Guesture Recognition using Deep Learning

## Project Description

Project is to develop a feature in the smart-TV that can recognize five different gestures performed by the user which will help users control the TV without using a remote.

* Thumbs up:  Increase the volume
* Thumbs down: Decrease the volume
* Left swipe: 'Jump' backwards 10 seconds
* Right swipe: 'Jump' forward 10 seconds
* Stop: Pause the movie

## Data Set:

Data Set contains train and validation folders. With each folder containing 30 frames from the video showing different guestures. Videos are captured using different cameras hence contains different image resolution.

## Solution:

Solve the problem by training on the multiple frames using deep learning models using 3D Convs and CNN-RNN Stack and save the models at each check-point using different hyper parameters and select the best model for use.

## Report:

This report captures the overall model building process and the results for the Guesture Recognition project from Deep Learning.

Updating the deep learning models built for Guesture Recognition the experiments are performed using two deep learning architectures **3D Convs and CNN-RNN Stack.**

**3D Convs:**

3D Convs CNN architecture is used to feed multiple frames (max: 30) after normalization and resizing image to 120 x 120 x 3 dimension 3 represents the color channels. The image is fed into CNN sequential model using 3D convolution and batch normalization using batch size of 32 to train the model with and without Drop-outs using 6 layer and classification through softmax to determine the number of classes.

**CNN-RNN Stack:**

**CNN-RNN stack** is used by combining Conv2D for image classification and feeding the image detection to LSTM stack using 5 Conv2D layers, followed by LSTM and 2 Dense Layer with and without dropouts.

The model output details from each model tabulated below under Appendix at the end of this document.

## Experiment Summary:

|  |  |  |  |
| --- | --- | --- | --- |
| **Experiment Number** | **Model** | **Result** | **Decision + Explanation** |
| **1** | **Conv3D without dropouts using Ablation test with 57 “train” and 13 “val” data set using batch\_size = 5**  **Epochs = 1** | **Throws Generator error** | **Stop Iteration Error**  **Verified generator logic.**  **Correct the generator logic and try to overfit on less amount of data** |
| **2** | **Conv3D without dropouts using complete data set**  **batch\_size = 32**  **epochs = 20**  **no of frames = 30**  **image size = (120 x 120)**  **i) 3 Conv3D convolution layers (16,32,64 filters) using batch normalization**  **ii) Flatten Layer**  **iii) 3 Dense layers (128, 64, 5 filters)** | **Model trained with 2,848,741**  **Trainable parameters**  **Accuracy: 0.57** | **Epoch 19 shown the highest accuracy**  **lr: 0.0200**  **Train loss: 0.65**  **Train\_accuracy: 0.76**  **val\_loss: 3.64**  **val\_ accuracy: 0.57** |
| **3** | **Conv3D with dropouts using complete data set**  **batch\_size = 32**  **epochs = 20**  **no of frames = 30**  **image size = (120 x 120)**  **i) 3 Conv3D convolution layers (16,32,64 filters) using batch normalization**  **ii) Flatten Layer**  **iii) 3 Dense layers (128, 64, 5 filters) and Dropout(0.25)** | **Accuracy: 0.37** | **Train\_accuracy 0.648**  **Val\_accuracy 0.368** |
| **4** | **Conv3D with dropouts using complete data set**  **batch\_size = 32**  **epochs = 20**  **no of frames = 20**  **image size = (120 x 120)**  **i) 3 Conv3D convolution layers (16,32,64 filters) using batch normalization**  **ii) Flatten Layer**  **iii) 3 Dense layers (128, 64, 5 filters) and Dropout(0.25)** |  | **Error with Sequence** |
| **5** | **Conv2D+LSTM with dropouts using TimeDistributed Feed on complete data set**  **batch\_size = 32**  **epochs = 20**  **no of frames = 30**  **image size = (120 x 120)**  **i) 5 Conv2D convolution layers (16,32,64, 128, 256 filters) using batch normalization**  **ii) Flatten Layer**  **iii) LSTM with 256 filters**  **iii) 2 Dense layers (256, 5 filters) and Dropout(0.2)** | **Model trained with 3,083,141**  **Trainable parameters**  **Accuracy: 0.58** | **Train Accuracy = 0.92**  **Val Accuracy = 0.58** |
| **Final Model** | **Conv2D+LSTM with dropouts using TimeDistributed Feed on complete data set**  **batch\_size = 64**  **epochs = 20**  **no of frames = 20**  **image size = (120 x 120)**  **i) 5 Conv2D convolution layers (16,32,64, 128, 256 filters) using batch normalization**  **ii) Flatten Layer**  **iii) LSTM with 256 filters**  **iii) 2 Dense layers (256, 5 filters) and Dropout(0.2)** | **Model trained with 3,083,141**  **Trainable parameters**  **Accuracy: 0.58** | **Train Accuracy 0.91**  **Val Accuracy 0.59** |

## Appendix

### Model#1: Conv3D without Drop-outs

#### Hyper Parameters:

**# batch\_size = 32**

**# epochs = 20**

**# no\_classes = 5**

**# input\_shape = (30,120,120,3)**

#### Model Summary:

Model: "sequential"

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Layer (type) Output Shape Param #

=================================================================

conv3d (Conv3D) (None, 28, 118, 118, 16) 1312

max\_pooling3d (MaxPooling3D (None, 14, 59, 59, 16) 0

)

batch\_normalization (BatchN (None, 14, 59, 59, 16) 64

ormalization)

conv3d\_1 (Conv3D) (None, 12, 57, 57, 32) 13856

max\_pooling3d\_1 (MaxPooling (None, 6, 28, 28, 32) 0

3D)

batch\_normalization\_1 (Batc (None, 6, 28, 28, 32) 128

hNormalization)

conv3d\_2 (Conv3D) (None, 4, 26, 26, 64) 55360

max\_pooling3d\_2 (MaxPooling (None, 2, 13, 13, 64) 0

3D)

batch\_normalization\_2 (Batc (None, 2, 13, 13, 64) 256

hNormalization)

flatten (Flatten) (None, 21632) 0

dense (Dense) (None, 128) 2769024

batch\_normalization\_3 (Batc (None, 128) 512

hNormalization)

dense\_1 (Dense) (None, 64) 8256

batch\_normalization\_4 (Batc (None, 64) 256

hNormalization)

dense\_2 (Dense) (None, 5) 325

=================================================================

Total params: 2,849,349

Trainable params: 2,848,741

Non-trainable params: 608

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

None

#### Model Fit:

Epoch 1/20

2024-07-31 10:29:17.820929: I tensorflow/stream\_executor/cuda/cuda\_dnn.cc:377] Loaded cuDNN version 8302

21/21 [==============================] - ETA: 0s - loss: 1.9227 - categorical\_accuracy: 0.3393

Epoch 00001: saving model to ./modelCheckpoint/cnn\_conv3d\_without\_dropoutsmodel\_init\_2024-07-3110\_24\_02.439563/model-00001-1.92268-0.33929-9327.68359-0.17969.h5

21/21 [==============================] - 155s 7s/step - loss: 1.9227 - categorical\_accuracy: 0.3393 - val\_loss: 9327.6836 - val\_categorical\_accuracy: 0.1797 - lr: 0.1000

Epoch 2/20

21/21 [==============================] - ETA: 0s - loss: 1.3981 - categorical\_accuracy: 0.4330

Epoch 00002: saving model to ./modelCheckpoint/cnn\_conv3d\_without\_dropoutsmodel\_init\_2024-07-3110\_24\_02.439563/model-00002-1.39810-0.43304-255.25769-0.16406.h5

21/21 [==============================] - 148s 7s/step - loss: 1.3981 - categorical\_accuracy: 0.4330 - val\_loss: 255.2577 - val\_categorical\_accuracy: 0.1641 - lr: 0.1000

Epoch 3/20

21/21 [==============================] - ETA: 0s - loss: 1.2374 - categorical\_accuracy: 0.4598

