In [4]:
```
import numpy as np
import os
import datetime
import os
import cv2
import warnings
warnings.filterwarnings('ignore')
import matplotlib.pyplot as plt
```

In [5]:
```
np.random.seed(30)
import random as rn
rn.seed(30)
from keras import backend as K
import tensorflow as tf
tf.random.set_seed(30)
```

In [6]:
```
basePath = "Project_data/"
train_path = basePath+'train'
val_path = basePath+'val'
print(train_path)
```

```
Project_data/train
```

In [7]:
```
train_doc = np.random.permutation(open(basePath+'train.csv').readlines())
val_doc = np.random.permutation(open(basePath+'val.csv').readlines())
```

In [20]:
```
import numpy as np
import cv2
import os

class VideoDataGenerator:
    def __init__(self, source_path,train_doc, batch_size, image_height, image_width
        self.source_path = source_path
        self.batch_size = batch_size
        self.image_height = image_height
        self.image_width = image_width
        self.frames_to_sample = frames_to_sample
        self.train_doc = train_doc


    def augment_image(self, image):
        """Apply transformations to the image for augmentation."""
        shifted = cv2.warpAffine(image, np.float32([[1, 0, np.random.randint(-30, 3
                                                    [0, 1, np.random.randint(-30, 3
                                 (image.shape[1], image.shape[0]))
        gray = cv2.cvtColor(shifted, cv2.COLOR_BGR2GRAY)
        x0, y0 = np.argwhere(gray > 0).min(axis=0)
        x1, y1 = np.argwhere(gray > 0).max(axis=0)
        cropped = shifted[x0:x1, y0:y1, :]
        resized = cv2.resize(cropped, (self.image_height, self.image_width))
        return resized / 255.0

    def process_image(self, image_path):
        """Load and process an individual image."""
        image = cv2.imread(image_path).astype(np.float32)
        image_resized = cv2.resize(image, (self.image_height, self.image_width))
        return image_resized / 255.0

    def generator(self):
        """Generator function to yield batches of data."""
        folder_list = os.listdir(self.source_path)
```

```
        img_idx = [i for i in range(self.frames_to_sample)]
        while True:
            t = np.random.permutation(folder_list)
            num_batches = len(t) // self.batch_size
            for batch in range(num_batches):
                batch_data, batch_labels = self.create_batch(t, batch, self.batch_s
                yield batch_data, batch_labels

            # Handle remaining data for last batch if not evenly divisible
            remaining_data_size = len(t) % self.batch_size
            if remaining_data_size:
                for batch in range(remaining_data_size):
                    batch_data, batch_labels = self.create_batch(t, batch, self.bat
                    yield batch_data, batch_labels


    def create_batch(self, shuffled_folders, batch_index, size, img_idx):
        x, y, z = len(img_idx), self.image_height, self.image_width
        batch_data = np.zeros((size, x, y, z, 3))  # Initialize batch data
        batch_labels = np.zeros((size, 5))  # Initialize batch labels

        for folder_idx in range(size):
            actual_idx = folder_idx + (batch_index * self.batch_size)
            if actual_idx < len(shuffled_folders):
                selectedFolder = shuffled_folders[actual_idx]
                imgs = os.listdir(self.source_path + '/' + selectedFolder.split(';'

                folder_elements = None
                for record in self.train_doc:
                    if record.startswith(selectedFolder):
                        folder_elements = record.split(';')
                        break

                for idx, img_num in enumerate(img_idx):
                    if img_num >= len(imgs):
                        continue
                    image_path = os.path.join(self.source_path, folder_elements[0],
                    image = self.process_image(image_path)

                    batch_data[folder_idx, idx] = image
                    label_index = int(folder_elements[2])

                batch_labels[folder_idx, label_index] = 1

        return batch_data, batch_labels
```

In [8]:

```
from keras.models import Sequential, Model
from keras.layers import Dense, GRU, Flatten, TimeDistributed, Flatten, BatchNormal
from tensorflow.keras.layers import Conv3D, MaxPooling3D,Conv2D, MaxPooling2D
from keras.callbacks import ModelCheckpoint, ReduceLROnPlateau
from keras import optimizers
from tensorflow.keras.layers import Dropout
from tensorflow.keras.callbacks import ReduceLROnPlateau
from keras.callbacks import EarlyStopping
from keras.layers import LSTM
```

In [9]:

```
def set_callbacks(model_number,checkPoint,bestModel,lr,earlyStop,monitoringMetric):
    model_number_str = str(model_number)
    curr_dt_time = datetime.datetime.now()

    parent_model_folder = 'models'
    if not os.path.exists(parent_model_folder):
        os.mkdir(parent_model_folder)
```

```
    model_folder = parent_model_folder + '/model-number-' + model_number_str
    if not os.path.exists(model_folder):
        os.mkdir(model_folder)

    model_name = model_folder + '/models-model_init-' + model_number_str \
                + '_' + str(curr_dt_time).replace(' ', '').replace(':', '_') + '/'

    if not os.path.exists(model_name):
        os.mkdir(model_name)

    callbackList = []

    if checkPoint:
        epoch_filepath = model_name + 'model-{epoch:05d}-{loss:.5f}-{categorical_ac
        # Callback to save the model checkpoints after each epoch
        epoch_checkpoint = ModelCheckpoint(epoch_filepath, monitor=monitoringMetric
                                           save_best_only=False, save_weights_only=Fals
        callbackList.append(epoch_checkpoint)

    if bestModel:
        # Filepath for saving the best model based on validation categorical accura
        best_model_filepath = model_folder+"/best_model.h5"
        # Callback to save the best model
        best_model_checkpoint = ModelCheckpoint(best_model_filepath, monitor=monitc
                                                verbose=1, save_best_only=True, save_we
        callbackList.append(best_model_checkpoint)

    if lr:
        LR=ReduceLROnPlateau(monitor=monitoringMetric,factor=0.2,
                                   patience=4,
                                   verbose=1)
        callbackList.append(LR)

    if earlyStop:
        # early_stopping = EarlyStopping(monitor='val_categorical_accuracy', patier
        earlystop = EarlyStopping( monitor=monitoringMetric, min_delta=0,patience=1
        callbackList.append(earlystop)


    return callbackList
```

In [30]:

```
def create_model(input_shape, num_classes,denseNeurons=64):
        model = Sequential()
        model.add(Conv3D(16, (3, 3, 3), padding='same',
                 input_shape=input_shape))
        model.add(Activation('relu'))
        model.add(BatchNormalization())
        model.add(MaxPooling3D(pool_size=(2, 2, 2)))

        model.add(Conv3D(32, (3, 3, 3), padding='same'))
        model.add(Activation('relu'))
        model.add(BatchNormalization())
        model.add(MaxPooling3D(pool_size=(2, 2, 2)))

        model.add(Conv3D(64, (3, 3, 3), padding='same'))
        model.add(Activation('relu'))
        model.add(BatchNormalization())
        model.add(MaxPooling3D(pool_size=(2, 2, 2)))

        model.add(Conv3D(128, (3, 3, 3), padding='same'))
        model.add(Activation('relu'))
        model.add(BatchNormalization())
        model.add(MaxPooling3D(pool_size=(2, 2, 2)))
```

```
        model.add(Flatten())
        model.add(Dense(denseNeurons,activation='relu'))
        model.add(BatchNormalization())
        model.add(Dropout(0.25))

        model.add(Dense(denseNeurons,activation='relu'))
        model.add(BatchNormalization())
        model.add(Dropout(0.25))


        model.add(Dense(num_classes,activation='softmax'))


        return model
```

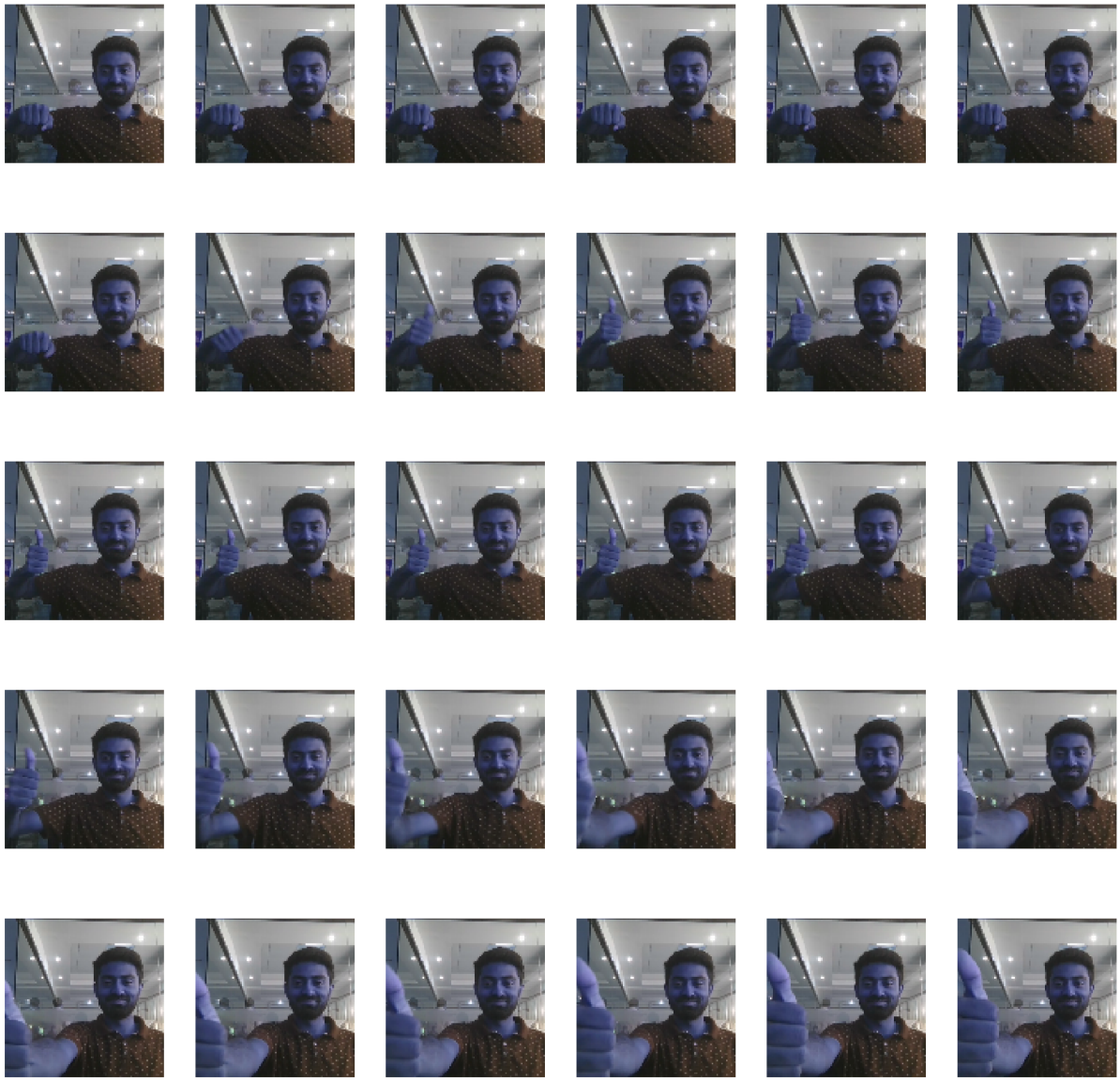
In [31]:
```
def get_sequence(trainDoc,valDoc,batchSize , epochs):

    num_train_sequences = len(trainDoc)
    num_val_sequences = len(valDoc)
    num_epochs = epochs

    if (num_train_sequences%batchSize) == 0:
        steps_per_epoch = int(num_train_sequences/batchSize)
    else:
        steps_per_epoch = (num_train_sequences//batchSize) + 1

    if (num_val_sequences%batch_size) == 0:
        validation_steps = int(num_val_sequences/batchSize)
    else:
        validation_steps = (num_val_sequences//batchSize) + 1

    print('training sequences =', num_train_sequences)
    print('validation sequences =', num_val_sequences)
    print ('epochs =', num_epochs)
    print("validation_steps",validation_steps)
    print("steps_per_epoch",steps_per_epoch)
    return steps_per_epoch,validation_steps
```

In [32]:
```
def plot_model(loss,val_loss,acc , val_acc):
        fig, axes = plt.subplots(nrows=1, ncols=2, figsize=(15,4))
        axes[0].plot(loss)
        axes[0].plot(val_loss)
        axes[0].legend(['Loss','Validation Loss'])

        axes[1].plot(acc)
        axes[1].plot(val_acc)
        axes[1].legend(['Accuracy','Validation Accuraccy'])
```

In [15]:
```
batch_size = 20
imageHeight = 100
imageWidth = 100
framesToSample = 30
```

In [61]:
```
train_data_generator = VideoDataGenerator(train_path,train_doc, batch_size, imageHe
val_data_generator = VideoDataGenerator(val_path,val_doc, batch_size, imageHeight,

# Use the generator method of the instances to get the generators
train_generator = train_data_generator.generator()
val_generator = val_data_generator.generator()

x_batch, y_batch = next(train_generator)
```

```
# Assuming you want to visualize the first frame of the first sample in the batch
num_rows = 5
num_columns = 6
plt.figure(figsize=(30, 30))
# Iterate over samples and frames to visualize all frames
for sample_index in range(x_batch.shape[0]):  # Iterate over samples
    for frame_index in range(x_batch.shape[1]):  # Iterate over frames
        plt.subplot(num_rows, num_columns, frame_index + 1)
        image_to_visualize = x_batch[sample_index, frame_index]
        plt.imshow(image_to_visualize)
        plt.axis('off')  # Turn off axis labels
    break;

plt.show()
```



Model 1 Conv3d - Batch Size - 24 , Image Size (100 x 100) , 30 Frames

In [10]:
```
model_number = 1
batch_size = 24
imageHeight = 100
imageWidth = 100
framesToSample = 30
rgbChannels = 3
input_shape = (framesToSample, imageWidth, imageHeight, rgbChannels)
num_classes = 5
```

In [11]:
```
model=create_model(input_shape, num_classes)
optimiser = optimizers.Adam()
model.compile(optimizer=optimiser, loss='categorical_crossentropy', metrics=['categ
callbacks_list = set_callbacks(model_number,True,True,True,True,'val_categorical_ac
```

In [12]:
```
train_data_generator = VideoDataGenerator(train_path,train_doc, batch_size, imageHe
val_data_generator = VideoDataGenerator(val_path,val_doc, batch_size, imageHeight,

# Use the generator method of the instances to get the generators
train_generator = train_data_generator.generator()
val_generator = val_data_generator.generator()
```

In [13]:
```
num_epochs = 100
steps_per_epoch ,validation_steps = get_sequence(train_doc,val_doc,batch_size,num_e
```

```
training sequences = 663
validation sequences = 100
epochs = 100
validation_steps 5
steps_per_epoch 28
```

In [14]:
```
model.summary()
```

```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv3d (Conv3D)             (None, 30, 100, 100, 16   1312
                             )

 activation (Activation)     (None, 30, 100, 100, 16   0
                             )

 batch_normalization (Batch  (None, 30, 100, 100, 16   64
 Normalization)              )

 max_pooling3d (MaxPooling3  (None, 15, 50, 50, 16)    0
 D)

 conv3d_1 (Conv3D)           (None, 15, 50, 50, 32)    13856

 activation_1 (Activation)   (None, 15, 50, 50, 32)    0

 batch_normalization_1 (Bat  (None, 15, 50, 50, 32)    128
 chNormalization)

 max_pooling3d_1 (MaxPoolin  (None, 7, 25, 25, 32)     0
 g3D)

 conv3d_2 (Conv3D)           (None, 7, 25, 25, 64)     55360

 activation_2 (Activation)   (None, 7, 25, 25, 64)     0

 batch_normalization_2 (Bat  (None, 7, 25, 25, 64)     256
 chNormalization)

 max_pooling3d_2 (MaxPoolin  (None, 3, 12, 12, 64)     0
 g3D)

 conv3d_3 (Conv3D)           (None, 3, 12, 12, 128)    221312

 activation_3 (Activation)   (None, 3, 12, 12, 128)    0

 batch_normalization_3 (Bat  (None, 3, 12, 12, 128)    512
 chNormalization)

 max_pooling3d_3 (MaxPoolin  (None, 1, 6, 6, 128)      0
 g3D)

 flatten (Flatten)           (None, 4608)              0

 dense (Dense)               (None, 64)                294976

 batch_normalization_4 (Bat  (None, 64)                256
 chNormalization)

 dropout (Dropout)           (None, 64)                0

 dense_1 (Dense)             (None, 64)                4160

 batch_normalization_5 (Bat  (None, 64)                256
 chNormalization)

 dropout_1 (Dropout)         (None, 64)                0

 dense_2 (Dense)             (None, 5)                 325
```

```
=================================================================
Total params: 592773 (2.26 MB)
Trainable params: 592037 (2.26 MB)
Non-trainable params: 736 (2.88 KB)
_________________________________________________________________
```

In [15]:
```
history=model.fit(train_generator, epochs=num_epochs, verbose=1,steps_per_epoch=ste
                  callbacks=callbacks_list, validation_data=val_generator,
                      validation_steps=validation_steps,class_weight=None, worker
                 )
```

```
Epoch 1/100
28/28 [==============================] - ETA: 0s - loss: 1.7072 - categorical_accu
racy: 0.3824
Epoch 1: saving model to models/model-number-1/models-model_init-1_2023-11-1023_27
_11.105753\model-00001-1.70725-0.38244-2.13615-0.20000.h5

Epoch 1: val_categorical_accuracy improved from -inf to 0.20000, saving model to m
odels/model-number-1\best_model.h5
28/28 [==============================] - 226s 8s/step - loss: 1.7072 - categorical
_accuracy: 0.3824 - val_loss: 2.1361 - val_categorical_accuracy: 0.2000 - lr: 0.00
10
Epoch 2/100
28/28 [==============================] - ETA: 0s - loss: 1.2737 - categorical_accu
racy: 0.4881
Epoch 2: saving model to models/model-number-1/models-model_init-1_2023-11-1023_27
_11.105753\model-00002-1.27374-0.48810-1.58958-0.28333.h5

Epoch 2: val_categorical_accuracy improved from 0.20000 to 0.28333, saving model t
o models/model-number-1\best_model.h5
28/28 [==============================] - 218s 8s/step - loss: 1.2737 - categorical
_accuracy: 0.4881 - val_loss: 1.5896 - val_categorical_accuracy: 0.2833 - lr: 0.00
10
Epoch 3/100
28/28 [==============================] - ETA: 0s - loss: 1.0162 - categorical_accu
racy: 0.6042
Epoch 3: saving model to models/model-number-1/models-model_init-1_2023-11-1023_27
_11.105753\model-00003-1.01621-0.60417-2.24017-0.28333.h5

Epoch 3: val_categorical_accuracy did not improve from 0.28333
28/28 [==============================] - 220s 8s/step - loss: 1.0162 - categorical
_accuracy: 0.6042 - val_loss: 2.2402 - val_categorical_accuracy: 0.2833 - lr: 0.00
10
Epoch 4/100
28/28 [==============================] - ETA: 0s - loss: 0.8791 - categorical_accu
racy: 0.6607
Epoch 4: saving model to models/model-number-1/models-model_init-1_2023-11-1023_27
_11.105753\model-00004-0.87908-0.66071-2.48007-0.22500.h5

Epoch 4: val_categorical_accuracy did not improve from 0.28333
28/28 [==============================] - 219s 8s/step - loss: 0.8791 - categorical
_accuracy: 0.6607 - val_loss: 2.4801 - val_categorical_accuracy: 0.2250 - lr: 0.00
10
Epoch 5/100
28/28 [==============================] - ETA: 0s - loss: 0.6603 - categorical_accu
racy: 0.7574
Epoch 5: saving model to models/model-number-1/models-model_init-1_2023-11-1023_27
_11.105753\model-00005-0.66034-0.75744-2.91300-0.25000.h5

Epoch 5: val_categorical_accuracy did not improve from 0.28333
28/28 [==============================] - 220s 8s/step - loss: 0.6603 - categorical
_accuracy: 0.7574 - val_loss: 2.9130 - val_categorical_accuracy: 0.2500 - lr: 0.00
10
Epoch 6/100
28/28 [==============================] - ETA: 0s - loss: 0.5559 - categorical_accu
racy: 0.7887
Epoch 6: saving model to models/model-number-1/models-model_init-1_2023-11-1023_27
_11.105753\model-00006-0.55589-0.78869-3.32009-0.25000.h5

Epoch 6: val_categorical_accuracy did not improve from 0.28333

Epoch 6: ReduceLROnPlateau reducing learning rate to 0.00020000000949949026.
28/28 [==============================] - 218s 8s/step - loss: 0.5559 - categorical
_accuracy: 0.7887 - val_loss: 3.3201 - val_categorical_accuracy: 0.2500 - lr: 0.00
10
```

```
Epoch 7/100
28/28 [==============================] - ETA: 0s - loss: 0.4541 - categorical_accu
racy: 0.8423
Epoch 7: saving model to models/model-number-1/models-model_init-1_2023-11-1023_27
_11.105753\model-00007-0.45415-0.84226-3.30058-0.30000.h5

Epoch 7: val_categorical_accuracy improved from 0.28333 to 0.30000, saving model t
o models/model-number-1\best_model.h5
28/28 [==============================] - 219s 8s/step - loss: 0.4541 - categorical
_accuracy: 0.8423 - val_loss: 3.3006 - val_categorical_accuracy: 0.3000 - lr: 2.00
00e-04
Epoch 8/100
28/28 [==============================] - ETA: 0s - loss: 0.3775 - categorical_accu
racy: 0.8750
Epoch 8: saving model to models/model-number-1/models-model_init-1_2023-11-1023_27
_11.105753\model-00008-0.37747-0.87500-2.99429-0.32500.h5

Epoch 8: val_categorical_accuracy improved from 0.30000 to 0.32500, saving model t
o models/model-number-1\best_model.h5
28/28 [==============================] - 218s 8s/step - loss: 0.3775 - categorical
_accuracy: 0.8750 - val_loss: 2.9943 - val_categorical_accuracy: 0.3250 - lr: 2.00
00e-04
Epoch 9/100
28/28 [==============================] - ETA: 0s - loss: 0.3288 - categorical_accu
racy: 0.9122
Epoch 9: saving model to models/model-number-1/models-model_init-1_2023-11-1023_27
_11.105753\model-00009-0.32879-0.91220-2.82436-0.30000.h5

Epoch 9: val_categorical_accuracy did not improve from 0.32500
28/28 [==============================] - 219s 8s/step - loss: 0.3288 - categorical
_accuracy: 0.9122 - val_loss: 2.8244 - val_categorical_accuracy: 0.3000 - lr: 2.00
00e-04
Epoch 10/100
28/28 [==============================] - ETA: 0s - loss: 0.2836 - categorical_accu
racy: 0.9077
Epoch 10: saving model to models/model-number-1/models-model_init-1_2023-11-1023_2
7_11.105753\model-00010-0.28365-0.90774-2.62837-0.29167.h5

Epoch 10: val_categorical_accuracy did not improve from 0.32500
28/28 [==============================] - 218s 8s/step - loss: 0.2836 - categorical
_accuracy: 0.9077 - val_loss: 2.6284 - val_categorical_accuracy: 0.2917 - lr: 2.00
00e-04
Epoch 11/100
28/28 [==============================] - ETA: 0s - loss: 0.2978 - categorical_accu
racy: 0.9062
Epoch 11: saving model to models/model-number-1/models-model_init-1_2023-11-1023_2
7_11.105753\model-00011-0.29781-0.90625-2.63995-0.29167.h5

Epoch 11: val_categorical_accuracy did not improve from 0.32500
28/28 [==============================] - 219s 8s/step - loss: 0.2978 - categorical
_accuracy: 0.9062 - val_loss: 2.6400 - val_categorical_accuracy: 0.2917 - lr: 2.00
00e-04
Epoch 12/100
28/28 [==============================] - ETA: 0s - loss: 0.2396 - categorical_accu
racy: 0.9330
Epoch 12: saving model to models/model-number-1/models-model_init-1_2023-11-1023_2
7_11.105753\model-00012-0.23959-0.93304-2.15555-0.28333.h5

Epoch 12: val_categorical_accuracy did not improve from 0.32500

Epoch 12: ReduceLROnPlateau reducing learning rate to 4.0000001899898055e-05.
28/28 [==============================] - 219s 8s/step - loss: 0.2396 - categorical
_accuracy: 0.9330 - val_loss: 2.1555 - val_categorical_accuracy: 0.2833 - lr: 2.00
00e-04
```

```
Epoch 13/100
28/28 [==============================] - ETA: 0s - loss: 0.2247 - categorical_accu
racy: 0.9286
Epoch 13: saving model to models/model-number-1/models-model_init-1_2023-11-1023_2
7_11.105753\model-00013-0.22473-0.92857-1.99308-0.34167.h5

Epoch 13: val_categorical_accuracy improved from 0.32500 to 0.34167, saving model
to models/model-number-1\best_model.h5
28/28 [==============================] - 218s 8s/step - loss: 0.2247 - categorical
_accuracy: 0.9286 - val_loss: 1.9931 - val_categorical_accuracy: 0.3417 - lr: 4.00
00e-05
Epoch 14/100
28/28 [==============================] - ETA: 0s - loss: 0.2466 - categorical_accu
racy: 0.9167
Epoch 14: saving model to models/model-number-1/models-model_init-1_2023-11-1023_2
7_11.105753\model-00014-0.24657-0.91667-1.44361-0.45833.h5

Epoch 14: val_categorical_accuracy improved from 0.34167 to 0.45833, saving model
to models/model-number-1\best_model.h5
28/28 [==============================] - 219s 8s/step - loss: 0.2466 - categorical
_accuracy: 0.9167 - val_loss: 1.4436 - val_categorical_accuracy: 0.4583 - lr: 4.00
00e-05
Epoch 15/100
28/28 [==============================] - ETA: 0s - loss: 0.2063 - categorical_accu
racy: 0.9435
Epoch 15: saving model to models/model-number-1/models-model_init-1_2023-11-1023_2
7_11.105753\model-00015-0.20634-0.94345-1.31190-0.49167.h5

Epoch 15: val_categorical_accuracy improved from 0.45833 to 0.49167, saving model
to models/model-number-1\best_model.h5
28/28 [==============================] - 217s 8s/step - loss: 0.2063 - categorical
_accuracy: 0.9435 - val_loss: 1.3119 - val_categorical_accuracy: 0.4917 - lr: 4.00
00e-05
Epoch 16/100
28/28 [==============================] - ETA: 0s - loss: 0.2329 - categorical_accu
racy: 0.9435
Epoch 16: saving model to models/model-number-1/models-model_init-1_2023-11-1023_2
7_11.105753\model-00016-0.23292-0.94345-1.06888-0.55833.h5

Epoch 16: val_categorical_accuracy improved from 0.49167 to 0.55833, saving model
to models/model-number-1\best_model.h5
28/28 [==============================] - 218s 8s/step - loss: 0.2329 - categorical
_accuracy: 0.9435 - val_loss: 1.0689 - val_categorical_accuracy: 0.5583 - lr: 4.00
00e-05
Epoch 17/100
28/28 [==============================] - ETA: 0s - loss: 0.1990 - categorical_accu
racy: 0.9405
Epoch 17: saving model to models/model-number-1/models-model_init-1_2023-11-1023_2
7_11.105753\model-00017-0.19904-0.94048-0.96220-0.60000.h5

Epoch 17: val_categorical_accuracy improved from 0.55833 to 0.60000, saving model
to models/model-number-1\best_model.h5
28/28 [==============================] - 218s 8s/step - loss: 0.1990 - categorical
_accuracy: 0.9405 - val_loss: 0.9622 - val_categorical_accuracy: 0.6000 - lr: 4.00
00e-05
Epoch 18/100
28/28 [==============================] - ETA: 0s - loss: 0.1902 - categorical_accu
racy: 0.9509
Epoch 18: saving model to models/model-number-1/models-model_init-1_2023-11-1023_2
7_11.105753\model-00018-0.19023-0.95089-0.80973-0.66667.h5

Epoch 18: val_categorical_accuracy improved from 0.60000 to 0.66667, saving model
to models/model-number-1\best_model.h5
28/28 [==============================] - 218s 8s/step - loss: 0.1902 - categorical
```

```
_accuracy: 0.9509 - val_loss: 0.8097 - val_categorical_accuracy: 0.6667 - lr: 4.00
00e-05
Epoch 19/100
28/28 [==============================] - ETA: 0s - loss: 0.1527 - categorical_accu
racy: 0.9717
Epoch 19: saving model to models/model-number-1/models-model_init-1_2023-11-1023_2
7_11.105753\model-00019-0.15269-0.97173-0.84810-0.73333.h5

Epoch 19: val_categorical_accuracy improved from 0.66667 to 0.73333, saving model
to models/model-number-1\best_model.h5
28/28 [==============================] - 219s 8s/step - loss: 0.1527 - categorical
_accuracy: 0.9717 - val_loss: 0.8481 - val_categorical_accuracy: 0.7333 - lr: 4.00
00e-05
Epoch 20/100
28/28 [==============================] - ETA: 0s - loss: 0.1632 - categorical_accu
racy: 0.9554
Epoch 20: saving model to models/model-number-1/models-model_init-1_2023-11-1023_2
7_11.105753\model-00020-0.16316-0.95536-0.78024-0.74167.h5

Epoch 20: val_categorical_accuracy improved from 0.73333 to 0.74167, saving model
to models/model-number-1\best_model.h5
28/28 [==============================] - 218s 8s/step - loss: 0.1632 - categorical
_accuracy: 0.9554 - val_loss: 0.7802 - val_categorical_accuracy: 0.7417 - lr: 4.00
00e-05
Epoch 21/100
28/28 [==============================] - ETA: 0s - loss: 0.1593 - categorical_accu
racy: 0.9643
Epoch 21: saving model to models/model-number-1/models-model_init-1_2023-11-1023_2
7_11.105753\model-00021-0.15929-0.96429-0.66293-0.80833.h5

Epoch 21: val_categorical_accuracy improved from 0.74167 to 0.80833, saving model
to models/model-number-1\best_model.h5
28/28 [==============================] - 218s 8s/step - loss: 0.1593 - categorical
_accuracy: 0.9643 - val_loss: 0.6629 - val_categorical_accuracy: 0.8083 - lr: 4.00
00e-05
Epoch 22/100
28/28 [==============================] - ETA: 0s - loss: 0.1637 - categorical_accu
racy: 0.9583
Epoch 22: saving model to models/model-number-1/models-model_init-1_2023-11-1023_2
7_11.105753\model-00022-0.16367-0.95833-0.73952-0.74167.h5

Epoch 22: val_categorical_accuracy did not improve from 0.80833
28/28 [==============================] - 217s 8s/step - loss: 0.1637 - categorical
_accuracy: 0.9583 - val_loss: 0.7395 - val_categorical_accuracy: 0.7417 - lr: 4.00
00e-05
Epoch 23/100
28/28 [==============================] - ETA: 0s - loss: 0.1452 - categorical_accu
racy: 0.9732
Epoch 23: saving model to models/model-number-1/models-model_init-1_2023-11-1023_2
7_11.105753\model-00023-0.14516-0.97321-0.60086-0.80000.h5

Epoch 23: val_categorical_accuracy did not improve from 0.80833
28/28 [==============================] - 219s 8s/step - loss: 0.1452 - categorical
_accuracy: 0.9732 - val_loss: 0.6009 - val_categorical_accuracy: 0.8000 - lr: 4.00
00e-05
Epoch 24/100
28/28 [==============================] - ETA: 0s - loss: 0.1524 - categorical_accu
racy: 0.9732
Epoch 24: saving model to models/model-number-1/models-model_init-1_2023-11-1023_2
7_11.105753\model-00024-0.15242-0.97321-0.69963-0.75833.h5

Epoch 24: val_categorical_accuracy did not improve from 0.80833
28/28 [==============================] - 218s 8s/step - loss: 0.1524 - categorical
_accuracy: 0.9732 - val_loss: 0.6996 - val_categorical_accuracy: 0.7583 - lr: 4.00
```

