Import

In [107…

```
import os
import warnings
import cv2
import keras
import matplotlib.pyplot as plt
import matplotlib.style as style
import numpy as np
import pandas as pd
from PIL import Image
from keras import models, layers, optimizers
from keras.applications import VGG16
from keras.callbacks import EarlyStopping, ModelCheckpoint
from keras.layers import Dense, Dropout, Flatten
from keras.models import Model
from keras.preprocessing import image as image_utils
from keras.preprocessing.image import ImageDataGenerator
from keras.utils import to_categorical
from sklearn.metrics import classification_report, confusion_matrix
from sklearn.model_selection import train_test_split
from PIL import ImageFile
ImageFile.LOAD_TRUNCATED_IMAGES = True
import datetime
import pickle
from matplotlib import pyplot as plt
from keras.models import load_model
from sklearn.metrics import confusion_matrix
from tabulate import tabulate
from sklearn.metrics import multilabel_confusion_matrix
print("Done@" + datetime.datetime.now().strftime("%Y-%m-%dT%HZ"))
```

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```

Use Colab ?

In [2]:

```
USE_COLAB = True # change to 0 if not use colab
RootFolder = ''
if (USE_COLAB):
    RootFolder = '/content/drive/MyDrive/MiAI_Hand_Lang/' # root folder tren drive
else:
    RootFolder = 'D:/Documents/_HOC_DAI_HOC/NAM_4/HocKi1/MachineLearning/___CuoiKi/C
```

In [5]:

```
if USE_COLAB:
    from google.colab import drive
    drive.mount('/content/drive')
```

```
Drive already mounted at /content/drive; to attempt to forcibly remount, call drive.
mount("/content/drive", force_remount=True).
```

In [6]:

```
if USE_COLAB:
    %cd $RootFolder
    %cd ..
print("Done@" + datetime.datetime.now().strftime("%Y-%m-%dT%HZ"))
```

```
/content/drive/MyDrive/MiAI_Hand_Lang
/content/drive/MyDrive
Done@2021-01-02T15Z
```

Declare variable and function

In [7]:

```
# Dinh nghia cac bien

gestures = {'L_': 'L',
           'fi': 'E',
           'ok': 'F',
           'pe': 'V',
           'pa': 'B'
            }

gestures_map = {'E': 0,
                'L': 1,
                'F': 2,
                'V': 3,
                'B': 4
                }


gesture_names = {0: 'E',
                 1: 'L',
                 2: 'F',
                 3: 'V',
                 4: 'B'}


image_path = RootFolder + 'data/'
models_path = RootFolder + 'models/saved_model.hdf5'
rgb = False
imageSize = 224


# Ham xu ly anh resize ve 224x224 va chuyen ve numpy array
def process_image(path):
    img = Image.open(path)
    img = img.resize((imageSize, imageSize))
    img = np.array(img)
    return img

# Xu ly du lieu dau vao
def process_data(X_data, y_data):
    X_data = np.array(X_data, dtype = 'float32')
    if rgb:
        pass
    else:
        X_data = np.stack((X_data,)*3, axis=-1)
    X_data /= 255
    y_data = np.array(y_data)
    y_data = to_categorical(y_data)
    return X_data, y_data

# Ham duyet thu muc anh dung de train
def walk_file_tree(image_path):
    X_data = []
    y_data = []
    for directory, subdirectories, files in os.walk(image_path):
        for file in files:
            if not file.startswith('.'):
                path = os.path.join(directory, file)
                gesture_name = gestures[file[0:2]]
                # print(gesture_name)
                # print(gestures_map[gesture_name])
                y_data.append(gestures_map[gesture_name])
                X_data.append(process_image(path))

            else:
                continue

    X_data, y_data = process_data(X_data, y_data)
    return X_data, y_data
import datetime
print("Done@" + datetime.datetime.now().strftime("%Y-%m-%dT%HZ"))
```

```
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```

In [14]:

```
# Load du lieu vao X va Y
print(image_path)
X_data, y_data = walk_file_tree(image_path)
print("X_data.shape = ", X_data.shape)
print("y_data.shape = ", y_data.shape)
import datetime
print("Done@" + datetime.datetime.now().strftime("%Y-%m-%dT%HZ"))
```

```
/content/drive/MyDrive/MiAI_Hand_Lang/data/
X_data.shape =  (2748, 224, 224, 3)
y_data.shape =  (2748, 5)
Done@2021-01-02T16Z
```

Initialize model

In [39]:

```
# Dat cac checkpoint de luu lai model tot nhat
model_checkpoint = ModelCheckpoint(filepath=models_path, save_best_only=True)
early_stopping = EarlyStopping(monitor='val_accuracy',
                              min_delta=0,
                              patience=10,
                              verbose=1,
                              mode='auto',
                              restore_best_weights=True)
```

In [40]:

```
# Khoi tao model
model1 = VGG16(weights='imagenet', include_top=False, input_shape=(imageSize, imageS
optimizer1 = optimizers.Adam()
base_model = model1
```

In [41]:

```
# Them cac lop ben tren
x = base_model.output
x = Flatten()(x)
x = Dense(128, activation='relu', name='fc1')(x)
x = Dense(128, activation='relu', name='fc2')(x)
x = Dense(128, activation='relu', name='fc2a')(x)
x = Dense(128, activation='relu', name='fc3')(x)
x = Dropout(0.5)(x)
x = Dense(64, activation='relu', name='fc4')(x)
```

In [42]:

```
# Them lop cuoi
predictions = Dense(5, activation='softmax')(x)
model = Model(inputs=base_model.input, outputs=predictions)
```

In [43]:

```
# Dong bang cac lop duoi, chi train lop ben tren minh them vao
for layer in base_model.layers:
    layer.trainable = False
```

Split whold data to Train, Test Set

- Train Set: use K-Fold (K=5) in order to evaluation model, after evaluation, train model base whole Train Set
- Test Set: use final model to test on this

In [20]:

```
# Phan chia du lieu train va test theo ty le 80/20
X_train, X_test, y_train, y_test = train_test_split(X_data, y_data, test_size = 0.2,
```

In [21]:

```
# split X_train to 5-Fold
from sklearn.model_selection import KFold
kf = KFold(n_splits=5, shuffle=True, random_state=12)
splits = list(kf.split(X_train))
print("Done@" + datetime.datetime.now().strftime("%Y-%m-%dT%HZ"))
```

```
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```

Train 6 model: 5 model to evaluation (use K-Fold), 1 model is final model (trained on whole train set)

Train Fold 0 --> Fold 4, save history to file

In [71]:

```
for i in range(5):
  train_indices, val_indices = splits[i]
  X_train_k = X_train[train_indices]
  X_val_k = X_train[val_indices]
  y_train_k = y_train[train_indices]
  y_val_k = y_train[val_indices]
  # Train Fold
  model.compile(optimizer='Adam', loss='categorical_crossentropy', metrics=['accurac
  hist_k = model.fit(X_train_k, y_train_k, epochs=50, batch_size=64, validation_data
  # save history to file
  f_k = open(RootFolder + 'history/history_final' + str(i) + '.pckl', 'wb')
  pickle.dump(hist_k.history, f_k)
  f_k.close()
  print("Done@" + datetime.datetime.now().strftime("%Y-%m-%dT%HZ"))
```

```
Epoch 1/50
28/28 [==============================] - 12s 417ms/step - loss: 0.0565 - accuracy:
0.9813 - val_loss: 0.0317 - val_accuracy: 0.9886
```

```
Epoch 2/50
28/28 [==============================] - 8s 290ms/step - loss: 0.0189 - accuracy: 0.
9930 - val_loss: 2.9690e-04 - val_accuracy: 1.0000
Epoch 3/50
28/28 [==============================] - 8s 294ms/step - loss: 0.0020 - accuracy: 0.
9994 - val_loss: 3.9960e-04 - val_accuracy: 1.0000
Epoch 4/50
28/28 [==============================] - 8s 298ms/step - loss: 4.8359e-04 - accurac
y: 1.0000 - val_loss: 0.0049 - val_accuracy: 0.9977
Epoch 5/50
28/28 [==============================] - 8s 302ms/step - loss: 5.9630e-04 - accurac
y: 1.0000 - val_loss: 6.8982e-04 - val_accuracy: 1.0000
Epoch 6/50
28/28 [==============================] - 9s 306ms/step - loss: 0.0060 - accuracy: 0.
9988 - val_loss: 0.0025 - val_accuracy: 0.9977
Epoch 7/50
28/28 [==============================] - 8s 303ms/step - loss: 0.0443 - accuracy: 0.
9848 - val_loss: 0.0429 - val_accuracy: 0.9909
Epoch 8/50
28/28 [==============================] - 8s 306ms/step - loss: 0.0316 - accuracy: 0.
9896 - val_loss: 0.0154 - val_accuracy: 0.9955
Epoch 9/50
28/28 [==============================] - 8s 295ms/step - loss: 0.0076 - accuracy: 0.
9985 - val_loss: 0.0047 - val_accuracy: 0.9977
Epoch 10/50
28/28 [==============================] - 8s 294ms/step - loss: 0.0079 - accuracy: 0.
9965 - val_loss: 0.0048 - val_accuracy: 0.9955
Epoch 11/50
28/28 [==============================] - 8s 294ms/step - loss: 0.0319 - accuracy: 0.
9901 - val_loss: 0.1241 - val_accuracy: 0.9636
Epoch 12/50
28/28 [==============================] - 8s 295ms/step - loss: 0.0382 - accuracy: 0.
9868 - val_loss: 0.0524 - val_accuracy: 0.9818
Epoch 13/50
28/28 [==============================] - 8s 297ms/step - loss: 0.0200 - accuracy: 0.
9909 - val_loss: 0.0207 - val_accuracy: 0.9955
Epoch 14/50
28/28 [==============================] - 8s 298ms/step - loss: 4.3929e-04 - accurac
y: 1.0000 - val_loss: 0.0019 - val_accuracy: 1.0000
Epoch 15/50
28/28 [==============================] - 8s 299ms/step - loss: 6.0877e-04 - accurac
y: 1.0000 - val_loss: 0.0013 - val_accuracy: 1.0000
Epoch 16/50
28/28 [==============================] - 8s 300ms/step - loss: 2.4361e-04 - accurac
y: 1.0000 - val_loss: 0.0021 - val_accuracy: 1.0000
Epoch 17/50
28/28 [==============================] - 8s 300ms/step - loss: 6.8740e-05 - accurac
y: 1.0000 - val_loss: 0.0018 - val_accuracy: 1.0000
Epoch 18/50
28/28 [==============================] - 8s 298ms/step - loss: 1.0599e-04 - accurac
y: 1.0000 - val_loss: 0.0016 - val_accuracy: 1.0000
Epoch 19/50
28/28 [==============================] - 8s 297ms/step - loss: 1.3297e-04 - accurac
y: 1.0000 - val_loss: 0.0015 - val_accuracy: 1.0000
Epoch 20/50
28/28 [==============================] - 8s 297ms/step - loss: 1.3362e-04 - accurac
y: 1.0000 - val_loss: 9.3271e-04 - val_accuracy: 1.0000
Epoch 21/50
28/28 [==============================] - 8s 296ms/step - loss: 6.0635e-05 - accurac
y: 1.0000 - val_loss: 8.9187e-04 - val_accuracy: 1.0000