Epoch 00003: saving model to ./modelCheckpoint/cnn\_conv3d\_without\_dropoutsmodel\_init\_2024-07-3110\_24\_02.439563/model-00003-1.23738-0.45982-32.33496-0.11719.h5

21/21 [==============================] - 147s 7s/step - loss: 1.2374 - categorical\_accuracy: 0.4598 - val\_loss: 32.3350 - val\_categorical\_accuracy: 0.1172 - lr: 0.1000

Epoch 4/20

21/21 [==============================] - ETA: 0s - loss: 1.1407 - categorical\_accuracy: 0.5119

Epoch 00004: saving model to ./modelCheckpoint/cnn\_conv3d\_without\_dropoutsmodel\_init\_2024-07-3110\_24\_02.439563/model-00004-1.14072-0.51190-5.86117-0.34375.h5

21/21 [==============================] - 145s 7s/step - loss: 1.1407 - categorical\_accuracy: 0.5119 - val\_loss: 5.8612 - val\_categorical\_accuracy: 0.3438 - lr: 0.1000

Epoch 5/20

21/21 [==============================] - ETA: 0s - loss: 1.1189 - categorical\_accuracy: 0.5312

Epoch 00005: saving model to ./modelCheckpoint/cnn\_conv3d\_without\_dropoutsmodel\_init\_2024-07-3110\_24\_02.439563/model-00005-1.11889-0.53125-7.21467-0.14062.h5

21/21 [==============================] - 148s 7s/step - loss: 1.1189 - categorical\_accuracy: 0.5312 - val\_loss: 7.2147 - val\_categorical\_accuracy: 0.1406 - lr: 0.1000

Epoch 6/20

21/21 [==============================] - ETA: 0s - loss: 0.9922 - categorical\_accuracy: 0.5744

Epoch 00006: saving model to ./modelCheckpoint/cnn\_conv3d\_without\_dropoutsmodel\_init\_2024-07-3110\_24\_02.439563/model-00006-0.99218-0.57440-11.31261-0.13281.h5

21/21 [==============================] - 149s 7s/step - loss: 0.9922 - categorical\_accuracy: 0.5744 - val\_loss: 11.3126 - val\_categorical\_accuracy: 0.1328 - lr: 0.1000

Epoch 7/20

21/21 [==============================] - ETA: 0s - loss: 0.9366 - categorical\_accuracy: 0.6295

Epoch 00007: saving model to ./modelCheckpoint/cnn\_conv3d\_without\_dropoutsmodel\_init\_2024-07-3110\_24\_02.439563/model-00007-0.93660-0.62946-5.68899-0.24219.h5

21/21 [==============================] - 151s 8s/step - loss: 0.9366 - categorical\_accuracy: 0.6295 - val\_loss: 5.6890 - val\_categorical\_accuracy: 0.2422 - lr: 0.1000

Epoch 8/20

21/21 [==============================] - ETA: 0s - loss: 1.2512 - categorical\_accuracy: 0.4509

Epoch 00008: saving model to ./modelCheckpoint/cnn\_conv3d\_without\_dropoutsmodel\_init\_2024-07-3110\_24\_02.439563/model-00008-1.25124-0.45089-3.49147-0.22656.h5

21/21 [==============================] - 145s 7s/step - loss: 1.2512 - categorical\_accuracy: 0.4509 - val\_loss: 3.4915 - val\_categorical\_accuracy: 0.2266 - lr: 0.1000

Epoch 9/20

21/21 [==============================] - ETA: 0s - loss: 0.9981 - categorical\_accuracy: 0.5967

Epoch 00009: saving model to ./modelCheckpoint/cnn\_conv3d\_without\_dropoutsmodel\_init\_2024-07-3110\_24\_02.439563/model-00009-0.99807-0.59673-7.74299-0.32031.h5

21/21 [==============================] - 150s 8s/step - loss: 0.9981 - categorical\_accuracy: 0.5967 - val\_loss: 7.7430 - val\_categorical\_accuracy: 0.3203 - lr: 0.1000

Epoch 10/20

21/21 [==============================] - ETA: 0s - loss: 0.9205 - categorical\_accuracy: 0.6295

Epoch 00010: saving model to ./modelCheckpoint/cnn\_conv3d\_without\_dropoutsmodel\_init\_2024-07-3110\_24\_02.439563/model-00010-0.92049-0.62946-3.61242-0.24219.h5

21/21 [==============================] - 150s 7s/step - loss: 0.9205 - categorical\_accuracy: 0.6295 - val\_loss: 3.6124 - val\_categorical\_accuracy: 0.2422 - lr: 0.1000

Epoch 11/20

21/21 [==============================] - ETA: 0s - loss: 0.8368 - categorical\_accuracy: 0.6696

Epoch 00011: saving model to ./modelCheckpoint/cnn\_conv3d\_without\_dropoutsmodel\_init\_2024-07-3110\_24\_02.439563/model-00011-0.83679-0.66964-3.01277-0.31250.h5

21/21 [==============================] - 153s 8s/step - loss: 0.8368 - categorical\_accuracy: 0.6696 - val\_loss: 3.0128 - val\_categorical\_accuracy: 0.3125 - lr: 0.1000

Epoch 12/20

21/21 [==============================] - ETA: 0s - loss: 1.0280 - categorical\_accuracy: 0.6815

Epoch 00012: saving model to ./modelCheckpoint/cnn\_conv3d\_without\_dropoutsmodel\_init\_2024-07-3110\_24\_02.439563/model-00012-1.02798-0.68155-3.83194-0.33594.h5

21/21 [==============================] - 147s 7s/step - loss: 1.0280 - categorical\_accuracy: 0.6815 - val\_loss: 3.8319 - val\_categorical\_accuracy: 0.3359 - lr: 0.1000

Epoch 13/20

21/21 [==============================] - ETA: 0s - loss: 1.1637 - categorical\_accuracy: 0.6116

Epoch 00013: saving model to ./modelCheckpoint/cnn\_conv3d\_without\_dropoutsmodel\_init\_2024-07-3110\_24\_02.439563/model-00013-1.16372-0.61161-6.89969-0.14844.h5

21/21 [==============================] - 152s 8s/step - loss: 1.1637 - categorical\_accuracy: 0.6116 - val\_loss: 6.8997 - val\_categorical\_accuracy: 0.1484 - lr: 0.1000

Epoch 14/20

21/21 [==============================] - ETA: 0s - loss: 0.9392 - categorical\_accuracy: 0.6518

Epoch 00014: saving model to ./modelCheckpoint/cnn\_conv3d\_without\_dropoutsmodel\_init\_2024-07-3110\_24\_02.439563/model-00014-0.93924-0.65179-6.32742-0.32812.h5

21/21 [==============================] - 150s 7s/step - loss: 0.9392 - categorical\_accuracy: 0.6518 - val\_loss: 6.3274 - val\_categorical\_accuracy: 0.3281 - lr: 0.1000

Epoch 15/20

21/21 [==============================] - ETA: 0s - loss: 1.0430 - categorical\_accuracy: 0.6815

Epoch 00015: saving model to ./modelCheckpoint/cnn\_conv3d\_without\_dropoutsmodel\_init\_2024-07-3110\_24\_02.439563/model-00015-1.04299-0.68155-5.14106-0.33594.h5

21/21 [==============================] - 153s 8s/step - loss: 1.0430 - categorical\_accuracy: 0.6815 - val\_loss: 5.1411 - val\_categorical\_accuracy: 0.3359 - lr: 0.1000

Epoch 16/20

21/21 [==============================] - ETA: 0s - loss: 1.3058 - categorical\_accuracy: 0.6295

Epoch 00016: saving model to ./modelCheckpoint/cnn\_conv3d\_without\_dropoutsmodel\_init\_2024-07-3110\_24\_02.439563/model-00016-1.30577-0.62946-5.85811-0.28906.h5

21/21 [==============================] - 145s 7s/step - loss: 1.3058 - categorical\_accuracy: 0.6295 - val\_loss: 5.8581 - val\_categorical\_accuracy: 0.2891 - lr: 0.1000