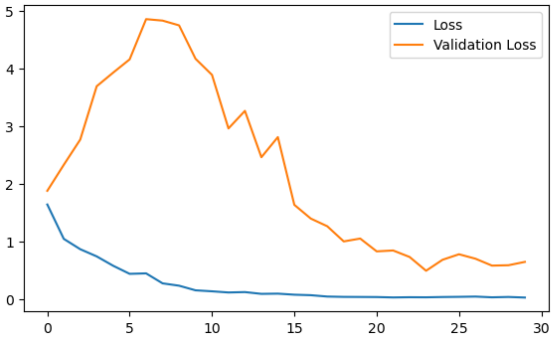
```
00e-05
Epoch 25/100
28/28 [==============================] - ETA: 0s - loss: 0.1681 - categorical_accu
racy: 0.9613
Epoch 25: saving model to models/model-number-1/models-model_init-1_2023-11-1023_2
7_11.105753\model-00025-0.16811-0.96131-0.59388-0.80833.h5

Epoch 25: val_categorical_accuracy did not improve from 0.80833

Epoch 25: ReduceLROnPlateau reducing learning rate to 8.000000525498762e-06.
28/28 [==============================] - 218s 8s/step - loss: 0.1681 - categorical
_accuracy: 0.9613 - val_loss: 0.5939 - val_categorical_accuracy: 0.8083 - lr: 4.00
00e-05
Epoch 26/100
28/28 [==============================] - ETA: 0s - loss: 0.1425 - categorical_accu
racy: 0.9732
Epoch 26: saving model to models/model-number-1/models-model_init-1_2023-11-1023_2
7_11.105753\model-00026-0.14250-0.97321-0.58125-0.80833.h5

Epoch 26: val_categorical_accuracy did not improve from 0.80833
28/28 [==============================] - 218s 8s/step - loss: 0.1425 - categorical
_accuracy: 0.9732 - val_loss: 0.5813 - val_categorical_accuracy: 0.8083 - lr: 8.00
00e-06
Epoch 27/100
28/28 [==============================] - ETA: 0s - loss: 0.1428 - categorical_accu
racy: 0.9658
Epoch 27: saving model to models/model-number-1/models-model_init-1_2023-11-1023_2
7_11.105753\model-00027-0.14280-0.96577-0.62525-0.80833.h5

Epoch 27: val_categorical_accuracy did not improve from 0.80833
28/28 [==============================] - 219s 8s/step - loss: 0.1428 - categorical
_accuracy: 0.9658 - val_loss: 0.6253 - val_categorical_accuracy: 0.8083 - lr: 8.00
00e-06
Epoch 28/100
28/28 [==============================] - ETA: 0s - loss: 0.1378 - categorical_accu
racy: 0.9688
Epoch 28: saving model to models/model-number-1/models-model_init-1_2023-11-1023_2
7_11.105753\model-00028-0.13778-0.96875-0.64459-0.79167.h5

Epoch 28: val_categorical_accuracy did not improve from 0.80833
28/28 [==============================] - 219s 8s/step - loss: 0.1378 - categorical
_accuracy: 0.9688 - val_loss: 0.6446 - val_categorical_accuracy: 0.7917 - lr: 8.00
00e-06
Epoch 29/100
28/28 [==============================] - ETA: 0s - loss: 0.1394 - categorical_accu
racy: 0.9732
Epoch 29: saving model to models/model-number-1/models-model_init-1_2023-11-1023_2
7_11.105753\model-00029-0.13935-0.97321-0.66083-0.79167.h5

Epoch 29: val_categorical_accuracy did not improve from 0.80833

Epoch 29: ReduceLROnPlateau reducing learning rate to 1.6000001778593287e-06.
28/28 [==============================] - 218s 8s/step - loss: 0.1394 - categorical
_accuracy: 0.9732 - val_loss: 0.6608 - val_categorical_accuracy: 0.7917 - lr: 8.00
00e-06
Epoch 30/100
28/28 [==============================] - ETA: 0s - loss: 0.1146 - categorical_accu
racy: 0.9747
Epoch 30: saving model to models/model-number-1/models-model_init-1_2023-11-1023_2
7_11.105753\model-00030-0.11463-0.97470-0.58510-0.82500.h5

Epoch 30: val_categorical_accuracy improved from 0.80833 to 0.82500, saving model
to models/model-number-1\best_model.h5
28/28 [==============================] - 219s 8s/step - loss: 0.1146 - categorical
```

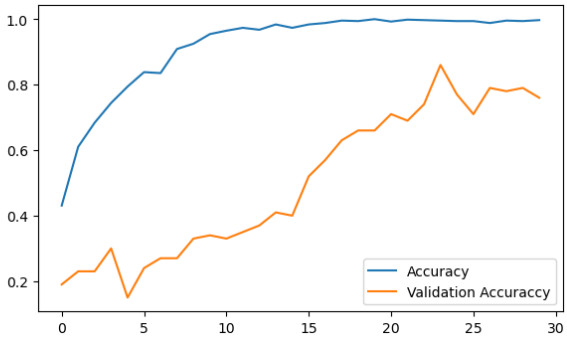
```
_accuracy: 0.9747 - val_loss: 0.5851 - val_categorical_accuracy: 0.8250 - lr: 1.60
00e-06
Epoch 31/100
28/28 [==============================] - ETA: 0s - loss: 0.1364 - categorical_accu
racy: 0.9673
Epoch 31: saving model to models/model-number-1/models-model_init-1_2023-11-1023_2
7_11.105753\model-00031-0.13636-0.96726-0.57543-0.81667.h5

Epoch 31: val_categorical_accuracy did not improve from 0.82500
28/28 [==============================] - 219s 8s/step - loss: 0.1364 - categorical
_accuracy: 0.9673 - val_loss: 0.5754 - val_categorical_accuracy: 0.8167 - lr: 1.60
00e-06
Epoch 32/100
28/28 [==============================] - ETA: 0s - loss: 0.1355 - categorical_accu
racy: 0.9777
Epoch 32: saving model to models/model-number-1/models-model_init-1_2023-11-1023_2
7_11.105753\model-00032-0.13552-0.97768-0.70553-0.79167.h5

Epoch 32: val_categorical_accuracy did not improve from 0.82500
28/28 [==============================] - 218s 8s/step - loss: 0.1355 - categorical
_accuracy: 0.9777 - val_loss: 0.7055 - val_categorical_accuracy: 0.7917 - lr: 1.60
00e-06
Epoch 33/100
28/28 [==============================] - ETA: 0s - loss: 0.1333 - categorical_accu
racy: 0.9747
Epoch 33: saving model to models/model-number-1/models-model_init-1_2023-11-1023_2
7_11.105753\model-00033-0.13332-0.97470-0.60891-0.81667.h5

Epoch 33: val_categorical_accuracy did not improve from 0.82500
28/28 [==============================] - 220s 8s/step - loss: 0.1333 - categorical
_accuracy: 0.9747 - val_loss: 0.6089 - val_categorical_accuracy: 0.8167 - lr: 1.60
00e-06
Epoch 34/100
28/28 [==============================] - ETA: 0s - loss: 0.1421 - categorical_accu
racy: 0.9702
Epoch 34: saving model to models/model-number-1/models-model_init-1_2023-11-1023_2
7_11.105753\model-00034-0.14208-0.97024-0.49206-0.82500.h5

Epoch 34: val_categorical_accuracy did not improve from 0.82500

Epoch 34: ReduceLROnPlateau reducing learning rate to 3.200000264769187e-07.
28/28 [==============================] - 219s 8s/step - loss: 0.1421 - categorical
_accuracy: 0.9702 - val_loss: 0.4921 - val_categorical_accuracy: 0.8250 - lr: 1.60
00e-06
Epoch 35/100
28/28 [==============================] - ETA: 0s - loss: 0.1522 - categorical_accu
racy: 0.9717
Epoch 35: saving model to models/model-number-1/models-model_init-1_2023-11-1023_2
7_11.105753\model-00035-0.15223-0.97173-0.59700-0.81667.h5

Epoch 35: val_categorical_accuracy did not improve from 0.82500
28/28 [==============================] - 220s 8s/step - loss: 0.1522 - categorical
_accuracy: 0.9717 - val_loss: 0.5970 - val_categorical_accuracy: 0.8167 - lr: 3.20
00e-07
Epoch 36/100
28/28 [==============================] - ETA: 0s - loss: 0.1325 - categorical_accu
racy: 0.9747
Epoch 36: saving model to models/model-number-1/models-model_init-1_2023-11-1023_2
7_11.105753\model-00036-0.13247-0.97470-0.59010-0.81667.h5

Epoch 36: val_categorical_accuracy did not improve from 0.82500
28/28 [==============================] - 218s 8s/step - loss: 0.1325 - categorical
_accuracy: 0.9747 - val_loss: 0.5901 - val_categorical_accuracy: 0.8167 - lr: 3.20
00e-07
```

```
Epoch 37/100
28/28 [==============================] - ETA: 0s - loss: 0.1437 - categorical_accu
racy: 0.9673
Epoch 37: saving model to models/model-number-1/models-model_init-1_2023-11-1023_2
7_11.105753\model-00037-0.14368-0.96726-0.51146-0.83333.h5

Epoch 37: val_categorical_accuracy improved from 0.82500 to 0.83333, saving model
to models/model-number-1\best_model.h5
28/28 [==============================] - 218s 8s/step - loss: 0.1437 - categorical
_accuracy: 0.9673 - val_loss: 0.5115 - val_categorical_accuracy: 0.8333 - lr: 3.20
00e-07
Epoch 38/100
28/28 [==============================] - ETA: 0s - loss: 0.1279 - categorical_accu
racy: 0.9777
Epoch 38: saving model to models/model-number-1/models-model_init-1_2023-11-1023_2
7_11.105753\model-00038-0.12787-0.97768-0.54866-0.84167.h5

Epoch 38: val_categorical_accuracy improved from 0.83333 to 0.84167, saving model
to models/model-number-1\best_model.h5
28/28 [==============================] - 218s 8s/step - loss: 0.1279 - categorical
_accuracy: 0.9777 - val_loss: 0.5487 - val_categorical_accuracy: 0.8417 - lr: 3.20
00e-07
Epoch 39/100
28/28 [==============================] - ETA: 0s - loss: 0.1431 - categorical_accu
racy: 0.9702
Epoch 39: saving model to models/model-number-1/models-model_init-1_2023-11-1023_2
7_11.105753\model-00039-0.14310-0.97024-0.59535-0.81667.h5

Epoch 39: val_categorical_accuracy did not improve from 0.84167
28/28 [==============================] - 217s 8s/step - loss: 0.1431 - categorical
_accuracy: 0.9702 - val_loss: 0.5954 - val_categorical_accuracy: 0.8167 - lr: 3.20
00e-07
Epoch 40/100
28/28 [==============================] - ETA: 0s - loss: 0.1297 - categorical_accu
racy: 0.9717
Epoch 40: saving model to models/model-number-1/models-model_init-1_2023-11-1023_2
7_11.105753\model-00040-0.12971-0.97173-0.55078-0.82500.h5

Epoch 40: val_categorical_accuracy did not improve from 0.84167
28/28 [==============================] - 218s 8s/step - loss: 0.1297 - categorical
_accuracy: 0.9717 - val_loss: 0.5508 - val_categorical_accuracy: 0.8250 - lr: 3.20
00e-07
Epoch 41/100
28/28 [==============================] - ETA: 0s - loss: 0.1393 - categorical_accu
racy: 0.9673
Epoch 41: saving model to models/model-number-1/models-model_init-1_2023-11-1023_2
7_11.105753\model-00041-0.13930-0.96726-0.49713-0.82500.h5

Epoch 41: val_categorical_accuracy did not improve from 0.84167
28/28 [==============================] - 218s 8s/step - loss: 0.1393 - categorical
_accuracy: 0.9673 - val_loss: 0.4971 - val_categorical_accuracy: 0.8250 - lr: 3.20
00e-07
Epoch 42/100
28/28 [==============================] - ETA: 0s - loss: 0.1356 - categorical_accu
racy: 0.9777
Epoch 42: saving model to models/model-number-1/models-model_init-1_2023-11-1023_2
7_11.105753\model-00042-0.13563-0.97768-0.63358-0.79167.h5

Epoch 42: val_categorical_accuracy did not improve from 0.84167

Epoch 42: ReduceLROnPlateau reducing learning rate to 6.400000529538374e-08.
28/28 [==============================] - 218s 8s/step - loss: 0.1356 - categorical
_accuracy: 0.9777 - val_loss: 0.6336 - val_categorical_accuracy: 0.7917 - lr: 3.20
00e-07
```

```
Epoch 43/100
28/28 [==============================] - ETA: 0s - loss: 0.1379 - categorical_accu
racy: 0.9717
Epoch 43: saving model to models/model-number-1/models-model_init-1_2023-11-1023_2
7_11.105753\model-00043-0.13786-0.97173-0.61725-0.79167.h5

Epoch 43: val_categorical_accuracy did not improve from 0.84167
28/28 [==============================] - 220s 8s/step - loss: 0.1379 - categorical
_accuracy: 0.9717 - val_loss: 0.6172 - val_categorical_accuracy: 0.7917 - lr: 6.40
00e-08
Epoch 44/100
28/28 [==============================] - ETA: 0s - loss: 0.1345 - categorical_accu
racy: 0.9777
Epoch 44: saving model to models/model-number-1/models-model_init-1_2023-11-1023_2
7_11.105753\model-00044-0.13447-0.97768-0.61727-0.82500.h5

Epoch 44: val_categorical_accuracy did not improve from 0.84167
28/28 [==============================] - 218s 8s/step - loss: 0.1345 - categorical
_accuracy: 0.9777 - val_loss: 0.6173 - val_categorical_accuracy: 0.8250 - lr: 6.40
00e-08
Epoch 45/100
28/28 [==============================] - ETA: 0s - loss: 0.1355 - categorical_accu
racy: 0.9628
Epoch 45: saving model to models/model-number-1/models-model_init-1_2023-11-1023_2
7_11.105753\model-00045-0.13545-0.96280-0.52292-0.81667.h5

Epoch 45: val_categorical_accuracy did not improve from 0.84167
28/28 [==============================] - 218s 8s/step - loss: 0.1355 - categorical
_accuracy: 0.9628 - val_loss: 0.5229 - val_categorical_accuracy: 0.8167 - lr: 6.40
00e-08
Epoch 46/100
28/28 [==============================] - ETA: 0s - loss: 0.1269 - categorical_accu
racy: 0.9747
Epoch 46: saving model to models/model-number-1/models-model_init-1_2023-11-1023_2
7_11.105753\model-00046-0.12688-0.97470-0.66880-0.80000.h5

Epoch 46: val_categorical_accuracy did not improve from 0.84167

Epoch 46: ReduceLROnPlateau reducing learning rate to 1.2800001059076749e-08.
28/28 [==============================] - 218s 8s/step - loss: 0.1269 - categorical
_accuracy: 0.9747 - val_loss: 0.6688 - val_categorical_accuracy: 0.8000 - lr: 6.40
00e-08
Epoch 47/100
28/28 [==============================] - ETA: 0s - loss: 0.1367 - categorical_accu
racy: 0.9732
Epoch 47: saving model to models/model-number-1/models-model_init-1_2023-11-1023_2
7_11.105753\model-00047-0.13665-0.97321-0.52788-0.83333.h5

Epoch 47: val_categorical_accuracy did not improve from 0.84167
28/28 [==============================] - 219s 8s/step - loss: 0.1367 - categorical
_accuracy: 0.9732 - val_loss: 0.5279 - val_categorical_accuracy: 0.8333 - lr: 1.28
00e-08
Epoch 48/100
28/28 [==============================] - ETA: 0s - loss: 0.1441 - categorical_accu
racy: 0.9658
Epoch 48: saving model to models/model-number-1/models-model_init-1_2023-11-1023_2
7_11.105753\model-00048-0.14410-0.96577-0.61311-0.80833.h5

Epoch 48: val_categorical_accuracy did not improve from 0.84167
28/28 [==============================] - 216s 8s/step - loss: 0.1441 - categorical
_accuracy: 0.9658 - val_loss: 0.6131 - val_categorical_accuracy: 0.8083 - lr: 1.28
00e-08
Epoch 48: early stopping
```

In [29]:
```
loss = history.history['loss']
val_loss = history.history['val_loss']
acc = history.history['categorical_accuracy']
val_acc = history.history['val_categorical_accuracy']

plot_model(loss,val_loss,acc,val_acc)
```





Observations :

- The model displayed inconsistent validation accuracy, with some improvement over epochs but significant fluctuations, indicating potential overfitting issues.
- Training stopped at epoch 48 due to early stopping, suggesting the model had reached its learning capacity under current settings.
- The highest validation accuracy achieved was around 84.17% at epoch 38, indicating the peak performance of the model.
- Despite the learning rate adjustments, later epochs (especially after epoch 30) did not show significant improvement in validation accuracy, suggesting the model might have reached its learning capacity with the given model layers and data.
- There is a consistent gap between training and validation accuracy, with training accuracy being significantly higher. This suggests overfitting, where the model performs well on training data but less so on unseen data.
- The model exhibited a significant disparity between training accuracy (peaking at 97.77%) and validation accuracy (max 84.17%), suggesting a notable overfitting issue.

Lets create another model making some changes with an increase in image size from (100 x 100) to (120 x 120) and reducing batch size to 20 and reducing frames from 30 to 20. This time we will also skip early stop callback to let it run for the full 30 epochs.

Model 2 Conv3d - Batch Size - 20, Image Size (120 x 120) , 20 Frames , Without Early Stop

In [16]:
```
model_number = 2
batch_size = 20
imageHeight = 120
imageWidth = 120
framesToSample = 20
rgbChannels = 3
input_shape = (framesToSample, imageWidth, imageHeight, rgbChannels)
num_classes = 5
```

In [17]:
```
model=create_model(input_shape, num_classes,128)
optimiser = optimizers.Adam()
model.compile(optimizer=optimiser, loss='categorical_crossentropy', metrics=['categ
callbacks_list = set_callbacks(model_number,True,True,True,False,'val_categorical_a
```

In [18]:
```
train_data_generator = VideoDataGenerator(train_path,train_doc, batch_size, imageHe
val_data_generator = VideoDataGenerator(val_path,val_doc, batch_size, imageHeight,

# Use the generator method of the instances to get the generators
train_generator = train_data_generator.generator()
val_generator = val_data_generator.generator()
```

In [19]:
```
num_epochs = 30
steps_per_epoch ,validation_steps = get_sequence(train_doc,val_doc,batch_size,num_e
```

```
training sequences = 663
validation sequences = 100
epochs = 30
validation_steps 5
steps_per_epoch 34
```

In [20]:
```
model.summary()
```

```
Model: "sequential_1"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv3d_4 (Conv3D)           (None, 20, 120, 120, 16   1312
                             )

 activation_4 (Activation)   (None, 20, 120, 120, 16   0
                             )

 batch_normalization_6 (Bat  (None, 20, 120, 120, 16   64
 chNormalization)            )

 max_pooling3d_4 (MaxPoolin  (None, 10, 60, 60, 16)    0
 g3D)

 conv3d_5 (Conv3D)           (None, 10, 60, 60, 32)    13856

 activation_5 (Activation)   (None, 10, 60, 60, 32)    0

 batch_normalization_7 (Bat  (None, 10, 60, 60, 32)    128
 chNormalization)

 max_pooling3d_5 (MaxPoolin  (None, 5, 30, 30, 32)     0
 g3D)

 conv3d_6 (Conv3D)           (None, 5, 30, 30, 64)     55360

 activation_6 (Activation)   (None, 5, 30, 30, 64)     0

 batch_normalization_8 (Bat  (None, 5, 30, 30, 64)     256
 chNormalization)

 max_pooling3d_6 (MaxPoolin  (None, 2, 15, 15, 64)     0
 g3D)

 conv3d_7 (Conv3D)           (None, 2, 15, 15, 128)    221312

 activation_7 (Activation)   (None, 2, 15, 15, 128)    0

 batch_normalization_9 (Bat  (None, 2, 15, 15, 128)    512
 chNormalization)

 max_pooling3d_7 (MaxPoolin  (None, 1, 7, 7, 128)      0
 g3D)

 flatten_1 (Flatten)         (None, 6272)              0

 dense_3 (Dense)             (None, 128)               802944

 batch_normalization_10 (Ba  (None, 128)               512
 tchNormalization)

 dropout_2 (Dropout)         (None, 128)               0

 dense_4 (Dense)             (None, 128)               16512

 batch_normalization_11 (Ba  (None, 128)               512
 tchNormalization)

 dropout_3 (Dropout)         (None, 128)               0

 dense_5 (Dense)             (None, 5)                 645
```

```
=================================================================
Total params: 1113925 (4.25 MB)
Trainable params: 1112933 (4.25 MB)
Non-trainable params: 992 (3.88 KB)
_________________________________________________________________
```

In [21]:
```
history=model.fit(train_generator, epochs=num_epochs, verbose=1,steps_per_epoch=ste
                  callbacks=callbacks_list, validation_data=val_generator,
                      validation_steps=validation_steps,class_weight=None, worker
                 )
```

```
Epoch 1/30
34/34 [==============================] - ETA: 0s - loss: 1.6382 - categorical_accu
racy: 0.4309
Epoch 1: saving model to models/model-number-2/models-model_init-2_2023-11-1102_22
_01.965352\model-00001-1.63822-0.43088-1.87583-0.19000.h5

Epoch 1: val_categorical_accuracy improved from -inf to 0.19000, saving model to m
odels/model-number-2\best_model.h5
34/34 [==============================] - 214s 6s/step - loss: 1.6382 - categorical
_accuracy: 0.4309 - val_loss: 1.8758 - val_categorical_accuracy: 0.1900 - lr: 0.00
10
Epoch 2/30
34/34 [==============================] - ETA: 0s - loss: 1.0419 - categorical_accu
racy: 0.6103
Epoch 2: saving model to models/model-number-2/models-model_init-2_2023-11-1102_22
_01.965352\model-00002-1.04188-0.61029-2.32679-0.23000.h5

Epoch 2: val_categorical_accuracy improved from 0.19000 to 0.23000, saving model t
o models/model-number-2\best_model.h5
34/34 [==============================] - 213s 6s/step - loss: 1.0419 - categorical
_accuracy: 0.6103 - val_loss: 2.3268 - val_categorical_accuracy: 0.2300 - lr: 0.00
10
Epoch 3/30
34/34 [==============================] - ETA: 0s - loss: 0.8622 - categorical_accu
racy: 0.6838
Epoch 3: saving model to models/model-number-2/models-model_init-2_2023-11-1102_22
_01.965352\model-00003-0.86221-0.68382-2.76508-0.23000.h5

Epoch 3: val_categorical_accuracy did not improve from 0.23000
34/34 [==============================] - 214s 6s/step - loss: 0.8622 - categorical
_accuracy: 0.6838 - val_loss: 2.7651 - val_categorical_accuracy: 0.2300 - lr: 0.00
10
Epoch 4/30
34/34 [==============================] - ETA: 0s - loss: 0.7374 - categorical_accu
racy: 0.7441
Epoch 4: saving model to models/model-number-2/models-model_init-2_2023-11-1102_22
_01.965352\model-00004-0.73745-0.74412-3.69097-0.30000.h5

Epoch 4: val_categorical_accuracy improved from 0.23000 to 0.30000, saving model t
o models/model-number-2\best_model.h5
34/34 [==============================] - 215s 6s/step - loss: 0.7374 - categorical
_accuracy: 0.7441 - val_loss: 3.6910 - val_categorical_accuracy: 0.3000 - lr: 0.00
10
Epoch 5/30
34/34 [==============================] - ETA: 0s - loss: 0.5750 - categorical_accu
racy: 0.7941
Epoch 5: saving model to models/model-number-2/models-model_init-2_2023-11-1102_22
_01.965352\model-00005-0.57498-0.79412-3.92743-0.15000.h5

Epoch 5: val_categorical_accuracy did not improve from 0.30000
34/34 [==============================] - 214s 6s/step - loss: 0.5750 - categorical
_accuracy: 0.7941 - val_loss: 3.9274 - val_categorical_accuracy: 0.1500 - lr: 0.00
10
Epoch 6/30
34/34 [==============================] - ETA: 0s - loss: 0.4348 - categorical_accu
racy: 0.8382
Epoch 6: saving model to models/model-number-2/models-model_init-2_2023-11-1102_22
_01.965352\model-00006-0.43478-0.83824-4.15739-0.24000.h5

Epoch 6: val_categorical_accuracy did not improve from 0.30000
34/34 [==============================] - 213s 6s/step - loss: 0.4348 - categorical
_accuracy: 0.8382 - val_loss: 4.1574 - val_categorical_accuracy: 0.2400 - lr: 0.00
10
Epoch 7/30
```