Epoch 22/50
28/28 [==============================] - 8s 297ms/step - loss: 6.2491e-05 - accurac
y: 1.0000 - val_loss: 6.6155e-04 - val_accuracy: 1.0000
Epoch 23/50
28/28 [==============================] - 8s 297ms/step - loss: 1.4238e-04 - accurac
y: 1.0000 - val_loss: 0.0013 - val_accuracy: 1.0000
Epoch 24/50
28/28 [==============================] - 8s 297ms/step - loss: 8.7263e-05 - accurac
y: 1.0000 - val_loss: 0.0024 - val_accuracy: 1.0000
```

```
Epoch 25/50
28/28 [==============================] - 8s 297ms/step - loss: 8.0975e-05 - accurac
y: 1.0000 - val_loss: 0.0017 - val_accuracy: 1.0000
Epoch 26/50
28/28 [==============================] - 8s 298ms/step - loss: 5.8225e-05 - accurac
y: 1.0000 - val_loss: 0.0011 - val_accuracy: 1.0000
Epoch 27/50
28/28 [==============================] - 8s 297ms/step - loss: 2.2665e-05 - accurac
y: 1.0000 - val_loss: 0.0011 - val_accuracy: 1.0000
Epoch 28/50
28/28 [==============================] - 8s 298ms/step - loss: 1.9540e-05 - accurac
y: 1.0000 - val_loss: 9.8116e-04 - val_accuracy: 1.0000
Epoch 29/50
28/28 [==============================] - 8s 298ms/step - loss: 7.1386e-06 - accurac
y: 1.0000 - val_loss: 9.6989e-04 - val_accuracy: 1.0000
Epoch 30/50
28/28 [==============================] - 8s 299ms/step - loss: 2.2239e-05 - accurac
y: 1.0000 - val_loss: 0.0010 - val_accuracy: 1.0000
Epoch 31/50
28/28 [==============================] - 8s 298ms/step - loss: 5.8852e-05 - accurac
y: 1.0000 - val_loss: 0.0014 - val_accuracy: 1.0000
Epoch 32/50
28/28 [==============================] - 8s 297ms/step - loss: 2.9945e-05 - accurac
y: 1.0000 - val_loss: 0.0017 - val_accuracy: 1.0000
Epoch 33/50
28/28 [==============================] - 8s 296ms/step - loss: 3.0663e-05 - accurac
y: 1.0000 - val_loss: 0.0016 - val_accuracy: 1.0000
Epoch 34/50
28/28 [==============================] - 8s 297ms/step - loss: 9.1279e-05 - accurac
y: 1.0000 - val_loss: 0.0012 - val_accuracy: 1.0000
Epoch 35/50
28/28 [==============================] - 8s 297ms/step - loss: 1.4353e-05 - accurac
y: 1.0000 - val_loss: 0.0010 - val_accuracy: 1.0000
Epoch 36/50
28/28 [==============================] - 8s 296ms/step - loss: 2.1034e-05 - accurac
y: 1.0000 - val_loss: 9.1551e-04 - val_accuracy: 1.0000
Epoch 37/50
28/28 [==============================] - 8s 296ms/step - loss: 1.1997e-05 - accurac
y: 1.0000 - val_loss: 8.8527e-04 - val_accuracy: 1.0000
Epoch 38/50
28/28 [==============================] - 8s 298ms/step - loss: 1.4529e-05 - accurac
y: 1.0000 - val_loss: 8.7775e-04 - val_accuracy: 1.0000
Epoch 39/50
28/28 [==============================] - 8s 297ms/step - loss: 6.6483e-06 - accurac
y: 1.0000 - val_loss: 8.4471e-04 - val_accuracy: 1.0000
Epoch 40/50
28/28 [==============================] - 8s 297ms/step - loss: 1.3194e-05 - accurac
y: 1.0000 - val_loss: 8.3187e-04 - val_accuracy: 1.0000
Epoch 41/50
28/28 [==============================] - 8s 297ms/step - loss: 8.2998e-05 - accurac
y: 1.0000 - val_loss: 8.9952e-04 - val_accuracy: 1.0000
Epoch 42/50
28/28 [==============================] - 8s 297ms/step - loss: 3.9010e-05 - accurac
y: 1.0000 - val_loss: 9.7201e-04 - val_accuracy: 1.0000
Epoch 43/50
28/28 [==============================] - 8s 298ms/step - loss: 1.1695e-05 - accurac
y: 1.0000 - val_loss: 8.6377e-04 - val_accuracy: 1.0000
Epoch 44/50
28/28 [==============================] - 8s 298ms/step - loss: 2.8973e-05 - accurac
y: 1.0000 - val_loss: 9.0124e-04 - val_accuracy: 1.0000
Epoch 45/50
28/28 [==============================] - 8s 298ms/step - loss: 1.1818e-05 - accurac
y: 1.0000 - val_loss: 7.7121e-04 - val_accuracy: 1.0000
Epoch 46/50
28/28 [==============================] - 8s 298ms/step - loss: 2.0926e-04 - accurac
y: 1.0000 - val_loss: 6.3384e-04 - val_accuracy: 1.0000
Epoch 47/50
28/28 [==============================] - 8s 298ms/step - loss: 1.2241e-05 - accurac
y: 1.0000 - val_loss: 8.7948e-04 - val_accuracy: 1.0000
```

```
Epoch 48/50
28/28 [==============================] - 8s 298ms/step - loss: 9.6091e-06 - accurac
y: 1.0000 - val_loss: 0.0023 - val_accuracy: 1.0000
Epoch 49/50
28/28 [==============================] - 8s 298ms/step - loss: 1.7274e-05 - accurac
y: 1.0000 - val_loss: 0.0012 - val_accuracy: 1.0000
Epoch 50/50
28/28 [==============================] - 8s 297ms/step - loss: 1.5294e-05 - accurac
y: 1.0000 - val_loss: 0.0012 - val_accuracy: 1.0000
Done@2021-01-02T17Z
Epoch 1/50
28/28 [==============================] - 9s 305ms/step - loss: 0.0168 - accuracy: 0.
9938 - val_loss: 0.0637 - val_accuracy: 0.9841
Epoch 2/50
28/28 [==============================] - 8s 298ms/step - loss: 0.0727 - accuracy: 0.
9900 - val_loss: 8.7279e-04 - val_accuracy: 1.0000
Epoch 3/50