Epoch 17/20

21/21 [==============================] - ETA: 0s - loss: 0.9922 - categorical\_accuracy: 0.6429

Epoch 00017: saving model to ./modelCheckpoint/cnn\_conv3d\_without\_dropoutsmodel\_init\_2024-07-3110\_24\_02.439563/model-00017-0.99216-0.64286-4.73798-0.49219.h5

21/21 [==============================] - 152s 8s/step - loss: 0.9922 - categorical\_accuracy: 0.6429 - val\_loss: 4.7380 - val\_categorical\_accuracy: 0.4922 - lr: 0.0200

**Epoch 18/20**

**21/21 [==============================] - ETA: 0s - loss: 0.7218 - categorical\_accuracy: 0.7188**

**Epoch 00018: saving model to ./modelCheckpoint/cnn\_conv3d\_without\_dropoutsmodel\_init\_2024-07-3110\_24\_02.439563/model-00018-0.72178-0.71875-5.02625-0.57031.h5**

**21/21 [==============================] - 153s 8s/step - loss: 0.7218 - categorical\_accuracy: 0.7188 - val\_loss: 5.0263 - val\_categorical\_accuracy: 0.5703 - lr: 0.0200**

Epoch 19/20

21/21 [==============================] - ETA: 0s - loss: 0.6532 - categorical\_accuracy: 0.7649

Epoch 00019: saving model to ./modelCheckpoint/cnn\_conv3d\_without\_dropoutsmodel\_init\_2024-07-3110\_24\_02.439563/model-00019-0.65324-0.76488-3.64035-0.57031.h5

21/21 [==============================] - 150s 7s/step - loss: 0.6532 - categorical\_accuracy: 0.7649 - val\_loss: 3.6403 - val\_categorical\_accuracy: 0.5703 - lr: 0.0200

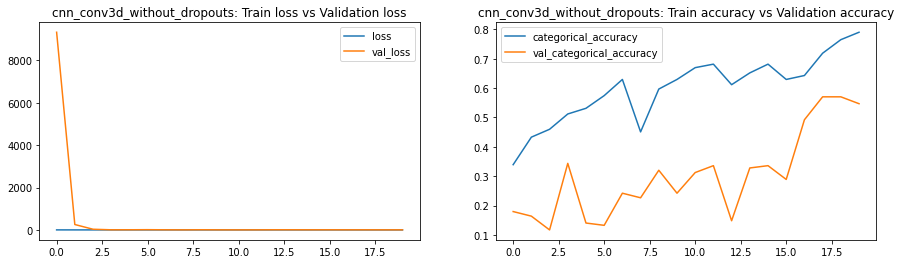
Epoch 20/20

21/21 [==============================] - ETA: 0s - loss: 0.5404 - categorical\_accuracy: 0.7902

Epoch 00020: saving model to ./modelCheckpoint/cnn\_conv3d\_without\_dropoutsmodel\_init\_2024-07-3110\_24\_02.439563/model-00020-0.54039-0.79018-4.05422-0.54688.h5

21/21 [==============================] - 143s 7s/step - loss: 0.5404 - categorical\_accuracy: 0.7902 - val\_loss: 4.0542 - val\_categorical\_accuracy: 0.5469 - lr: 0.0200

#### Model Plots for Training and Validation Accuracy:



**Max. Training Accuracy 0.7901785969734192**

**Max. Validaiton Accuracy 0.5703125**

### Model#2: Conv3D with dropouts

#### Hyper Parameters:

**# batch\_size = 32**

**# epochs = 20**

**# no\_classes = 5**

**# input\_shape = (30,120,120,3)**

#### Model Summary:

Model: "sequential\_1"

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Layer (type) Output Shape Param #

=================================================================

conv3d\_3 (Conv3D) (None, 28, 118, 118, 16) 1312

max\_pooling3d\_3 (MaxPooling (None, 14, 59, 59, 16) 0

3D)

batch\_normalization\_5 (Batc (None, 14, 59, 59, 16) 64

hNormalization)

conv3d\_4 (Conv3D) (None, 12, 57, 57, 32) 13856

max\_pooling3d\_4 (MaxPooling (None, 6, 28, 28, 32) 0

3D)

batch\_normalization\_6 (Batc (None, 6, 28, 28, 32) 128

hNormalization)

conv3d\_5 (Conv3D) (None, 4, 26, 26, 64) 55360

max\_pooling3d\_5 (MaxPooling (None, 2, 13, 13, 64) 0

3D)

batch\_normalization\_7 (Batc (None, 2, 13, 13, 64) 256

hNormalization)

flatten\_1 (Flatten) (None, 21632) 0

dense\_3 (Dense) (None, 128) 2769024

batch\_normalization\_8 (Batc (None, 128) 512

hNormalization)

dropout (Dropout) (None, 128) 0

dense\_4 (Dense) (None, 64) 8256

batch\_normalization\_9 (Batc (None, 64) 256

hNormalization)

dropout\_1 (Dropout) (None, 64) 0

dense\_5 (Dense) (None, 5) 325

=================================================================

Total params: 2,849,349

**Trainable params: 2,848,741**

Non-trainable params: 608

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

None

#### Model Fit:

Epoch 1/20

21/21 [==============================] - ETA: 0s - loss: 1.9204 - categorical\_accuracy: 0.3378

Epoch 00001: saving model to ./modelCheckpoint/cnn\_conv3d\_with\_dropoutsmodel\_init\_2024-07-3110\_24\_02.439563/model-00001-1.92045-0.33780-9115.18262-0.17969.h5

21/21 [==============================] - 150s 7s/step - loss: 1.9204 - categorical\_accuracy: 0.3378 - val\_loss: 9115.1826 - val\_categorical\_accuracy: 0.1797 - lr: 0.1000

Epoch 2/20

21/21 [==============================] - ETA: 0s - loss: 1.3893 - categorical\_accuracy: 0.3780

Epoch 00002: saving model to ./modelCheckpoint/cnn\_conv3d\_with\_dropoutsmodel\_init\_2024-07-3110\_24\_02.439563/model-00002-1.38930-0.37798-307.59222-0.21094.h5

21/21 [==============================] - 153s 8s/step - loss: 1.3893 - categorical\_accuracy: 0.3780 - val\_loss: 307.5922 - val\_categorical\_accuracy: 0.2109 - lr: 0.1000

Epoch 3/20

21/21 [==============================] - ETA: 0s - loss: 1.2858 - categorical\_accuracy: 0.4330

Epoch 00003: saving model to ./modelCheckpoint/cnn\_conv3d\_with\_dropoutsmodel\_init\_2024-07-3110\_24\_02.439563/model-00003-1.28581-0.43304-74.43939-0.14844.h5

21/21 [==============================] - 149s 7s/step - loss: 1.2858 - categorical\_accuracy: 0.4330 - val\_loss: 74.4394 - val\_categorical\_accuracy: 0.1484 - lr: 0.1000

Epoch 4/20

21/21 [==============================] - ETA: 0s - loss: 1.1751 - categorical\_accuracy: 0.4688

Epoch 00004: saving model to ./modelCheckpoint/cnn\_conv3d\_with\_dropoutsmodel\_init\_2024-07-3110\_24\_02.439563/model-00004-1.17508-0.46875-39.14673-0.18750.h5

21/21 [==============================] - 152s 8s/step - loss: 1.1751 - categorical\_accuracy: 0.4688 - val\_loss: 39.1467 - val\_categorical\_accuracy: 0.1875 - lr: 0.1000

Epoch 5/20

21/21 [==============================] - ETA: 0s - loss: 1.1861 - categorical\_accuracy: 0.4821

Epoch 00005: saving model to ./modelCheckpoint/cnn\_conv3d\_with\_dropoutsmodel\_init\_2024-07-3110\_24\_02.439563/model-00005-1.18610-0.48214-21.50174-0.17188.h5

21/21 [==============================] - 158s 8s/step - loss: 1.1861 - categorical\_accuracy: 0.4821 - val\_loss: 21.5017 - val\_categorical\_accuracy: 0.1719 - lr: 0.1000

