, 30, 256) — output: (None, 28, 28, 512)

zero_padding2d_9: ZeroPadding2D — input: (None, 28, 28, 512) — output: (None, 30, 30, 512)

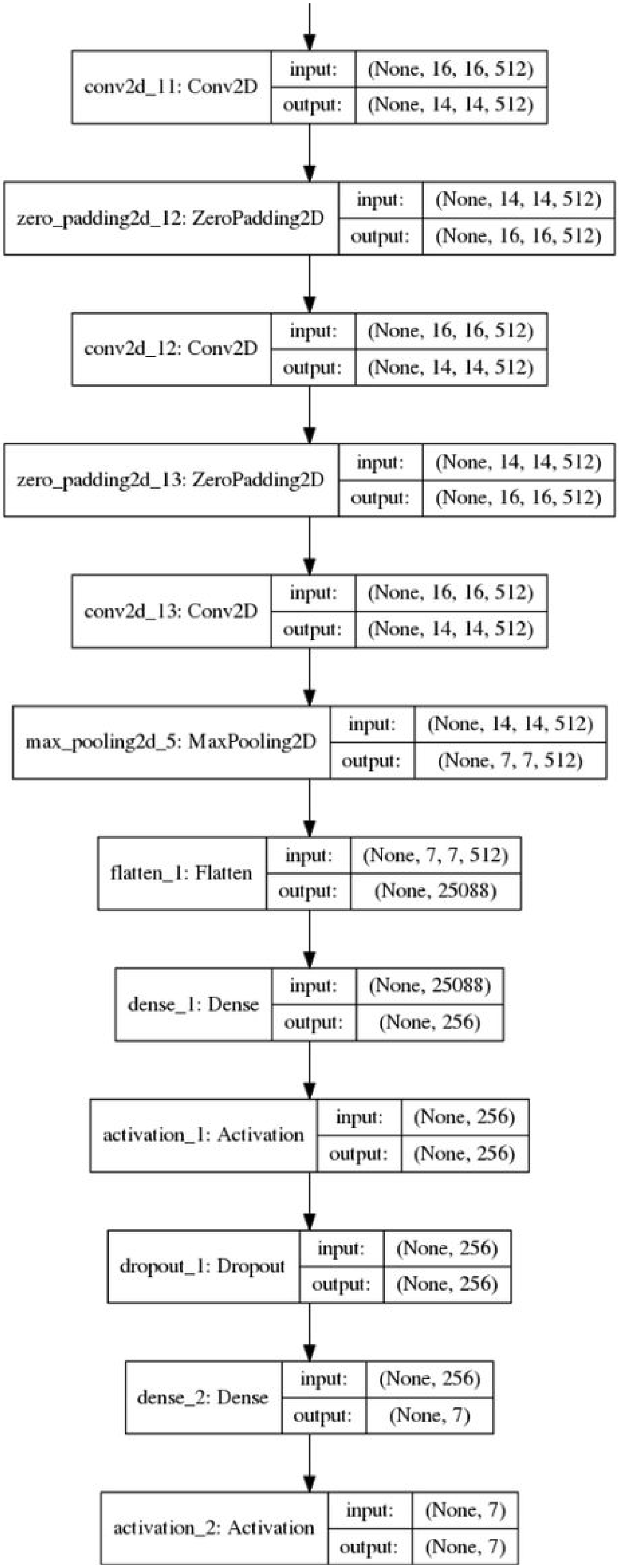
conv2d_9: Conv2D — input: (None, 30, 30, 512) — output: (None, 28, 28, 512)

zero_padding2d_10: ZeroPadding2D — input: (None, 28, 28, 512) — output: (None, 30, 30, 512)

conv2d_10: Conv2D — input: (None, 30, 30, 512) — output: (None, 28, 28, 512)

max_pooling2d_4: MaxPooling2D — input: (None, 28, 28, 512) — output: (None, 14, 14, 512)

zero_padding2d_11: ZeroPadding2D — input: (None, 14, 14, 512) — output: (None, 16, 16, 512)