28/28 [==============================] - 8s 297ms/step - loss: 0.0282 - accuracy: 0.
9930 - val_loss: 4.1326e-05 - val_accuracy: 1.0000
Epoch 4/50
28/28 [==============================] - 8s 299ms/step - loss: 0.0021 - accuracy: 0.
9990 - val_loss: 0.0360 - val_accuracy: 0.9909
Epoch 5/50
28/28 [==============================] - 8s 298ms/step - loss: 0.0984 - accuracy: 0.
9835 - val_loss: 0.0403 - val_accuracy: 0.9932
Epoch 6/50
28/28 [==============================] - 8s 298ms/step - loss: 0.0126 - accuracy: 0.
9966 - val_loss: 9.0453e-04 - val_accuracy: 1.0000
Epoch 7/50
28/28 [==============================] - 8s 298ms/step - loss: 8.6769e-04 - accurac
y: 0.9997 - val_loss: 0.0183 - val_accuracy: 0.9977
Epoch 8/50
28/28 [==============================] - 8s 297ms/step - loss: 0.0015 - accuracy: 0.
9991 - val_loss: 7.8370e-05 - val_accuracy: 1.0000
Epoch 9/50
28/28 [==============================] - 8s 298ms/step - loss: 1.2984e-04 - accurac
y: 1.0000 - val_loss: 8.1286e-05 - val_accuracy: 1.0000
Epoch 10/50
28/28 [==============================] - 8s 298ms/step - loss: 9.0831e-05 - accurac
y: 1.0000 - val_loss: 6.3365e-05 - val_accuracy: 1.0000
Epoch 11/50
28/28 [==============================] - 8s 297ms/step - loss: 2.3310e-04 - accurac
y: 1.0000 - val_loss: 6.7924e-05 - val_accuracy: 1.0000
Epoch 12/50
28/28 [==============================] - 8s 302ms/step - loss: 8.8114e-05 - accurac
y: 1.0000 - val_loss: 5.8643e-05 - val_accuracy: 1.0000
Epoch 13/50
28/28 [==============================] - 8s 297ms/step - loss: 4.7375e-05 - accurac
y: 1.0000 - val_loss: 4.4159e-05 - val_accuracy: 1.0000
Epoch 14/50
28/28 [==============================] - 8s 297ms/step - loss: 3.7240e-05 - accurac
y: 1.0000 - val_loss: 4.1662e-05 - val_accuracy: 1.0000
Epoch 15/50
28/28 [==============================] - 8s 296ms/step - loss: 3.0042e-05 - accurac
y: 1.0000 - val_loss: 3.9391e-05 - val_accuracy: 1.0000
Epoch 16/50
28/28 [==============================] - 8s 297ms/step - loss: 9.5932e-05 - accurac
y: 1.0000 - val_loss: 3.3043e-05 - val_accuracy: 1.0000
Epoch 17/50
28/28 [==============================] - 8s 297ms/step - loss: 6.3974e-05 - accurac
y: 1.0000 - val_loss: 2.6839e-05 - val_accuracy: 1.0000
Epoch 18/50
28/28 [==============================] - 8s 297ms/step - loss: 7.7754e-05 - accurac
y: 1.0000 - val_loss: 2.5308e-05 - val_accuracy: 1.0000
Epoch 19/50
28/28 [==============================] - 8s 299ms/step - loss: 1.9637e-05 - accurac
y: 1.0000 - val_loss: 2.3854e-05 - val_accuracy: 1.0000
Epoch 20/50
28/28 [==============================] - 8s 298ms/step - loss: 1.3271e-05 - accurac
```

```
y: 1.0000 - val_loss: 2.0809e-05 - val_accuracy: 1.0000
Epoch 21/50
28/28 [==============================] - 8s 298ms/step - loss: 2.7633e-05 - accurac
y: 1.0000 - val_loss: 1.9737e-05 - val_accuracy: 1.0000
Epoch 22/50
28/28 [==============================] - 8s 298ms/step - loss: 1.8013e-05 - accurac
y: 1.0000 - val_loss: 1.8696e-05 - val_accuracy: 1.0000
Epoch 23/50
28/28 [==============================] - 8s 298ms/step - loss: 1.3657e-05 - accurac
y: 1.0000 - val_loss: 1.7744e-05 - val_accuracy: 1.0000
Epoch 24/50
28/28 [==============================] - 8s 298ms/step - loss: 3.0917e-05 - accurac
y: 1.0000 - val_loss: 1.7177e-05 - val_accuracy: 1.0000
Epoch 25/50
28/28 [==============================] - 8s 298ms/step - loss: 2.5498e-05 - accurac
y: 1.0000 - val_loss: 1.6883e-05 - val_accuracy: 1.0000
Epoch 26/50
28/28 [==============================] - 8s 299ms/step - loss: 1.0490e-05 - accurac
y: 1.0000 - val_loss: 1.6834e-05 - val_accuracy: 1.0000
Epoch 27/50
28/28 [==============================] - 8s 298ms/step - loss: 1.1845e-05 - accurac
y: 1.0000 - val_loss: 1.6437e-05 - val_accuracy: 1.0000
Epoch 28/50
28/28 [==============================] - 8s 298ms/step - loss: 8.9343e-05 - accurac
y: 1.0000 - val_loss: 1.4565e-05 - val_accuracy: 1.0000
Epoch 29/50
28/28 [==============================] - 8s 298ms/step - loss: 3.6504e-05 - accurac
y: 1.0000 - val_loss: 1.3971e-05 - val_accuracy: 1.0000
Epoch 30/50
28/28 [==============================] - 8s 299ms/step - loss: 1.0067e-05 - accurac
y: 1.0000 - val_loss: 1.3492e-05 - val_accuracy: 1.0000
Epoch 31/50
28/28 [==============================] - 8s 298ms/step - loss: 3.4805e-06 - accurac
y: 1.0000 - val_loss: 1.3255e-05 - val_accuracy: 1.0000
Epoch 32/50
28/28 [==============================] - 8s 298ms/step - loss: 5.0670e-06 - accurac
y: 1.0000 - val_loss: 1.3009e-05 - val_accuracy: 1.0000
Epoch 33/50
28/28 [==============================] - 8s 298ms/step - loss: 6.7921e-06 - accurac
y: 1.0000 - val_loss: 1.2858e-05 - val_accuracy: 1.0000
Epoch 34/50
28/28 [==============================] - 8s 298ms/step - loss: 1.0335e-04 - accurac
y: 1.0000 - val_loss: 1.1995e-05 - val_accuracy: 1.0000