Epoch 6/20

21/21 [==============================] - ETA: 0s - loss: 1.1204 - categorical\_accuracy: 0.5030

Epoch 00006: saving model to ./modelCheckpoint/cnn\_conv3d\_with\_dropoutsmodel\_init\_2024-07-3110\_24\_02.439563/model-00006-1.12039-0.50298-13.41509-0.20312.h5

21/21 [==============================] - 153s 8s/step - loss: 1.1204 - categorical\_accuracy: 0.5030 - val\_loss: 13.4151 - val\_categorical\_accuracy: 0.2031 - lr: 0.1000

Epoch 7/20

21/21 [==============================] - ETA: 0s - loss: 1.1231 - categorical\_accuracy: 0.5060

Epoch 00007: saving model to ./modelCheckpoint/cnn\_conv3d\_with\_dropoutsmodel\_init\_2024-07-3110\_24\_02.439563/model-00007-1.12307-0.50595-8.21989-0.20312.h5

21/21 [==============================] - 156s 8s/step - loss: 1.1231 - categorical\_accuracy: 0.5060 - val\_loss: 8.2199 - val\_categorical\_accuracy: 0.2031 - lr: 0.1000

Epoch 8/20

21/21 [==============================] - ETA: 0s - loss: 0.9919 - categorical\_accuracy: 0.5580

Epoch 00008: saving model to ./modelCheckpoint/cnn\_conv3d\_with\_dropoutsmodel\_init\_2024-07-3110\_24\_02.439563/model-00008-0.99191-0.55804-5.40665-0.23438.h5

21/21 [==============================] - 151s 8s/step - loss: 0.9919 - categorical\_accuracy: 0.5580 - val\_loss: 5.4067 - val\_categorical\_accuracy: 0.2344 - lr: 0.1000

Epoch 9/20

21/21 [==============================] - ETA: 0s - loss: 0.9807 - categorical\_accuracy: 0.5774

Epoch 00009: saving model to ./modelCheckpoint/cnn\_conv3d\_with\_dropoutsmodel\_init\_2024-07-3110\_24\_02.439563/model-00009-0.98070-0.57738-2.47871-0.26562.h5

21/21 [==============================] - 154s 8s/step - loss: 0.9807 - categorical\_accuracy: 0.5774 - val\_loss: 2.4787 - val\_categorical\_accuracy: 0.2656 - lr: 0.1000

Epoch 10/20

21/21 [==============================] - ETA: 0s - loss: 1.0959 - categorical\_accuracy: 0.5417

Epoch 00010: saving model to ./modelCheckpoint/cnn\_conv3d\_with\_dropoutsmodel\_init\_2024-07-3110\_24\_02.439563/model-00010-1.09592-0.54167-1.77212-0.35156.h5

21/21 [==============================] - 153s 8s/step - loss: 1.0959 - categorical\_accuracy: 0.5417 - val\_loss: 1.7721 - val\_categorical\_accuracy: 0.3516 - lr: 0.1000

Epoch 11/20

21/21 [==============================] - ETA: 0s - loss: 0.9431 - categorical\_accuracy: 0.6161

Epoch 00011: saving model to ./modelCheckpoint/cnn\_conv3d\_with\_dropoutsmodel\_init\_2024-07-3110\_24\_02.439563/model-00011-0.94314-0.61607-1.42801-0.35938.h5

21/21 [==============================] - 154s 8s/step - loss: 0.9431 - categorical\_accuracy: 0.6161 - val\_loss: 1.4280 - val\_categorical\_accuracy: 0.3594 - lr: 0.1000

Epoch 12/20

21/21 [==============================] - ETA: 0s - loss: 0.9012 - categorical\_accuracy: 0.6369

Epoch 00012: saving model to ./modelCheckpoint/cnn\_conv3d\_with\_dropoutsmodel\_init\_2024-07-3110\_24\_02.439563/model-00012-0.90120-0.63690-3.05648-0.28125.h5

21/21 [==============================] - 149s 7s/step - loss: 0.9012 - categorical\_accuracy: 0.6369 - val\_loss: 3.0565 - val\_categorical\_accuracy: 0.2812 - lr: 0.1000

Epoch 13/20

21/21 [==============================] - ETA: 0s - loss: 1.0654 - categorical\_accuracy: 0.5774

Epoch 00013: saving model to ./modelCheckpoint/cnn\_conv3d\_with\_dropoutsmodel\_init\_2024-07-3110\_24\_02.439563/model-00013-1.06543-0.57738-9.97771-0.22656.h5

21/21 [==============================] - 156s 8s/step - loss: 1.0654 - categorical\_accuracy: 0.5774 - val\_loss: 9.9777 - val\_categorical\_accuracy: 0.2266 - lr: 0.1000

Epoch 14/20

21/21 [==============================] - ETA: 0s - loss: 1.0925 - categorical\_accuracy: 0.6354

Epoch 00014: saving model to ./modelCheckpoint/cnn\_conv3d\_with\_dropoutsmodel\_init\_2024-07-3110\_24\_02.439563/model-00014-1.09249-0.63542-54.65474-0.16406.h5

21/21 [==============================] - 168s 8s/step - loss: 1.0925 - categorical\_accuracy: 0.6354 - val\_loss: 54.6547 - val\_categorical\_accuracy: 0.1641 - lr: 0.1000

Epoch 15/20

21/21 [==============================] - ETA: 0s - loss: 1.6314 - categorical\_accuracy: 0.4420

Epoch 00015: saving model to ./modelCheckpoint/cnn\_conv3d\_with\_dropoutsmodel\_init\_2024-07-3110\_24\_02.439563/model-00015-1.63137-0.44196-64.46223-0.35156.h5

21/21 [==============================] - 156s 8s/step - loss: 1.6314 - categorical\_accuracy: 0.4420 - val\_loss: 64.4622 - val\_categorical\_accuracy: 0.3516 - lr: 0.1000

Epoch 16/20

21/21 [==============================] - ETA: 0s - loss: 1.5750 - categorical\_accuracy: 0.4494

Epoch 00016: saving model to ./modelCheckpoint/cnn\_conv3d\_with\_dropoutsmodel\_init\_2024-07-3110\_24\_02.439563/model-00016-1.57500-0.44940-98.85470-0.10156.h5

21/21 [==============================] - 149s 7s/step - loss: 1.5750 - categorical\_accuracy: 0.4494 - val\_loss: 98.8547 - val\_categorical\_accuracy: 0.1016 - lr: 0.1000

Epoch 17/20

21/21 [==============================] - ETA: 0s - loss: 1.2940 - categorical\_accuracy: 0.5134

Epoch 00017: saving model to ./modelCheckpoint/cnn\_conv3d\_with\_dropoutsmodel\_init\_2024-07-3110\_24\_02.439563/model-00017-1.29398-0.51339-22.92751-0.17969.h5

21/21 [==============================] - 160s 8s/step - loss: 1.2940 - categorical\_accuracy: 0.5134 - val\_loss: 22.9275 - val\_categorical\_accuracy: 0.1797 - lr: 0.0200

Epoch 18/20

21/21 [==============================] - ETA: 0s - loss: 1.0407 - categorical\_accuracy: 0.6146

Epoch 00018: saving model to ./modelCheckpoint/cnn\_conv3d\_with\_dropoutsmodel\_init\_2024-07-3110\_24\_02.439563/model-00018-1.04067-0.61458-16.01778-0.16406.h5

21/21 [==============================] - 160s 8s/step - loss: 1.0407 - categorical\_accuracy: 0.6146 - val\_loss: 16.0178 - val\_categorical\_accuracy: 0.1641 - lr: 0.0200

**Epoch 19/20**

**21/21 [==============================] - ETA: 0s - loss: 0.9989 - categorical\_accuracy: 0.6369**

**Epoch 00019: saving model to ./modelCheckpoint/cnn\_conv3d\_with\_dropoutsmodel\_init\_2024-07-3110\_24\_02.439563/model-00019-0.99892-0.63690-11.49731-0.36719.h5**