conv2d_11: Conv2D
input: (None, 16, 16, 512)
output: (None, 14, 14, 512)
zero_padding2d_12: ZeroPadding2D
input: (None, 14, 14, 512)
output: (None, 16, 16, 512)
conv2d_12: Conv2D
input: (None, 16, 16, 512)
output: (None, 14, 14, 512)
zero_padding2d_13: ZeroPadding2D
input: (None, 14, 14, 512)
output: (None, 16, 16, 512)
conv2d_13: Conv2D
input: (None, 16, 16, 512)
output: (None, 14, 14, 512)
max_pooling2d_5: MaxPooling2D
input: (None, 14, 14, 512)
output: (None, 7, 7, 512)
flatten_1: Flatten
input: (None, 7, 7, 512)
output: (None, 25088)
dense_1: Dense
input: (None, 25088)
output: (None, 256)
activation_1: Activation
input: (None, 256)
output: (None, 256)
dropout_1: Dropout
input: (None, 256)
output: (None, 256)
dense_2: Dense
input: (None, 256)
output: (None, 7)
activation_2: Activation
input: (None, 7)
output: (None, 7)

Sequential Model:

- The **Convolutional part** and the **fully-connected layer with 256 neurons** is made **non-trainable** so it acts as feature extractor

- 2 x LSTM layers
- Classification: Softmax
- Loss: Categorical Cross Entropy
- Optimizer: Adam

- Total parameters: 21,183,015
- Total Trainable parameters: 45,543

Hyper-parameters:

- LSTM cells : 32 cells x 2 layers
- Regularization: Dropout (probability: 0.5)
- Batch size: 32
- Learning Rate: 1e-4
- Decay Rate: 1e-2

- Due to memory constraint on Henry cluster, batch size is reduced to 32.
- The entire convolutional part with one fully connected layer with 256 neurons are **non-trainable**.
- **Only the LSTM layers are trainable**

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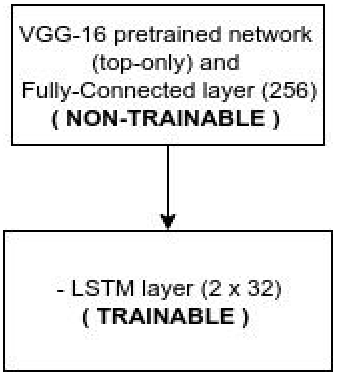
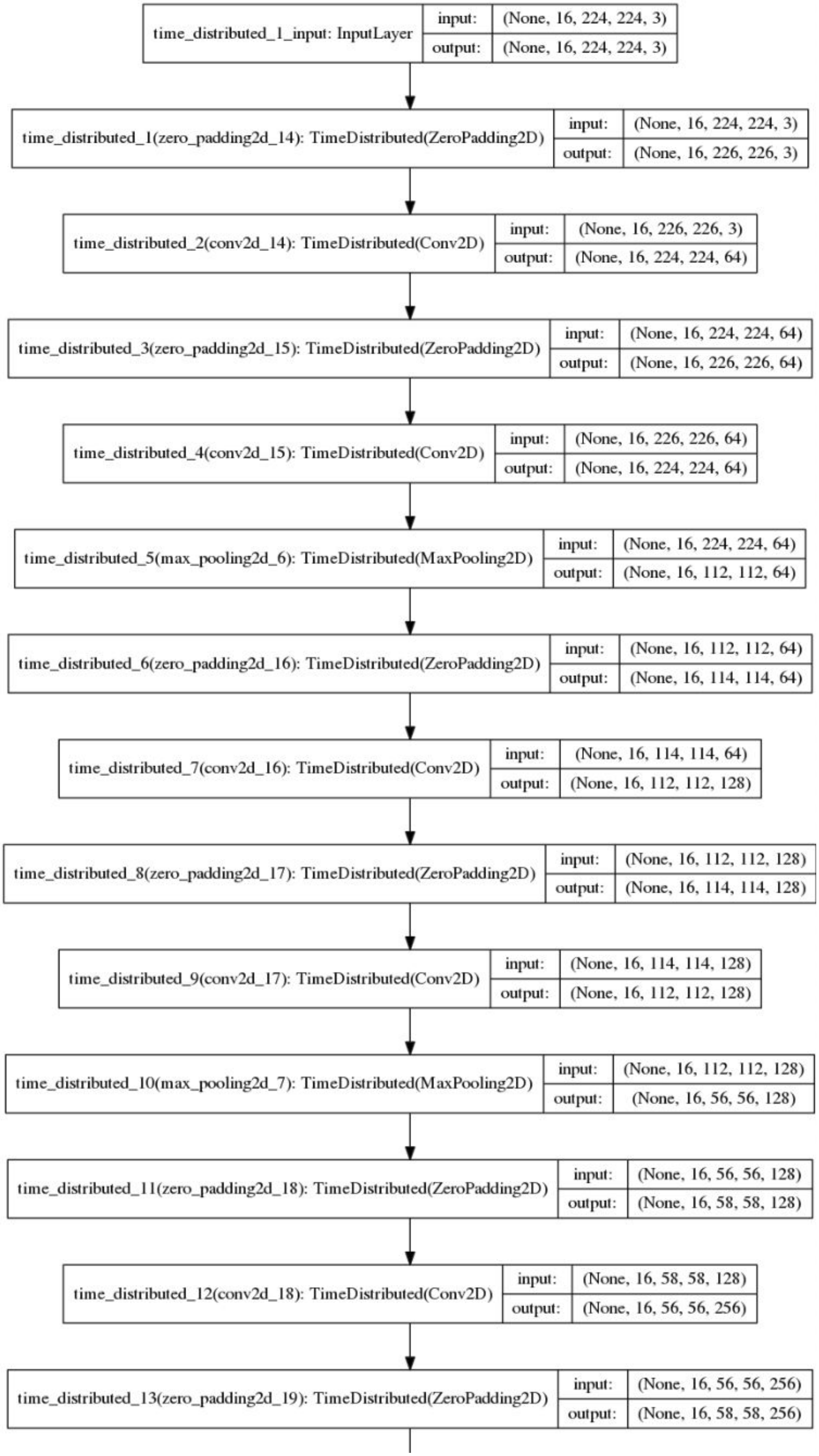