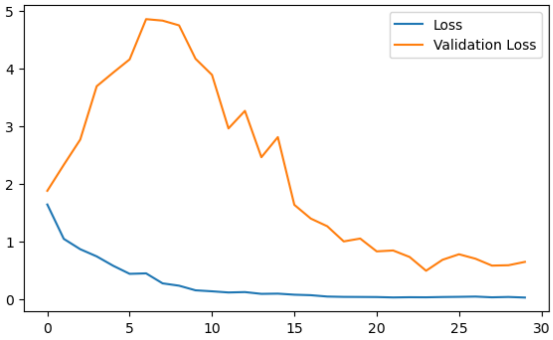
```
34/34 [==============================] - ETA: 0s - loss: 0.4429 - categorical_accu
racy: 0.8353
Epoch 7: saving model to models/model-number-2/models-model_init-2_2023-11-1102_22
_01.965352\model-00007-0.44285-0.83529-4.85562-0.27000.h5

Epoch 7: val_categorical_accuracy did not improve from 0.30000
34/34 [==============================] - 214s 6s/step - loss: 0.4429 - categorical
_accuracy: 0.8353 - val_loss: 4.8556 - val_categorical_accuracy: 0.2700 - lr: 0.00
10
Epoch 8/30
34/34 [==============================] - ETA: 0s - loss: 0.2696 - categorical_accu
racy: 0.9088
Epoch 8: saving model to models/model-number-2/models-model_init-2_2023-11-1102_22
_01.965352\model-00008-0.26962-0.90882-4.83024-0.27000.h5

Epoch 8: val_categorical_accuracy did not improve from 0.30000

Epoch 8: ReduceLROnPlateau reducing learning rate to 0.00020000000949949026.
34/34 [==============================] - 213s 6s/step - loss: 0.2696 - categorical
_accuracy: 0.9088 - val_loss: 4.8302 - val_categorical_accuracy: 0.2700 - lr: 0.00
10
Epoch 9/30
34/34 [==============================] - ETA: 0s - loss: 0.2289 - categorical_accu
racy: 0.9250
Epoch 9: saving model to models/model-number-2/models-model_init-2_2023-11-1102_22
_01.965352\model-00009-0.22894-0.92500-4.74797-0.33000.h5

Epoch 9: val_categorical_accuracy improved from 0.30000 to 0.33000, saving model t
o models/model-number-2\best_model.h5
34/34 [==============================] - 212s 6s/step - loss: 0.2289 - categorical
_accuracy: 0.9250 - val_loss: 4.7480 - val_categorical_accuracy: 0.3300 - lr: 2.00
00e-04
Epoch 10/30
34/34 [==============================] - ETA: 0s - loss: 0.1487 - categorical_accu
racy: 0.9544
Epoch 10: saving model to models/model-number-2/models-model_init-2_2023-11-1102_2
2_01.965352\model-00010-0.14869-0.95441-4.16793-0.34000.h5

Epoch 10: val_categorical_accuracy improved from 0.33000 to 0.34000, saving model
to models/model-number-2\best_model.h5
34/34 [==============================] - 213s 6s/step - loss: 0.1487 - categorical
_accuracy: 0.9544 - val_loss: 4.1679 - val_categorical_accuracy: 0.3400 - lr: 2.00
00e-04
Epoch 11/30
34/34 [==============================] - ETA: 0s - loss: 0.1316 - categorical_accu
racy: 0.9647
Epoch 11: saving model to models/model-number-2/models-model_init-2_2023-11-1102_2
2_01.965352\model-00011-0.13158-0.96471-3.88822-0.33000.h5

Epoch 11: val_categorical_accuracy did not improve from 0.34000
34/34 [==============================] - 213s 6s/step - loss: 0.1316 - categorical
_accuracy: 0.9647 - val_loss: 3.8882 - val_categorical_accuracy: 0.3300 - lr: 2.00
00e-04
Epoch 12/30
34/34 [==============================] - ETA: 0s - loss: 0.1113 - categorical_accu
racy: 0.9735
Epoch 12: saving model to models/model-number-2/models-model_init-2_2023-11-1102_2
2_01.965352\model-00012-0.11134-0.97353-2.95848-0.35000.h5

Epoch 12: val_categorical_accuracy improved from 0.34000 to 0.35000, saving model
to models/model-number-2\best_model.h5
34/34 [==============================] - 213s 6s/step - loss: 0.1113 - categorical
_accuracy: 0.9735 - val_loss: 2.9585 - val_categorical_accuracy: 0.3500 - lr: 2.00
00e-04
```

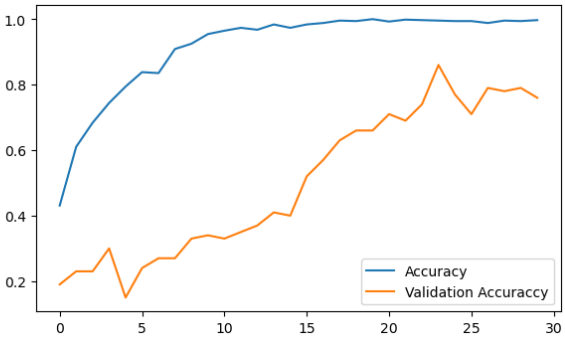
```
Epoch 13/30
34/34 [==============================] - ETA: 0s - loss: 0.1180 - categorical_accu
racy: 0.9676
Epoch 13: saving model to models/model-number-2/models-model_init-2_2023-11-1102_2
2_01.965352\model-00013-0.11802-0.96765-3.26330-0.37000.h5

Epoch 13: val_categorical_accuracy improved from 0.35000 to 0.37000, saving model
to models/model-number-2\best_model.h5
34/34 [==============================] - 214s 6s/step - loss: 0.1180 - categorical
_accuracy: 0.9676 - val_loss: 3.2633 - val_categorical_accuracy: 0.3700 - lr: 2.00
00e-04
Epoch 14/30
34/34 [==============================] - ETA: 0s - loss: 0.0873 - categorical_accu
racy: 0.9838
Epoch 14: saving model to models/model-number-2/models-model_init-2_2023-11-1102_2
2_01.965352\model-00014-0.08728-0.98382-2.45886-0.41000.h5

Epoch 14: val_categorical_accuracy improved from 0.37000 to 0.41000, saving model
to models/model-number-2\best_model.h5
34/34 [==============================] - 214s 6s/step - loss: 0.0873 - categorical
_accuracy: 0.9838 - val_loss: 2.4589 - val_categorical_accuracy: 0.4100 - lr: 2.00
00e-04
Epoch 15/30
34/34 [==============================] - ETA: 0s - loss: 0.0910 - categorical_accu
racy: 0.9735
Epoch 15: saving model to models/model-number-2/models-model_init-2_2023-11-1102_2
2_01.965352\model-00015-0.09099-0.97353-2.80818-0.40000.h5

Epoch 15: val_categorical_accuracy did not improve from 0.41000
34/34 [==============================] - 213s 6s/step - loss: 0.0910 - categorical
_accuracy: 0.9735 - val_loss: 2.8082 - val_categorical_accuracy: 0.4000 - lr: 2.00
00e-04
Epoch 16/30
34/34 [==============================] - ETA: 0s - loss: 0.0727 - categorical_accu
racy: 0.9838
Epoch 16: saving model to models/model-number-2/models-model_init-2_2023-11-1102_2
2_01.965352\model-00016-0.07273-0.98382-1.63267-0.52000.h5

Epoch 16: val_categorical_accuracy improved from 0.41000 to 0.52000, saving model
to models/model-number-2\best_model.h5
34/34 [==============================] - 213s 6s/step - loss: 0.0727 - categorical
_accuracy: 0.9838 - val_loss: 1.6327 - val_categorical_accuracy: 0.5200 - lr: 2.00
00e-04
Epoch 17/30
34/34 [==============================] - ETA: 0s - loss: 0.0640 - categorical_accu
racy: 0.9882
Epoch 17: saving model to models/model-number-2/models-model_init-2_2023-11-1102_2
2_01.965352\model-00017-0.06402-0.98824-1.39392-0.57000.h5

Epoch 17: val_categorical_accuracy improved from 0.52000 to 0.57000, saving model
to models/model-number-2\best_model.h5
34/34 [==============================] - 214s 6s/step - loss: 0.0640 - categorical
_accuracy: 0.9882 - val_loss: 1.3939 - val_categorical_accuracy: 0.5700 - lr: 2.00
00e-04
Epoch 18/30
34/34 [==============================] - ETA: 0s - loss: 0.0405 - categorical_accu
racy: 0.9956
Epoch 18: saving model to models/model-number-2/models-model_init-2_2023-11-1102_2
2_01.965352\model-00018-0.04053-0.99559-1.26071-0.63000.h5

Epoch 18: val_categorical_accuracy improved from 0.57000 to 0.63000, saving model
to models/model-number-2\best_model.h5
34/34 [==============================] - 213s 6s/step - loss: 0.0405 - categorical
_accuracy: 0.9956 - val_loss: 1.2607 - val_categorical_accuracy: 0.6300 - lr: 2.00
```

```
00e-04
Epoch 19/30
34/34 [==============================] - ETA: 0s - loss: 0.0348 - categorical_accu
racy: 0.9941
Epoch 19: saving model to models/model-number-2/models-model_init-2_2023-11-1102_2
2_01.965352\model-00019-0.03484-0.99412-0.99748-0.66000.h5

Epoch 19: val_categorical_accuracy improved from 0.63000 to 0.66000, saving model
to models/model-number-2\best_model.h5
34/34 [==============================] - 213s 6s/step - loss: 0.0348 - categorical
_accuracy: 0.9941 - val_loss: 0.9975 - val_categorical_accuracy: 0.6600 - lr: 2.00
00e-04
Epoch 20/30
34/34 [==============================] - ETA: 0s - loss: 0.0334 - categorical_accu
racy: 1.0000
Epoch 20: saving model to models/model-number-2/models-model_init-2_2023-11-1102_2
2_01.965352\model-00020-0.03343-1.00000-1.04719-0.66000.h5

Epoch 20: val_categorical_accuracy did not improve from 0.66000
34/34 [==============================] - 214s 6s/step - loss: 0.0334 - categorical
_accuracy: 1.0000 - val_loss: 1.0472 - val_categorical_accuracy: 0.6600 - lr: 2.00
00e-04
Epoch 21/30
34/34 [==============================] - ETA: 0s - loss: 0.0319 - categorical_accu
racy: 0.9926
Epoch 21: saving model to models/model-number-2/models-model_init-2_2023-11-1102_2
2_01.965352\model-00021-0.03187-0.99265-0.82491-0.71000.h5

Epoch 21: val_categorical_accuracy improved from 0.66000 to 0.71000, saving model
to models/model-number-2\best_model.h5
34/34 [==============================] - 214s 6s/step - loss: 0.0319 - categorical
_accuracy: 0.9926 - val_loss: 0.8249 - val_categorical_accuracy: 0.7100 - lr: 2.00
00e-04
Epoch 22/30
34/34 [==============================] - ETA: 0s - loss: 0.0249 - categorical_accu
racy: 0.9985
Epoch 22: saving model to models/model-number-2/models-model_init-2_2023-11-1102_2
2_01.965352\model-00022-0.02495-0.99853-0.84020-0.69000.h5

Epoch 22: val_categorical_accuracy did not improve from 0.71000
34/34 [==============================] - 214s 6s/step - loss: 0.0249 - categorical
_accuracy: 0.9985 - val_loss: 0.8402 - val_categorical_accuracy: 0.6900 - lr: 2.00
00e-04
Epoch 23/30
34/34 [==============================] - ETA: 0s - loss: 0.0288 - categorical_accu
racy: 0.9971
Epoch 23: saving model to models/model-number-2/models-model_init-2_2023-11-1102_2
2_01.965352\model-00023-0.02875-0.99706-0.72746-0.74000.h5

Epoch 23: val_categorical_accuracy improved from 0.71000 to 0.74000, saving model
to models/model-number-2\best_model.h5
34/34 [==============================] - 214s 6s/step - loss: 0.0288 - categorical
_accuracy: 0.9971 - val_loss: 0.7275 - val_categorical_accuracy: 0.7400 - lr: 2.00
00e-04
Epoch 24/30
34/34 [==============================] - ETA: 0s - loss: 0.0273 - categorical_accu
racy: 0.9956
Epoch 24: saving model to models/model-number-2/models-model_init-2_2023-11-1102_2
2_01.965352\model-00024-0.02729-0.99559-0.48834-0.86000.h5

Epoch 24: val_categorical_accuracy improved from 0.74000 to 0.86000, saving model
to models/model-number-2\best_model.h5
34/34 [==============================] - 213s 6s/step - loss: 0.0273 - categorical
_accuracy: 0.9956 - val_loss: 0.4883 - val_categorical_accuracy: 0.8600 - lr: 2.00
```

```
00e-04
Epoch 25/30
34/34 [==============================] - ETA: 0s - loss: 0.0325 - categorical_accu
racy: 0.9941
Epoch 25: saving model to models/model-number-2/models-model_init-2_2023-11-1102_2
2_01.965352\model-00025-0.03248-0.99412-0.67885-0.77000.h5

Epoch 25: val_categorical_accuracy did not improve from 0.86000
34/34 [==============================] - 214s 6s/step - loss: 0.0325 - categorical
_accuracy: 0.9941 - val_loss: 0.6788 - val_categorical_accuracy: 0.7700 - lr: 2.00
00e-04
Epoch 26/30
34/34 [==============================] - ETA: 0s - loss: 0.0356 - categorical_accu
racy: 0.9941
Epoch 26: saving model to models/model-number-2/models-model_init-2_2023-11-1102_2
2_01.965352\model-00026-0.03564-0.99412-0.77456-0.71000.h5

Epoch 26: val_categorical_accuracy did not improve from 0.86000
34/34 [==============================] - 213s 6s/step - loss: 0.0356 - categorical
_accuracy: 0.9941 - val_loss: 0.7746 - val_categorical_accuracy: 0.7100 - lr: 2.00
00e-04
Epoch 27/30
34/34 [==============================] - ETA: 0s - loss: 0.0401 - categorical_accu
racy: 0.9882
Epoch 27: saving model to models/model-number-2/models-model_init-2_2023-11-1102_2
2_01.965352\model-00027-0.04013-0.98824-0.69730-0.79000.h5

Epoch 27: val_categorical_accuracy did not improve from 0.86000
34/34 [==============================] - 213s 6s/step - loss: 0.0401 - categorical
_accuracy: 0.9882 - val_loss: 0.6973 - val_categorical_accuracy: 0.7900 - lr: 2.00
00e-04
Epoch 28/30
34/34 [==============================] - ETA: 0s - loss: 0.0272 - categorical_accu
racy: 0.9956
Epoch 28: saving model to models/model-number-2/models-model_init-2_2023-11-1102_2
2_01.965352\model-00028-0.02720-0.99559-0.57771-0.78000.h5

Epoch 28: val_categorical_accuracy did not improve from 0.86000

Epoch 28: ReduceLROnPlateau reducing learning rate to 4.0000001899898055e-05.
34/34 [==============================] - 215s 6s/step - loss: 0.0272 - categorical
_accuracy: 0.9956 - val_loss: 0.5777 - val_categorical_accuracy: 0.7800 - lr: 2.00
00e-04
Epoch 29/30
34/34 [==============================] - ETA: 0s - loss: 0.0334 - categorical_accu
racy: 0.9941
Epoch 29: saving model to models/model-number-2/models-model_init-2_2023-11-1102_2
2_01.965352\model-00029-0.03337-0.99412-0.58394-0.79000.h5

Epoch 29: val_categorical_accuracy did not improve from 0.86000
34/34 [==============================] - 214s 6s/step - loss: 0.0334 - categorical
_accuracy: 0.9941 - val_loss: 0.5839 - val_categorical_accuracy: 0.7900 - lr: 4.00
00e-05
Epoch 30/30
34/34 [==============================] - ETA: 0s - loss: 0.0232 - categorical_accu
racy: 0.9971
Epoch 30: saving model to models/model-number-2/models-model_init-2_2023-11-1102_2
2_01.965352\model-00030-0.02322-0.99706-0.64217-0.76000.h5

Epoch 30: val_categorical_accuracy did not improve from 0.86000
34/34 [==============================] - 215s 6s/step - loss: 0.0232 - categorical
_accuracy: 0.9971 - val_loss: 0.6422 - val_categorical_accuracy: 0.7600 - lr: 4.00
00e-05
```

In [30]:
```
loss = history.history['loss']
val_loss = history.history['val_loss']
acc = history.history['categorical_accuracy']
val_acc = history.history['val_categorical_accuracy']

plot_model(loss,val_loss,acc,val_acc)
```





Observation

- consistent improvement in training categorical accuracy, reaching a peak of 99.71% by the final epoch
- There was an overall upward trend in validation accuracy, peaking at 86.00% in epoch 24, but it fluctuated and didn't consistently match training accuracy improvements.
- Similar to the first model, Model 2 exhibited a significant gap between training and validation performance, indicating possible overfitting issues.

Model 2, despite running for fewer epochs, managed to reach a higher validation accuracy peak, which shows that changes made like increasing image size , reducing batch size and reduced frames have shown some positive impacts. But before drawing conclusion over the same , lets do a sample run by changing these features on the opposite sides

Model 3 Conv3d - Batch Size -20, Image Size (100 x 100) , 30 Frames

In [33]:
```
model_number = 3
batch_size = 20
imageHeight = 100
imageWidth = 100
framesToSample = 30
num_epochs = 50
rgbChannels = 3
input_shape = (framesToSample, imageWidth, imageHeight, rgbChannels)
num_classes = 5
```

In [34]:
```
model=create_model(input_shape, num_classes,128)
optimiser = optimizers.Adam()
model.compile(optimizer=optimiser, loss='categorical_crossentropy', metrics=['categ
callbacks_list = set_callbacks(model_number,True,True,True,True,'val_categorical_ac
```

In [35]:
```
train_data_generator = VideoDataGenerator(train_path,train_doc, batch_size, imageHe
val_data_generator = VideoDataGenerator(val_path,val_doc, batch_size, imageHeight,

# Use the generator method of the instances to get the generators
```

```
train_generator = train_data_generator.generator()
val_generator = val_data_generator.generator()
```

In [36]:
```
steps_per_epoch ,validation_steps = get_sequence(train_doc,val_doc,batch_size,num_e
```

```
training sequences = 663
validation sequences = 100
epochs = 50
validation_steps 5
steps_per_epoch 34
```

In [37]:
```
model.summary()
```

```
Model: "sequential_1"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv3d_4 (Conv3D)           (None, 30, 100, 100, 16   1312
                             )

 activation_4 (Activation)   (None, 30, 100, 100, 16   0
                             )

 batch_normalization_6 (Bat  (None, 30, 100, 100, 16   64
 chNormalization)            )

 max_pooling3d_4 (MaxPoolin  (None, 15, 50, 50, 16)    0
 g3D)

 conv3d_5 (Conv3D)           (None, 15, 50, 50, 32)    13856

 activation_5 (Activation)   (None, 15, 50, 50, 32)    0

 batch_normalization_7 (Bat  (None, 15, 50, 50, 32)    128
 chNormalization)

 max_pooling3d_5 (MaxPoolin  (None, 7, 25, 25, 32)     0
 g3D)

 conv3d_6 (Conv3D)           (None, 7, 25, 25, 64)     55360

 activation_6 (Activation)   (None, 7, 25, 25, 64)     0

 batch_normalization_8 (Bat  (None, 7, 25, 25, 64)     256
 chNormalization)

 max_pooling3d_6 (MaxPoolin  (None, 3, 12, 12, 64)     0
 g3D)

 conv3d_7 (Conv3D)           (None, 3, 12, 12, 128)    221312

 activation_7 (Activation)   (None, 3, 12, 12, 128)    0

 batch_normalization_9 (Bat  (None, 3, 12, 12, 128)    512
 chNormalization)

 max_pooling3d_7 (MaxPoolin  (None, 1, 6, 6, 128)      0
 g3D)

 flatten_1 (Flatten)         (None, 4608)              0

 dense_3 (Dense)             (None, 128)               589952

 batch_normalization_10 (Ba  (None, 128)               512
 tchNormalization)

 dropout_2 (Dropout)         (None, 128)               0

 dense_4 (Dense)             (None, 128)               16512

 batch_normalization_11 (Ba  (None, 128)               512
 tchNormalization)

 dropout_3 (Dropout)         (None, 128)               0

 dense_5 (Dense)             (None, 5)                 645
```

```
=================================================================
Total params: 900933 (3.44 MB)
Trainable params: 899941 (3.43 MB)
Non-trainable params: 992 (3.88 KB)
_________________________________________________________________
```

In [38]:
```
history=model.fit(train_generator, epochs=num_epochs, verbose=1,steps_per_epoch=ste
                  callbacks=callbacks_list, validation_data=val_generator,
                      validation_steps=validation_steps,class_weight=None, worker
                 )
```

```
Epoch 1/50
34/34 [==============================] - ETA: 0s - loss: 1.6326 - categorical_accu
racy: 0.4456
Epoch 1: saving model to models/model-number-3/models-model_init-3_2023-11-1310_46
_14.706348\model-00001-1.63260-0.44559-1.76581-0.25000.h5

Epoch 1: val_categorical_accuracy improved from -inf to 0.25000, saving model to m
odels/model-number-3\best_model.h5
34/34 [==============================] - 222s 6s/step - loss: 1.6326 - categorical
_accuracy: 0.4456 - val_loss: 1.7658 - val_categorical_accuracy: 0.2500 - lr: 0.00
10
Epoch 2/50
34/34 [==============================] - ETA: 0s - loss: 1.0012 - categorical_accu
racy: 0.6176
Epoch 2: saving model to models/model-number-3/models-model_init-3_2023-11-1310_46
_14.706348\model-00002-1.00124-0.61765-2.97226-0.16000.h5

Epoch 2: val_categorical_accuracy did not improve from 0.25000
34/34 [==============================] - 221s 7s/step - loss: 1.0012 - categorical
_accuracy: 0.6176 - val_loss: 2.9723 - val_categorical_accuracy: 0.1600 - lr: 0.00
10
Epoch 3/50
34/34 [==============================] - ETA: 0s - loss: 0.7043 - categorical_accu
racy: 0.7397
Epoch 3: saving model to models/model-number-3/models-model_init-3_2023-11-1310_46
_14.706348\model-00003-0.70429-0.73971-3.82638-0.16000.h5

Epoch 3: val_categorical_accuracy did not improve from 0.25000
34/34 [==============================] - 222s 7s/step - loss: 0.7043 - categorical
_accuracy: 0.7397 - val_loss: 3.8264 - val_categorical_accuracy: 0.1600 - lr: 0.00
10
Epoch 4/50
34/34 [==============================] - ETA: 0s - loss: 0.5403 - categorical_accu
racy: 0.7926
Epoch 4: saving model to models/model-number-3/models-model_init-3_2023-11-1310_46
_14.706348\model-00004-0.54035-0.79265-4.20585-0.15000.h5

Epoch 4: val_categorical_accuracy did not improve from 0.25000
34/34 [==============================] - 222s 7s/step - loss: 0.5403 - categorical
_accuracy: 0.7926 - val_loss: 4.2059 - val_categorical_accuracy: 0.1500 - lr: 0.00
10
Epoch 5/50
34/34 [==============================] - ETA: 0s - loss: 0.4065 - categorical_accu
racy: 0.8618
Epoch 5: saving model to models/model-number-3/models-model_init-3_2023-11-1310_46
_14.706348\model-00005-0.40653-0.86176-5.04352-0.13000.h5

Epoch 5: val_categorical_accuracy did not improve from 0.25000

Epoch 5: ReduceLROnPlateau reducing learning rate to 0.00020000000949949026.
34/34 [==============================] - 220s 6s/step - loss: 0.4065 - categorical
_accuracy: 0.8618 - val_loss: 5.0435 - val_categorical_accuracy: 0.1300 - lr: 0.00
10
Epoch 6/50
34/34 [==============================] - ETA: 0s - loss: 0.3287 - categorical_accu
racy: 0.8809
Epoch 6: saving model to models/model-number-3/models-model_init-3_2023-11-1310_46
_14.706348\model-00006-0.32869-0.88088-4.52293-0.16000.h5

Epoch 6: val_categorical_accuracy did not improve from 0.25000
34/34 [==============================] - 220s 6s/step - loss: 0.3287 - categorical
_accuracy: 0.8809 - val_loss: 4.5229 - val_categorical_accuracy: 0.1600 - lr: 2.00
00e-04
Epoch 7/50
```

```
34/34 [==============================] - ETA: 0s - loss: 0.2513 - categorical_accu
racy: 0.9176
Epoch 7: saving model to models/model-number-3/models-model_init-3_2023-11-1310_46
_14.706348\model-00007-0.25125-0.91765-4.05893-0.19000.h5

Epoch 7: val_categorical_accuracy did not improve from 0.25000
34/34 [==============================] - 222s 7s/step - loss: 0.2513 - categorical
_accuracy: 0.9176 - val_loss: 4.0589 - val_categorical_accuracy: 0.1900 - lr: 2.00
00e-04
Epoch 8/50
34/34 [==============================] - ETA: 0s - loss: 0.1982 - categorical_accu
racy: 0.9500
Epoch 8: saving model to models/model-number-3/models-model_init-3_2023-11-1310_46
_14.706348\model-00008-0.19817-0.95000-4.53645-0.13000.h5

Epoch 8: val_categorical_accuracy did not improve from 0.25000
34/34 [==============================] - 222s 7s/step - loss: 0.1982 - categorical
_accuracy: 0.9500 - val_loss: 4.5365 - val_categorical_accuracy: 0.1300 - lr: 2.00
00e-04
Epoch 9/50
34/34 [==============================] - ETA: 0s - loss: 0.2094 - categorical_accu
racy: 0.9309
Epoch 9: saving model to models/model-number-3/models-model_init-3_2023-11-1310_46
_14.706348\model-00009-0.20942-0.93088-3.78857-0.24000.h5

Epoch 9: val_categorical_accuracy did not improve from 0.25000

Epoch 9: ReduceLROnPlateau reducing learning rate to 4.0000001899898055e-05.
34/34 [==============================] - 221s 7s/step - loss: 0.2094 - categorical
_accuracy: 0.9309 - val_loss: 3.7886 - val_categorical_accuracy: 0.2400 - lr: 2.00
00e-04
Epoch 10/50
34/34 [==============================] - ETA: 0s - loss: 0.1953 - categorical_accu
racy: 0.9382
Epoch 10: saving model to models/model-number-3/models-model_init-3_2023-11-1310_4
6_14.706348\model-00010-0.19532-0.93824-3.43500-0.29000.h5

Epoch 10: val_categorical_accuracy improved from 0.25000 to 0.29000, saving model
to models/model-number-3\best_model.h5
34/34 [==============================] - 222s 7s/step - loss: 0.1953 - categorical
_accuracy: 0.9382 - val_loss: 3.4350 - val_categorical_accuracy: 0.2900 - lr: 4.00
00e-05
Epoch 11/50
34/34 [==============================] - ETA: 0s - loss: 0.1615 - categorical_accu
racy: 0.9544
Epoch 11: saving model to models/model-number-3/models-model_init-3_2023-11-1310_4
6_14.706348\model-00011-0.16151-0.95441-2.93277-0.31000.h5

Epoch 11: val_categorical_accuracy improved from 0.29000 to 0.31000, saving model
to models/model-number-3\best_model.h5
34/34 [==============================] - 221s 7s/step - loss: 0.1615 - categorical
_accuracy: 0.9544 - val_loss: 2.9328 - val_categorical_accuracy: 0.3100 - lr: 4.00
00e-05
Epoch 12/50
34/34 [==============================] - ETA: 0s - loss: 0.1517 - categorical_accu
racy: 0.9485
Epoch 12: saving model to models/model-number-3/models-model_init-3_2023-11-1310_4
6_14.706348\model-00012-0.15169-0.94853-2.30629-0.37000.h5

Epoch 12: val_categorical_accuracy improved from 0.31000 to 0.37000, saving model
to models/model-number-3\best_model.h5
34/34 [==============================] - 220s 6s/step - loss: 0.1517 - categorical
_accuracy: 0.9485 - val_loss: 2.3063 - val_categorical_accuracy: 0.3700 - lr: 4.00
00e-05
```

```
Epoch 13/50
34/34 [==============================] - ETA: 0s - loss: 0.1483 - categorical_accu
racy: 0.9603
Epoch 13: saving model to models/model-number-3/models-model_init-3_2023-11-1310_4
6_14.706348\model-00013-0.14830-0.96029-1.61080-0.43000.h5

Epoch 13: val_categorical_accuracy improved from 0.37000 to 0.43000, saving model
to models/model-number-3\best_model.h5
34/34 [==============================] - 220s 6s/step - loss: 0.1483 - categorical
_accuracy: 0.9603 - val_loss: 1.6108 - val_categorical_accuracy: 0.4300 - lr: 4.00
00e-05
Epoch 14/50
34/34 [==============================] - ETA: 0s - loss: 0.1234 - categorical_accu
racy: 0.9676
Epoch 14: saving model to models/model-number-3/models-model_init-3_2023-11-1310_4
6_14.706348\model-00014-0.12342-0.96765-1.30983-0.56000.h5

Epoch 14: val_categorical_accuracy improved from 0.43000 to 0.56000, saving model
to models/model-number-3\best_model.h5
34/34 [==============================] - 222s 7s/step - loss: 0.1234 - categorical
_accuracy: 0.9676 - val_loss: 1.3098 - val_categorical_accuracy: 0.5600 - lr: 4.00
00e-05
Epoch 15/50
34/34 [==============================] - ETA: 0s - loss: 0.1030 - categorical_accu
racy: 0.9765
Epoch 15: saving model to models/model-number-3/models-model_init-3_2023-11-1310_4
6_14.706348\model-00015-0.10304-0.97647-1.22111-0.61000.h5

Epoch 15: val_categorical_accuracy improved from 0.56000 to 0.61000, saving model
to models/model-number-3\best_model.h5
34/34 [==============================] - 221s 7s/step - loss: 0.1030 - categorical
_accuracy: 0.9765 - val_loss: 1.2211 - val_categorical_accuracy: 0.6100 - lr: 4.00
00e-05
Epoch 16/50
34/34 [==============================] - ETA: 0s - loss: 0.1072 - categorical_accu
racy: 0.9691
Epoch 16: saving model to models/model-number-3/models-model_init-3_2023-11-1310_4
6_14.706348\model-00016-0.10724-0.96912-0.86104-0.67000.h5

Epoch 16: val_categorical_accuracy improved from 0.61000 to 0.67000, saving model
to models/model-number-3\best_model.h5
34/34 [==============================] - 222s 7s/step - loss: 0.1072 - categorical
_accuracy: 0.9691 - val_loss: 0.8610 - val_categorical_accuracy: 0.6700 - lr: 4.00
00e-05
Epoch 17/50
34/34 [==============================] - ETA: 0s - loss: 0.1025 - categorical_accu
racy: 0.9735
Epoch 17: saving model to models/model-number-3/models-model_init-3_2023-11-1310_4
6_14.706348\model-00017-0.10250-0.97353-0.72849-0.72000.h5

Epoch 17: val_categorical_accuracy improved from 0.67000 to 0.72000, saving model
to models/model-number-3\best_model.h5
34/34 [==============================] - 220s 6s/step - loss: 0.1025 - categorical
_accuracy: 0.9735 - val_loss: 0.7285 - val_categorical_accuracy: 0.7200 - lr: 4.00
00e-05
Epoch 18/50
34/34 [==============================] - ETA: 0s - loss: 0.0991 - categorical_accu
racy: 0.9765
Epoch 18: saving model to models/model-number-3/models-model_init-3_2023-11-1310_4
6_14.706348\model-00018-0.09909-0.97647-0.57691-0.81000.h5

Epoch 18: val_categorical_accuracy improved from 0.72000 to 0.81000, saving model
to models/model-number-3\best_model.h5
34/34 [==============================] - 221s 7s/step - loss: 0.0991 - categorical
```