**21/21 [==============================] - 157s 8s/step - loss: 0.9989 - categorical\_accuracy: 0.6369 - val\_loss: 11.4973 - val\_categorical\_accuracy: 0.3672 - lr: 0.0200**

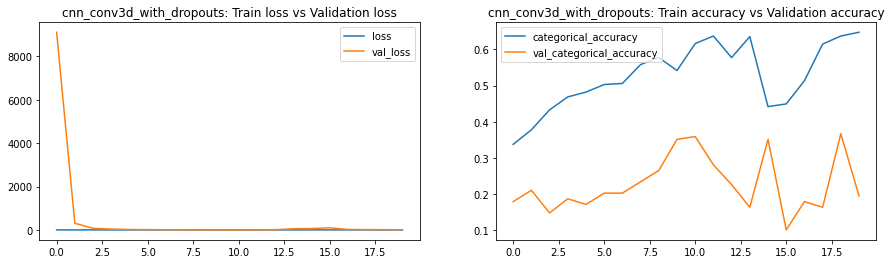
Epoch 20/20

21/21 [==============================] - ETA: 0s - loss: 0.8549 - categorical\_accuracy: 0.6473

Epoch 00020: saving model to ./modelCheckpoint/cnn\_conv3d\_with\_dropoutsmodel\_init\_2024-07-3110\_24\_02.439563/model-00020-0.85489-0.64732-7.60048-0.19531.h5

21/21 [==============================] - 149s 7s/step - loss: 0.8549 - categorical\_accuracy: 0.6473 - val\_loss: 7.6005 - val\_categorical\_accuracy: 0.1953 - lr: 0.0200

#### Plot CNN Model History with Conv3D and Dropouts



**Max. Training Accuracy 0.6473214030265808**

**Max. Validaiton Accuracy 0.3671875**

### Model#3: Feed conv2D + RNN-LSTM stack

#### Hyper Parameters:

**# batch\_size = 32**

**# epochs = 20**

**# no\_classes = 5**

**# input\_shape = (30,120,120,3)**

#### Model Summary:

Model: "sequential\_3"

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Layer (type) Output Shape Param #

=================================================================

time\_distributed (TimeDistr (None, 30, 120, 120, 16) 448

ibuted)

time\_distributed\_1 (TimeDis (None, 30, 120, 120, 16) 64

tributed)

time\_distributed\_2 (TimeDis (None, 30, 60, 60, 16) 0

tributed)

time\_distributed\_3 (TimeDis (None, 30, 60, 60, 32) 4640

tributed)

time\_distributed\_4 (TimeDis (None, 30, 60, 60, 32) 128

tributed)

time\_distributed\_5 (TimeDis (None, 30, 30, 30, 32) 0

tributed)

time\_distributed\_6 (TimeDis (None, 30, 30, 30, 64) 18496

tributed)

time\_distributed\_7 (TimeDis (None, 30, 30, 30, 64) 256

tributed)

time\_distributed\_8 (TimeDis (None, 30, 15, 15, 64) 0

tributed)

time\_distributed\_9 (TimeDis (None, 30, 15, 15, 128) 73856

tributed)

time\_distributed\_10 (TimeDi (None, 30, 15, 15, 128) 512

stributed)

time\_distributed\_11 (TimeDi (None, 30, 7, 7, 128) 0

stributed)

time\_distributed\_12 (TimeDi (None, 30, 7, 7, 256) 295168

stributed)

time\_distributed\_13 (TimeDi (None, 30, 7, 7, 256) 1024

stributed)

time\_distributed\_14 (TimeDi (None, 30, 3, 3, 256) 0

stributed)

time\_distributed\_15 (TimeDi (None, 30, 2304) 0

stributed)

lstm (LSTM) (None, 256) 2622464

dropout\_2 (Dropout) (None, 256) 0

dense\_6 (Dense) (None, 256) 65792

dropout\_3 (Dropout) (None, 256) 0

dense\_7 (Dense) (None, 5) 1285

=================================================================

Total params: 3,084,133

Trainable params: 3,083,141

Non-trainable params: 992

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

None

#### Model Fit:

Epoch 1/20

2024-07-31 13:19:10.950821: I tensorflow/stream\_executor/cuda/cuda\_dnn.cc:377] Loaded cuDNN version 8302

21/21 [==============================] - ETA: 0s - loss: 1.3138 - categorical\_accuracy: 0.4211

Epoch 00001: saving model to ./modelCheckpoint/cnn\_rnn\_with\_dropoutsmodel\_init\_2024-07-3113\_17\_00.182979/model-00001-1.31385-0.42113-1.89326-0.19531.h5

21/21 [==============================] - 180s 9s/step - loss: 1.3138 - categorical\_accuracy: 0.4211 - val\_loss: 1.8933 - val\_categorical\_accuracy: 0.1953 - lr: 0.0010

Epoch 2/20

21/21 [==============================] - ETA: 0s - loss: 1.0821 - categorical\_accuracy: 0.5670

Epoch 00002: saving model to ./modelCheckpoint/cnn\_rnn\_with\_dropoutsmodel\_init\_2024-07-3113\_17\_00.182979/model-00002-1.08214-0.56696-1.99328-0.14062.h5

21/21 [==============================] - 165s 8s/step - loss: 1.0821 - categorical\_accuracy: 0.5670 - val\_loss: 1.9933 - val\_categorical\_accuracy: 0.1406 - lr: 0.0010

Epoch 3/20

21/21 [==============================] - ETA: 0s - loss: 0.9241 - categorical\_accuracy: 0.5967

Epoch 00003: saving model to ./modelCheckpoint/cnn\_rnn\_with\_dropoutsmodel\_init\_2024-07-3113\_17\_00.182979/model-00003-0.92406-0.59673-2.21455-0.21875.h5

21/21 [==============================] - 157s 8s/step - loss: 0.9241 - categorical\_accuracy: 0.5967 - val\_loss: 2.2145 - val\_categorical\_accuracy: 0.2188 - lr: 0.0010

Epoch 4/20

21/21 [==============================] - ETA: 0s - loss: 0.7965 - categorical\_accuracy: 0.6607

Epoch 00004: saving model to ./modelCheckpoint/cnn\_rnn\_with\_dropoutsmodel\_init\_2024-07-3113\_17\_00.182979/model-00004-0.79650-0.66071-1.99645-0.20312.h5

21/21 [==============================] - 152s 8s/step - loss: 0.7965 - categorical\_accuracy: 0.6607 - val\_loss: 1.9964 - val\_categorical\_accuracy: 0.2031 - lr: 0.0010

Epoch 5/20

21/21 [==============================] - ETA: 0s - loss: 0.7257 - categorical\_accuracy: 0.7083

Epoch 00005: saving model to ./modelCheckpoint/cnn\_rnn\_with\_dropoutsmodel\_init\_2024-07-3113\_17\_00.182979/model-00005-0.72570-0.70833-1.58349-0.26562.h5

21/21 [==============================] - 159s 8s/step - loss: 0.7257 - categorical\_accuracy: 0.7083 - val\_loss: 1.5835 - val\_categorical\_accuracy: 0.2656 - lr: 0.0010

Epoch 6/20

21/21 [==============================] - ETA: 0s - loss: 0.6402 - categorical\_accuracy: 0.7426

Epoch 00006: saving model to ./modelCheckpoint/cnn\_rnn\_with\_dropoutsmodel\_init\_2024-07-3113\_17\_00.182979/model-00006-0.64023-0.74256-1.29056-0.30469.h5

21/21 [==============================] - 157s 8s/step - loss: 0.6402 - categorical\_accuracy: 0.7426 - val\_loss: 1.2906 - val\_categorical\_accuracy: 0.3047 - lr: 0.0010

Epoch 7/20

21/21 [==============================] - ETA: 0s - loss: 0.5225 - categorical\_accuracy: 0.7976