VGG-16 pretrained network (top-only) and Fully-Connected layer (256)
( NON-TRAINABLE )
- LSTM layer (2 x 32)
( TRAINABLE )



time_distributed_1_input: InputLayer | input: (None, 16, 224, 224, 3) | output: (None, 16, 224, 224, 3)

time_distributed_1(zero_padding2d_14): TimeDistributed(ZeroPadding2D) | input: (None, 16, 224, 224, 3) | output: (None, 16, 226, 226, 3)

time_distributed_2(conv2d_14): TimeDistributed(Conv2D) | input: (None, 16, 226, 226, 3) | output: (None, 16, 224, 224, 64)

time_distributed_3(zero_padding2d_15): TimeDistributed(ZeroPadding2D) | input: (None, 16, 224, 224, 64) | output: (None, 16, 226, 226, 64)

time_distributed_4(conv2d_15): TimeDistributed(Conv2D) | input: (None, 16, 226, 226, 64) | output: (None, 16, 224, 224, 64)

time_distributed_5(max_pooling2d_6): TimeDistributed(MaxPooling2D) | input: (None, 16, 224, 224, 64) | output: (None, 16, 112, 112, 64)

time_distributed_6(zero_padding2d_16): TimeDistributed(ZeroPadding2D) | input: (None, 16, 112, 112, 64) | output: (None, 16, 114, 114, 64)

time_distributed_7(conv2d_16): TimeDistributed(Conv2D) | input: (None, 16, 114, 114, 64) | output: (None, 16, 112, 112, 128)

time_distributed_8(zero_padding2d_17): TimeDistributed(ZeroPadding2D) | input: (None, 16, 112, 112, 128) | output: (None, 16, 114, 114, 128)