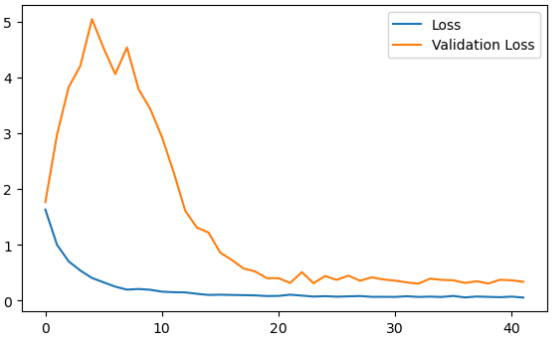
```
_accuracy: 0.9765 - val_loss: 0.5769 - val_categorical_accuracy: 0.8100 - lr: 4.00
00e-05
Epoch 19/50
34/34 [==============================] - ETA: 0s - loss: 0.0950 - categorical_accu
racy: 0.9706
Epoch 19: saving model to models/model-number-3/models-model_init-3_2023-11-1310_4
6_14.706348\model-00019-0.09505-0.97059-0.52418-0.76000.h5

Epoch 19: val_categorical_accuracy did not improve from 0.81000
34/34 [==============================] - 221s 7s/step - loss: 0.0950 - categorical
_accuracy: 0.9706 - val_loss: 0.5242 - val_categorical_accuracy: 0.7600 - lr: 4.00
00e-05
Epoch 20/50
34/34 [==============================] - ETA: 0s - loss: 0.0836 - categorical_accu
racy: 0.9882
Epoch 20: saving model to models/model-number-3/models-model_init-3_2023-11-1310_4
6_14.706348\model-00020-0.08356-0.98824-0.40299-0.87000.h5

Epoch 20: val_categorical_accuracy improved from 0.81000 to 0.87000, saving model
to models/model-number-3\best_model.h5
34/34 [==============================] - 221s 7s/step - loss: 0.0836 - categorical
_accuracy: 0.9882 - val_loss: 0.4030 - val_categorical_accuracy: 0.8700 - lr: 4.00
00e-05
Epoch 21/50
34/34 [==============================] - ETA: 0s - loss: 0.0856 - categorical_accu
racy: 0.9853
Epoch 21: saving model to models/model-number-3/models-model_init-3_2023-11-1310_4
6_14.706348\model-00021-0.08561-0.98529-0.40321-0.85000.h5

Epoch 21: val_categorical_accuracy did not improve from 0.87000
34/34 [==============================] - 222s 7s/step - loss: 0.0856 - categorical
_accuracy: 0.9853 - val_loss: 0.4032 - val_categorical_accuracy: 0.8500 - lr: 4.00
00e-05
Epoch 22/50
34/34 [==============================] - ETA: 0s - loss: 0.1076 - categorical_accu
racy: 0.9721
Epoch 22: saving model to models/model-number-3/models-model_init-3_2023-11-1310_4
6_14.706348\model-00022-0.10765-0.97206-0.31788-0.90000.h5

Epoch 22: val_categorical_accuracy improved from 0.87000 to 0.90000, saving model
to models/model-number-3\best_model.h5
34/34 [==============================] - 222s 7s/step - loss: 0.1076 - categorical
_accuracy: 0.9721 - val_loss: 0.3179 - val_categorical_accuracy: 0.9000 - lr: 4.00
00e-05
Epoch 23/50
34/34 [==============================] - ETA: 0s - loss: 0.0909 - categorical_accu
racy: 0.9750
Epoch 23: saving model to models/model-number-3/models-model_init-3_2023-11-1310_4
6_14.706348\model-00023-0.09095-0.97500-0.51243-0.79000.h5

Epoch 23: val_categorical_accuracy did not improve from 0.90000
34/34 [==============================] - 222s 7s/step - loss: 0.0909 - categorical
_accuracy: 0.9750 - val_loss: 0.5124 - val_categorical_accuracy: 0.7900 - lr: 4.00
00e-05
Epoch 24/50
34/34 [==============================] - ETA: 0s - loss: 0.0740 - categorical_accu
racy: 0.9868
Epoch 24: saving model to models/model-number-3/models-model_init-3_2023-11-1310_4
6_14.706348\model-00024-0.07398-0.98676-0.31374-0.87000.h5

Epoch 24: val_categorical_accuracy did not improve from 0.90000
34/34 [==============================] - 220s 6s/step - loss: 0.0740 - categorical
_accuracy: 0.9868 - val_loss: 0.3137 - val_categorical_accuracy: 0.8700 - lr: 4.00
00e-05
```

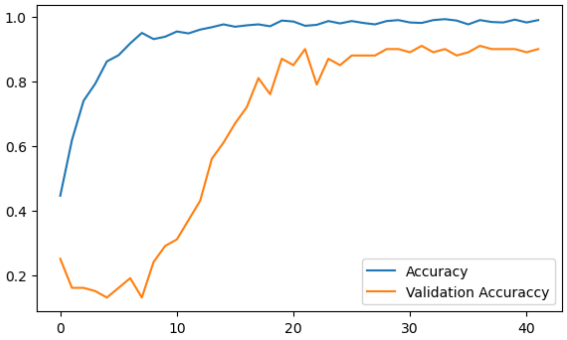
```
Epoch 25/50
34/34 [==============================] - ETA: 0s - loss: 0.0811 - categorical_accu
racy: 0.9794
Epoch 25: saving model to models/model-number-3/models-model_init-3_2023-11-1310_4
6_14.706348\model-00025-0.08106-0.97941-0.44207-0.85000.h5

Epoch 25: val_categorical_accuracy did not improve from 0.90000
34/34 [==============================] - 222s 7s/step - loss: 0.0811 - categorical
_accuracy: 0.9794 - val_loss: 0.4421 - val_categorical_accuracy: 0.8500 - lr: 4.00
00e-05
Epoch 26/50
34/34 [==============================] - ETA: 0s - loss: 0.0717 - categorical_accu
racy: 0.9868
Epoch 26: saving model to models/model-number-3/models-model_init-3_2023-11-1310_4
6_14.706348\model-00026-0.07169-0.98676-0.37369-0.88000.h5

Epoch 26: val_categorical_accuracy did not improve from 0.90000

Epoch 26: ReduceLROnPlateau reducing learning rate to 8.000000525498762e-06.
34/34 [==============================] - 221s 6s/step - loss: 0.0717 - categorical
_accuracy: 0.9868 - val_loss: 0.3737 - val_categorical_accuracy: 0.8800 - lr: 4.00
00e-05
Epoch 27/50
34/34 [==============================] - ETA: 0s - loss: 0.0777 - categorical_accu
racy: 0.9809
Epoch 27: saving model to models/model-number-3/models-model_init-3_2023-11-1310_4
6_14.706348\model-00027-0.07772-0.98088-0.44841-0.88000.h5

Epoch 27: val_categorical_accuracy did not improve from 0.90000
34/34 [==============================] - 221s 7s/step - loss: 0.0777 - categorical
_accuracy: 0.9809 - val_loss: 0.4484 - val_categorical_accuracy: 0.8800 - lr: 8.00
00e-06
Epoch 28/50
34/34 [==============================] - ETA: 0s - loss: 0.0833 - categorical_accu
racy: 0.9765
Epoch 28: saving model to models/model-number-3/models-model_init-3_2023-11-1310_4
6_14.706348\model-00028-0.08333-0.97647-0.35735-0.88000.h5

Epoch 28: val_categorical_accuracy did not improve from 0.90000
34/34 [==============================] - 220s 6s/step - loss: 0.0833 - categorical
_accuracy: 0.9765 - val_loss: 0.3574 - val_categorical_accuracy: 0.8800 - lr: 8.00
00e-06
Epoch 29/50
34/34 [==============================] - ETA: 0s - loss: 0.0688 - categorical_accu
racy: 0.9868
Epoch 29: saving model to models/model-number-3/models-model_init-3_2023-11-1310_4
6_14.706348\model-00029-0.06879-0.98676-0.41820-0.90000.h5

Epoch 29: val_categorical_accuracy did not improve from 0.90000
34/34 [==============================] - 222s 7s/step - loss: 0.0688 - categorical
_accuracy: 0.9868 - val_loss: 0.4182 - val_categorical_accuracy: 0.9000 - lr: 8.00
00e-06
Epoch 30/50
34/34 [==============================] - ETA: 0s - loss: 0.0696 - categorical_accu
racy: 0.9897
Epoch 30: saving model to models/model-number-3/models-model_init-3_2023-11-1310_4
6_14.706348\model-00030-0.06958-0.98971-0.38029-0.90000.h5

Epoch 30: val_categorical_accuracy did not improve from 0.90000

Epoch 30: ReduceLROnPlateau reducing learning rate to 1.6000001778593287e-06.
34/34 [==============================] - 221s 7s/step - loss: 0.0696 - categorical
_accuracy: 0.9897 - val_loss: 0.3803 - val_categorical_accuracy: 0.9000 - lr: 8.00
00e-06
```

```
Epoch 31/50
34/34 [==============================] - ETA: 0s - loss: 0.0678 - categorical_accu
racy: 0.9824
Epoch 31: saving model to models/model-number-3/models-model_init-3_2023-11-1310_4
6_14.706348\model-00031-0.06779-0.98235-0.35945-0.89000.h5

Epoch 31: val_categorical_accuracy did not improve from 0.90000
34/34 [==============================] - 221s 7s/step - loss: 0.0678 - categorical
_accuracy: 0.9824 - val_loss: 0.3595 - val_categorical_accuracy: 0.8900 - lr: 1.60
00e-06
Epoch 32/50
34/34 [==============================] - ETA: 0s - loss: 0.0795 - categorical_accu
racy: 0.9809
Epoch 32: saving model to models/model-number-3/models-model_init-3_2023-11-1310_4
6_14.706348\model-00032-0.07954-0.98088-0.32696-0.91000.h5

Epoch 32: val_categorical_accuracy improved from 0.90000 to 0.91000, saving model
to models/model-number-3\best_model.h5
34/34 [==============================] - 223s 7s/step - loss: 0.0795 - categorical
_accuracy: 0.9809 - val_loss: 0.3270 - val_categorical_accuracy: 0.9100 - lr: 1.60
00e-06
Epoch 33/50
34/34 [==============================] - ETA: 0s - loss: 0.0672 - categorical_accu
racy: 0.9897
Epoch 33: saving model to models/model-number-3/models-model_init-3_2023-11-1310_4
6_14.706348\model-00033-0.06717-0.98971-0.30615-0.89000.h5

Epoch 33: val_categorical_accuracy did not improve from 0.91000
34/34 [==============================] - 222s 7s/step - loss: 0.0672 - categorical
_accuracy: 0.9897 - val_loss: 0.3062 - val_categorical_accuracy: 0.8900 - lr: 1.60
00e-06
Epoch 34/50
34/34 [==============================] - ETA: 0s - loss: 0.0729 - categorical_accu
racy: 0.9926
Epoch 34: saving model to models/model-number-3/models-model_init-3_2023-11-1310_4
6_14.706348\model-00034-0.07291-0.99265-0.39482-0.90000.h5

Epoch 34: val_categorical_accuracy did not improve from 0.91000
34/34 [==============================] - 222s 7s/step - loss: 0.0729 - categorical
_accuracy: 0.9926 - val_loss: 0.3948 - val_categorical_accuracy: 0.9000 - lr: 1.60
00e-06
Epoch 35/50
34/34 [==============================] - ETA: 0s - loss: 0.0667 - categorical_accu
racy: 0.9882
Epoch 35: saving model to models/model-number-3/models-model_init-3_2023-11-1310_4
6_14.706348\model-00035-0.06668-0.98824-0.37333-0.88000.h5

Epoch 35: val_categorical_accuracy did not improve from 0.91000
34/34 [==============================] - 223s 7s/step - loss: 0.0667 - categorical
_accuracy: 0.9882 - val_loss: 0.3733 - val_categorical_accuracy: 0.8800 - lr: 1.60
00e-06
Epoch 36/50
34/34 [==============================] - ETA: 0s - loss: 0.0854 - categorical_accu
racy: 0.9765
Epoch 36: saving model to models/model-number-3/models-model_init-3_2023-11-1310_4
6_14.706348\model-00036-0.08539-0.97647-0.36501-0.89000.h5

Epoch 36: val_categorical_accuracy did not improve from 0.91000

Epoch 36: ReduceLROnPlateau reducing learning rate to 3.200000264769187e-07.
34/34 [==============================] - 222s 7s/step - loss: 0.0854 - categorical
_accuracy: 0.9765 - val_loss: 0.3650 - val_categorical_accuracy: 0.8900 - lr: 1.60
00e-06
Epoch 37/50
```

```
34/34 [==============================] - ETA: 0s - loss: 0.0584 - categorical_accu
racy: 0.9897
Epoch 37: saving model to models/model-number-3/models-model_init-3_2023-11-1310_4
6_14.706348\model-00037-0.05841-0.98971-0.31785-0.91000.h5

Epoch 37: val_categorical_accuracy did not improve from 0.91000
34/34 [==============================] - 221s 7s/step - loss: 0.0584 - categorical
_accuracy: 0.9897 - val_loss: 0.3179 - val_categorical_accuracy: 0.9100 - lr: 3.20
00e-07
Epoch 38/50
34/34 [==============================] - ETA: 0s - loss: 0.0747 - categorical_accu
racy: 0.9838
Epoch 38: saving model to models/model-number-3/models-model_init-3_2023-11-1310_4
6_14.706348\model-00038-0.07475-0.98382-0.34880-0.90000.h5

Epoch 38: val_categorical_accuracy did not improve from 0.91000
34/34 [==============================] - 221s 6s/step - loss: 0.0747 - categorical
_accuracy: 0.9838 - val_loss: 0.3488 - val_categorical_accuracy: 0.9000 - lr: 3.20
00e-07
Epoch 39/50
34/34 [==============================] - ETA: 0s - loss: 0.0685 - categorical_accu
racy: 0.9824
Epoch 39: saving model to models/model-number-3/models-model_init-3_2023-11-1310_4
6_14.706348\model-00039-0.06850-0.98235-0.30715-0.90000.h5

Epoch 39: val_categorical_accuracy did not improve from 0.91000
34/34 [==============================] - 220s 6s/step - loss: 0.0685 - categorical
_accuracy: 0.9824 - val_loss: 0.3072 - val_categorical_accuracy: 0.9000 - lr: 3.20
00e-07
Epoch 40/50
34/34 [==============================] - ETA: 0s - loss: 0.0627 - categorical_accu
racy: 0.9912
Epoch 40: saving model to models/model-number-3/models-model_init-3_2023-11-1310_4
6_14.706348\model-00040-0.06268-0.99118-0.37517-0.90000.h5

Epoch 40: val_categorical_accuracy did not improve from 0.91000

Epoch 40: ReduceLROnPlateau reducing learning rate to 6.400000529538374e-08.
34/34 [==============================] - 222s 7s/step - loss: 0.0627 - categorical
_accuracy: 0.9912 - val_loss: 0.3752 - val_categorical_accuracy: 0.9000 - lr: 3.20
00e-07
Epoch 41/50
34/34 [==============================] - ETA: 0s - loss: 0.0729 - categorical_accu
racy: 0.9824
Epoch 41: saving model to models/model-number-3/models-model_init-3_2023-11-1310_4
6_14.706348\model-00041-0.07286-0.98235-0.36467-0.89000.h5

Epoch 41: val_categorical_accuracy did not improve from 0.91000
34/34 [==============================] - 223s 7s/step - loss: 0.0729 - categorical
_accuracy: 0.9824 - val_loss: 0.3647 - val_categorical_accuracy: 0.8900 - lr: 6.40
00e-08
Epoch 42/50
34/34 [==============================] - ETA: 0s - loss: 0.0563 - categorical_accu
racy: 0.9897
Epoch 42: saving model to models/model-number-3/models-model_init-3_2023-11-1310_4
6_14.706348\model-00042-0.05627-0.98971-0.33855-0.90000.h5

Epoch 42: val_categorical_accuracy did not improve from 0.91000
34/34 [==============================] - 222s 7s/step - loss: 0.0563 - categorical
_accuracy: 0.9897 - val_loss: 0.3386 - val_categorical_accuracy: 0.9000 - lr: 6.40
00e-08
Epoch 42: early stopping
```

In [39]:
```
loss = history.history['loss']
val_loss = history.history['val_loss']
acc = history.history['categorical_accuracy']
val_acc = history.history['val_categorical_accuracy']

plot_model(loss,val_loss,acc,val_acc)
```





Observations

- Model 3 demonstrated a steady increase in training accuracy, peaking at an impressive 99.71%
- The validation accuracy showed a gradual improvement, reaching its highest at 92.00% in epoch 43.
- As with the previous models, there's a notable gap between training and validation accuracy, suggesting overfitting issues.
- The learning rate was reduced multiple times to improve learning efficiency, and the training was stopped early at epoch 43, indicating no further significant improvement was being made.

Model 3 achieved a higher peak in validation accuracy (92.00%) compared to both Model 1 (84.17%) and Model 2 (86.00%), indicating better generalization.

Like Model 2, Model 3 also reached a high training accuracy (over 99%), but it did so while maintaining a slightly better balance with its validation accuracy.

All three models showed signs of overfitting, but Model 3 managed to keep a slightly closer gap between training and validation accuracies.

Model 3 seems to have the best overall performance among the three in terms of balancing high training accuracy with reasonably high validation accuracy, suggesting more effective learning or possibly a more suitable model architecture for the given task.

Based on the above models , lets try 1 more model picking what best seems to work , We will be keeping frames as 30 , batch size as 20 but increase the image size to 150 x 150. Lets see how it performs

Model 4 Conv3d - Batch Size -20, Image Size (150 x 150) , 30 Frames

In [38]:
```
model_number = 4
batch_size = 20
imageHeight = 150
imageWidth = 150
framesToSample = 30
num_epochs = 50
rgbChannels = 3
input_shape = (framesToSample, imageWidth, imageHeight, rgbChannels)
num_classes = 5
```

In [39]:
```
model=create_model(input_shape, num_classes,128)
optimiser = optimizers.Adam()
model.compile(optimizer=optimiser, loss='categorical_crossentropy', metrics=['categ
callbacks_list = set_callbacks(model_number,True,True,True,True,'val_categorical_ac
```

In [40]:
```
train_data_generator = VideoDataGenerator(train_path,train_doc, batch_size, imageHe
val_data_generator = VideoDataGenerator(val_path,val_doc, batch_size, imageHeight,

# Use the generator method of the instances to get the generators
train_generator = train_data_generator.generator()
val_generator = val_data_generator.generator()
```

In [41]:
```
steps_per_epoch ,validation_steps = get_sequence(train_doc,val_doc,batch_size,num_e
```

```
training sequences = 663
validation sequences = 100
epochs = 50
validation_steps 5
steps_per_epoch 34
```

In [ ]:
```

```

In [42]:
```
model.summary()
```

```
Model: "sequential_3"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv3d_12 (Conv3D)          (None, 30, 150, 150, 16   1312
                             )

 activation_12 (Activation)  (None, 30, 150, 150, 16   0
                             )

 batch_normalization_18 (Ba  (None, 30, 150, 150, 16   64
 tchNormalization)           )

 max_pooling3d_12 (MaxPooli  (None, 15, 75, 75, 16)    0
 ng3D)

 conv3d_13 (Conv3D)          (None, 15, 75, 75, 32)    13856

 activation_13 (Activation)  (None, 15, 75, 75, 32)    0

 batch_normalization_19 (Ba  (None, 15, 75, 75, 32)    128
 tchNormalization)

 max_pooling3d_13 (MaxPooli  (None, 7, 37, 37, 32)     0
 ng3D)

 conv3d_14 (Conv3D)          (None, 7, 37, 37, 64)     55360

 activation_14 (Activation)  (None, 7, 37, 37, 64)     0

 batch_normalization_20 (Ba  (None, 7, 37, 37, 64)     256
 tchNormalization)

 max_pooling3d_14 (MaxPooli  (None, 3, 18, 18, 64)     0
 ng3D)

 conv3d_15 (Conv3D)          (None, 3, 18, 18, 128)    221312

 activation_15 (Activation)  (None, 3, 18, 18, 128)    0

 batch_normalization_21 (Ba  (None, 3, 18, 18, 128)    512
 tchNormalization)

 max_pooling3d_15 (MaxPooli  (None, 1, 9, 9, 128)      0
 ng3D)

 flatten_3 (Flatten)         (None, 10368)             0

 dense_9 (Dense)             (None, 128)               1327232

 batch_normalization_22 (Ba  (None, 128)               512
 tchNormalization)

 dropout_6 (Dropout)         (None, 128)               0

 dense_10 (Dense)            (None, 128)               16512

 batch_normalization_23 (Ba  (None, 128)               512
 tchNormalization)

 dropout_7 (Dropout)         (None, 128)               0

 dense_11 (Dense)            (None, 5)                 645
```

```
=================================================================
Total params: 1638213 (6.25 MB)
Trainable params: 1637221 (6.25 MB)
Non-trainable params: 992 (3.88 KB)
_________________________________________________________________
```

In [43]:
```
history=model.fit(train_generator, epochs=num_epochs, verbose=1,steps_per_epoch=ste
                  callbacks=callbacks_list, validation_data=val_generator,
                      validation_steps=validation_steps,class_weight=None, worker
                 )
```

```
Epoch 1/50
34/34 [==============================] - ETA: 0s - loss: 1.7051 - categorical_accu
racy: 0.4044
Epoch 1: saving model to models/model-number-4/models-model_init-4_2023-11-1111_13
_28.838639\model-00001-1.70515-0.40441-1.66511-0.22000.h5

Epoch 1: val_categorical_accuracy improved from -inf to 0.22000, saving model to m
odels/model-number-4\best_model.h5
34/34 [==============================] - 502s 15s/step - loss: 1.7051 - categorica
l_accuracy: 0.4044 - val_loss: 1.6651 - val_categorical_accuracy: 0.2200 - lr: 0.0
010
Epoch 2/50
34/34 [==============================] - ETA: 0s - loss: 0.9782 - categorical_accu
racy: 0.6471
Epoch 2: saving model to models/model-number-4/models-model_init-4_2023-11-1111_13
_28.838639\model-00002-0.97818-0.64706-3.05248-0.21000.h5

Epoch 2: val_categorical_accuracy did not improve from 0.22000
34/34 [==============================] - 497s 15s/step - loss: 0.9782 - categorica
l_accuracy: 0.6471 - val_loss: 3.0525 - val_categorical_accuracy: 0.2100 - lr: 0.0
010
Epoch 3/50
34/34 [==============================] - ETA: 0s - loss: 0.7272 - categorical_accu
racy: 0.7353
Epoch 3: saving model to models/model-number-4/models-model_init-4_2023-11-1111_13
_28.838639\model-00003-0.72723-0.73529-3.15179-0.13000.h5

Epoch 3: val_categorical_accuracy did not improve from 0.22000
34/34 [==============================] - 496s 15s/step - loss: 0.7272 - categorica
l_accuracy: 0.7353 - val_loss: 3.1518 - val_categorical_accuracy: 0.1300 - lr: 0.0
010
Epoch 4/50
34/34 [==============================] - ETA: 0s - loss: 0.6686 - categorical_accu
racy: 0.7603
Epoch 4: saving model to models/model-number-4/models-model_init-4_2023-11-1111_13
_28.838639\model-00004-0.66858-0.76029-4.90880-0.20000.h5

Epoch 4: val_categorical_accuracy did not improve from 0.22000
34/34 [==============================] - 496s 15s/step - loss: 0.6686 - categorica
l_accuracy: 0.7603 - val_loss: 4.9088 - val_categorical_accuracy: 0.2000 - lr: 0.0
010
Epoch 5/50
34/34 [==============================] - ETA: 0s - loss: 0.5677 - categorical_accu
racy: 0.7912
Epoch 5: saving model to models/model-number-4/models-model_init-4_2023-11-1111_13
_28.838639\model-00005-0.56767-0.79118-3.45300-0.25000.h5

Epoch 5: val_categorical_accuracy improved from 0.22000 to 0.25000, saving model t
o models/model-number-4\best_model.h5
34/34 [==============================] - 497s 15s/step - loss: 0.5677 - categorica
l_accuracy: 0.7912 - val_loss: 3.4530 - val_categorical_accuracy: 0.2500 - lr: 0.0
010
Epoch 6/50
34/34 [==============================] - ETA: 0s - loss: 0.4533 - categorical_accu
racy: 0.8544
Epoch 6: saving model to models/model-number-4/models-model_init-4_2023-11-1111_13
_28.838639\model-00006-0.45325-0.85441-3.04917-0.21000.h5

Epoch 6: val_categorical_accuracy did not improve from 0.25000
34/34 [==============================] - 500s 15s/step - loss: 0.4533 - categorica
l_accuracy: 0.8544 - val_loss: 3.0492 - val_categorical_accuracy: 0.2100 - lr: 0.0
010
Epoch 7/50
34/34 [==============================] - ETA: 0s - loss: 0.4081 - categorical_accu
```

```
racy: 0.8485
Epoch 7: saving model to models/model-number-4/models-model_init-4_2023-11-1111_13
_28.838639\model-00007-0.40807-0.84853-4.47531-0.23000.h5

Epoch 7: val_categorical_accuracy did not improve from 0.25000
34/34 [==============================] - 502s 15s/step - loss: 0.4081 - categorica
l_accuracy: 0.8485 - val_loss: 4.4753 - val_categorical_accuracy: 0.2300 - lr: 0.0
010
Epoch 8/50
34/34 [==============================] - ETA: 0s - loss: 0.3228 - categorical_accu
racy: 0.8838
Epoch 8: saving model to models/model-number-4/models-model_init-4_2023-11-1111_13
_28.838639\model-00008-0.32276-0.88382-3.80729-0.16000.h5

Epoch 8: val_categorical_accuracy did not improve from 0.25000
34/34 [==============================] - 429s 13s/step - loss: 0.3228 - categorica
l_accuracy: 0.8838 - val_loss: 3.8073 - val_categorical_accuracy: 0.1600 - lr: 0.0
010
Epoch 9/50
34/34 [==============================] - ETA: 0s - loss: 0.2919 - categorical_accu
racy: 0.9103
Epoch 9: saving model to models/model-number-4/models-model_init-4_2023-11-1111_13
_28.838639\model-00009-0.29187-0.91029-3.47520-0.36000.h5

Epoch 9: val_categorical_accuracy improved from 0.25000 to 0.36000, saving model t
o models/model-number-4\best_model.h5
34/34 [==============================] - 435s 13s/step - loss: 0.2919 - categorica
l_accuracy: 0.9103 - val_loss: 3.4752 - val_categorical_accuracy: 0.3600 - lr: 0.0
010
Epoch 10/50
34/34 [==============================] - ETA: 0s - loss: 0.2522 - categorical_accu
racy: 0.9088
Epoch 10: saving model to models/model-number-4/models-model_init-4_2023-11-1111_1
3_28.838639\model-00010-0.25216-0.90882-2.53893-0.40000.h5

Epoch 10: val_categorical_accuracy improved from 0.36000 to 0.40000, saving model
to models/model-number-4\best_model.h5
34/34 [==============================] - 441s 13s/step - loss: 0.2522 - categorica
l_accuracy: 0.9088 - val_loss: 2.5389 - val_categorical_accuracy: 0.4000 - lr: 0.0
010
Epoch 11/50
34/34 [==============================] - ETA: 0s - loss: 0.2049 - categorical_accu
racy: 0.9221
Epoch 11: saving model to models/model-number-4/models-model_init-4_2023-11-1111_1
3_28.838639\model-00011-0.20492-0.92206-1.33596-0.60000.h5

Epoch 11: val_categorical_accuracy improved from 0.40000 to 0.60000, saving model
to models/model-number-4\best_model.h5
34/34 [==============================] - 435s 13s/step - loss: 0.2049 - categorica
l_accuracy: 0.9221 - val_loss: 1.3360 - val_categorical_accuracy: 0.6000 - lr: 0.0
010
Epoch 12/50
34/34 [==============================] - ETA: 0s - loss: 0.1753 - categorical_accu
racy: 0.9368
Epoch 12: saving model to models/model-number-4/models-model_init-4_2023-11-1111_1
3_28.838639\model-00012-0.17529-0.93676-1.24237-0.63000.h5

Epoch 12: val_categorical_accuracy improved from 0.60000 to 0.63000, saving model
to models/model-number-4\best_model.h5
34/34 [==============================] - 432s 13s/step - loss: 0.1753 - categorica
l_accuracy: 0.9368 - val_loss: 1.2424 - val_categorical_accuracy: 0.6300 - lr: 0.0
010
Epoch 13/50
34/34 [==============================] - ETA: 0s - loss: 0.1579 - categorical_accu
```