Epoch 00007: saving model to ./modelCheckpoint/cnn\_rnn\_with\_dropoutsmodel\_init\_2024-07-3113\_17\_00.182979/model-00007-0.52249-0.79762-1.32974-0.32031.h5

21/21 [==============================] - 157s 8s/step - loss: 0.5225 - categorical\_accuracy: 0.7976 - val\_loss: 1.3297 - val\_categorical\_accuracy: 0.3203 - lr: 0.0010

Epoch 8/20

21/21 [==============================] - ETA: 0s - loss: 0.6164 - categorical\_accuracy: 0.7485

Epoch 00008: saving model to ./modelCheckpoint/cnn\_rnn\_with\_dropoutsmodel\_init\_2024-07-3113\_17\_00.182979/model-00008-0.61643-0.74851-2.07191-0.22656.h5

21/21 [==============================] - 150s 7s/step - loss: 0.6164 - categorical\_accuracy: 0.7485 - val\_loss: 2.0719 - val\_categorical\_accuracy: 0.2266 - lr: 0.0010

Epoch 9/20

21/21 [==============================] - ETA: 0s - loss: 0.4496 - categorical\_accuracy: 0.8140

Epoch 00009: saving model to ./modelCheckpoint/cnn\_rnn\_with\_dropoutsmodel\_init\_2024-07-3113\_17\_00.182979/model-00009-0.44959-0.81399-1.45944-0.30469.h5

21/21 [==============================] - 166s 8s/step - loss: 0.4496 - categorical\_accuracy: 0.8140 - val\_loss: 1.4594 - val\_categorical\_accuracy: 0.3047 - lr: 0.0010

Epoch 10/20

21/21 [==============================] - ETA: 0s - loss: 0.3590 - categorical\_accuracy: 0.8557

Epoch 00010: saving model to ./modelCheckpoint/cnn\_rnn\_with\_dropoutsmodel\_init\_2024-07-3113\_17\_00.182979/model-00010-0.35895-0.85565-0.86145-0.49219.h5

21/21 [==============================] - 161s 8s/step - loss: 0.3590 - categorical\_accuracy: 0.8557 - val\_loss: 0.8614 - val\_categorical\_accuracy: 0.4922 - lr: 0.0010

Epoch 11/20

21/21 [==============================] - ETA: 0s - loss: 0.2750 - categorical\_accuracy: 0.8869

Epoch 00011: saving model to ./modelCheckpoint/cnn\_rnn\_with\_dropoutsmodel\_init\_2024-07-3113\_17\_00.182979/model-00011-0.27503-0.88690-0.74086-0.57812.h5

21/21 [==============================] - 158s 8s/step - loss: 0.2750 - categorical\_accuracy: 0.8869 - val\_loss: 0.7409 - val\_categorical\_accuracy: 0.5781 - lr: 0.0010

Epoch 12/20

21/21 [==============================] - ETA: 0s - loss: 0.2231 - categorical\_accuracy: 0.9196

Epoch 00012: saving model to ./modelCheckpoint/cnn\_rnn\_with\_dropoutsmodel\_init\_2024-07-3113\_17\_00.182979/model-00012-0.22305-0.91964-0.85114-0.53125.h5

21/21 [==============================] - 152s 8s/step - loss: 0.2231 - categorical\_accuracy: 0.9196 - val\_loss: 0.8511 - val\_categorical\_accuracy: 0.5312 - lr: 0.0010

Epoch 13/20

21/21 [==============================] - ETA: 0s - loss: 0.3058 - categorical\_accuracy: 0.8735

Epoch 00013: saving model to ./modelCheckpoint/cnn\_rnn\_with\_dropoutsmodel\_init\_2024-07-3113\_17\_00.182979/model-00013-0.30575-0.87351-0.83628-0.50781.h5

21/21 [==============================] - 157s 8s/step - loss: 0.3058 - categorical\_accuracy: 0.8735 - val\_loss: 0.8363 - val\_categorical\_accuracy: 0.5078 - lr: 0.0010

Epoch 14/20

21/21 [==============================] - ETA: 0s - loss: 0.3458 - categorical\_accuracy: 0.8586

Epoch 00014: saving model to ./modelCheckpoint/cnn\_rnn\_with\_dropoutsmodel\_init\_2024-07-3113\_17\_00.182979/model-00014-0.34575-0.85863-0.76996-0.53125.h5

21/21 [==============================] - 159s 8s/step - loss: 0.3458 - categorical\_accuracy: 0.8586 - val\_loss: 0.7700 - val\_categorical\_accuracy: 0.5312 - lr: 0.0010

Epoch 15/20

21/21 [==============================] - ETA: 0s - loss: 0.3166 - categorical\_accuracy: 0.8750

Epoch 00015: saving model to ./modelCheckpoint/cnn\_rnn\_with\_dropoutsmodel\_init\_2024-07-3113\_17\_00.182979/model-00015-0.31661-0.87500-0.73083-0.57812.h5

21/21 [==============================] - 162s 8s/step - loss: 0.3166 - categorical\_accuracy: 0.8750 - val\_loss: 0.7308 - val\_categorical\_accuracy: 0.5781 - lr: 0.0010

Epoch 16/20

21/21 [==============================] - ETA: 0s - loss: 0.3454 - categorical\_accuracy: 0.8646

Epoch 00016: saving model to ./modelCheckpoint/cnn\_rnn\_with\_dropoutsmodel\_init\_2024-07-3113\_17\_00.182979/model-00016-0.34542-0.86458-0.79027-0.50000.h5

21/21 [==============================] - 154s 8s/step - loss: 0.3454 - categorical\_accuracy: 0.8646 - val\_loss: 0.7903 - val\_categorical\_accuracy: 0.5000 - lr: 0.0010

Epoch 17/20

21/21 [==============================] - ETA: 0s - loss: 0.3684 - categorical\_accuracy: 0.8512

Epoch 00017: saving model to ./modelCheckpoint/cnn\_rnn\_with\_dropoutsmodel\_init\_2024-07-3113\_17\_00.182979/model-00017-0.36844-0.85119-1.07227-0.50000.h5

21/21 [==============================] - 159s 8s/step - loss: 0.3684 - categorical\_accuracy: 0.8512 - val\_loss: 1.0723 - val\_categorical\_accuracy: 0.5000 - lr: 0.0010

Epoch 18/20

21/21 [==============================] - ETA: 0s - loss: 0.3280 - categorical\_accuracy: 0.8810

Epoch 00018: saving model to ./modelCheckpoint/cnn\_rnn\_with\_dropoutsmodel\_init\_2024-07-3113\_17\_00.182979/model-00018-0.32795-0.88095-0.84944-0.47656.h5

21/21 [==============================] - 158s 8s/step - loss: 0.3280 - categorical\_accuracy: 0.8810 - val\_loss: 0.8494 - val\_categorical\_accuracy: 0.4766 - lr: 0.0010

Epoch 19/20

21/21 [==============================] - ETA: 0s - loss: 0.3845 - categorical\_accuracy: 0.8438

Epoch 00019: saving model to ./modelCheckpoint/cnn\_rnn\_with\_dropoutsmodel\_init\_2024-07-3113\_17\_00.182979/model-00019-0.38450-0.84375-1.41952-0.34375.h5

21/21 [==============================] - 160s 8s/step - loss: 0.3845 - categorical\_accuracy: 0.8438 - val\_loss: 1.4195 - val\_categorical\_accuracy: 0.3438 - lr: 0.0010

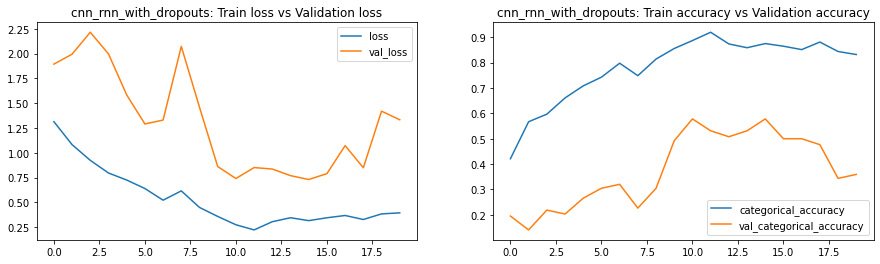
Epoch 20/20

21/21 [==============================] - ETA: 0s - loss: 0.3949 - categorical\_accuracy: 0.8318