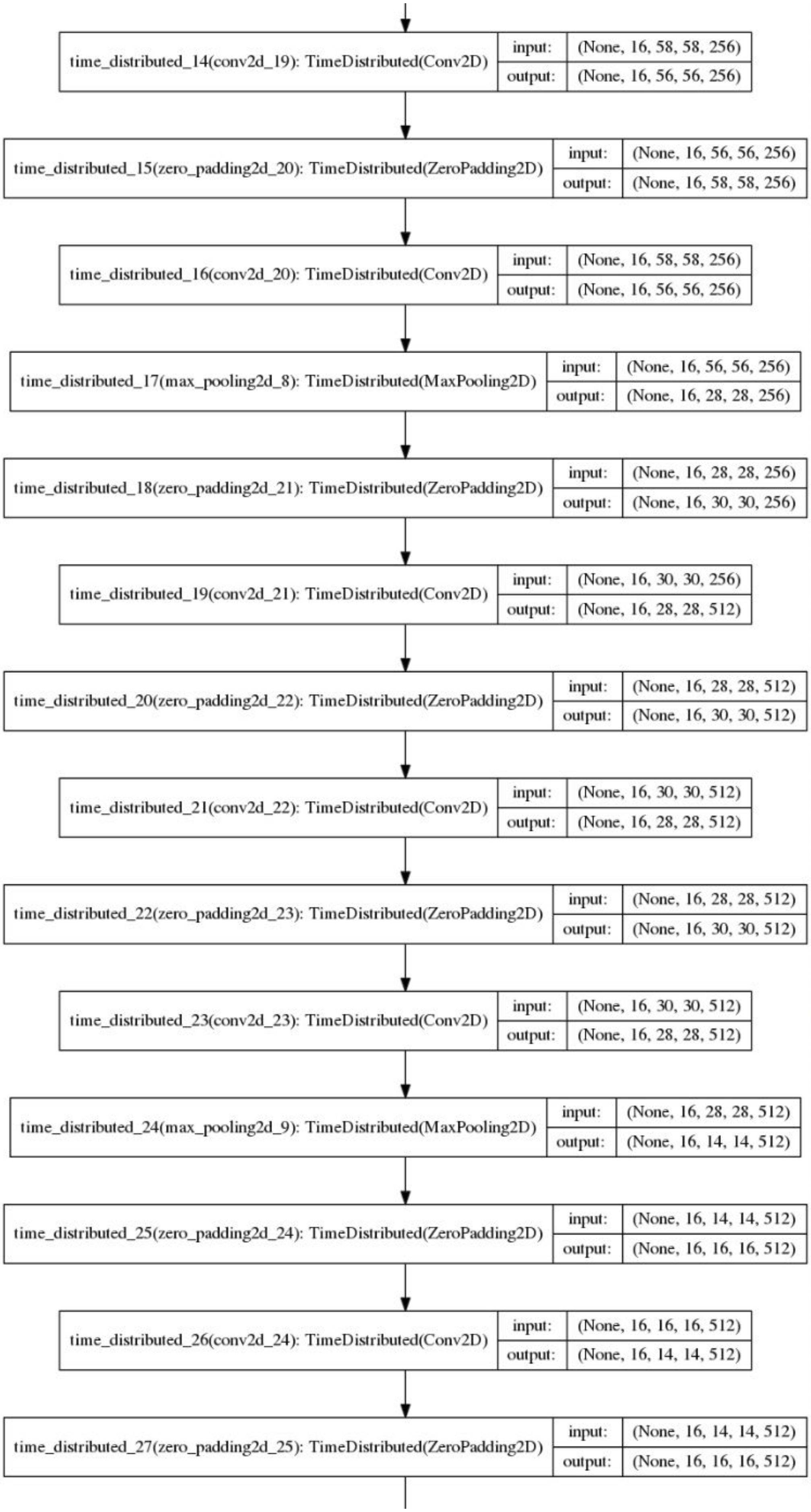
time_distributed_9(conv2d_17): TimeDistributed(Conv2D) | input: (None, 16, 114, 114, 128) | output: (None, 16, 112, 112, 128)