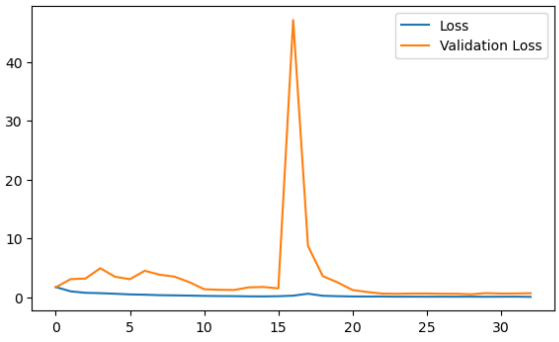
```
racy: 0.9500
Epoch 13: saving model to models/model-number-4/models-model_init-4_2023-11-1111_1
3_28.838639\model-00013-0.15786-0.95000-1.20691-0.66000.h5

Epoch 13: val_categorical_accuracy improved from 0.63000 to 0.66000, saving model
to models/model-number-4\best_model.h5
34/34 [==============================] - 440s 13s/step - loss: 0.1579 - categorica
l_accuracy: 0.9500 - val_loss: 1.2069 - val_categorical_accuracy: 0.6600 - lr: 0.0
010
Epoch 14/50
34/34 [==============================] - ETA: 0s - loss: 0.1243 - categorical_accu
racy: 0.9588
Epoch 14: saving model to models/model-number-4/models-model_init-4_2023-11-1111_1
3_28.838639\model-00014-0.12428-0.95882-1.65132-0.53000.h5

Epoch 14: val_categorical_accuracy did not improve from 0.66000
34/34 [==============================] - 440s 13s/step - loss: 0.1243 - categorica
l_accuracy: 0.9588 - val_loss: 1.6513 - val_categorical_accuracy: 0.5300 - lr: 0.0
010
Epoch 15/50
34/34 [==============================] - ETA: 0s - loss: 0.1138 - categorical_accu
racy: 0.9574
Epoch 15: saving model to models/model-number-4/models-model_init-4_2023-11-1111_1
3_28.838639\model-00015-0.11383-0.95735-1.72204-0.54000.h5

Epoch 15: val_categorical_accuracy did not improve from 0.66000
34/34 [==============================] - 438s 13s/step - loss: 0.1138 - categorica
l_accuracy: 0.9574 - val_loss: 1.7220 - val_categorical_accuracy: 0.5400 - lr: 0.0
010
Epoch 16/50
34/34 [==============================] - ETA: 0s - loss: 0.1478 - categorical_accu
racy: 0.9515
Epoch 16: saving model to models/model-number-4/models-model_init-4_2023-11-1111_1
3_28.838639\model-00016-0.14777-0.95147-1.47119-0.64000.h5

Epoch 16: val_categorical_accuracy did not improve from 0.66000
34/34 [==============================] - 446s 13s/step - loss: 0.1478 - categorica
l_accuracy: 0.9515 - val_loss: 1.4712 - val_categorical_accuracy: 0.6400 - lr: 0.0
010
Epoch 17/50
34/34 [==============================] - ETA: 0s - loss: 0.2421 - categorical_accu
racy: 0.9235
Epoch 17: saving model to models/model-number-4/models-model_init-4_2023-11-1111_1
3_28.838639\model-00017-0.24209-0.92353-47.12043-0.29000.h5

Epoch 17: val_categorical_accuracy did not improve from 0.66000

Epoch 17: ReduceLROnPlateau reducing learning rate to 0.00020000000949949026.
34/34 [==============================] - 441s 13s/step - loss: 0.2421 - categorica
l_accuracy: 0.9235 - val_loss: 47.1204 - val_categorical_accuracy: 0.2900 - lr: 0.
0010
Epoch 18/50
34/34 [==============================] - ETA: 0s - loss: 0.5750 - categorical_accu
racy: 0.8044
Epoch 18: saving model to models/model-number-4/models-model_init-4_2023-11-1111_1
3_28.838639\model-00018-0.57501-0.80441-8.67461-0.26000.h5

Epoch 18: val_categorical_accuracy did not improve from 0.66000
34/34 [==============================] - 437s 13s/step - loss: 0.5750 - categorica
l_accuracy: 0.8044 - val_loss: 8.6746 - val_categorical_accuracy: 0.2600 - lr: 2.0
000e-04
Epoch 19/50
34/34 [==============================] - ETA: 0s - loss: 0.2214 - categorical_accu
racy: 0.9162
```

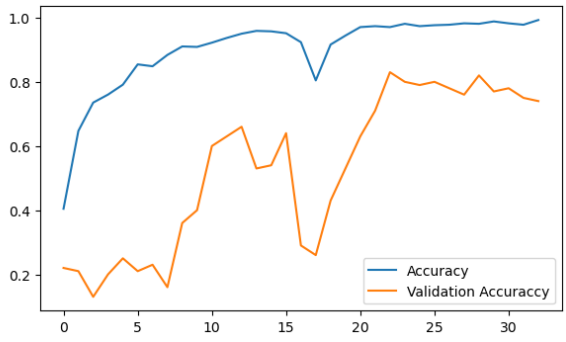
```
Epoch 19: saving model to models/model-number-4/models-model_init-4_2023-11-1111_1
3_28.838639\model-00019-0.22140-0.91618-3.55841-0.43000.h5

Epoch 19: val_categorical_accuracy did not improve from 0.66000
34/34 [==============================] - 430s 13s/step - loss: 0.2214 - categorica
l_accuracy: 0.9162 - val_loss: 3.5584 - val_categorical_accuracy: 0.4300 - lr: 2.0
000e-04
Epoch 20/50
34/34 [==============================] - ETA: 0s - loss: 0.1540 - categorical_accu
racy: 0.9441
Epoch 20: saving model to models/model-number-4/models-model_init-4_2023-11-1111_1
3_28.838639\model-00020-0.15404-0.94412-2.49172-0.53000.h5

Epoch 20: val_categorical_accuracy did not improve from 0.66000
34/34 [==============================] - 430s 13s/step - loss: 0.1540 - categorica
l_accuracy: 0.9441 - val_loss: 2.4917 - val_categorical_accuracy: 0.5300 - lr: 2.0
000e-04
Epoch 21/50
34/34 [==============================] - ETA: 0s - loss: 0.1060 - categorical_accu
racy: 0.9706
Epoch 21: saving model to models/model-number-4/models-model_init-4_2023-11-1111_1
3_28.838639\model-00021-0.10599-0.97059-1.20137-0.63000.h5

Epoch 21: val_categorical_accuracy did not improve from 0.66000

Epoch 21: ReduceLROnPlateau reducing learning rate to 4.0000001899898055e-05.
34/34 [==============================] - 441s 13s/step - loss: 0.1060 - categorica
l_accuracy: 0.9706 - val_loss: 1.2014 - val_categorical_accuracy: 0.6300 - lr: 2.0
000e-04
Epoch 22/50
34/34 [==============================] - ETA: 0s - loss: 0.0954 - categorical_accu
racy: 0.9735
Epoch 22: saving model to models/model-number-4/models-model_init-4_2023-11-1111_1
3_28.838639\model-00022-0.09544-0.97353-0.86138-0.71000.h5

Epoch 22: val_categorical_accuracy improved from 0.66000 to 0.71000, saving model
to models/model-number-4\best_model.h5
34/34 [==============================] - 443s 13s/step - loss: 0.0954 - categorica
l_accuracy: 0.9735 - val_loss: 0.8614 - val_categorical_accuracy: 0.7100 - lr: 4.0
000e-05
Epoch 23/50
34/34 [==============================] - ETA: 0s - loss: 0.1009 - categorical_accu
racy: 0.9706
Epoch 23: saving model to models/model-number-4/models-model_init-4_2023-11-1111_1
3_28.838639\model-00023-0.10093-0.97059-0.59759-0.83000.h5

Epoch 23: val_categorical_accuracy improved from 0.71000 to 0.83000, saving model
to models/model-number-4\best_model.h5
34/34 [==============================] - 437s 13s/step - loss: 0.1009 - categorica
l_accuracy: 0.9706 - val_loss: 0.5976 - val_categorical_accuracy: 0.8300 - lr: 4.0
000e-05
Epoch 24/50
34/34 [==============================] - ETA: 0s - loss: 0.0701 - categorical_accu
racy: 0.9809
Epoch 24: saving model to models/model-number-4/models-model_init-4_2023-11-1111_1
3_28.838639\model-00024-0.07008-0.98088-0.56556-0.80000.h5

Epoch 24: val_categorical_accuracy did not improve from 0.83000
34/34 [==============================] - 430s 13s/step - loss: 0.0701 - categorica
l_accuracy: 0.9809 - val_loss: 0.5656 - val_categorical_accuracy: 0.8000 - lr: 4.0
000e-05
Epoch 25/50
34/34 [==============================] - ETA: 0s - loss: 0.0775 - categorical_accu
racy: 0.9735
```

```
Epoch 25: saving model to models/model-number-4/models-model_init-4_2023-11-1111_1
3_28.838639\model-00025-0.07745-0.97353-0.60175-0.79000.h5

Epoch 25: val_categorical_accuracy did not improve from 0.83000
34/34 [==============================] - 430s 13s/step - loss: 0.0775 - categorica
l_accuracy: 0.9735 - val_loss: 0.6017 - val_categorical_accuracy: 0.7900 - lr: 4.0
000e-05
Epoch 26/50
34/34 [==============================] - ETA: 0s - loss: 0.0673 - categorical_accu
racy: 0.9765
Epoch 26: saving model to models/model-number-4/models-model_init-4_2023-11-1111_1
3_28.838639\model-00026-0.06730-0.97647-0.60382-0.80000.h5

Epoch 26: val_categorical_accuracy did not improve from 0.83000
34/34 [==============================] - 431s 13s/step - loss: 0.0673 - categorica
l_accuracy: 0.9765 - val_loss: 0.6038 - val_categorical_accuracy: 0.8000 - lr: 4.0
000e-05
Epoch 27/50
34/34 [==============================] - ETA: 0s - loss: 0.0739 - categorical_accu
racy: 0.9779
Epoch 27: saving model to models/model-number-4/models-model_init-4_2023-11-1111_1
3_28.838639\model-00027-0.07388-0.97794-0.57168-0.78000.h5

Epoch 27: val_categorical_accuracy did not improve from 0.83000

Epoch 27: ReduceLROnPlateau reducing learning rate to 8.000000525498762e-06.
34/34 [==============================] - 433s 13s/step - loss: 0.0739 - categorica
l_accuracy: 0.9779 - val_loss: 0.5717 - val_categorical_accuracy: 0.7800 - lr: 4.0
000e-05
Epoch 28/50
34/34 [==============================] - ETA: 0s - loss: 0.0648 - categorical_accu
racy: 0.9824
Epoch 28: saving model to models/model-number-4/models-model_init-4_2023-11-1111_1
3_28.838639\model-00028-0.06483-0.98235-0.56688-0.76000.h5

Epoch 28: val_categorical_accuracy did not improve from 0.83000
34/34 [==============================] - 440s 13s/step - loss: 0.0648 - categorica
l_accuracy: 0.9824 - val_loss: 0.5669 - val_categorical_accuracy: 0.7600 - lr: 8.0
000e-06
Epoch 29/50
34/34 [==============================] - ETA: 0s - loss: 0.0742 - categorical_accu
racy: 0.9809
Epoch 29: saving model to models/model-number-4/models-model_init-4_2023-11-1111_1
3_28.838639\model-00029-0.07425-0.98088-0.48183-0.82000.h5

Epoch 29: val_categorical_accuracy did not improve from 0.83000
34/34 [==============================] - 434s 13s/step - loss: 0.0742 - categorica
l_accuracy: 0.9809 - val_loss: 0.4818 - val_categorical_accuracy: 0.8200 - lr: 8.0
000e-06
Epoch 30/50
34/34 [==============================] - ETA: 0s - loss: 0.0578 - categorical_accu
racy: 0.9882
Epoch 30: saving model to models/model-number-4/models-model_init-4_2023-11-1111_1
3_28.838639\model-00030-0.05780-0.98824-0.67276-0.77000.h5

Epoch 30: val_categorical_accuracy did not improve from 0.83000
34/34 [==============================] - 430s 13s/step - loss: 0.0578 - categorica
l_accuracy: 0.9882 - val_loss: 0.6728 - val_categorical_accuracy: 0.7700 - lr: 8.0
000e-06
Epoch 31/50
34/34 [==============================] - ETA: 0s - loss: 0.0721 - categorical_accu
racy: 0.9824
Epoch 31: saving model to models/model-number-4/models-model_init-4_2023-11-1111_1
3_28.838639\model-00031-0.07214-0.98235-0.60166-0.78000.h5
```

```
Epoch 31: val_categorical_accuracy did not improve from 0.83000

Epoch 31: ReduceLROnPlateau reducing learning rate to 1.6000001778593287e-06.
34/34 [==============================] - 430s 13s/step - loss: 0.0721 - categorica
l_accuracy: 0.9824 - val_loss: 0.6017 - val_categorical_accuracy: 0.7800 - lr: 8.0
000e-06
Epoch 32/50
34/34 [==============================] - ETA: 0s - loss: 0.0764 - categorical_accu
racy: 0.9779
Epoch 32: saving model to models/model-number-4/models-model_init-4_2023-11-1111_1
3_28.838639\model-00032-0.07641-0.97794-0.61350-0.75000.h5

Epoch 32: val_categorical_accuracy did not improve from 0.83000
34/34 [==============================] - 430s 13s/step - loss: 0.0764 - categorica
l_accuracy: 0.9779 - val_loss: 0.6135 - val_categorical_accuracy: 0.7500 - lr: 1.6
000e-06
Epoch 33/50
34/34 [==============================] - ETA: 0s - loss: 0.0449 - categorical_accu
racy: 0.9926
Epoch 33: saving model to models/model-number-4/models-model_init-4_2023-11-1111_1
3_28.838639\model-00033-0.04487-0.99265-0.66180-0.74000.h5

Epoch 33: val_categorical_accuracy did not improve from 0.83000
34/34 [==============================] - 431s 13s/step - loss: 0.0449 - categorica
l_accuracy: 0.9926 - val_loss: 0.6618 - val_categorical_accuracy: 0.7400 - lr: 1.6
000e-06
Epoch 33: early stopping
```

In [44]:
```
loss = history.history['loss']
val_loss = history.history['val_loss']
acc = history.history['categorical_accuracy']
val_acc = history.history['val_categorical_accuracy']

plot_model(loss,val_loss,acc,val_acc)
```





Observations

Based on the performance metrics of the previous models, it's observed that Model 3 outperforms the others with a validation accuracy of 91%, suggesting a good balance between model complexity and ability to generalize. However, there is still a discrepancy between training and validation accuracy, indicating potential overfitting.

For further experimentation, we would be changes below : a) Image Size - Images that are too large fails to perform well as compare to others but the image size should be good enough to capture the information. We will choose it to be 110 x 110

b)Batch Size to be kept as 22

c) Increasing the density of the neurons in the dense layers to 136 could potentially capture more complex patterns without significantly increasing the risk of overfitting.

In [46]:
```
model_number = 5
batch_size = 22
imageHeight = 110
imageWidth = 110
framesToSample = 30
num_epochs = 50
rgbChannels = 3
input_shape = (framesToSample, imageWidth, imageHeight, rgbChannels)
num_classes = 5
denseNeurons = 136
```

In [47]:
```
model=create_model(input_shape, num_classes,denseNeurons)
optimiser = optimizers.Adam()
model.compile(optimizer=optimiser, loss='categorical_crossentropy', metrics=['categ
callbacks_list = set_callbacks(model_number,True,True,True,True,'val_categorical_ac
```

In [48]:
```
train_data_generator = VideoDataGenerator(train_path,train_doc, batch_size, imageHe
val_data_generator = VideoDataGenerator(val_path,val_doc, batch_size, imageHeight,

# Use the generator method of the instances to get the generators
train_generator = train_data_generator.generator()
val_generator = val_data_generator.generator()
```

In [49]:
```
steps_per_epoch ,validation_steps = get_sequence(train_doc,val_doc,batch_size,num_e
```

```
training sequences = 663
validation sequences = 100
epochs = 50
validation_steps 5
steps_per_epoch 31
```

In [50]:
```
model.summary()
```

```
Model: "sequential_4"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv3d_16 (Conv3D)          (None, 30, 110, 110, 16   1312
                             )

 activation_16 (Activation)  (None, 30, 110, 110, 16   0
                             )

 batch_normalization_24 (Ba  (None, 30, 110, 110, 16   64
 tchNormalization)           )

 max_pooling3d_16 (MaxPooli  (None, 15, 55, 55, 16)    0
 ng3D)

 conv3d_17 (Conv3D)          (None, 15, 55, 55, 32)    13856

 activation_17 (Activation)  (None, 15, 55, 55, 32)    0

 batch_normalization_25 (Ba  (None, 15, 55, 55, 32)    128
 tchNormalization)

 max_pooling3d_17 (MaxPooli  (None, 7, 27, 27, 32)     0
 ng3D)

 conv3d_18 (Conv3D)          (None, 7, 27, 27, 64)     55360

 activation_18 (Activation)  (None, 7, 27, 27, 64)     0

 batch_normalization_26 (Ba  (None, 7, 27, 27, 64)     256
 tchNormalization)

 max_pooling3d_18 (MaxPooli  (None, 3, 13, 13, 64)     0
 ng3D)

 conv3d_19 (Conv3D)          (None, 3, 13, 13, 128)    221312

 activation_19 (Activation)  (None, 3, 13, 13, 128)    0

 batch_normalization_27 (Ba  (None, 3, 13, 13, 128)    512
 tchNormalization)

 max_pooling3d_19 (MaxPooli  (None, 1, 6, 6, 128)      0
 ng3D)

 flatten_4 (Flatten)         (None, 4608)              0

 dense_12 (Dense)            (None, 136)               626824

 batch_normalization_28 (Ba  (None, 136)               544
 tchNormalization)

 dropout_8 (Dropout)         (None, 136)               0

 dense_13 (Dense)            (None, 136)               18632

 batch_normalization_29 (Ba  (None, 136)               544
 tchNormalization)

 dropout_9 (Dropout)         (None, 136)               0

 dense_14 (Dense)            (None, 5)                 685
```

```
=================================================================
Total params: 940029 (3.59 MB)
Trainable params: 939005 (3.58 MB)
Non-trainable params: 1024 (4.00 KB)
_________________________________________________________________
```

In [51]:
```
history=model.fit(train_generator, epochs=num_epochs, verbose=1,steps_per_epoch=ste
                  callbacks=callbacks_list, validation_data=val_generator,
                      validation_steps=validation_steps,class_weight=None, worker
                 )
```

```
Epoch 1/50
31/31 [==============================] - ETA: 0s - loss: 1.7492 - categorical_accu
racy: 0.3886
Epoch 1: saving model to models/model-number-5/models-model_init-5_2023-11-1116_09
_02.108394\model-00001-1.74921-0.38856-1.93527-0.24545.h5

Epoch 1: val_categorical_accuracy improved from -inf to 0.24545, saving model to m
odels/model-number-5\best_model.h5
31/31 [==============================] - 227s 7s/step - loss: 1.7492 - categorical
_accuracy: 0.3886 - val_loss: 1.9353 - val_categorical_accuracy: 0.2455 - lr: 0.00
10
Epoch 2/50
31/31 [==============================] - ETA: 0s - loss: 1.0685 - categorical_accu
racy: 0.5850
Epoch 2: saving model to models/model-number-5/models-model_init-5_2023-11-1116_09
_02.108394\model-00002-1.06847-0.58504-1.89860-0.05455.h5

Epoch 2: val_categorical_accuracy did not improve from 0.24545
31/31 [==============================] - 224s 7s/step - loss: 1.0685 - categorical
_accuracy: 0.5850 - val_loss: 1.8986 - val_categorical_accuracy: 0.0545 - lr: 0.00
10
Epoch 3/50
31/31 [==============================] - ETA: 0s - loss: 0.7738 - categorical_accu
racy: 0.7155
Epoch 3: saving model to models/model-number-5/models-model_init-5_2023-11-1116_09
_02.108394\model-00003-0.77382-0.71554-2.86051-0.09091.h5

Epoch 3: val_categorical_accuracy did not improve from 0.24545
31/31 [==============================] - 226s 7s/step - loss: 0.7738 - categorical
_accuracy: 0.7155 - val_loss: 2.8605 - val_categorical_accuracy: 0.0909 - lr: 0.00
10
Epoch 4/50
31/31 [==============================] - ETA: 0s - loss: 0.6295 - categorical_accu
racy: 0.7654
Epoch 4: saving model to models/model-number-5/models-model_init-5_2023-11-1116_09
_02.108394\model-00004-0.62951-0.76540-4.20804-0.19091.h5

Epoch 4: val_categorical_accuracy did not improve from 0.24545
31/31 [==============================] - 227s 7s/step - loss: 0.6295 - categorical
_accuracy: 0.7654 - val_loss: 4.2080 - val_categorical_accuracy: 0.1909 - lr: 0.00
10
Epoch 5/50
31/31 [==============================] - ETA: 0s - loss: 0.4801 - categorical_accu
racy: 0.8196
Epoch 5: saving model to models/model-number-5/models-model_init-5_2023-11-1116_09
_02.108394\model-00005-0.48005-0.81965-1.02498-0.04545.h5

Epoch 5: val_categorical_accuracy did not improve from 0.24545

Epoch 5: ReduceLROnPlateau reducing learning rate to 0.00020000000949949026.
31/31 [==============================] - 229s 7s/step - loss: 0.4801 - categorical
_accuracy: 0.8196 - val_loss: 1.0250 - val_categorical_accuracy: 0.0455 - lr: 0.00
10
Epoch 6/50
31/31 [==============================] - ETA: 0s - loss: 0.3778 - categorical_accu
racy: 0.8578
Epoch 6: saving model to models/model-number-5/models-model_init-5_2023-11-1116_09
_02.108394\model-00006-0.37778-0.85777-4.89145-0.27273.h5

Epoch 6: val_categorical_accuracy improved from 0.24545 to 0.27273, saving model t
o models/model-number-5\best_model.h5
31/31 [==============================] - 230s 7s/step - loss: 0.3778 - categorical
_accuracy: 0.8578 - val_loss: 4.8914 - val_categorical_accuracy: 0.2727 - lr: 2.00
00e-04
```

```
Epoch 7/50
31/31 [==============================] - ETA: 0s - loss: 0.2626 - categorical_accu
racy: 0.9091
Epoch 7: saving model to models/model-number-5/models-model_init-5_2023-11-1116_09
_02.108394\model-00007-0.26263-0.90909-0.47609-0.02727.h5

Epoch 7: val_categorical_accuracy did not improve from 0.27273
31/31 [==============================] - 225s 7s/step - loss: 0.2626 - categorical
_accuracy: 0.9091 - val_loss: 0.4761 - val_categorical_accuracy: 0.0273 - lr: 2.00
00e-04
Epoch 8/50
31/31 [==============================] - ETA: 0s - loss: 0.2254 - categorical_accu
racy: 0.9252
Epoch 8: saving model to models/model-number-5/models-model_init-5_2023-11-1116_09
_02.108394\model-00008-0.22540-0.92522-3.50696-0.18182.h5

Epoch 8: val_categorical_accuracy did not improve from 0.27273
31/31 [==============================] - 227s 7s/step - loss: 0.2254 - categorical
_accuracy: 0.9252 - val_loss: 3.5070 - val_categorical_accuracy: 0.1818 - lr: 2.00
00e-04
Epoch 9/50
31/31 [==============================] - ETA: 0s - loss: 0.1768 - categorical_accu
racy: 0.9487
Epoch 9: saving model to models/model-number-5/models-model_init-5_2023-11-1116_09
_02.108394\model-00009-0.17680-0.94868-2.78761-0.18182.h5

Epoch 9: val_categorical_accuracy did not improve from 0.27273
31/31 [==============================] - 226s 7s/step - loss: 0.1768 - categorical
_accuracy: 0.9487 - val_loss: 2.7876 - val_categorical_accuracy: 0.1818 - lr: 2.00
00e-04
Epoch 10/50
31/31 [==============================] - ETA: 0s - loss: 0.1883 - categorical_accu
racy: 0.9443
Epoch 10: saving model to models/model-number-5/models-model_init-5_2023-11-1116_0
9_02.108394\model-00010-0.18827-0.94428-1.40600-0.09091.h5

Epoch 10: val_categorical_accuracy did not improve from 0.27273

Epoch 10: ReduceLROnPlateau reducing learning rate to 4.0000001899898055e-05.
31/31 [==============================] - 225s 7s/step - loss: 0.1883 - categorical
_accuracy: 0.9443 - val_loss: 1.4060 - val_categorical_accuracy: 0.0909 - lr: 2.00
00e-04
Epoch 11/50
31/31 [==============================] - ETA: 0s - loss: 0.1513 - categorical_accu
racy: 0.9589
Epoch 11: saving model to models/model-number-5/models-model_init-5_2023-11-1116_0
9_02.108394\model-00011-0.15129-0.95894-3.34128-0.22727.h5

Epoch 11: val_categorical_accuracy did not improve from 0.27273
31/31 [==============================] - 227s 7s/step - loss: 0.1513 - categorical
_accuracy: 0.9589 - val_loss: 3.3413 - val_categorical_accuracy: 0.2273 - lr: 4.00
00e-05
Epoch 12/50
31/31 [==============================] - ETA: 0s - loss: 0.1430 - categorical_accu
racy: 0.9663
Epoch 12: saving model to models/model-number-5/models-model_init-5_2023-11-1116_0
9_02.108394\model-00012-0.14298-0.96628-0.00000-0.00000.h5

Epoch 12: val_categorical_accuracy did not improve from 0.27273
31/31 [==============================] - 224s 7s/step - loss: 0.1430 - categorical
_accuracy: 0.9663 - val_loss: 0.0000e+00 - val_categorical_accuracy: 0.0000e+00 -
lr: 4.0000e-05
Epoch 13/50
31/31 [==============================] - ETA: 0s - loss: 0.1276 - categorical_accu
```

```
racy: 0.9648
Epoch 13: saving model to models/model-number-5/models-model_init-5_2023-11-1116_0
9_02.108394\model-00013-0.12760-0.96481-2.29753-0.30909.h5

Epoch 13: val_categorical_accuracy improved from 0.27273 to 0.30909, saving model
to models/model-number-5\best_model.h5
31/31 [==============================] - 228s 7s/step - loss: 0.1276 - categorical
_accuracy: 0.9648 - val_loss: 2.2975 - val_categorical_accuracy: 0.3091 - lr: 4.00
00e-05
Epoch 14/50
31/31 [==============================] - ETA: 0s - loss: 0.1293 - categorical_accu
racy: 0.9736
Epoch 14: saving model to models/model-number-5/models-model_init-5_2023-11-1116_0
9_02.108394\model-00014-0.12928-0.97361-1.04109-0.21818.h5

Epoch 14: val_categorical_accuracy did not improve from 0.30909
31/31 [==============================] - 226s 7s/step - loss: 0.1293 - categorical
_accuracy: 0.9736 - val_loss: 1.0411 - val_categorical_accuracy: 0.2182 - lr: 4.00
00e-05
Epoch 15/50
31/31 [==============================] - ETA: 0s - loss: 0.1505 - categorical_accu
racy: 0.9545
Epoch 15: saving model to models/model-number-5/models-model_init-5_2023-11-1116_0
9_02.108394\model-00015-0.15047-0.95455-0.88138-0.32727.h5

Epoch 15: val_categorical_accuracy improved from 0.30909 to 0.32727, saving model
to models/model-number-5\best_model.h5
31/31 [==============================] - 226s 7s/step - loss: 0.1505 - categorical
_accuracy: 0.9545 - val_loss: 0.8814 - val_categorical_accuracy: 0.3273 - lr: 4.00
00e-05
Epoch 16/50
31/31 [==============================] - ETA: 0s - loss: 0.1101 - categorical_accu
racy: 0.9721
Epoch 16: saving model to models/model-number-5/models-model_init-5_2023-11-1116_0
9_02.108394\model-00016-0.11012-0.97214-1.10365-0.54545.h5

Epoch 16: val_categorical_accuracy improved from 0.32727 to 0.54545, saving model
to models/model-number-5\best_model.h5
31/31 [==============================] - 228s 7s/step - loss: 0.1101 - categorical
_accuracy: 0.9721 - val_loss: 1.1037 - val_categorical_accuracy: 0.5455 - lr: 4.00
00e-05
Epoch 17/50
31/31 [==============================] - ETA: 0s - loss: 0.0865 - categorical_accu
racy: 0.9883
Epoch 17: saving model to models/model-number-5/models-model_init-5_2023-11-1116_0
9_02.108394\model-00017-0.08650-0.98827-0.28231-0.11818.h5

Epoch 17: val_categorical_accuracy did not improve from 0.54545
31/31 [==============================] - 226s 7s/step - loss: 0.0865 - categorical
_accuracy: 0.9883 - val_loss: 0.2823 - val_categorical_accuracy: 0.1182 - lr: 4.00
00e-05
Epoch 18/50
31/31 [==============================] - ETA: 0s - loss: 0.0985 - categorical_accu
racy: 0.9809
Epoch 18: saving model to models/model-number-5/models-model_init-5_2023-11-1116_0
9_02.108394\model-00018-0.09855-0.98094-0.78838-0.72727.h5

Epoch 18: val_categorical_accuracy improved from 0.54545 to 0.72727, saving model
to models/model-number-5\best_model.h5
31/31 [==============================] - 227s 7s/step - loss: 0.0985 - categorical
_accuracy: 0.9809 - val_loss: 0.7884 - val_categorical_accuracy: 0.7273 - lr: 4.00
00e-05
Epoch 19/50
31/31 [==============================] - ETA: 0s - loss: 0.0978 - categorical_accu
```

```
racy: 0.9853
Epoch 19: saving model to models/model-number-5/models-model_init-5_2023-11-1116_0
9_02.108394\model-00019-0.09780-0.98534-0.09093-0.08182.h5

Epoch 19: val_categorical_accuracy did not improve from 0.72727
31/31 [==============================] - 225s 7s/step - loss: 0.0978 - categorical
_accuracy: 0.9853 - val_loss: 0.0909 - val_categorical_accuracy: 0.0818 - lr: 4.00
00e-05
Epoch 20/50
31/31 [==============================] - ETA: 0s - loss: 0.0878 - categorical_accu
racy: 0.9824
Epoch 20: saving model to models/model-number-5/models-model_init-5_2023-11-1116_0
9_02.108394\model-00020-0.08780-0.98240-0.48489-0.61818.h5

Epoch 20: val_categorical_accuracy did not improve from 0.72727
31/31 [==============================] - 227s 7s/step - loss: 0.0878 - categorical
_accuracy: 0.9824 - val_loss: 0.4849 - val_categorical_accuracy: 0.6182 - lr: 4.00
00e-05
Epoch 21/50
31/31 [==============================] - ETA: 0s - loss: 0.1049 - categorical_accu
racy: 0.9795
Epoch 21: saving model to models/model-number-5/models-model_init-5_2023-11-1116_0
9_02.108394\model-00021-0.10493-0.97947-0.42606-0.55455.h5

Epoch 21: val_categorical_accuracy did not improve from 0.72727
31/31 [==============================] - 235s 8s/step - loss: 0.1049 - categorical
_accuracy: 0.9795 - val_loss: 0.4261 - val_categorical_accuracy: 0.5545 - lr: 4.00
00e-05
Epoch 22/50
31/31 [==============================] - ETA: 0s - loss: 0.0809 - categorical_accu
racy: 0.9795
Epoch 22: saving model to models/model-number-5/models-model_init-5_2023-11-1116_0
9_02.108394\model-00022-0.08086-0.97947-0.26495-0.31818.h5

Epoch 22: val_categorical_accuracy did not improve from 0.72727

Epoch 22: ReduceLROnPlateau reducing learning rate to 8.000000525498762e-06.
31/31 [==============================] - 231s 7s/step - loss: 0.0809 - categorical
_accuracy: 0.9795 - val_loss: 0.2650 - val_categorical_accuracy: 0.3182 - lr: 4.00
00e-05
Epoch 23/50
31/31 [==============================] - ETA: 0s - loss: 0.0921 - categorical_accu
racy: 0.9780
Epoch 23: saving model to models/model-number-5/models-model_init-5_2023-11-1116_0
9_02.108394\model-00023-0.09208-0.97801-0.51427-0.83636.h5

Epoch 23: val_categorical_accuracy improved from 0.72727 to 0.83636, saving model
to models/model-number-5\best_model.h5
31/31 [==============================] - 240s 8s/step - loss: 0.0921 - categorical
_accuracy: 0.9780 - val_loss: 0.5143 - val_categorical_accuracy: 0.8364 - lr: 8.00
00e-06
Epoch 24/50
31/31 [==============================] - ETA: 0s - loss: 0.0892 - categorical_accu
racy: 0.9853
Epoch 24: saving model to models/model-number-5/models-model_init-5_2023-11-1116_0
9_02.108394\model-00024-0.08919-0.98534-0.00000-0.00000.h5

Epoch 24: val_categorical_accuracy did not improve from 0.83636
31/31 [==============================] - 234s 8s/step - loss: 0.0892 - categorical
_accuracy: 0.9853 - val_loss: 0.0000e+00 - val_categorical_accuracy: 0.0000e+00 -
lr: 8.0000e-06
Epoch 25/50
31/31 [==============================] - ETA: 0s - loss: 0.0887 - categorical_accu
racy: 0.9809
```