Epoch 35/50
28/28 [==============================] - 8s 299ms/step - loss: 2.7569e-05 - accurac
y: 1.0000 - val_loss: 1.2347e-05 - val_accuracy: 1.0000
Epoch 36/50
28/28 [==============================] - 8s 298ms/step - loss: 5.0325e-06 - accurac
y: 1.0000 - val_loss: 1.2320e-05 - val_accuracy: 1.0000
Epoch 37/50
28/28 [==============================] - 8s 297ms/step - loss: 6.1245e-06 - accurac
y: 1.0000 - val_loss: 1.1948e-05 - val_accuracy: 1.0000
Epoch 38/50
28/28 [==============================] - 8s 299ms/step - loss: 3.3241e-05 - accurac
y: 1.0000 - val_loss: 1.2094e-05 - val_accuracy: 1.0000
Epoch 39/50
28/28 [==============================] - 8s 298ms/step - loss: 4.7550e-06 - accurac
y: 1.0000 - val_loss: 1.1863e-05 - val_accuracy: 1.0000
Epoch 40/50
28/28 [==============================] - 8s 298ms/step - loss: 9.3857e-06 - accurac
y: 1.0000 - val_loss: 1.1805e-05 - val_accuracy: 1.0000
Epoch 41/50
28/28 [==============================] - 8s 299ms/step - loss: 2.3719e-05 - accurac
y: 1.0000 - val_loss: 1.0052e-05 - val_accuracy: 1.0000
Epoch 42/50
28/28 [==============================] - 8s 299ms/step - loss: 8.7311e-06 - accurac
y: 1.0000 - val_loss: 9.7391e-06 - val_accuracy: 1.0000
Epoch 43/50
28/28 [==============================] - 8s 298ms/step - loss: 1.9533e-06 - accurac
```

```
y: 1.0000 - val_loss: 9.7261e-06 - val_accuracy: 1.0000
Epoch 44/50
28/28 [==============================] - 8s 298ms/step - loss: 1.9969e-05 - accurac
y: 1.0000 - val_loss: 8.9676e-06 - val_accuracy: 1.0000
Epoch 45/50
28/28 [==============================] - 8s 298ms/step - loss: 7.5270e-06 - accurac
y: 1.0000 - val_loss: 6.7522e-06 - val_accuracy: 1.0000
Epoch 46/50
28/28 [==============================] - 8s 299ms/step - loss: 1.8728e-05 - accurac
y: 1.0000 - val_loss: 5.2842e-06 - val_accuracy: 1.0000
Epoch 47/50
28/28 [==============================] - 8s 298ms/step - loss: 1.2491e-05 - accurac
y: 1.0000 - val_loss: 4.4972e-06 - val_accuracy: 1.0000
Epoch 48/50
28/28 [==============================] - 8s 299ms/step - loss: 2.0171e-06 - accurac
y: 1.0000 - val_loss: 4.4384e-06 - val_accuracy: 1.0000
Epoch 49/50
28/28 [==============================] - 8s 297ms/step - loss: 2.3564e-06 - accurac
y: 1.0000 - val_loss: 4.3255e-06 - val_accuracy: 1.0000
Epoch 50/50
28/28 [==============================] - 8s 297ms/step - loss: 1.8239e-05 - accurac
y: 1.0000 - val_loss: 3.9201e-06 - val_accuracy: 1.0000
Done@2021-01-02T17Z
Epoch 1/50
28/28 [==============================] - 9s 306ms/step - loss: 0.0115 - accuracy: 0.
9958 - val_loss: 1.8341e-06 - val_accuracy: 1.0000
Epoch 2/50
28/28 [==============================] - 8s 297ms/step - loss: 0.0245 - accuracy: 0.
9973 - val_loss: 3.9608e-05 - val_accuracy: 1.0000
Epoch 3/50
28/28 [==============================] - 8s 298ms/step - loss: 0.0049 - accuracy: 0.
9989 - val_loss: 5.0361e-04 - val_accuracy: 1.0000
Epoch 4/50
28/28 [==============================] - 8s 298ms/step - loss: 0.0091 - accuracy: 0.
9965 - val_loss: 1.6391e-07 - val_accuracy: 1.0000
Epoch 5/50
28/28 [==============================] - 8s 299ms/step - loss: 4.0191e-05 - accurac
y: 1.0000 - val_loss: 1.3330e-07 - val_accuracy: 1.0000
Epoch 6/50
28/28 [==============================] - 8s 298ms/step - loss: 1.8179e-05 - accurac
y: 1.0000 - val_loss: 9.4283e-08 - val_accuracy: 1.0000
Epoch 7/50
28/28 [==============================] - 8s 298ms/step - loss: 1.1353e-04 - accurac
y: 1.0000 - val_loss: 1.9236e-08 - val_accuracy: 1.0000
Epoch 8/50
28/28 [==============================] - 8s 297ms/step - loss: 1.3882e-06 - accurac
y: 1.0000 - val_loss: 1.1650e-08 - val_accuracy: 1.0000
Epoch 9/50
28/28 [==============================] - 8s 296ms/step - loss: 1.2018e-05 - accurac
y: 1.0000 - val_loss: 9.4825e-09 - val_accuracy: 1.0000
Epoch 10/50
28/28 [==============================] - 8s 296ms/step - loss: 2.8366e-06 - accurac
y: 1.0000 - val_loss: 8.9407e-09 - val_accuracy: 1.0000
Epoch 11/50
28/28 [==============================] - 8s 295ms/step - loss: 1.7307e-06 - accurac
y: 1.0000 - val_loss: 8.3988e-09 - val_accuracy: 1.0000
Epoch 12/50
28/28 [==============================] - 8s 295ms/step - loss: 9.9256e-06 - accurac
y: 1.0000 - val_loss: 7.3151e-09 - val_accuracy: 1.0000
Epoch 13/50
28/28 [==============================] - 8s 294ms/step - loss: 1.6493e-06 - accurac
y: 1.0000 - val_loss: 6.2314e-09 - val_accuracy: 1.0000
Epoch 14/50
28/28 [==============================] - 8s 295ms/step - loss: 2.3909e-05 - accurac
y: 1.0000 - val_loss: 5.4186e-09 - val_accuracy: 1.0000
Epoch 15/50
28/28 [==============================] - 8s 293ms/step - loss: 3.8594e-06 - accurac
y: 1.0000 - val_loss: 3.2512e-09 - val_accuracy: 1.0000
Epoch 16/50
```