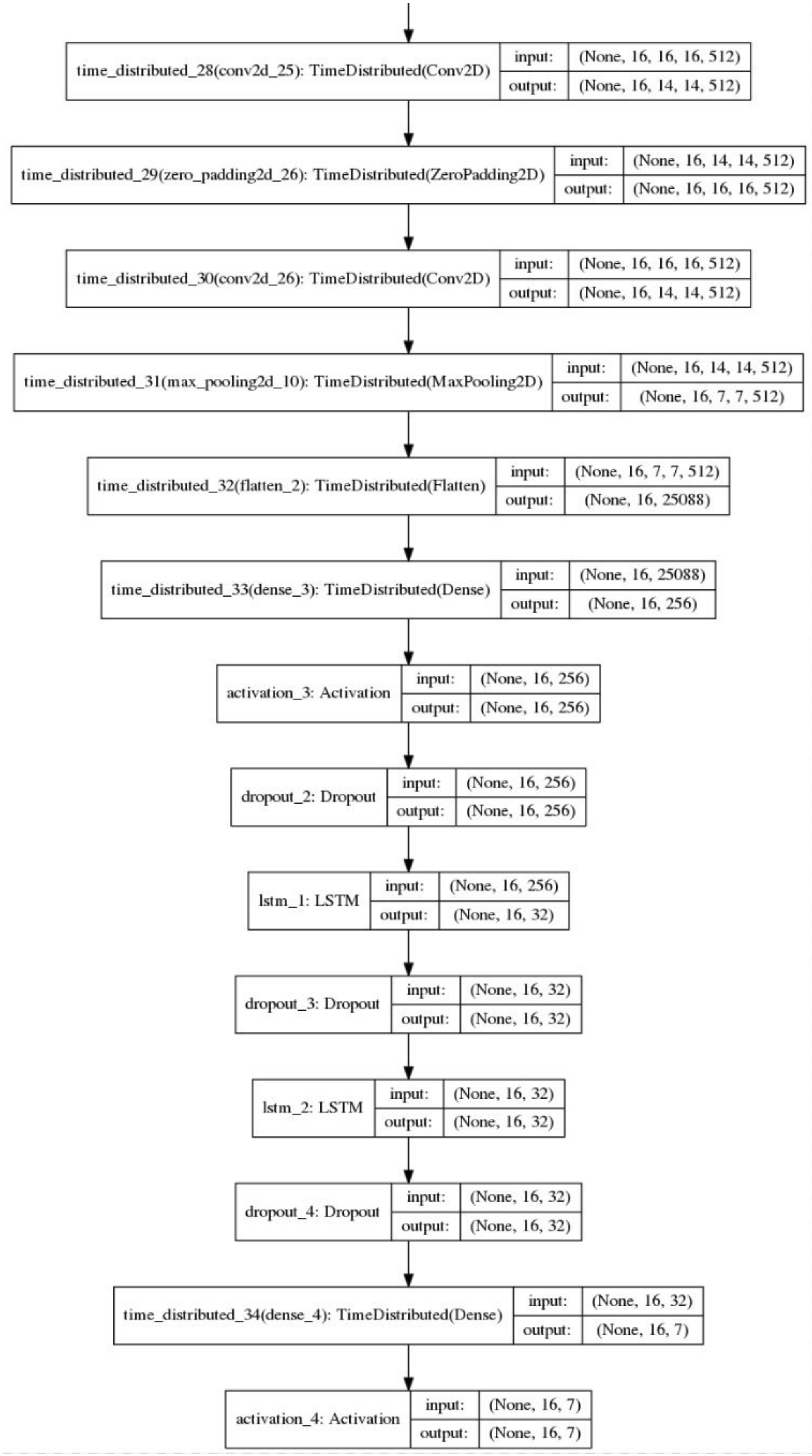
time_distributed_10(max_pooling2d_7): TimeDistributed(MaxPooling2D) | input: (None, 16, 112, 112, 128) | output: (None, 16, 56, 56, 128)

time_distributed_11(zero_padding2d_18): TimeDistributed(ZeroPadding2D) | input: (None, 16, 56, 56, 128) | output: (None, 16, 58, 58, 128)

time_distributed_12(conv2d_18): TimeDistributed(Conv2D) | input: (None, 16, 58, 58, 128) | output: (None, 16, 56, 56, 256)

time_distributed_13(zero_padding2d_19): TimeDistributed(ZeroPadding2D) | input: (None, 16, 56, 56, 256) | output: (None, 16, 58, 58, 256)