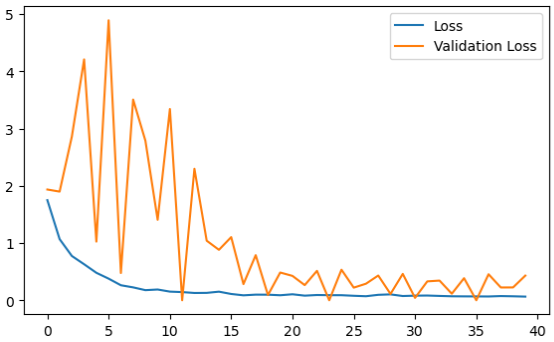
```
Epoch 25: saving model to models/model-number-5/models-model_init-5_2023-11-1116_0
9_02.108394\model-00025-0.08873-0.98094-0.53433-0.81818.h5

Epoch 25: val_categorical_accuracy did not improve from 0.83636
31/31 [==============================] - 236s 8s/step - loss: 0.0887 - categorical
_accuracy: 0.9809 - val_loss: 0.5343 - val_categorical_accuracy: 0.8182 - lr: 8.00
00e-06
Epoch 26/50
31/31 [==============================] - ETA: 0s - loss: 0.0786 - categorical_accu
racy: 0.9868
Epoch 26: saving model to models/model-number-5/models-model_init-5_2023-11-1116_0
9_02.108394\model-00026-0.07859-0.98680-0.22082-0.40000.h5

Epoch 26: val_categorical_accuracy did not improve from 0.83636
31/31 [==============================] - 235s 8s/step - loss: 0.0786 - categorical
_accuracy: 0.9868 - val_loss: 0.2208 - val_categorical_accuracy: 0.4000 - lr: 8.00
00e-06
Epoch 27/50
31/31 [==============================] - ETA: 0s - loss: 0.0707 - categorical_accu
racy: 0.9868
Epoch 27: saving model to models/model-number-5/models-model_init-5_2023-11-1116_0
9_02.108394\model-00027-0.07071-0.98680-0.28974-0.50909.h5

Epoch 27: val_categorical_accuracy did not improve from 0.83636

Epoch 27: ReduceLROnPlateau reducing learning rate to 1.6000001778593287e-06.
31/31 [==============================] - 234s 8s/step - loss: 0.0707 - categorical
_accuracy: 0.9868 - val_loss: 0.2897 - val_categorical_accuracy: 0.5091 - lr: 8.00
00e-06
Epoch 28/50
31/31 [==============================] - ETA: 0s - loss: 0.0954 - categorical_accu
racy: 0.9751
Epoch 28: saving model to models/model-number-5/models-model_init-5_2023-11-1116_0
9_02.108394\model-00028-0.09543-0.97507-0.43254-0.75455.h5

Epoch 28: val_categorical_accuracy did not improve from 0.83636
31/31 [==============================] - 236s 8s/step - loss: 0.0954 - categorical
_accuracy: 0.9751 - val_loss: 0.4325 - val_categorical_accuracy: 0.7545 - lr: 1.60
00e-06
Epoch 29/50
31/31 [==============================] - ETA: 0s - loss: 0.1033 - categorical_accu
racy: 0.9751
Epoch 29: saving model to models/model-number-5/models-model_init-5_2023-11-1116_0
9_02.108394\model-00029-0.10328-0.97507-0.11055-0.16364.h5

Epoch 29: val_categorical_accuracy did not improve from 0.83636
31/31 [==============================] - 236s 8s/step - loss: 0.1033 - categorical
_accuracy: 0.9751 - val_loss: 0.1105 - val_categorical_accuracy: 0.1636 - lr: 1.60
00e-06
Epoch 30/50
31/31 [==============================] - ETA: 0s - loss: 0.0743 - categorical_accu
racy: 0.9839
Epoch 30: saving model to models/model-number-5/models-model_init-5_2023-11-1116_0
9_02.108394\model-00030-0.07435-0.98387-0.46090-0.85455.h5

Epoch 30: val_categorical_accuracy improved from 0.83636 to 0.85455, saving model
to models/model-number-5\best_model.h5
31/31 [==============================] - 237s 8s/step - loss: 0.0743 - categorical
_accuracy: 0.9839 - val_loss: 0.4609 - val_categorical_accuracy: 0.8545 - lr: 1.60
00e-06
Epoch 31/50
31/31 [==============================] - ETA: 0s - loss: 0.0808 - categorical_accu
racy: 0.9809
Epoch 31: saving model to models/model-number-5/models-model_init-5_2023-11-1116_0
```

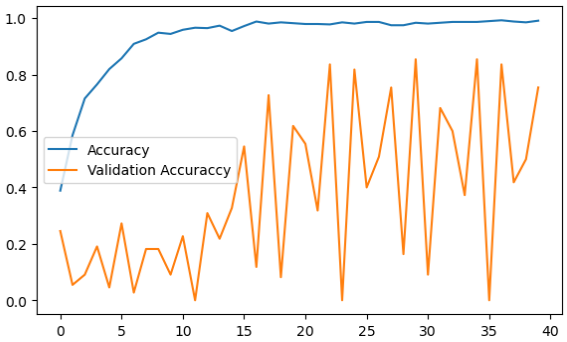
```
9_02.108394\model-00031-0.08081-0.98094-0.04196-0.09091.h5

Epoch 31: val_categorical_accuracy did not improve from 0.85455
31/31 [==============================] - 235s 8s/step - loss: 0.0808 - categorical
_accuracy: 0.9809 - val_loss: 0.0420 - val_categorical_accuracy: 0.0909 - lr: 1.60
00e-06
Epoch 32/50
31/31 [==============================] - ETA: 0s - loss: 0.0829 - categorical_accu
racy: 0.9839
Epoch 32: saving model to models/model-number-5/models-model_init-5_2023-11-1116_0
9_02.108394\model-00032-0.08293-0.98387-0.33030-0.68182.h5

Epoch 32: val_categorical_accuracy did not improve from 0.85455
31/31 [==============================] - 236s 8s/step - loss: 0.0829 - categorical
_accuracy: 0.9839 - val_loss: 0.3303 - val_categorical_accuracy: 0.6818 - lr: 1.60
00e-06
Epoch 33/50
31/31 [==============================] - ETA: 0s - loss: 0.0760 - categorical_accu
racy: 0.9868
Epoch 33: saving model to models/model-number-5/models-model_init-5_2023-11-1116_0
9_02.108394\model-00033-0.07601-0.98680-0.34427-0.60000.h5

Epoch 33: val_categorical_accuracy did not improve from 0.85455
31/31 [==============================] - 233s 8s/step - loss: 0.0760 - categorical
_accuracy: 0.9868 - val_loss: 0.3443 - val_categorical_accuracy: 0.6000 - lr: 1.60
00e-06
Epoch 34/50
31/31 [==============================] - ETA: 0s - loss: 0.0699 - categorical_accu
racy: 0.9868
Epoch 34: saving model to models/model-number-5/models-model_init-5_2023-11-1116_0
9_02.108394\model-00034-0.06988-0.98680-0.11449-0.37273.h5

Epoch 34: val_categorical_accuracy did not improve from 0.85455

Epoch 34: ReduceLROnPlateau reducing learning rate to 3.200000264769187e-07.
31/31 [==============================] - 235s 8s/step - loss: 0.0699 - categorical
_accuracy: 0.9868 - val_loss: 0.1145 - val_categorical_accuracy: 0.3727 - lr: 1.60
00e-06
Epoch 35/50
31/31 [==============================] - ETA: 0s - loss: 0.0683 - categorical_accu
racy: 0.9868
Epoch 35: saving model to models/model-number-5/models-model_init-5_2023-11-1116_0
9_02.108394\model-00035-0.06829-0.98680-0.38594-0.85455.h5

Epoch 35: val_categorical_accuracy did not improve from 0.85455
31/31 [==============================] - 239s 8s/step - loss: 0.0683 - categorical
_accuracy: 0.9868 - val_loss: 0.3859 - val_categorical_accuracy: 0.8545 - lr: 3.20
00e-07
Epoch 36/50
31/31 [==============================] - ETA: 0s - loss: 0.0676 - categorical_accu
racy: 0.9897
Epoch 36: saving model to models/model-number-5/models-model_init-5_2023-11-1116_0
9_02.108394\model-00036-0.06757-0.98974-0.00000-0.00000.h5

Epoch 36: val_categorical_accuracy did not improve from 0.85455
31/31 [==============================] - 237s 8s/step - loss: 0.0676 - categorical
_accuracy: 0.9897 - val_loss: 0.0000e+00 - val_categorical_accuracy: 0.0000e+00 -
lr: 3.2000e-07
Epoch 37/50
31/31 [==============================] - ETA: 0s - loss: 0.0664 - categorical_accu
racy: 0.9927
Epoch 37: saving model to models/model-number-5/models-model_init-5_2023-11-1116_0
9_02.108394\model-00037-0.06640-0.99267-0.45486-0.83636.h5
```

```
Epoch 37: val_categorical_accuracy did not improve from 0.85455
31/31 [==============================] - 236s 8s/step - loss: 0.0664 - categorical
_accuracy: 0.9927 - val_loss: 0.4549 - val_categorical_accuracy: 0.8364 - lr: 3.20
00e-07
Epoch 38/50
31/31 [==============================] - ETA: 0s - loss: 0.0736 - categorical_accu
racy: 0.9883
Epoch 38: saving model to models/model-number-5/models-model_init-5_2023-11-1116_0
9_02.108394\model-00038-0.07361-0.98827-0.22374-0.41818.h5

Epoch 38: val_categorical_accuracy did not improve from 0.85455

Epoch 38: ReduceLROnPlateau reducing learning rate to 6.400000529538374e-08.
31/31 [==============================] - 231s 7s/step - loss: 0.0736 - categorical
_accuracy: 0.9883 - val_loss: 0.2237 - val_categorical_accuracy: 0.4182 - lr: 3.20
00e-07
Epoch 39/50
31/31 [==============================] - ETA: 0s - loss: 0.0697 - categorical_accu
racy: 0.9853
Epoch 39: saving model to models/model-number-5/models-model_init-5_2023-11-1116_0
9_02.108394\model-00039-0.06969-0.98534-0.22464-0.50000.h5

Epoch 39: val_categorical_accuracy did not improve from 0.85455
31/31 [==============================] - 232s 7s/step - loss: 0.0697 - categorical
_accuracy: 0.9853 - val_loss: 0.2246 - val_categorical_accuracy: 0.5000 - lr: 6.40
00e-08
Epoch 40/50
31/31 [==============================] - ETA: 0s - loss: 0.0641 - categorical_accu
racy: 0.9912
Epoch 40: saving model to models/model-number-5/models-model_init-5_2023-11-1116_0
9_02.108394\model-00040-0.06413-0.99120-0.43122-0.75455.h5

Epoch 40: val_categorical_accuracy did not improve from 0.85455
31/31 [==============================] - 233s 8s/step - loss: 0.0641 - categorical
_accuracy: 0.9912 - val_loss: 0.4312 - val_categorical_accuracy: 0.7545 - lr: 6.40
00e-08
Epoch 40: early stopping
```

In [52]:

```
loss = history.history['loss']
val_loss = history.history['val_loss']
acc = history.history['categorical_accuracy']
val_acc = history.history['val_categorical_accuracy']

plot_model(loss,val_loss,acc,val_acc)
```





Observation

- The training starts with a relatively high categorical accuracy of 38.86% which improves consistently over epochs, reaching a high of 99.12%. This indicates that the model is learning and improving its performance on the training set over time.

- The validation categorical accuracy starts at 24.55%, indicating the model's initial performance on unseen data. It experiences a significant fluctuation and peaks at 85.455% before dropping. This peak is lower than that of Model 3, which reached 91%.

- Model 5 shows signs of overfitting, as evidenced by the high training accuracy compared to the validation accuracy. Overfitting is further suggested by the validation accuracy's fluctuations and the fact that the model's performance on the validation set does not improve consistently in line with the training accuracy.

- Early stopping is triggered at epoch 40, suggesting that the model's performance on the validation set was not improving for a number of epochs, which is a safeguard to prevent overfitting and unnecessary computations.

This model shows a strong start in training accuracy, quickly reaching above 98% accuracy by the 16th epoch. However, its validation accuracy is quite volatile, peaking at 85.455% on the 30th epoch and showing significant fluctuations throughout the training process. This suggests that the model may be overfitting to the training data and not generalizing well to the validation set.

Model 3 is superior in terms of validation accuracy and stability throughout training epochs, making it a better model in terms of generalization to new data. Model 5, despite its high training accuracy, does not generalize as effectively as evidenced by its lower and more volatile validation accuracy.

Model 6 (CNN- LSTM)

In [30]:
```
model_number = 6
batch_size = 20
imageHeight = 120
imageWidth = 120
framesToSample = 30
num_epochs = 30
rgbChannels = 3
input_shape = (framesToSample, imageWidth, imageHeight, rgbChannels)
num_classes = 5
lstm_cells=64
dense_neurons = 64
dropout = 0.50
```

In [37]:
```
    model = Sequential()

#     model.add(TimeDistributed(Conv2D(16, (3, 3) , padding='same', activation='rel
#                                 input_shape=input_shape))
#     model.add(TimeDistributed(BatchNormalization()))
#     model.add(TimeDistributed(MaxPooling2D((2, 2))))

    model.add(TimeDistributed(Conv2D(32, (3, 3), activation='relu', padding='same')
                          input_shape=input_shape))
    model.add(TimeDistributed(BatchNormalization()))
    model.add(TimeDistributed(MaxPooling2D((2, 2))))

    model.add(TimeDistributed(Conv2D(64, (3, 3) , padding='same', activation='relu'
    model.add(TimeDistributed(BatchNormalization()))
    model.add(TimeDistributed(MaxPooling2D((2, 2))))
```

```
    model.add(TimeDistributed(Conv2D(128, (3, 3) , padding='same', activation='relu
    model.add(TimeDistributed(BatchNormalization()))
    model.add(TimeDistributed(MaxPooling2D((2, 2))))

#     model.add(TimeDistributed(Conv2D(256, (3, 3) , padding='same', activation='re
#     model.add(TimeDistributed(BatchNormalization()))
#     model.add(TimeDistributed(MaxPooling2D((2, 2))))

    #model.add(TimeDistributed(Conv2D(512, (2, 2) , padding='valid', activation='re
    # model.add(TimeDistributed(BatchNormalization()))
    # model.add(TimeDistributed(MaxPooling2D((2, 2))))

    model.add(TimeDistributed(Flatten()))


    model.add(LSTM(lstm_cells))
    model.add(Dropout(dropout))

    model.add(Dense(dense_neurons,activation='relu'))
    model.add(Dropout(dropout))

    model.add(Dense(num_classes, activation='softmax'))
```

In [38]:
```
optimiser = optimizers.Adam()
model.compile(optimizer=optimiser, loss='categorical_crossentropy', metrics=['categ
callbacks_list = set_callbacks(model_number,True,True,True,True,'val_categorical_ac
```

In [39]:
```
train_data_generator = VideoDataGenerator(train_path,train_doc, batch_size, imageHe
val_data_generator = VideoDataGenerator(val_path,val_doc, batch_size, imageHeight,

# Use the generator method of the instances to get the generators
train_generator = train_data_generator.generator()
val_generator = val_data_generator.generator()
```

In [40]:
```
steps_per_epoch ,validation_steps = get_sequence(train_doc,val_doc,batch_size,num_e
```

```
training sequences = 663
validation sequences = 100
epochs = 30
validation_steps 5
steps_per_epoch 34
```

In [41]:
```
model.summary()
```

```
Model: "sequential_5"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 time_distributed_56 (TimeD  (None, 30, 120, 120, 32   896
 istributed)                 )

 time_distributed_57 (TimeD  (None, 30, 120, 120, 32   128
 istributed)                 )

 time_distributed_58 (TimeD  (None, 30, 60, 60, 32)    0
 istributed)

 time_distributed_59 (TimeD  (None, 30, 60, 60, 64)    18496
 istributed)

 time_distributed_60 (TimeD  (None, 30, 60, 60, 64)    256
 istributed)

 time_distributed_61 (TimeD  (None, 30, 30, 30, 64)    0
 istributed)

 time_distributed_62 (TimeD  (None, 30, 30, 30, 128)   73856
 istributed)

 time_distributed_63 (TimeD  (None, 30, 30, 30, 128)   512
 istributed)

 time_distributed_64 (TimeD  (None, 30, 15, 15, 128)   0
 istributed)

 time_distributed_65 (TimeD  (None, 30, 28800)         0
 istributed)

 lstm_5 (LSTM)               (None, 64)                7389440

 dropout_10 (Dropout)        (None, 64)                0

 dense_10 (Dense)            (None, 64)                4160

 dropout_11 (Dropout)        (None, 64)                0

 dense_11 (Dense)            (None, 5)                 325

=================================================================
Total params: 7488069 (28.56 MB)
Trainable params: 7487621 (28.56 MB)
Non-trainable params: 448 (1.75 KB)
_________________________________________________________________
```

In [42]:
```
history=model.fit(train_generator, epochs=num_epochs, verbose=1,steps_per_epoch=ste
                  callbacks=callbacks_list, validation_data=val_generator,
                      validation_steps=validation_steps,class_weight=None, worker
                  )
```

```
Epoch 1/30
34/34 [==============================] - ETA: 0s - loss: 1.7712 - categorical_accu
racy: 0.1853
Epoch 1: saving model to models/model-number-6/models-model_init-6_2023-11-1209_53
_30.057342\model-00001-1.77117-0.18529-1.66580-0.20000.h5

Epoch 1: val_categorical_accuracy improved from -inf to 0.20000, saving model to m
odels/model-number-6\best_model.h5
34/34 [==============================] - 648s 19s/step - loss: 1.7712 - categorica
l_accuracy: 0.1853 - val_loss: 1.6658 - val_categorical_accuracy: 0.2000 - lr: 0.0
010
Epoch 2/30
34/34 [==============================] - ETA: 0s - loss: 1.6895 - categorical_accu
racy: 0.2103
Epoch 2: saving model to models/model-number-6/models-model_init-6_2023-11-1209_53
_30.057342\model-00002-1.68951-0.21029-1.67783-0.19000.h5

Epoch 2: val_categorical_accuracy did not improve from 0.20000
34/34 [==============================] - 643s 19s/step - loss: 1.6895 - categorica
l_accuracy: 0.2103 - val_loss: 1.6778 - val_categorical_accuracy: 0.1900 - lr: 0.0
010
Epoch 3/30
34/34 [==============================] - ETA: 0s - loss: 1.6448 - categorical_accu
racy: 0.2588
Epoch 3: saving model to models/model-number-6/models-model_init-6_2023-11-1209_53
_30.057342\model-00003-1.64484-0.25882-1.66996-0.22000.h5

Epoch 3: val_categorical_accuracy improved from 0.20000 to 0.22000, saving model t
o models/model-number-6\best_model.h5
34/34 [==============================] - 645s 19s/step - loss: 1.6448 - categorica
l_accuracy: 0.2588 - val_loss: 1.6700 - val_categorical_accuracy: 0.2200 - lr: 0.0
010
Epoch 4/30
34/34 [==============================] - ETA: 0s - loss: 1.5528 - categorical_accu
racy: 0.3191
Epoch 4: saving model to models/model-number-6/models-model_init-6_2023-11-1209_53
_30.057342\model-00004-1.55278-0.31912-1.69273-0.18000.h5

Epoch 4: val_categorical_accuracy did not improve from 0.22000
34/34 [==============================] - 268s 8s/step - loss: 1.5528 - categorical
_accuracy: 0.3191 - val_loss: 1.6927 - val_categorical_accuracy: 0.1800 - lr: 0.00
10
Epoch 5/30
34/34 [==============================] - ETA: 0s - loss: 1.5072 - categorical_accu
racy: 0.3338
Epoch 5: saving model to models/model-number-6/models-model_init-6_2023-11-1209_53
_30.057342\model-00005-1.50715-0.33382-1.63568-0.16000.h5

Epoch 5: val_categorical_accuracy did not improve from 0.22000
34/34 [==============================] - 154s 5s/step - loss: 1.5072 - categorical
_accuracy: 0.3338 - val_loss: 1.6357 - val_categorical_accuracy: 0.1600 - lr: 0.00
10
Epoch 6/30
34/34 [==============================] - ETA: 0s - loss: 1.5629 - categorical_accu
racy: 0.2824
Epoch 6: saving model to models/model-number-6/models-model_init-6_2023-11-1209_53
_30.057342\model-00006-1.56293-0.28235-2.01475-0.16000.h5

Epoch 6: val_categorical_accuracy did not improve from 0.22000
34/34 [==============================] - 177s 5s/step - loss: 1.5629 - categorical
_accuracy: 0.2824 - val_loss: 2.0147 - val_categorical_accuracy: 0.1600 - lr: 0.00
10
Epoch 7/30
34/34 [==============================] - ETA: 0s - loss: 1.4998 - categorical_accu
```

```
racy: 0.3338
Epoch 7: saving model to models/model-number-6/models-model_init-6_2023-11-1209_53
_30.057342\model-00007-1.49980-0.33382-1.43656-0.32000.h5

Epoch 7: val_categorical_accuracy improved from 0.22000 to 0.32000, saving model t
o models/model-number-6\best_model.h5
34/34 [==============================] - 164s 5s/step - loss: 1.4998 - categorical
_accuracy: 0.3338 - val_loss: 1.4366 - val_categorical_accuracy: 0.3200 - lr: 0.00
10
Epoch 8/30
34/34 [==============================] - ETA: 0s - loss: 1.5072 - categorical_accu
racy: 0.3426
Epoch 8: saving model to models/model-number-6/models-model_init-6_2023-11-1209_53
_30.057342\model-00008-1.50718-0.34265-1.37364-0.35000.h5

Epoch 8: val_categorical_accuracy improved from 0.32000 to 0.35000, saving model t
o models/model-number-6\best_model.h5
34/34 [==============================] - 164s 5s/step - loss: 1.5072 - categorical
_accuracy: 0.3426 - val_loss: 1.3736 - val_categorical_accuracy: 0.3500 - lr: 0.00
10
Epoch 9/30
34/34 [==============================] - ETA: 0s - loss: 1.5107 - categorical_accu
racy: 0.3324
Epoch 9: saving model to models/model-number-6/models-model_init-6_2023-11-1209_53
_30.057342\model-00009-1.51069-0.33235-1.48972-0.27000.h5

Epoch 9: val_categorical_accuracy did not improve from 0.35000
34/34 [==============================] - 154s 5s/step - loss: 1.5107 - categorical
_accuracy: 0.3324 - val_loss: 1.4897 - val_categorical_accuracy: 0.2700 - lr: 0.00
10
Epoch 10/30
34/34 [==============================] - ETA: 0s - loss: 1.4600 - categorical_accu
racy: 0.3456
Epoch 10: saving model to models/model-number-6/models-model_init-6_2023-11-1209_5
3_30.057342\model-00010-1.46003-0.34559-1.66028-0.25000.h5

Epoch 10: val_categorical_accuracy did not improve from 0.35000
34/34 [==============================] - 149s 4s/step - loss: 1.4600 - categorical
_accuracy: 0.3456 - val_loss: 1.6603 - val_categorical_accuracy: 0.2500 - lr: 0.00
10
Epoch 11/30
34/34 [==============================] - ETA: 0s - loss: 1.4788 - categorical_accu
racy: 0.3544
Epoch 11: saving model to models/model-number-6/models-model_init-6_2023-11-1209_5
3_30.057342\model-00011-1.47881-0.35441-1.48137-0.32000.h5

Epoch 11: val_categorical_accuracy did not improve from 0.35000
34/34 [==============================] - 152s 4s/step - loss: 1.4788 - categorical
_accuracy: 0.3544 - val_loss: 1.4814 - val_categorical_accuracy: 0.3200 - lr: 0.00
10
Epoch 12/30
34/34 [==============================] - ETA: 0s - loss: 1.3953 - categorical_accu
racy: 0.4044
Epoch 12: saving model to models/model-number-6/models-model_init-6_2023-11-1209_5
3_30.057342\model-00012-1.39528-0.40441-1.36449-0.47000.h5

Epoch 12: val_categorical_accuracy improved from 0.35000 to 0.47000, saving model
to models/model-number-6\best_model.h5
34/34 [==============================] - 154s 5s/step - loss: 1.3953 - categorical
_accuracy: 0.4044 - val_loss: 1.3645 - val_categorical_accuracy: 0.4700 - lr: 0.00
10
Epoch 13/30
34/34 [==============================] - ETA: 0s - loss: 1.4651 - categorical_accu
racy: 0.3603
```