Epoch 00020: saving model to ./modelCheckpoint/cnn\_rnn\_with\_dropoutsmodel\_init\_2024-07-3113\_17\_00.182979/model-00020-0.39489-0.83185-1.33276-0.35938.h5

21/21 [==============================] - 153s 8s/step - loss: 0.3949 - categorical\_accuracy: 0.8318 - val\_loss: 1.3328 - val\_categorical\_accuracy: 0.3594 - lr: 0.0010

#### Plot CNN-RNN Stack Model History with Conv2D + LSTM and Dropouts



**Max. Training Accuracy 0.9196428656578064**

**Max. Validation Accuracy 0.578125**

### Model#4: conv2D + RNN-LSTM stack using 20 frames and 64 batch size

#### Hyper Parameters:

**# batch\_size = 64**

**# epochs = 20**

**# no\_classes = 5**

**# input\_shape = (20,120,120,3)**

#### Model Summary:

Model: "sequential\_2"

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Layer (type) Output Shape Param #

=================================================================

time\_distributed\_31 (TimeDi (None, 20, 120, 120, 16) 448

stributed)

time\_distributed\_32 (TimeDi (None, 20, 120, 120, 16) 64

stributed)

time\_distributed\_33 (TimeDi (None, 20, 60, 60, 16) 0

stributed)

time\_distributed\_34 (TimeDi (None, 20, 60, 60, 32) 4640

stributed)

time\_distributed\_35 (TimeDi (None, 20, 60, 60, 32) 128

stributed)

time\_distributed\_36 (TimeDi (None, 20, 30, 30, 32) 0

stributed)

time\_distributed\_37 (TimeDi (None, 20, 30, 30, 64) 18496

stributed)

time\_distributed\_38 (TimeDi (None, 20, 30, 30, 64) 256

stributed)

time\_distributed\_39 (TimeDi (None, 20, 15, 15, 64) 0

stributed)

time\_distributed\_40 (TimeDi (None, 20, 15, 15, 128) 73856

stributed)

time\_distributed\_41 (TimeDi (None, 20, 15, 15, 128) 512

stributed)

time\_distributed\_42 (TimeDi (None, 20, 7, 7, 128) 0

stributed)

time\_distributed\_43 (TimeDi (None, 20, 7, 7, 256) 295168

stributed)

time\_distributed\_44 (TimeDi (None, 20, 7, 7, 256) 1024

stributed)

time\_distributed\_45 (TimeDi (None, 20, 3, 3, 256) 0

stributed)

time\_distributed\_46 (TimeDi (None, 20, 2304) 0

stributed)

lstm\_1 (LSTM) (None, 256) 2622464

dropout\_2 (Dropout) (None, 256) 0

dense\_2 (Dense) (None, 256) 65792

dropout\_3 (Dropout) (None, 256) 0

dense\_3 (Dense) (None, 5) 1285

=================================================================

Total params: 3,084,133

Trainable params: 3,083,141

Non-trainable params: 992

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

None

#### Model Fit:

Epoch 1/20

21/21 [==============================] - ETA: 0s - loss: 1.2609 - categorical\_accuracy: 0.4182

Epoch 00001: saving model to ./modelCheckpoint/cnn\_rnn\_20f\_b64\_modelmodel\_init\_2024-07-3113\_17\_00.182979/model-00001-1.26090-0.41815-1.87136-0.19531.h5

21/21 [==============================] - 208s 10s/step - loss: 1.2609 - categorical\_accuracy: 0.4182 - val\_loss: 1.8714 - val\_categorical\_accuracy: 0.1953 - lr: 0.0010

Epoch 2/20

21/21 [==============================] - ETA: 0s - loss: 0.8681 - categorical\_accuracy: 0.6116

Epoch 00002: saving model to ./modelCheckpoint/cnn\_rnn\_20f\_b64\_modelmodel\_init\_2024-07-3113\_17\_00.182979/model-00002-0.86810-0.61161-1.77046-0.20312.h5

21/21 [==============================] - 204s 10s/step - loss: 0.8681 - categorical\_accuracy: 0.6116 - val\_loss: 1.7705 - val\_categorical\_accuracy: 0.2031 - lr: 0.0010

Epoch 3/20

21/21 [==============================] - ETA: 0s - loss: 0.6298 - categorical\_accuracy: 0.6994

Epoch 00003: saving model to ./modelCheckpoint/cnn\_rnn\_20f\_b64\_modelmodel\_init\_2024-07-3113\_17\_00.182979/model-00003-0.62977-0.69940-1.81782-0.24609.h5

21/21 [==============================] - 204s 10s/step - loss: 0.6298 - categorical\_accuracy: 0.6994 - val\_loss: 1.8178 - val\_categorical\_accuracy: 0.2461 - lr: 0.0010

Epoch 4/20

21/21 [==============================] - ETA: 0s - loss: 0.4875 - categorical\_accuracy: 0.7857

Epoch 00004: saving model to ./modelCheckpoint/cnn\_rnn\_20f\_b64\_modelmodel\_init\_2024-07-3113\_17\_00.182979/model-00004-0.48754-0.78571-2.31778-0.18750.h5

21/21 [==============================] - 201s 10s/step - loss: 0.4875 - categorical\_accuracy: 0.7857 - val\_loss: 2.3178 - val\_categorical\_accuracy: 0.1875 - lr: 0.0010

Epoch 5/20

21/21 [==============================] - ETA: 0s - loss: 0.3765 - categorical\_accuracy: 0.8214

Epoch 00005: saving model to ./modelCheckpoint/cnn\_rnn\_20f\_b64\_modelmodel\_init\_2024-07-3113\_17\_00.182979/model-00005-0.37654-0.82143-1.66848-0.28125.h5

21/21 [==============================] - 201s 10s/step - loss: 0.3765 - categorical\_accuracy: 0.8214 - val\_loss: 1.6685 - val\_categorical\_accuracy: 0.2812 - lr: 0.0010

Epoch 6/20

21/21 [==============================] - ETA: 0s - loss: 0.2543 - categorical\_accuracy: 0.8713

Epoch 00006: saving model to ./modelCheckpoint/cnn\_rnn\_20f\_b64\_modelmodel\_init\_2024-07-3113\_17\_00.182979/model-00006-0.25429-0.87128-0.99387-0.42188.h5

21/21 [==============================] - 200s 10s/step - loss: 0.2543 - categorical\_accuracy: 0.8713 - val\_loss: 0.9939 - val\_categorical\_accuracy: 0.4219 - lr: 0.0010

Epoch 7/20

21/21 [==============================] - ETA: 0s - loss: 0.3103 - categorical\_accuracy: 0.8490

Epoch 00007: saving model to ./modelCheckpoint/cnn\_rnn\_20f\_b64\_modelmodel\_init\_2024-07-3113\_17\_00.182979/model-00007-0.31028-0.84896-1.37075-0.28125.h5

21/21 [==============================] - 202s 10s/step - loss: 0.3103 - categorical\_accuracy: 0.8490 - val\_loss: 1.3707 - val\_categorical\_accuracy: 0.2812 - lr: 0.0010

Epoch 8/20

21/21 [==============================] - ETA: 0s - loss: 0.5095 - categorical\_accuracy: 0.7485

Epoch 00008: saving model to ./modelCheckpoint/cnn\_rnn\_20f\_b64\_modelmodel\_init\_2024-07-3113\_17\_00.182979/model-00008-0.50952-0.74851-1.37156-0.35156.h5

21/21 [==============================] - 203s 10s/step - loss: 0.5095 - categorical\_accuracy: 0.7485 - val\_loss: 1.3716 - val\_categorical\_accuracy: 0.3516 - lr: 0.0010