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28/28 [==============================] - 8s 294ms/step - loss: 5.4771e-06 - accurac
y: 1.0000 - val_loss: 2.1674e-09 - val_accuracy: 1.0000
Epoch 17/50
28/28 [==============================] - 8s 294ms/step - loss: 4.4611e-05 - accurac
y: 1.0000 - val_loss: 2.1674e-09 - val_accuracy: 1.0000
Epoch 18/50
28/28 [==============================] - 8s 294ms/step - loss: 4.0601e-07 - accurac
y: 1.0000 - val_loss: 1.8965e-09 - val_accuracy: 1.0000
Epoch 19/50
28/28 [==============================] - 8s 298ms/step - loss: 3.6867e-07 - accurac
y: 1.0000 - val_loss: 1.6256e-09 - val_accuracy: 1.0000
Epoch 20/50
28/28 [==============================] - 8s 293ms/step - loss: 3.3846e-06 - accurac
y: 1.0000 - val_loss: 1.6256e-09 - val_accuracy: 1.0000
Epoch 21/50
28/28 [==============================] - 8s 293ms/step - loss: 1.7281e-07 - accurac
y: 1.0000 - val_loss: 1.6256e-09 - val_accuracy: 1.0000
Epoch 22/50
28/28 [==============================] - 8s 293ms/step - loss: 9.4902e-07 - accurac
y: 1.0000 - val_loss: 1.3547e-09 - val_accuracy: 1.0000
Epoch 23/50
28/28 [==============================] - 8s 294ms/step - loss: 8.0804e-07 - accurac
y: 1.0000 - val_loss: 8.1279e-10 - val_accuracy: 1.0000
Epoch 24/50
28/28 [==============================] - 8s 294ms/step - loss: 4.2384e-06 - accurac
y: 1.0000 - val_loss: 2.7093e-10 - val_accuracy: 1.0000
Epoch 25/50
28/28 [==============================] - 8s 293ms/step - loss: 3.7280e-07 - accurac
y: 1.0000 - val_loss: 2.7093e-10 - val_accuracy: 1.0000
Epoch 26/50
28/28 [==============================] - 8s 293ms/step - loss: 1.0319e-07 - accurac
y: 1.0000 - val_loss: 2.7093e-10 - val_accuracy: 1.0000
Epoch 27/50
28/28 [==============================] - 8s 294ms/step - loss: 6.1677e-07 - accurac
y: 1.0000 - val_loss: 2.7093e-10 - val_accuracy: 1.0000
Epoch 28/50
28/28 [==============================] - 8s 293ms/step - loss: 8.9355e-08 - accurac
y: 1.0000 - val_loss: 2.7093e-10 - val_accuracy: 1.0000
Epoch 29/50
28/28 [==============================] - 8s 293ms/step - loss: 6.3125e-08 - accurac
y: 1.0000 - val_loss: 2.7093e-10 - val_accuracy: 1.0000
Epoch 30/50
28/28 [==============================] - 8s 292ms/step - loss: 1.3994e-06 - accurac
y: 1.0000 - val_loss: 0.0000e+00 - val_accuracy: 1.0000
Epoch 31/50
28/28 [==============================] - 8s 293ms/step - loss: 2.1277e-06 - accurac
y: 1.0000 - val_loss: 0.0000e+00 - val_accuracy: 1.0000
Epoch 32/50
28/28 [==============================] - 8s 293ms/step - loss: 1.9568e-06 - accurac
y: 1.0000 - val_loss: 0.0000e+00 - val_accuracy: 1.0000
Epoch 33/50
28/28 [==============================] - 8s 292ms/step - loss: 9.8031e-09 - accurac
y: 1.0000 - val_loss: 0.0000e+00 - val_accuracy: 1.0000
Epoch 34/50
28/28 [==============================] - 8s 291ms/step - loss: 5.0774e-07 - accurac
y: 1.0000 - val_loss: 0.0000e+00 - val_accuracy: 1.0000
Epoch 35/50
28/28 [==============================] - 8s 291ms/step - loss: 1.6083e-06 - accurac
y: 1.0000 - val_loss: 0.0000e+00 - val_accuracy: 1.0000
Epoch 36/50
28/28 [==============================] - 8s 293ms/step - loss: 4.6914e-07 - accurac
y: 1.0000 - val_loss: 0.0000e+00 - val_accuracy: 1.0000
Epoch 37/50
28/28 [==============================] - 8s 292ms/step - loss: 9.9780e-07 - accurac
y: 1.0000 - val_loss: 0.0000e+00 - val_accuracy: 1.0000
Epoch 38/50
28/28 [==============================] - 8s 292ms/step - loss: 1.8429e-07 - accurac
y: 1.0000 - val_loss: 0.0000e+00 - val_accuracy: 1.0000