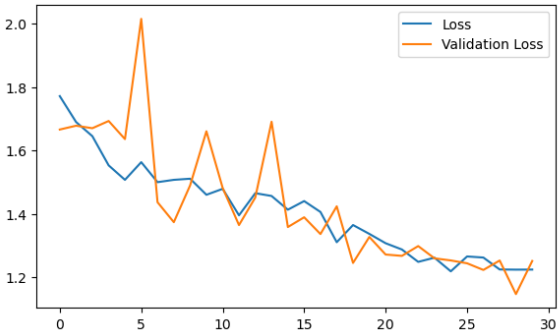
```
Epoch 13: saving model to models/model-number-6/models-model_init-6_2023-11-1209_5
3_30.057342\model-00013-1.46507-0.36029-1.45141-0.37000.h5

Epoch 13: val_categorical_accuracy did not improve from 0.47000
34/34 [==============================] - 157s 5s/step - loss: 1.4651 - categorical
_accuracy: 0.3603 - val_loss: 1.4514 - val_categorical_accuracy: 0.3700 - lr: 0.00
10
Epoch 14/30
34/34 [==============================] - ETA: 0s - loss: 1.4563 - categorical_accu
racy: 0.3647
Epoch 14: saving model to models/model-number-6/models-model_init-6_2023-11-1209_5
3_30.057342\model-00014-1.45628-0.36471-1.69050-0.21000.h5

Epoch 14: val_categorical_accuracy did not improve from 0.47000
34/34 [==============================] - 168s 5s/step - loss: 1.4563 - categorical
_accuracy: 0.3647 - val_loss: 1.6905 - val_categorical_accuracy: 0.2100 - lr: 0.00
10
Epoch 15/30
34/34 [==============================] - ETA: 0s - loss: 1.4130 - categorical_accu
racy: 0.4059
Epoch 15: saving model to models/model-number-6/models-model_init-6_2023-11-1209_5
3_30.057342\model-00015-1.41300-0.40588-1.35830-0.47000.h5

Epoch 15: val_categorical_accuracy did not improve from 0.47000
34/34 [==============================] - 163s 5s/step - loss: 1.4130 - categorical
_accuracy: 0.4059 - val_loss: 1.3583 - val_categorical_accuracy: 0.4700 - lr: 0.00
10
Epoch 16/30
34/34 [==============================] - ETA: 0s - loss: 1.4402 - categorical_accu
racy: 0.3838
Epoch 16: saving model to models/model-number-6/models-model_init-6_2023-11-1209_5
3_30.057342\model-00016-1.44015-0.38382-1.38907-0.43000.h5

Epoch 16: val_categorical_accuracy did not improve from 0.47000

Epoch 16: ReduceLROnPlateau reducing learning rate to 0.00020000000949949026.
34/34 [==============================] - 155s 5s/step - loss: 1.4402 - categorical
_accuracy: 0.3838 - val_loss: 1.3891 - val_categorical_accuracy: 0.4300 - lr: 0.00
10
Epoch 17/30
34/34 [==============================] - ETA: 0s - loss: 1.4058 - categorical_accu
racy: 0.4118
Epoch 17: saving model to models/model-number-6/models-model_init-6_2023-11-1209_5
3_30.057342\model-00017-1.40584-0.41176-1.33620-0.46000.h5

Epoch 17: val_categorical_accuracy did not improve from 0.47000
34/34 [==============================] - 151s 4s/step - loss: 1.4058 - categorical
_accuracy: 0.4118 - val_loss: 1.3362 - val_categorical_accuracy: 0.4600 - lr: 2.00
00e-04
Epoch 18/30
34/34 [==============================] - ETA: 0s - loss: 1.3105 - categorical_accu
racy: 0.4191
Epoch 18: saving model to models/model-number-6/models-model_init-6_2023-11-1209_5
3_30.057342\model-00018-1.31050-0.41912-1.42368-0.30000.h5

Epoch 18: val_categorical_accuracy did not improve from 0.47000
34/34 [==============================] - 148s 4s/step - loss: 1.3105 - categorical
_accuracy: 0.4191 - val_loss: 1.4237 - val_categorical_accuracy: 0.3000 - lr: 2.00
00e-04
Epoch 19/30
34/34 [==============================] - ETA: 0s - loss: 1.3646 - categorical_accu
racy: 0.4132
Epoch 19: saving model to models/model-number-6/models-model_init-6_2023-11-1209_5
3_30.057342\model-00019-1.36463-0.41324-1.24512-0.46000.h5
```

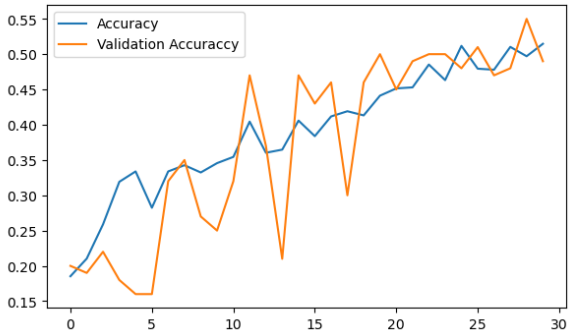
```
Epoch 19: val_categorical_accuracy did not improve from 0.47000
34/34 [==============================] - 146s 4s/step - loss: 1.3646 - categorical
_accuracy: 0.4132 - val_loss: 1.2451 - val_categorical_accuracy: 0.4600 - lr: 2.00
00e-04
Epoch 20/30
34/34 [==============================] - ETA: 0s - loss: 1.3367 - categorical_accu
racy: 0.4412
Epoch 20: saving model to models/model-number-6/models-model_init-6_2023-11-1209_5
3_30.057342\model-00020-1.33672-0.44118-1.32703-0.50000.h5

Epoch 20: val_categorical_accuracy improved from 0.47000 to 0.50000, saving model
to models/model-number-6\best_model.h5
34/34 [==============================] - 146s 4s/step - loss: 1.3367 - categorical
_accuracy: 0.4412 - val_loss: 1.3270 - val_categorical_accuracy: 0.5000 - lr: 2.00
00e-04
Epoch 21/30
34/34 [==============================] - ETA: 0s - loss: 1.3073 - categorical_accu
racy: 0.4515
Epoch 21: saving model to models/model-number-6/models-model_init-6_2023-11-1209_5
3_30.057342\model-00021-1.30728-0.45147-1.27163-0.45000.h5

Epoch 21: val_categorical_accuracy did not improve from 0.50000
34/34 [==============================] - 146s 4s/step - loss: 1.3073 - categorical
_accuracy: 0.4515 - val_loss: 1.2716 - val_categorical_accuracy: 0.4500 - lr: 2.00
00e-04
Epoch 22/30
34/34 [==============================] - ETA: 0s - loss: 1.2875 - categorical_accu
racy: 0.4529
Epoch 22: saving model to models/model-number-6/models-model_init-6_2023-11-1209_5
3_30.057342\model-00022-1.28749-0.45294-1.26738-0.49000.h5

Epoch 22: val_categorical_accuracy did not improve from 0.50000
34/34 [==============================] - 146s 4s/step - loss: 1.2875 - categorical
_accuracy: 0.4529 - val_loss: 1.2674 - val_categorical_accuracy: 0.4900 - lr: 2.00
00e-04
Epoch 23/30
34/34 [==============================] - ETA: 0s - loss: 1.2485 - categorical_accu
racy: 0.4853
Epoch 23: saving model to models/model-number-6/models-model_init-6_2023-11-1209_5
3_30.057342\model-00023-1.24848-0.48529-1.29827-0.50000.h5

Epoch 23: val_categorical_accuracy did not improve from 0.50000
34/34 [==============================] - 147s 4s/step - loss: 1.2485 - categorical
_accuracy: 0.4853 - val_loss: 1.2983 - val_categorical_accuracy: 0.5000 - lr: 2.00
00e-04
Epoch 24/30
34/34 [==============================] - ETA: 0s - loss: 1.2617 - categorical_accu
racy: 0.4632
Epoch 24: saving model to models/model-number-6/models-model_init-6_2023-11-1209_5
3_30.057342\model-00024-1.26167-0.46324-1.25962-0.50000.h5

Epoch 24: val_categorical_accuracy did not improve from 0.50000

Epoch 24: ReduceLROnPlateau reducing learning rate to 4.0000001899898055e-05.
34/34 [==============================] - 153s 5s/step - loss: 1.2617 - categorical
_accuracy: 0.4632 - val_loss: 1.2596 - val_categorical_accuracy: 0.5000 - lr: 2.00
00e-04
Epoch 25/30
34/34 [==============================] - ETA: 0s - loss: 1.2187 - categorical_accu
racy: 0.5118
Epoch 25: saving model to models/model-number-6/models-model_init-6_2023-11-1209_5
3_30.057342\model-00025-1.21867-0.51176-1.25298-0.48000.h5
```

```
Epoch 25: val_categorical_accuracy did not improve from 0.50000
34/34 [==============================] - 146s 4s/step - loss: 1.2187 - categorical
_accuracy: 0.5118 - val_loss: 1.2530 - val_categorical_accuracy: 0.4800 - lr: 4.00
00e-05
Epoch 26/30
34/34 [==============================] - ETA: 0s - loss: 1.2656 - categorical_accu
racy: 0.4794
Epoch 26: saving model to models/model-number-6/models-model_init-6_2023-11-1209_5
3_30.057342\model-00026-1.26555-0.47941-1.24397-0.51000.h5

Epoch 26: val_categorical_accuracy improved from 0.50000 to 0.51000, saving model
to models/model-number-6\best_model.h5
34/34 [==============================] - 146s 4s/step - loss: 1.2656 - categorical
_accuracy: 0.4794 - val_loss: 1.2440 - val_categorical_accuracy: 0.5100 - lr: 4.00
00e-05
Epoch 27/30
34/34 [==============================] - ETA: 0s - loss: 1.2621 - categorical_accu
racy: 0.4779
Epoch 27: saving model to models/model-number-6/models-model_init-6_2023-11-1209_5
3_30.057342\model-00027-1.26209-0.47794-1.22299-0.47000.h5

Epoch 27: val_categorical_accuracy did not improve from 0.51000
34/34 [==============================] - 146s 4s/step - loss: 1.2621 - categorical
_accuracy: 0.4779 - val_loss: 1.2230 - val_categorical_accuracy: 0.4700 - lr: 4.00
00e-05
Epoch 28/30
34/34 [==============================] - ETA: 0s - loss: 1.2245 - categorical_accu
racy: 0.5103
Epoch 28: saving model to models/model-number-6/models-model_init-6_2023-11-1209_5
3_30.057342\model-00028-1.22453-0.51029-1.25273-0.48000.h5

Epoch 28: val_categorical_accuracy did not improve from 0.51000
34/34 [==============================] - 147s 4s/step - loss: 1.2245 - categorical
_accuracy: 0.5103 - val_loss: 1.2527 - val_categorical_accuracy: 0.4800 - lr: 4.00
00e-05
Epoch 29/30
34/34 [==============================] - ETA: 0s - loss: 1.2240 - categorical_accu
racy: 0.4971
Epoch 29: saving model to models/model-number-6/models-model_init-6_2023-11-1209_5
3_30.057342\model-00029-1.22397-0.49706-1.14686-0.55000.h5

Epoch 29: val_categorical_accuracy improved from 0.51000 to 0.55000, saving model
to models/model-number-6\best_model.h5
34/34 [==============================] - 147s 4s/step - loss: 1.2240 - categorical
_accuracy: 0.4971 - val_loss: 1.1469 - val_categorical_accuracy: 0.5500 - lr: 4.00
00e-05
Epoch 30/30
34/34 [==============================] - ETA: 0s - loss: 1.2242 - categorical_accu
racy: 0.5147
Epoch 30: saving model to models/model-number-6/models-model_init-6_2023-11-1209_5
3_30.057342\model-00030-1.22420-0.51471-1.25134-0.49000.h5

Epoch 30: val_categorical_accuracy did not improve from 0.55000
34/34 [==============================] - 147s 4s/step - loss: 1.2242 - categorical
_accuracy: 0.5147 - val_loss: 1.2513 - val_categorical_accuracy: 0.4900 - lr: 4.00
00e-05
```

In [43]:

```
loss = history.history['loss']
val_loss = history.history['val_loss']
acc = history.history['categorical_accuracy']
val_acc = history.history['val_categorical_accuracy']

plot_model(loss,val_loss,acc,val_acc)
```





Model 7 (Transfer Learning Using ResNet50)

In [41]:
```
model_number = 7
batch_size = 20
imageHeight = 120
imageWidth = 120
framesToSample = 30
num_epochs = 30
rgbChannels = 3
input_shape = (framesToSample, imageWidth, imageHeight, rgbChannels)
num_classes = 5
lstm_cells=64
dense_neurons = 64
dropout = 0.50
```

In [73]:
```
from tensorflow.keras.applications import ResNet50

resnet_transfer = ResNet50(weights='imagenet', include_top=False) #False means that

def model_transfer(input_shape, num_classes, dense_neurons=64, dropout=0.25):
    model = Sequential()
    model.add(TimeDistributed(resnet_transfer, input_shape=input_shape))

    for layer in model.layers:
        layer.trainable = False

    model.add(TimeDistributed(BatchNormalization()))
    model.add(TimeDistributed(MaxPooling2D((2, 2))))
    model.add(TimeDistributed(Flatten()))

    model.add(TimeDistributed(Dense(dense_neurons, activation='relu')))
    model.add(TimeDistributed(Dropout(dropout)))


    model.add(Flatten())

    model.add(Dense(num_classes, activation='softmax'))

    model.compile(optimizer='adam', loss='categorical_crossentropy', metrics=['cate
    return model
```

In [79]:
```
model = model_transfer(input_shape,5)
```

In [80]:
```
callbacks_list = set_callbacks(model_number,True,True,True,True,'val_categorical_ac
```

In [81]:
```
train_data_generator = VideoDataGenerator(train_path,train_doc, batch_size, imageHe
val_data_generator = VideoDataGenerator(val_path,val_doc, batch_size, imageHeight,

# Use the generator method of the instances to get the generators
```

```
train_generator = train_data_generator.generator()
val_generator = val_data_generator.generator()
```

In [82]:
```
steps_per_epoch ,validation_steps = get_sequence(train_doc,val_doc,batch_size,num_e
```

```
training sequences = 663
validation sequences = 100
epochs = 30
validation_steps 5
steps_per_epoch 34
```

In [83]:
```
model.summary()
```

```
Model: "sequential_13"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 time_distributed_96 (TimeD  (None, 30, 4, 4, 2048)    23587712
 istributed)

 time_distributed_97 (TimeD  (None, 30, 4, 4, 2048)    8192
 istributed)

 time_distributed_98 (TimeD  (None, 30, 2, 2, 2048)    0
 istributed)

 time_distributed_99 (TimeD  (None, 30, 8192)          0
 istributed)

 time_distributed_100 (Time  (None, 30, 64)            524352
 Distributed)

 time_distributed_101 (Time  (None, 30, 64)            0
 Distributed)

 flatten_12 (Flatten)        (None, 1920)              0

 dense_19 (Dense)            (None, 5)                 9605

=================================================================
Total params: 24129861 (92.05 MB)
Trainable params: 538053 (2.05 MB)
Non-trainable params: 23591808 (90.00 MB)
_________________________________________________________________
```

In [84]:
```
history=model.fit(train_generator, epochs=num_epochs, verbose=1,steps_per_epoch=ste
                    callbacks=callbacks_list, validation_data=val_generator,
                        validation_steps=validation_steps,class_weight=None, worker
                   )
```

```
Epoch 1/30
34/34 [==============================] - ETA: 0s - loss: 2.1448 - categorical_accu
racy: 0.2162
Epoch 1: saving model to models/model-number-6/models-model_init-6_2023-11-1120_09
_56.082332\model-00001-2.14479-0.21618-1.58634-0.24000.h5

Epoch 1: val_categorical_accuracy improved from -inf to 0.24000, saving model to m
odels/model-number-6\best_model.h5
34/34 [==============================] - 149s 4s/step - loss: 2.1448 - categorical
_accuracy: 0.2162 - val_loss: 1.5863 - val_categorical_accuracy: 0.2400 - lr: 0.00
10
Epoch 2/30
34/34 [==============================] - ETA: 0s - loss: 1.5199 - categorical_accu
racy: 0.2897
Epoch 2: saving model to models/model-number-6/models-model_init-6_2023-11-1120_09
_56.082332\model-00002-1.51992-0.28971-1.59232-0.32000.h5

Epoch 2: val_categorical_accuracy improved from 0.24000 to 0.32000, saving model t
o models/model-number-6\best_model.h5
34/34 [==============================] - 139s 4s/step - loss: 1.5199 - categorical
_accuracy: 0.2897 - val_loss: 1.5923 - val_categorical_accuracy: 0.3200 - lr: 0.00
10
Epoch 3/30
34/34 [==============================] - ETA: 0s - loss: 1.5170 - categorical_accu
racy: 0.3265
Epoch 3: saving model to models/model-number-6/models-model_init-6_2023-11-1120_09
_56.082332\model-00003-1.51699-0.32647-1.47719-0.34000.h5

Epoch 3: val_categorical_accuracy improved from 0.32000 to 0.34000, saving model t
o models/model-number-6\best_model.h5
34/34 [==============================] - 135s 4s/step - loss: 1.5170 - categorical
_accuracy: 0.3265 - val_loss: 1.4772 - val_categorical_accuracy: 0.3400 - lr: 0.00
10
Epoch 4/30
34/34 [==============================] - ETA: 0s - loss: 1.4676 - categorical_accu
racy: 0.3559
Epoch 4: saving model to models/model-number-6/models-model_init-6_2023-11-1120_09
_56.082332\model-00004-1.46758-0.35588-1.46165-0.41000.h5

Epoch 4: val_categorical_accuracy improved from 0.34000 to 0.41000, saving model t
o models/model-number-6\best_model.h5
34/34 [==============================] - 187s 6s/step - loss: 1.4676 - categorical
_accuracy: 0.3559 - val_loss: 1.4616 - val_categorical_accuracy: 0.4100 - lr: 0.00
10
Epoch 5/30
34/34 [==============================] - ETA: 0s - loss: 1.4499 - categorical_accu
racy: 0.3779
Epoch 5: saving model to models/model-number-6/models-model_init-6_2023-11-1120_09
_56.082332\model-00005-1.44986-0.37794-1.46944-0.38000.h5

Epoch 5: val_categorical_accuracy did not improve from 0.41000
34/34 [==============================] - 194s 6s/step - loss: 1.4499 - categorical
_accuracy: 0.3779 - val_loss: 1.4694 - val_categorical_accuracy: 0.3800 - lr: 0.00
10
Epoch 6/30
34/34 [==============================] - ETA: 0s - loss: 1.3466 - categorical_accu
racy: 0.4206
Epoch 6: saving model to models/model-number-6/models-model_init-6_2023-11-1120_09
_56.082332\model-00006-1.34661-0.42059-1.47903-0.42000.h5

Epoch 6: val_categorical_accuracy improved from 0.41000 to 0.42000, saving model t
o models/model-number-6\best_model.h5
34/34 [==============================] - 140s 4s/step - loss: 1.3466 - categorical
_accuracy: 0.4206 - val_loss: 1.4790 - val_categorical_accuracy: 0.4200 - lr: 0.00
```

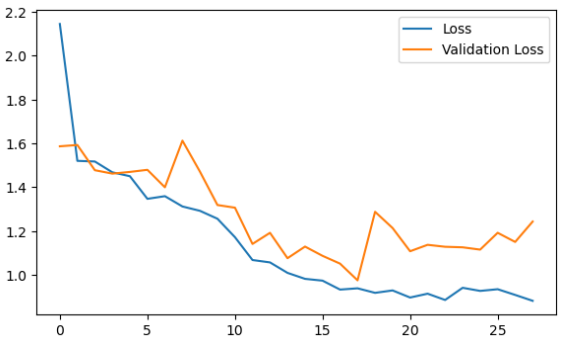
```
10
Epoch 7/30
34/34 [==============================] - ETA: 0s - loss: 1.3587 - categorical_accu
racy: 0.4088
Epoch 7: saving model to models/model-number-6/models-model_init-6_2023-11-1120_09
_56.082332\model-00007-1.35871-0.40882-1.39926-0.46000.h5

Epoch 7: val_categorical_accuracy improved from 0.42000 to 0.46000, saving model t
o models/model-number-6\best_model.h5
34/34 [==============================] - 135s 4s/step - loss: 1.3587 - categorical
_accuracy: 0.4088 - val_loss: 1.3993 - val_categorical_accuracy: 0.4600 - lr: 0.00
10
Epoch 8/30
34/34 [==============================] - ETA: 0s - loss: 1.3117 - categorical_accu
racy: 0.4176
Epoch 8: saving model to models/model-number-6/models-model_init-6_2023-11-1120_09
_56.082332\model-00008-1.31174-0.41765-1.61211-0.23000.h5

Epoch 8: val_categorical_accuracy did not improve from 0.46000
34/34 [==============================] - 136s 4s/step - loss: 1.3117 - categorical
_accuracy: 0.4176 - val_loss: 1.6121 - val_categorical_accuracy: 0.2300 - lr: 0.00
10
Epoch 9/30
34/34 [==============================] - ETA: 0s - loss: 1.2919 - categorical_accu
racy: 0.4574
Epoch 9: saving model to models/model-number-6/models-model_init-6_2023-11-1120_09
_56.082332\model-00009-1.29186-0.45735-1.47069-0.35000.h5

Epoch 9: val_categorical_accuracy did not improve from 0.46000
34/34 [==============================] - 134s 4s/step - loss: 1.2919 - categorical
_accuracy: 0.4574 - val_loss: 1.4707 - val_categorical_accuracy: 0.3500 - lr: 0.00
10
Epoch 10/30
34/34 [==============================] - ETA: 0s - loss: 1.2557 - categorical_accu
racy: 0.4632
Epoch 10: saving model to models/model-number-6/models-model_init-6_2023-11-1120_0
9_56.082332\model-00010-1.25569-0.46324-1.31831-0.46000.h5

Epoch 10: val_categorical_accuracy did not improve from 0.46000
34/34 [==============================] - 133s 4s/step - loss: 1.2557 - categorical
_accuracy: 0.4632 - val_loss: 1.3183 - val_categorical_accuracy: 0.4600 - lr: 0.00
10
Epoch 11/30
34/34 [==============================] - ETA: 0s - loss: 1.1715 - categorical_accu
racy: 0.5103
Epoch 11: saving model to models/model-number-6/models-model_init-6_2023-11-1120_0
9_56.082332\model-00011-1.17147-0.51029-1.30613-0.42000.h5

Epoch 11: val_categorical_accuracy did not improve from 0.46000

Epoch 11: ReduceLROnPlateau reducing learning rate to 0.00020000000949949026.
34/34 [==============================] - 133s 4s/step - loss: 1.1715 - categorical
_accuracy: 0.5103 - val_loss: 1.3061 - val_categorical_accuracy: 0.4200 - lr: 0.00
10
Epoch 12/30
34/34 [==============================] - ETA: 0s - loss: 1.0672 - categorical_accu
racy: 0.5721
Epoch 12: saving model to models/model-number-6/models-model_init-6_2023-11-1120_0
9_56.082332\model-00012-1.06724-0.57206-1.14062-0.59000.h5

Epoch 12: val_categorical_accuracy improved from 0.46000 to 0.59000, saving model
to models/model-number-6\best_model.h5
34/34 [==============================] - 133s 4s/step - loss: 1.0672 - categorical
_accuracy: 0.5721 - val_loss: 1.1406 - val_categorical_accuracy: 0.5900 - lr: 2.00
```

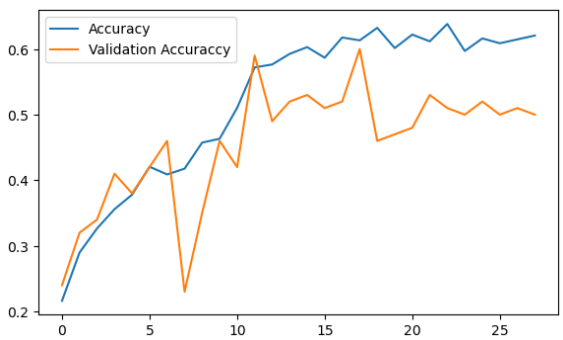
```
00e-04
Epoch 13/30
34/34 [==============================] - ETA: 0s - loss: 1.0564 - categorical_accu
racy: 0.5765
Epoch 13: saving model to models/model-number-6/models-model_init-6_2023-11-1120_0
9_56.082332\model-00013-1.05636-0.57647-1.19142-0.49000.h5

Epoch 13: val_categorical_accuracy did not improve from 0.59000
34/34 [==============================] - 133s 4s/step - loss: 1.0564 - categorical
_accuracy: 0.5765 - val_loss: 1.1914 - val_categorical_accuracy: 0.4900 - lr: 2.00
00e-04
Epoch 14/30
34/34 [==============================] - ETA: 0s - loss: 1.0086 - categorical_accu
racy: 0.5926
Epoch 14: saving model to models/model-number-6/models-model_init-6_2023-11-1120_0
9_56.082332\model-00014-1.00857-0.59265-1.07553-0.52000.h5

Epoch 14: val_categorical_accuracy did not improve from 0.59000
34/34 [==============================] - 134s 4s/step - loss: 1.0086 - categorical
_accuracy: 0.5926 - val_loss: 1.0755 - val_categorical_accuracy: 0.5200 - lr: 2.00
00e-04
Epoch 15/30
34/34 [==============================] - ETA: 0s - loss: 0.9813 - categorical_accu
racy: 0.6029
Epoch 15: saving model to models/model-number-6/models-model_init-6_2023-11-1120_0
9_56.082332\model-00015-0.98132-0.60294-1.12860-0.53000.h5

Epoch 15: val_categorical_accuracy did not improve from 0.59000
34/34 [==============================] - 136s 4s/step - loss: 0.9813 - categorical
_accuracy: 0.6029 - val_loss: 1.1286 - val_categorical_accuracy: 0.5300 - lr: 2.00
00e-04
Epoch 16/30
34/34 [==============================] - ETA: 0s - loss: 0.9731 - categorical_accu
racy: 0.5868
Epoch 16: saving model to models/model-number-6/models-model_init-6_2023-11-1120_0
9_56.082332\model-00016-0.97311-0.58676-1.08636-0.51000.h5

Epoch 16: val_categorical_accuracy did not improve from 0.59000

Epoch 16: ReduceLROnPlateau reducing learning rate to 4.0000001899898055e-05.
34/34 [==============================] - 134s 4s/step - loss: 0.9731 - categorical
_accuracy: 0.5868 - val_loss: 1.0864 - val_categorical_accuracy: 0.5100 - lr: 2.00
00e-04
Epoch 17/30
34/34 [==============================] - ETA: 0s - loss: 0.9323 - categorical_accu
racy: 0.6176
Epoch 17: saving model to models/model-number-6/models-model_init-6_2023-11-1120_0
9_56.082332\model-00017-0.93229-0.61765-1.05077-0.52000.h5

Epoch 17: val_categorical_accuracy did not improve from 0.59000
34/34 [==============================] - 133s 4s/step - loss: 0.9323 - categorical
_accuracy: 0.6176 - val_loss: 1.0508 - val_categorical_accuracy: 0.5200 - lr: 4.00
00e-05
Epoch 18/30
34/34 [==============================] - ETA: 0s - loss: 0.9381 - categorical_accu
racy: 0.6132
Epoch 18: saving model to models/model-number-6/models-model_init-6_2023-11-1120_0
9_56.082332\model-00018-0.93809-0.61324-0.97452-0.60000.h5

Epoch 18: val_categorical_accuracy improved from 0.59000 to 0.60000, saving model
to models/model-number-6\best_model.h5
34/34 [==============================] - 134s 4s/step - loss: 0.9381 - categorical
_accuracy: 0.6132 - val_loss: 0.9745 - val_categorical_accuracy: 0.6000 - lr: 4.00
00e-05
```

```
Epoch 19/30
34/34 [==============================] - ETA: 0s - loss: 0.9174 - categorical_accu
racy: 0.6324
Epoch 19: saving model to models/model-number-6/models-model_init-6_2023-11-1120_0
9_56.082332\model-00019-0.91739-0.63235-1.28744-0.46000.h5

Epoch 19: val_categorical_accuracy did not improve from 0.60000
34/34 [==============================] - 133s 4s/step - loss: 0.9174 - categorical
_accuracy: 0.6324 - val_loss: 1.2874 - val_categorical_accuracy: 0.4600 - lr: 4.00
00e-05
Epoch 20/30
34/34 [==============================] - ETA: 0s - loss: 0.9285 - categorical_accu
racy: 0.6015
Epoch 20: saving model to models/model-number-6/models-model_init-6_2023-11-1120_0
9_56.082332\model-00020-0.92845-0.60147-1.21330-0.47000.h5

Epoch 20: val_categorical_accuracy did not improve from 0.60000
34/34 [==============================] - 133s 4s/step - loss: 0.9285 - categorical
_accuracy: 0.6015 - val_loss: 1.2133 - val_categorical_accuracy: 0.4700 - lr: 4.00
00e-05
Epoch 21/30
34/34 [==============================] - ETA: 0s - loss: 0.8960 - categorical_accu
racy: 0.6221
Epoch 21: saving model to models/model-number-6/models-model_init-6_2023-11-1120_0
9_56.082332\model-00021-0.89603-0.62206-1.10732-0.48000.h5

Epoch 21: val_categorical_accuracy did not improve from 0.60000
34/34 [==============================] - 134s 4s/step - loss: 0.8960 - categorical
_accuracy: 0.6221 - val_loss: 1.1073 - val_categorical_accuracy: 0.4800 - lr: 4.00
00e-05
Epoch 22/30
34/34 [==============================] - ETA: 0s - loss: 0.9136 - categorical_accu
racy: 0.6118
Epoch 22: saving model to models/model-number-6/models-model_init-6_2023-11-1120_0
9_56.082332\model-00022-0.91357-0.61176-1.13664-0.53000.h5

Epoch 22: val_categorical_accuracy did not improve from 0.60000

Epoch 22: ReduceLROnPlateau reducing learning rate to 8.000000525498762e-06.
34/34 [==============================] - 133s 4s/step - loss: 0.9136 - categorical
_accuracy: 0.6118 - val_loss: 1.1366 - val_categorical_accuracy: 0.5300 - lr: 4.00
00e-05
Epoch 23/30
34/34 [==============================] - ETA: 0s - loss: 0.8849 - categorical_accu
racy: 0.6382
Epoch 23: saving model to models/model-number-6/models-model_init-6_2023-11-1120_0
9_56.082332\model-00023-0.88485-0.63824-1.12771-0.51000.h5

Epoch 23: val_categorical_accuracy did not improve from 0.60000
34/34 [==============================] - 133s 4s/step - loss: 0.8849 - categorical
_accuracy: 0.6382 - val_loss: 1.1277 - val_categorical_accuracy: 0.5100 - lr: 8.00
00e-06
Epoch 24/30
34/34 [==============================] - ETA: 0s - loss: 0.9405 - categorical_accu
racy: 0.5971
Epoch 24: saving model to models/model-number-6/models-model_init-6_2023-11-1120_0
9_56.082332\model-00024-0.94047-0.59706-1.12525-0.50000.h5

Epoch 24: val_categorical_accuracy did not improve from 0.60000
34/34 [==============================] - 133s 4s/step - loss: 0.9405 - categorical
_accuracy: 0.5971 - val_loss: 1.1253 - val_categorical_accuracy: 0.5000 - lr: 8.00
00e-06
Epoch 25/30
34/34 [==============================] - ETA: 0s - loss: 0.9263 - categorical_accu
```

```
racy: 0.6162
Epoch 25: saving model to models/model-number-6/models-model_init-6_2023-11-1120_0
9_56.082332\model-00025-0.92627-0.61618-1.11470-0.52000.h5

Epoch 25: val_categorical_accuracy did not improve from 0.60000
34/34 [==============================] - 137s 4s/step - loss: 0.9263 - categorical
_accuracy: 0.6162 - val_loss: 1.1147 - val_categorical_accuracy: 0.5200 - lr: 8.00
00e-06
Epoch 26/30
34/34 [==============================] - ETA: 0s - loss: 0.9340 - categorical_accu
racy: 0.6088
Epoch 26: saving model to models/model-number-6/models-model_init-6_2023-11-1120_0
9_56.082332\model-00026-0.93398-0.60882-1.19154-0.50000.h5

Epoch 26: val_categorical_accuracy did not improve from 0.60000

Epoch 26: ReduceLROnPlateau reducing learning rate to 1.6000001778593287e-06.
34/34 [==============================] - 140s 4s/step - loss: 0.9340 - categorical
_accuracy: 0.6088 - val_loss: 1.1915 - val_categorical_accuracy: 0.5000 - lr: 8.00
00e-06
Epoch 27/30
34/34 [==============================] - ETA: 0s - loss: 0.9079 - categorical_accu
racy: 0.6147
Epoch 27: saving model to models/model-number-6/models-model_init-6_2023-11-1120_0
9_56.082332\model-00027-0.90792-0.61471-1.14976-0.51000.h5

Epoch 27: val_categorical_accuracy did not improve from 0.60000
34/34 [==============================] - 138s 4s/step - loss: 0.9079 - categorical
_accuracy: 0.6147 - val_loss: 1.1498 - val_categorical_accuracy: 0.5100 - lr: 1.60
00e-06
Epoch 28/30
34/34 [==============================] - ETA: 0s - loss: 0.8810 - categorical_accu
racy: 0.6206
Epoch 28: saving model to models/model-number-6/models-model_init-6_2023-11-1120_0
9_56.082332\model-00028-0.88102-0.62059-1.24299-0.50000.h5

Epoch 28: val_categorical_accuracy did not improve from 0.60000
34/34 [==============================] - 134s 4s/step - loss: 0.8810 - categorical
_accuracy: 0.6206 - val_loss: 1.2430 - val_categorical_accuracy: 0.5000 - lr: 1.60
00e-06
Epoch 28: early stopping
```