Epoch 9/20

21/21 [==============================] - ETA: 0s - loss: 0.4117 - categorical\_accuracy: 0.7909

Epoch 00009: saving model to ./modelCheckpoint/cnn\_rnn\_20f\_b64\_modelmodel\_init\_2024-07-3113\_17\_00.182979/model-00009-0.41169-0.79092-1.34839-0.50000.h5

21/21 [==============================] - 202s 10s/step - loss: 0.4117 - categorical\_accuracy: 0.7909 - val\_loss: 1.3484 - val\_categorical\_accuracy: 0.5000 - lr: 0.0010

Epoch 10/20

21/21 [==============================] - ETA: 0s - loss: 0.6246 - categorical\_accuracy: 0.7121

Epoch 00010: saving model to ./modelCheckpoint/cnn\_rnn\_20f\_b64\_modelmodel\_init\_2024-07-3113\_17\_00.182979/model-00010-0.62456-0.71205-1.74785-0.19531.h5

21/21 [==============================] - 200s 10s/step - loss: 0.6246 - categorical\_accuracy: 0.7121 - val\_loss: 1.7478 - val\_categorical\_accuracy: 0.1953 - lr: 0.0010

Epoch 11/20

21/21 [==============================] - ETA: 0s - loss: 0.5994 - categorical\_accuracy: 0.7314

Epoch 00011: saving model to ./modelCheckpoint/cnn\_rnn\_20f\_b64\_modelmodel\_init\_2024-07-3113\_17\_00.182979/model-00011-0.59944-0.73140-1.57025-0.21484.h5

21/21 [==============================] - 206s 10s/step - loss: 0.5994 - categorical\_accuracy: 0.7314 - val\_loss: 1.5702 - val\_categorical\_accuracy: 0.2148 - lr: 0.0010

Epoch 12/20

21/21 [==============================] - ETA: 0s - loss: 0.6282 - categorical\_accuracy: 0.7396

Epoch 00012: saving model to ./modelCheckpoint/cnn\_rnn\_20f\_b64\_modelmodel\_init\_2024-07-3113\_17\_00.182979/model-00012-0.62816-0.73958-0.95109-0.44141.h5

21/21 [==============================] - 209s 10s/step - loss: 0.6282 - categorical\_accuracy: 0.7396 - val\_loss: 0.9511 - val\_categorical\_accuracy: 0.4414 - lr: 0.0010

Epoch 13/20

21/21 [==============================] - ETA: 0s - loss: 0.4015 - categorical\_accuracy: 0.8006

Epoch 00013: saving model to ./modelCheckpoint/cnn\_rnn\_20f\_b64\_modelmodel\_init\_2024-07-3113\_17\_00.182979/model-00013-0.40153-0.80060-0.87620-0.44922.h5

21/21 [==============================] - 218s 11s/step - loss: 0.4015 - categorical\_accuracy: 0.8006 - val\_loss: 0.8762 - val\_categorical\_accuracy: 0.4492 - lr: 0.0010

Epoch 14/20

21/21 [==============================] - ETA: 0s - loss: 0.3227 - categorical\_accuracy: 0.8423

Epoch 00014: saving model to ./modelCheckpoint/cnn\_rnn\_20f\_b64\_modelmodel\_init\_2024-07-3113\_17\_00.182979/model-00014-0.32269-0.84226-0.84167-0.42969.h5

21/21 [==============================] - 205s 10s/step - loss: 0.3227 - categorical\_accuracy: 0.8423 - val\_loss: 0.8417 - val\_categorical\_accuracy: 0.4297 - lr: 0.0010

Epoch 15/20

21/21 [==============================] - ETA: 0s - loss: 0.2161 - categorical\_accuracy: 0.8713

Epoch 00015: saving model to ./modelCheckpoint/cnn\_rnn\_20f\_b64\_modelmodel\_init\_2024-07-3113\_17\_00.182979/model-00015-0.21607-0.87128-1.05579-0.41406.h5

21/21 [==============================] - 207s 10s/step - loss: 0.2161 - categorical\_accuracy: 0.8713 - val\_loss: 1.0558 - val\_categorical\_accuracy: 0.4141 - lr: 0.0010

Epoch 16/20

21/21 [==============================] - ETA: 0s - loss: 0.1573 - categorical\_accuracy: 0.8981

Epoch 00016: saving model to ./modelCheckpoint/cnn\_rnn\_20f\_b64\_modelmodel\_init\_2024-07-3113\_17\_00.182979/model-00016-0.15729-0.89807-0.75315-0.55078.h5

21/21 [==============================] - 202s 10s/step - loss: 0.1573 - categorical\_accuracy: 0.8981 - val\_loss: 0.7531 - val\_categorical\_accuracy: 0.5508 - lr: 0.0010

Epoch 17/20

21/21 [==============================] - ETA: 0s - loss: 0.1028 - categorical\_accuracy: 0.9085

Epoch 00017: saving model to ./modelCheckpoint/cnn\_rnn\_20f\_b64\_modelmodel\_init\_2024-07-3113\_17\_00.182979/model-00017-0.10285-0.90848-1.33202-0.48047.h5

21/21 [==============================] - 211s 11s/step - loss: 0.1028 - categorical\_accuracy: 0.9085 - val\_loss: 1.3320 - val\_categorical\_accuracy: 0.4805 - lr: 0.0010

Epoch 18/20

21/21 [==============================] - ETA: 0s - loss: 0.1340 - categorical\_accuracy: 0.9048

Epoch 00018: saving model to ./modelCheckpoint/cnn\_rnn\_20f\_b64\_modelmodel\_init\_2024-07-3113\_17\_00.182979/model-00018-0.13400-0.90476-1.17548-0.43359.h5

21/21 [==============================] - 205s 10s/step - loss: 0.1340 - categorical\_accuracy: 0.9048 - val\_loss: 1.1755 - val\_categorical\_accuracy: 0.4336 - lr: 0.0010

Epoch 19/20

21/21 [==============================] - ETA: 0s - loss: 0.1241 - categorical\_accuracy: 0.9129

Epoch 00019: saving model to ./modelCheckpoint/cnn\_rnn\_20f\_b64\_modelmodel\_init\_2024-07-3113\_17\_00.182979/model-00019-0.12414-0.91295-1.02430-0.51172.h5

21/21 [==============================] - 207s 10s/step - loss: 0.1241 - categorical\_accuracy: 0.9129 - val\_loss: 1.0243 - val\_categorical\_accuracy: 0.5117 - lr: 0.0010

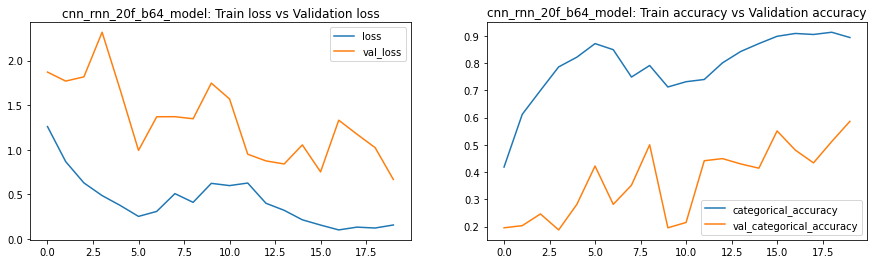
Epoch 20/20

21/21 [==============================] - ETA: 0s - loss: 0.1582 - categorical\_accuracy: 0.8936

Epoch 00020: saving model to ./modelCheckpoint/cnn\_rnn\_20f\_b64\_modelmodel\_init\_2024-07-3113\_17\_00.182979/model-00020-0.15820-0.89360-0.66792-0.58594.h5

21/21 [==============================] - 204s 10s/step - loss: 0.1582 - categorical\_accuracy: 0.8936 - val\_loss: 0.6679 - val\_categorical\_accuracy: 0.5859 - lr: 0.0010

#### Plot CNN-RNN Stack Model History with Conv2D + LSTM and Dropouts



**Max. Training Accuracy 0.9129464030265808**

**Max. Validaiton Accuracy 0.5859375**