Epoch 39/50
```

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28/28 [==============================] - 8s 292ms/step - loss: 3.9616e-06 - accurac
y: 1.0000 - val_loss: 0.0000e+00 - val_accuracy: 1.0000
Epoch 40/50
28/28 [==============================] - 8s 293ms/step - loss: 2.7662e-06 - accurac
y: 1.0000 - val_loss: 0.0000e+00 - val_accuracy: 1.0000
Epoch 41/50
28/28 [==============================] - 8s 293ms/step - loss: 3.9766e-07 - accurac
y: 1.0000 - val_loss: 0.0000e+00 - val_accuracy: 1.0000
Epoch 42/50
28/28 [==============================] - 8s 292ms/step - loss: 8.9089e-08 - accurac
y: 1.0000 - val_loss: 0.0000e+00 - val_accuracy: 1.0000
Epoch 43/50
28/28 [==============================] - 8s 292ms/step - loss: 1.5156e-08 - accurac
y: 1.0000 - val_loss: 0.0000e+00 - val_accuracy: 1.0000
Epoch 44/50
28/28 [==============================] - 8s 293ms/step - loss: 5.0532e-08 - accurac
y: 1.0000 - val_loss: 0.0000e+00 - val_accuracy: 1.0000
Epoch 45/50
28/28 [==============================] - 8s 292ms/step - loss: 5.0101e-08 - accurac
y: 1.0000 - val_loss: 0.0000e+00 - val_accuracy: 1.0000
Epoch 46/50
28/28 [==============================] - 8s 293ms/step - loss: 5.5187e-08 - accurac
y: 1.0000 - val_loss: 0.0000e+00 - val_accuracy: 1.0000
Epoch 47/50
28/28 [==============================] - 8s 292ms/step - loss: 5.7349e-07 - accurac
y: 1.0000 - val_loss: 0.0000e+00 - val_accuracy: 1.0000
Epoch 48/50
28/28 [==============================] - 8s 293ms/step - loss: 5.4799e-08 - accurac
y: 1.0000 - val_loss: 0.0000e+00 - val_accuracy: 1.0000
Epoch 49/50
28/28 [==============================] - 8s 293ms/step - loss: 3.0393e-07 - accurac
y: 1.0000 - val_loss: 0.0000e+00 - val_accuracy: 1.0000
Epoch 50/50
28/28 [==============================] - 8s 292ms/step - loss: 7.0186e-07 - accurac
y: 1.0000 - val_loss: 0.0000e+00 - val_accuracy: 1.0000
Done@2021-01-02T17Z
Epoch 1/50
28/28 [==============================] - 9s 299ms/step - loss: 1.7152e-07 - accurac
y: 1.0000 - val_loss: 1.0862e-09 - val_accuracy: 1.0000
Epoch 2/50
28/28 [==============================] - 8s 292ms/step - loss: 4.9843e-09 - accurac
y: 1.0000 - val_loss: 2.7155e-10 - val_accuracy: 1.0000
Epoch 3/50
28/28 [==============================] - 8s 291ms/step - loss: 0.0030 - accuracy: 0.
9995 - val_loss: 0.0601 - val_accuracy: 0.9886
Epoch 4/50
28/28 [==============================] - 8s 292ms/step - loss: 0.1191 - accuracy: 0.
9830 - val_loss: 0.4136 - val_accuracy: 0.9567
Epoch 5/50
28/28 [==============================] - 8s 292ms/step - loss: 0.0722 - accuracy: 0.
9928 - val_loss: 0.0040 - val_accuracy: 0.9977
Epoch 6/50
28/28 [==============================] - 8s 292ms/step - loss: 0.0116 - accuracy: 0.
9964 - val_loss: 2.4730e-05 - val_accuracy: 1.0000
Epoch 7/50
28/28 [==============================] - 8s 291ms/step - loss: 2.3655e-04 - accurac
y: 1.0000 - val_loss: 9.5882e-04 - val_accuracy: 1.0000
Epoch 8/50
28/28 [==============================] - 8s 293ms/step - loss: 3.8289e-05 - accurac
y: 1.0000 - val_loss: 4.6462e-05 - val_accuracy: 1.0000
Epoch 9/50
28/28 [==============================] - 8s 292ms/step - loss: 3.8658e-05 - accurac
y: 1.0000 - val_loss: 2.9765e-05 - val_accuracy: 1.0000
Epoch 10/50
28/28 [==============================] - 8s 291ms/step - loss: 5.5035e-06 - accurac
y: 1.0000 - val_loss: 2.7394e-05 - val_accuracy: 1.0000
Epoch 11/50
28/28 [==============================] - 8s 292ms/step - loss: 2.8505e-06 - accurac
y: 1.0000 - val_loss: 2.6654e-05 - val_accuracy: 1.0000
```