In [85]:
```
loss = history.history['loss']
val_loss = history.history['val_loss']
acc = history.history['categorical_accuracy']
val_acc = history.history['val_categorical_accuracy']

plot_model(loss,val_loss,acc,val_acc)
```





Model 8

In [58]:
```
model_number = 8
batch_size = 20
imageHeight = 100
imageWidth = 100
framesToSample = 30
num_epochs = 30
rgbChannels = 3
input_shape = (framesToSample, imageWidth, imageHeight, rgbChannels)
num_classes = 5
lstm_cells=64
dense_neurons = 64
dropout = 0.50
```

In [59]:
```
from keras.models import Sequential
from keras.layers import TimeDistributed, Conv2D, MaxPooling2D, Flatten, BatchNorma
from keras import optimizers

def GRU_LSTM_model(input_shape, num_classes, lstm_cells=64, dense_neurons=64, dropo

    model = Sequential()

    model.add(TimeDistributed(Conv2D(16, (3, 3), padding='same', activation='relu')
    model.add(TimeDistributed(BatchNormalization()))
    model.add(TimeDistributed(MaxPooling2D((2, 2))))

    model.add(TimeDistributed(Conv2D(32, (3, 3), padding='same', activation='relu')
    model.add(TimeDistributed(BatchNormalization()))
    model.add(TimeDistributed(MaxPooling2D((2, 2))))

    model.add(TimeDistributed(Conv2D(64, (3, 3), padding='same', activation='relu')
    model.add(TimeDistributed(BatchNormalization()))
    model.add(TimeDistributed(MaxPooling2D((2, 2))))

    model.add(TimeDistributed(Conv2D(128, (3, 3), padding='same', activation='relu'
    model.add(TimeDistributed(BatchNormalization()))
    model.add(TimeDistributed(MaxPooling2D((2, 2))))

    model.add(TimeDistributed(Conv2D(256, (3, 3), padding='same', activation='relu'
    model.add(TimeDistributed(BatchNormalization()))
    model.add(TimeDistributed(MaxPooling2D((2, 2))))

    model.add(TimeDistributed(Flatten()))

    # Combine GRU and LSTM layers
    model.add(GRU(lstm_cells, return_sequences=True))
    model.add(LSTM(lstm_cells))
    model.add(Dropout(dropout))

    model.add(Dense(dense_neurons, activation='relu'))
    model.add(Dropout(dropout))

    model.add(Dense(num_classes, activation='softmax'))

    optimiser = optimizers.Adam()
    model.compile(optimizer=optimiser, loss='categorical_crossentropy', metrics=['c
    return model
```

In [60]:
```
model = GRU_LSTM_model(input_shape,num_classes)
```

In [61]:
```
callbacks_list = set_callbacks(model_number,True,True,True,True,'val_categorical_ac
```

In [62]:
```
train_data_generator = VideoDataGenerator(train_path,train_doc, batch_size, imageHe
val_data_generator = VideoDataGenerator(val_path,val_doc, batch_size, imageHeight,

# Use the generator method of the instances to get the generators
train_generator = train_data_generator.generator()
val_generator = val_data_generator.generator()
```

In [63]:
```
steps_per_epoch ,validation_steps = get_sequence(train_doc,val_doc,batch_size,num_e
```

```
training sequences = 663
validation sequences = 100
epochs = 30
validation_steps 5
steps_per_epoch 34
```

In [64]:
```
model.summary()
```

```
Model: "sequential_4"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 time_distributed_32 (TimeD  (None, 30, 100, 100, 16   448
 istributed)                 )

 time_distributed_33 (TimeD  (None, 30, 100, 100, 16   64
 istributed)                 )

 time_distributed_34 (TimeD  (None, 30, 50, 50, 16)    0
 istributed)

 time_distributed_35 (TimeD  (None, 30, 50, 50, 32)    4640
 istributed)

 time_distributed_36 (TimeD  (None, 30, 50, 50, 32)    128
 istributed)

 time_distributed_37 (TimeD  (None, 30, 25, 25, 32)    0
 istributed)

 time_distributed_38 (TimeD  (None, 30, 25, 25, 64)    18496
 istributed)

 time_distributed_39 (TimeD  (None, 30, 25, 25, 64)    256
 istributed)

 time_distributed_40 (TimeD  (None, 30, 12, 12, 64)    0
 istributed)

 time_distributed_41 (TimeD  (None, 30, 12, 12, 128)   73856
 istributed)

 time_distributed_42 (TimeD  (None, 30, 12, 12, 128)   512
 istributed)

 time_distributed_43 (TimeD  (None, 30, 6, 6, 128)     0
 istributed)

 time_distributed_44 (TimeD  (None, 30, 6, 6, 256)     295168
 istributed)

 time_distributed_45 (TimeD  (None, 30, 6, 6, 256)     1024
 istributed)

 time_distributed_46 (TimeD  (None, 30, 3, 3, 256)     0
 istributed)

 time_distributed_47 (TimeD  (None, 30, 2304)          0
 istributed)

 gru_2 (GRU)                 (None, 30, 64)            455040

 lstm_2 (LSTM)               (None, 64)                33024

 dropout_8 (Dropout)         (None, 64)                0

 dense_10 (Dense)            (None, 64)                4160

 dropout_9 (Dropout)         (None, 64)                0

 dense_11 (Dense)            (None, 5)                 325
```

```
=================================================================
Total params: 887141 (3.38 MB)
Trainable params: 886149 (3.38 MB)
Non-trainable params: 992 (3.88 KB)
_________________________________________________________________
```

In [65]:
```
history=model.fit(train_generator, epochs=num_epochs, verbose=1,steps_per_epoch=ste
                  callbacks=callbacks_list, validation_data=val_generator,
                      validation_steps=validation_steps,class_weight=None, worker
                 )
```

```
Epoch 1/30
34/34 [==============================] - ETA: 0s - loss: 1.6008 - categorical_accu
racy: 0.2559
Epoch 1: saving model to models/model-number-8/models-model_init-8_2023-11-1321_12
_28.286070\model-00001-1.60082-0.25588-1.63381-0.29000.h5

Epoch 1: val_categorical_accuracy improved from -inf to 0.29000, saving model to m
odels/model-number-8\best_model.h5
34/34 [==============================] - 68s 2s/step - loss: 1.6008 - categorical_
accuracy: 0.2559 - val_loss: 1.6338 - val_categorical_accuracy: 0.2900 - lr: 0.001
0
Epoch 2/30
34/34 [==============================] - ETA: 0s - loss: 1.4410 - categorical_accu
racy: 0.3588
Epoch 2: saving model to models/model-number-8/models-model_init-8_2023-11-1321_12
_28.286070\model-00002-1.44099-0.35882-1.76350-0.19000.h5

Epoch 2: val_categorical_accuracy did not improve from 0.29000
34/34 [==============================] - 70s 2s/step - loss: 1.4410 - categorical_
accuracy: 0.3588 - val_loss: 1.7635 - val_categorical_accuracy: 0.1900 - lr: 0.001
0
Epoch 3/30
34/34 [==============================] - ETA: 0s - loss: 1.2749 - categorical_accu
racy: 0.4721
Epoch 3: saving model to models/model-number-8/models-model_init-8_2023-11-1321_12
_28.286070\model-00003-1.27487-0.47206-1.95972-0.13000.h5

Epoch 3: val_categorical_accuracy did not improve from 0.29000
34/34 [==============================] - 67s 2s/step - loss: 1.2749 - categorical_
accuracy: 0.4721 - val_loss: 1.9597 - val_categorical_accuracy: 0.1300 - lr: 0.001
0
Epoch 4/30
34/34 [==============================] - ETA: 0s - loss: 1.1100 - categorical_accu
racy: 0.5559
Epoch 4: saving model to models/model-number-8/models-model_init-8_2023-11-1321_12
_28.286070\model-00004-1.11000-0.55588-2.03859-0.19000.h5

Epoch 4: val_categorical_accuracy did not improve from 0.29000
34/34 [==============================] - 66s 2s/step - loss: 1.1100 - categorical_
accuracy: 0.5559 - val_loss: 2.0386 - val_categorical_accuracy: 0.1900 - lr: 0.001
0
Epoch 5/30
34/34 [==============================] - ETA: 0s - loss: 1.0855 - categorical_accu
racy: 0.5706
Epoch 5: saving model to models/model-number-8/models-model_init-8_2023-11-1321_12
_28.286070\model-00005-1.08554-0.57059-2.12112-0.22000.h5

Epoch 5: val_categorical_accuracy did not improve from 0.29000

Epoch 5: ReduceLROnPlateau reducing learning rate to 0.00020000000949949026.
34/34 [==============================] - 72s 2s/step - loss: 1.0855 - categorical_
accuracy: 0.5706 - val_loss: 2.1211 - val_categorical_accuracy: 0.2200 - lr: 0.001
0
Epoch 6/30
34/34 [==============================] - ETA: 0s - loss: 0.8739 - categorical_accu
racy: 0.6559
Epoch 6: saving model to models/model-number-8/models-model_init-8_2023-11-1321_12
_28.286070\model-00006-0.87394-0.65588-2.39226-0.21000.h5

Epoch 6: val_categorical_accuracy did not improve from 0.29000
34/34 [==============================] - 67s 2s/step - loss: 0.8739 - categorical_
accuracy: 0.6559 - val_loss: 2.3923 - val_categorical_accuracy: 0.2100 - lr: 2.000
0e-04
Epoch 7/30
```

```
34/34 [==============================] - ETA: 0s - loss: 0.7637 - categorical_accu
racy: 0.7382
Epoch 7: saving model to models/model-number-8/models-model_init-8_2023-11-1321_12
_28.286070\model-00007-0.76373-0.73824-2.42824-0.24000.h5

Epoch 7: val_categorical_accuracy did not improve from 0.29000
34/34 [==============================] - 63s 2s/step - loss: 0.7637 - categorical_
accuracy: 0.7382 - val_loss: 2.4282 - val_categorical_accuracy: 0.2400 - lr: 2.000
0e-04
Epoch 8/30
34/34 [==============================] - ETA: 0s - loss: 0.6518 - categorical_accu
racy: 0.7897
Epoch 8: saving model to models/model-number-8/models-model_init-8_2023-11-1321_12
_28.286070\model-00008-0.65176-0.78971-2.28811-0.23000.h5

Epoch 8: val_categorical_accuracy did not improve from 0.29000
34/34 [==============================] - 62s 2s/step - loss: 0.6518 - categorical_
accuracy: 0.7897 - val_loss: 2.2881 - val_categorical_accuracy: 0.2300 - lr: 2.000
0e-04
Epoch 9/30
34/34 [==============================] - ETA: 0s - loss: 0.5732 - categorical_accu
racy: 0.8265
Epoch 9: saving model to models/model-number-8/models-model_init-8_2023-11-1321_12
_28.286070\model-00009-0.57318-0.82647-1.83308-0.35000.h5

Epoch 9: val_categorical_accuracy improved from 0.29000 to 0.35000, saving model t
o models/model-number-8\best_model.h5
34/34 [==============================] - 61s 2s/step - loss: 0.5732 - categorical_
accuracy: 0.8265 - val_loss: 1.8331 - val_categorical_accuracy: 0.3500 - lr: 2.000
0e-04
Epoch 10/30
34/34 [==============================] - ETA: 0s - loss: 0.5451 - categorical_accu
racy: 0.8235
Epoch 10: saving model to models/model-number-8/models-model_init-8_2023-11-1321_1
2_28.286070\model-00010-0.54507-0.82353-1.70451-0.35000.h5

Epoch 10: val_categorical_accuracy did not improve from 0.35000
34/34 [==============================] - 60s 2s/step - loss: 0.5451 - categorical_
accuracy: 0.8235 - val_loss: 1.7045 - val_categorical_accuracy: 0.3500 - lr: 2.000
0e-04
Epoch 11/30
34/34 [==============================] - ETA: 0s - loss: 0.5199 - categorical_accu
racy: 0.8426
Epoch 11: saving model to models/model-number-8/models-model_init-8_2023-11-1321_1
2_28.286070\model-00011-0.51989-0.84265-1.78886-0.36000.h5

Epoch 11: val_categorical_accuracy improved from 0.35000 to 0.36000, saving model
to models/model-number-8\best_model.h5
34/34 [==============================] - 59s 2s/step - loss: 0.5199 - categorical_
accuracy: 0.8426 - val_loss: 1.7889 - val_categorical_accuracy: 0.3600 - lr: 2.000
0e-04
Epoch 12/30
34/34 [==============================] - ETA: 0s - loss: 0.4152 - categorical_accu
racy: 0.8676
Epoch 12: saving model to models/model-number-8/models-model_init-8_2023-11-1321_1
2_28.286070\model-00012-0.41515-0.86765-1.54658-0.41000.h5

Epoch 12: val_categorical_accuracy improved from 0.36000 to 0.41000, saving model
to models/model-number-8\best_model.h5
34/34 [==============================] - 59s 2s/step - loss: 0.4152 - categorical_
accuracy: 0.8676 - val_loss: 1.5466 - val_categorical_accuracy: 0.4100 - lr: 2.000
0e-04
Epoch 13/30
34/34 [==============================] - ETA: 0s - loss: 0.3836 - categorical_accu
```

```
racy: 0.8985
Epoch 13: saving model to models/model-number-8/models-model_init-8_2023-11-1321_1
2_28.286070\model-00013-0.38361-0.89853-1.58408-0.42000.h5

Epoch 13: val_categorical_accuracy improved from 0.41000 to 0.42000, saving model
to models/model-number-8\best_model.h5
34/34 [==============================] - 61s 2s/step - loss: 0.3836 - categorical_
accuracy: 0.8985 - val_loss: 1.5841 - val_categorical_accuracy: 0.4200 - lr: 2.000
0e-04
Epoch 14/30
34/34 [==============================] - ETA: 0s - loss: 0.3370 - categorical_accu
racy: 0.9029
Epoch 14: saving model to models/model-number-8/models-model_init-8_2023-11-1321_1
2_28.286070\model-00014-0.33703-0.90294-1.26162-0.58000.h5

Epoch 14: val_categorical_accuracy improved from 0.42000 to 0.58000, saving model
to models/model-number-8\best_model.h5
34/34 [==============================] - 59s 2s/step - loss: 0.3370 - categorical_
accuracy: 0.9029 - val_loss: 1.2616 - val_categorical_accuracy: 0.5800 - lr: 2.000
0e-04
Epoch 15/30
34/34 [==============================] - ETA: 0s - loss: 0.2745 - categorical_accu
racy: 0.9191
Epoch 15: saving model to models/model-number-8/models-model_init-8_2023-11-1321_1
2_28.286070\model-00015-0.27447-0.91912-0.98019-0.67000.h5

Epoch 15: val_categorical_accuracy improved from 0.58000 to 0.67000, saving model
to models/model-number-8\best_model.h5
34/34 [==============================] - 60s 2s/step - loss: 0.2745 - categorical_
accuracy: 0.9191 - val_loss: 0.9802 - val_categorical_accuracy: 0.6700 - lr: 2.000
0e-04
Epoch 16/30
34/34 [==============================] - ETA: 0s - loss: 0.2998 - categorical_accu
racy: 0.9206
Epoch 16: saving model to models/model-number-8/models-model_init-8_2023-11-1321_1
2_28.286070\model-00016-0.29981-0.92059-0.88444-0.71000.h5

Epoch 16: val_categorical_accuracy improved from 0.67000 to 0.71000, saving model
to models/model-number-8\best_model.h5
34/34 [==============================] - 61s 2s/step - loss: 0.2998 - categorical_
accuracy: 0.9206 - val_loss: 0.8844 - val_categorical_accuracy: 0.7100 - lr: 2.000
0e-04
Epoch 17/30
34/34 [==============================] - ETA: 0s - loss: 0.2637 - categorical_accu
racy: 0.9353
Epoch 17: saving model to models/model-number-8/models-model_init-8_2023-11-1321_1
2_28.286070\model-00017-0.26373-0.93529-0.88838-0.76000.h5

Epoch 17: val_categorical_accuracy improved from 0.71000 to 0.76000, saving model
to models/model-number-8\best_model.h5
34/34 [==============================] - 60s 2s/step - loss: 0.2637 - categorical_
accuracy: 0.9353 - val_loss: 0.8884 - val_categorical_accuracy: 0.7600 - lr: 2.000
0e-04
Epoch 18/30
34/34 [==============================] - ETA: 0s - loss: 0.2420 - categorical_accu
racy: 0.9500
Epoch 18: saving model to models/model-number-8/models-model_init-8_2023-11-1321_1
2_28.286070\model-00018-0.24201-0.95000-0.95145-0.75000.h5

Epoch 18: val_categorical_accuracy did not improve from 0.76000
34/34 [==============================] - 60s 2s/step - loss: 0.2420 - categorical_
accuracy: 0.9500 - val_loss: 0.9514 - val_categorical_accuracy: 0.7500 - lr: 2.000
0e-04
Epoch 19/30
```

```
34/34 [==============================] - ETA: 0s - loss: 0.1888 - categorical_accu
racy: 0.9500
Epoch 19: saving model to models/model-number-8/models-model_init-8_2023-11-1321_1
2_28.286070\model-00019-0.18883-0.95000-0.82633-0.79000.h5

Epoch 19: val_categorical_accuracy improved from 0.76000 to 0.79000, saving model
to models/model-number-8\best_model.h5
34/34 [==============================] - 62s 2s/step - loss: 0.1888 - categorical_
accuracy: 0.9500 - val_loss: 0.8263 - val_categorical_accuracy: 0.7900 - lr: 2.000
0e-04
Epoch 20/30
34/34 [==============================] - ETA: 0s - loss: 0.1972 - categorical_accu
racy: 0.9515
Epoch 20: saving model to models/model-number-8/models-model_init-8_2023-11-1321_1
2_28.286070\model-00020-0.19719-0.95147-1.01317-0.76000.h5

Epoch 20: val_categorical_accuracy did not improve from 0.79000
34/34 [==============================] - 61s 2s/step - loss: 0.1972 - categorical_
accuracy: 0.9515 - val_loss: 1.0132 - val_categorical_accuracy: 0.7600 - lr: 2.000
0e-04
Epoch 21/30
34/34 [==============================] - ETA: 0s - loss: 0.1678 - categorical_accu
racy: 0.9647
Epoch 21: saving model to models/model-number-8/models-model_init-8_2023-11-1321_1
2_28.286070\model-00021-0.16777-0.96471-0.83750-0.79000.h5

Epoch 21: val_categorical_accuracy did not improve from 0.79000
34/34 [==============================] - 61s 2s/step - loss: 0.1678 - categorical_
accuracy: 0.9647 - val_loss: 0.8375 - val_categorical_accuracy: 0.7900 - lr: 2.000
0e-04
Epoch 22/30
34/34 [==============================] - ETA: 0s - loss: 0.1351 - categorical_accu
racy: 0.9691
Epoch 22: saving model to models/model-number-8/models-model_init-8_2023-11-1321_1
2_28.286070\model-00022-0.13505-0.96912-0.69902-0.77000.h5

Epoch 22: val_categorical_accuracy did not improve from 0.79000
34/34 [==============================] - 60s 2s/step - loss: 0.1351 - categorical_
accuracy: 0.9691 - val_loss: 0.6990 - val_categorical_accuracy: 0.7700 - lr: 2.000
0e-04
Epoch 23/30
34/34 [==============================] - ETA: 0s - loss: 0.1453 - categorical_accu
racy: 0.9647
Epoch 23: saving model to models/model-number-8/models-model_init-8_2023-11-1321_1
2_28.286070\model-00023-0.14533-0.96471-0.94307-0.78000.h5

Epoch 23: val_categorical_accuracy did not improve from 0.79000

Epoch 23: ReduceLROnPlateau reducing learning rate to 4.0000001899898055e-05.
34/34 [==============================] - 59s 2s/step - loss: 0.1453 - categorical_
accuracy: 0.9647 - val_loss: 0.9431 - val_categorical_accuracy: 0.7800 - lr: 2.000
0e-04
Epoch 24/30
34/34 [==============================] - ETA: 0s - loss: 0.1389 - categorical_accu
racy: 0.9721
Epoch 24: saving model to models/model-number-8/models-model_init-8_2023-11-1321_1
2_28.286070\model-00024-0.13888-0.97206-0.87026-0.77000.h5

Epoch 24: val_categorical_accuracy did not improve from 0.79000
34/34 [==============================] - 60s 2s/step - loss: 0.1389 - categorical_
accuracy: 0.9721 - val_loss: 0.8703 - val_categorical_accuracy: 0.7700 - lr: 4.000
0e-05
Epoch 25/30
34/34 [==============================] - ETA: 0s - loss: 0.1123 - categorical_accu
```

```
racy: 0.9750
Epoch 25: saving model to models/model-number-8/models-model_init-8_2023-11-1321_1
2_28.286070\model-00025-0.11229-0.97500-0.85392-0.79000.h5

Epoch 25: val_categorical_accuracy did not improve from 0.79000
34/34 [==============================] - 61s 2s/step - loss: 0.1123 - categorical_
accuracy: 0.9750 - val_loss: 0.8539 - val_categorical_accuracy: 0.7900 - lr: 4.000
0e-05
Epoch 26/30
34/34 [==============================] - ETA: 0s - loss: 0.1108 - categorical_accu
racy: 0.9779
Epoch 26: saving model to models/model-number-8/models-model_init-8_2023-11-1321_1
2_28.286070\model-00026-0.11075-0.97794-0.78702-0.80000.h5

Epoch 26: val_categorical_accuracy improved from 0.79000 to 0.80000, saving model
to models/model-number-8\best_model.h5
34/34 [==============================] - 60s 2s/step - loss: 0.1108 - categorical_
accuracy: 0.9779 - val_loss: 0.7870 - val_categorical_accuracy: 0.8000 - lr: 4.000
0e-05
Epoch 27/30
34/34 [==============================] - ETA: 0s - loss: 0.0967 - categorical_accu
racy: 0.9897
Epoch 27: saving model to models/model-number-8/models-model_init-8_2023-11-1321_1
2_28.286070\model-00027-0.09668-0.98971-0.78428-0.80000.h5

Epoch 27: val_categorical_accuracy did not improve from 0.80000
34/34 [==============================] - 60s 2s/step - loss: 0.0967 - categorical_
accuracy: 0.9897 - val_loss: 0.7843 - val_categorical_accuracy: 0.8000 - lr: 4.000
0e-05
Epoch 28/30
34/34 [==============================] - ETA: 0s - loss: 0.0906 - categorical_accu
racy: 0.9897
Epoch 28: saving model to models/model-number-8/models-model_init-8_2023-11-1321_1
2_28.286070\model-00028-0.09063-0.98971-0.81985-0.78000.h5

Epoch 28: val_categorical_accuracy did not improve from 0.80000
34/34 [==============================] - 60s 2s/step - loss: 0.0906 - categorical_
accuracy: 0.9897 - val_loss: 0.8198 - val_categorical_accuracy: 0.7800 - lr: 4.000
0e-05
Epoch 29/30
34/34 [==============================] - ETA: 0s - loss: 0.0873 - categorical_accu
racy: 0.9882
Epoch 29: saving model to models/model-number-8/models-model_init-8_2023-11-1321_1
2_28.286070\model-00029-0.08735-0.98824-0.64590-0.82000.h5

Epoch 29: val_categorical_accuracy improved from 0.80000 to 0.82000, saving model
to models/model-number-8\best_model.h5
34/34 [==============================] - 60s 2s/step - loss: 0.0873 - categorical_
accuracy: 0.9882 - val_loss: 0.6459 - val_categorical_accuracy: 0.8200 - lr: 4.000
0e-05
Epoch 30/30
34/34 [==============================] - ETA: 0s - loss: 0.0826 - categorical_accu
racy: 0.9912
Epoch 30: saving model to models/model-number-8/models-model_init-8_2023-11-1321_1
2_28.286070\model-00030-0.08257-0.99118-0.70762-0.81000.h5

Epoch 30: val_categorical_accuracy did not improve from 0.82000
34/34 [==============================] - 60s 2s/step - loss: 0.0826 - categorical_
accuracy: 0.9912 - val_loss: 0.7076 - val_categorical_accuracy: 0.8100 - lr: 4.000
0e-05
```

In [66]:

```
loss = history.history['loss']
val_loss = history.history['val_loss']
acc = history.history['categorical_accuracy']
```

```
val_acc = history.history['val_categorical_accuracy']

plot_model(loss,val_loss,acc,val_acc)
```