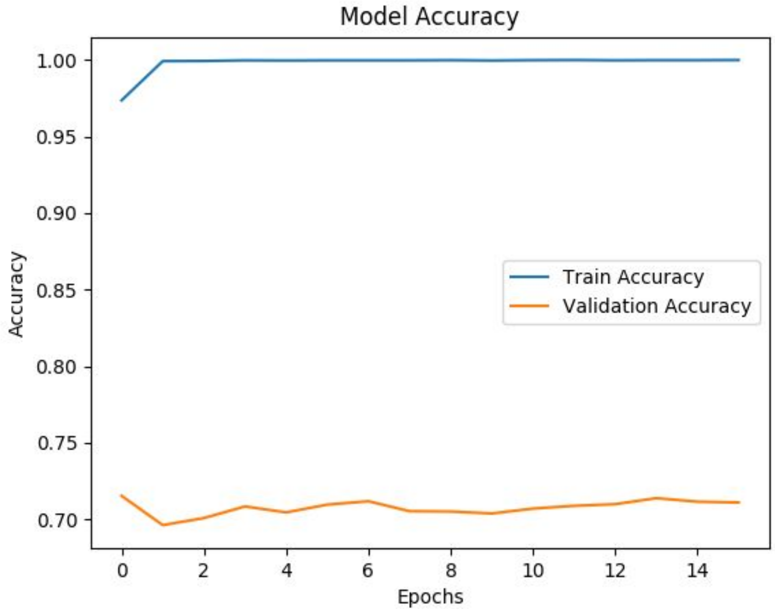

time_distributed_14(conv2d_19): TimeDistributed(Conv2D)
input: (None, 16, 58, 58, 256)
output: (None, 16, 56, 56, 256)
time_distributed_15(zero_padding2d_20): TimeDistributed(ZeroPadding2D)
input: (None, 16, 56, 56, 256)
output: (None, 16, 58, 58, 256)
time_distributed_16(conv2d_20): TimeDistributed(Conv2D)
input: (None, 16, 58, 58, 256)
output: (None, 16, 56, 56, 256)
time_distributed_17(max_pooling2d_8): TimeDistributed(MaxPooling2D)
input: (None, 16, 56, 56, 256)
output: (None, 16, 28, 28, 256)
time_distributed_18(zero_padding2d_21): TimeDistributed(ZeroPadding2D)
input: (None, 16, 28, 28, 256)
output: (None, 16, 30, 30, 256)
time_distributed_19(conv2d_21): TimeDistributed(Conv2D)
input: (None, 16, 30, 30, 256)
output: (None, 16, 28, 28, 512)
time_distributed_20(zero_padding2d_22): TimeDistributed(ZeroPadding2D)
input: (None, 16, 28, 28, 512)
output: (None, 16, 30, 30, 512)
time_distributed_21(conv2d_22): TimeDistributed(Conv2D)
input: (None, 16, 30, 30, 512)
output: (None, 16, 28, 28, 512)
time_distributed_22(zero_padding2d_23): TimeDistributed(ZeroPadding2D)
input: (None, 16, 28, 28, 512)
output: (None, 16, 30, 30, 512)
time_distributed_23(conv2d_23): TimeDistributed(Conv2D)
input: (None, 16, 30, 30, 512)
output: (None, 16, 28, 28, 512)
time_distributed_24(max_pooling2d_9): TimeDistributed(MaxPooling2D)
input: (None, 16, 28, 28, 512)
output: (None, 16, 14, 14, 512)
time_distributed_25(zero_padding2d_24): TimeDistributed(ZeroPadding2D)
input: (None, 16, 14, 14, 512)
output: (None, 16, 16, 16, 512)
time_distributed_26(conv2d_24): TimeDistributed(Conv2D)
input: (None, 16, 16, 16, 512)
output: (None, 16, 14, 14, 512)
time_distributed_27(zero_padding2d_25): TimeDistributed(ZeroPadding2D)
input: (None, 16, 14, 14, 512)
output: (None, 16, 16, 16, 512)

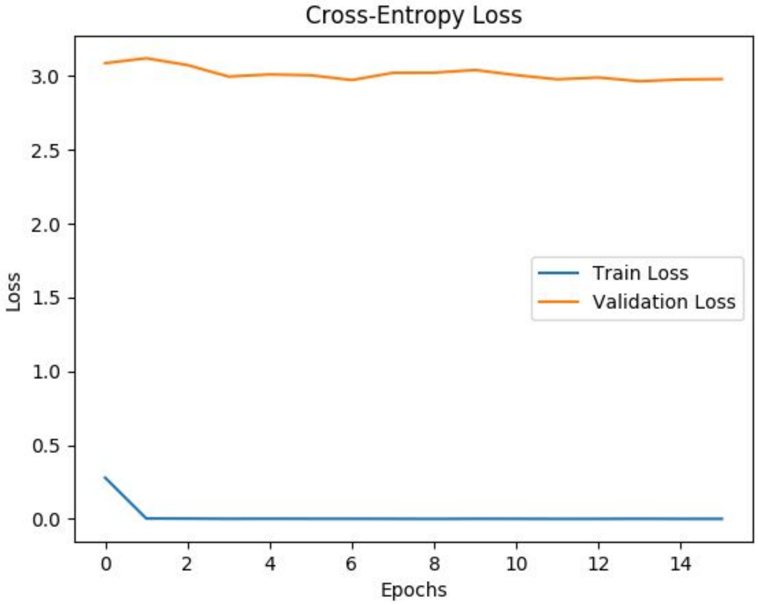

time_distributed_28(conv2d_25): TimeDistributed(Conv2D)
input: (None, 16, 16, 16, 512)
output: (None, 16, 14, 14, 512)
time_distributed_29(zero_padding2d_26): TimeDistributed(ZeroPadding2D)
input: (None, 16, 14, 14, 512)
output: (None, 16, 16, 16, 512)
time_distributed_30(conv2d_26): TimeDistributed(Conv2D)
input: (None, 16, 16, 16, 512)
output: (None, 16, 14, 14, 512)
time_distributed_31(max_pooling2d_10): TimeDistributed(MaxPooling2D)
input: (None, 16, 14, 14, 512)
output: (None, 16, 7, 7, 512)
time_distributed_32(flatten_2): TimeDistributed(Flatten)
input: (None, 16, 7, 7, 512)
output: (None, 16, 25088)
time_distributed_33(dense_3): TimeDistributed(Dense)
input: (None, 16, 25088)
output: (None, 16, 256)
activation_3: Activation
input: (None, 16, 256)
output: (None, 16, 256)
dropout_2: Dropout
input: (None, 16, 256)
output: (None, 16, 256)
lstm_1: LSTM
input: (None, 16, 256)
output: (None, 16, 32)
dropout_3: Dropout
input: (None, 16, 32)
output: (None, 16, 32)
lstm_2: LSTM
input: (None, 16, 32)
output: (None, 16, 32)
dropout_4: Dropout
input: (None, 16, 32)
output: (None, 16, 32)
time_distributed_34(dense_4): TimeDistributed(Dense)
input: (None, 16, 32)
output: (None, 16, 7)
activation_4: Activation
input: (None, 16, 7)
output: (None, 16, 7)

## Result:

### Classification:

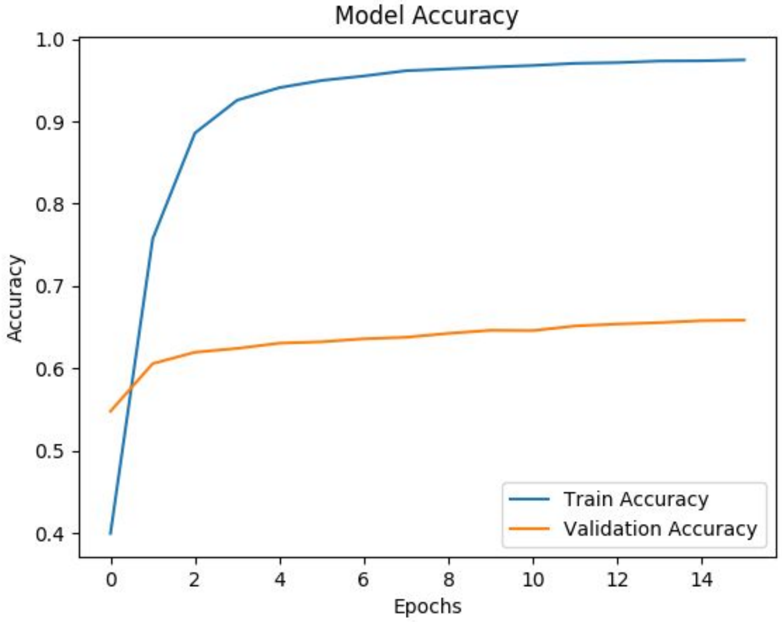
| | |
|---|---|
| Train Loss | : 1.193947e-7 |
| Cross Validation Loss | : 2.9791 |
| Test Loss | : 4.08048 |
| | |
| Train Accuracy | : 100.00 % |
| Cross Validation Accuracy | : **71.52** % (Improvement over Approach 1(Sequential) : 40.62%) |
| Test Accuracy | : **65.71** % (Improvement over Approach 1(Sequential) : 47.72%) |





Sequential:

| | | | |
|---|---|---|---|
| Train Loss | : | 0.1603 | |
| Cross Validation Loss | : | 1.6146 | |
| Test Loss | : | 1.8774 | |
| Train Accuracy | : | 97.47 % | |
| Cross Validation Accuracy | : | **65.86** % | ( Results did not improve compared to classification. |
| Test Accuracy | : | **70.03** % | Requires Hyper-parameter tuning. ) |



Code implementation of the report:
https://github.com/suraj-maniyar/Activity-Recognition-From-Video