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Epoch 12/50
28/28 [==============================] - 8s 292ms/step - loss: 2.8704e-06 - accurac
y: 1.0000 - val_loss: 2.5340e-05 - val_accuracy: 1.0000
Epoch 13/50
28/28 [==============================] - 8s 291ms/step - loss: 7.3346e-06 - accurac
y: 1.0000 - val_loss: 2.0385e-05 - val_accuracy: 1.0000
Epoch 14/50
28/28 [==============================] - 8s 292ms/step - loss: 5.1043e-06 - accurac
y: 1.0000 - val_loss: 2.0978e-05 - val_accuracy: 1.0000
Epoch 15/50
28/28 [==============================] - 8s 292ms/step - loss: 1.2499e-05 - accurac
y: 1.0000 - val_loss: 2.2042e-05 - val_accuracy: 1.0000
Epoch 16/50
28/28 [==============================] - 8s 293ms/step - loss: 2.9820e-05 - accurac
y: 1.0000 - val_loss: 2.5106e-05 - val_accuracy: 1.0000
Epoch 17/50
28/28 [==============================] - 8s 295ms/step - loss: 1.4827e-04 - accurac
y: 0.9999 - val_loss: 2.5496e-05 - val_accuracy: 1.0000
Epoch 18/50
28/28 [==============================] - 8s 300ms/step - loss: 3.4142e-06 - accurac
y: 1.0000 - val_loss: 1.8114e-05 - val_accuracy: 1.0000
Epoch 19/50
28/28 [==============================] - 8s 301ms/step - loss: 1.1266e-05 - accurac
y: 1.0000 - val_loss: 1.5837e-05 - val_accuracy: 1.0000
Epoch 20/50
28/28 [==============================] - 8s 301ms/step - loss: 9.2275e-07 - accurac
y: 1.0000 - val_loss: 1.3673e-05 - val_accuracy: 1.0000
Epoch 21/50
28/28 [==============================] - 8s 300ms/step - loss: 2.2411e-07 - accurac
y: 1.0000 - val_loss: 1.3364e-05 - val_accuracy: 1.0000
Epoch 22/50
28/28 [==============================] - 8s 299ms/step - loss: 1.0265e-06 - accurac
y: 1.0000 - val_loss: 1.3017e-05 - val_accuracy: 1.0000
Epoch 23/50
28/28 [==============================] - 8s 297ms/step - loss: 5.4902e-08 - accurac
y: 1.0000 - val_loss: 1.2869e-05 - val_accuracy: 1.0000
Epoch 24/50
28/28 [==============================] - 8s 296ms/step - loss: 2.5261e-06 - accurac
y: 1.0000 - val_loss: 1.2681e-05 - val_accuracy: 1.0000
Epoch 25/50
28/28 [==============================] - 8s 301ms/step - loss: 2.6772e-07 - accurac
y: 1.0000 - val_loss: 1.2589e-05 - val_accuracy: 1.0000
Epoch 26/50
28/28 [==============================] - 8s 297ms/step - loss: 3.9451e-04 - accurac
y: 1.0000 - val_loss: 8.6956e-06 - val_accuracy: 1.0000
Epoch 27/50
28/28 [==============================] - 8s 298ms/step - loss: 3.3866e-05 - accurac
y: 1.0000 - val_loss: 4.6019e-06 - val_accuracy: 1.0000
Epoch 28/50
28/28 [==============================] - 8s 298ms/step - loss: 3.2922e-05 - accurac
y: 1.0000 - val_loss: 2.3140e-06 - val_accuracy: 1.0000
Epoch 29/50
28/28 [==============================] - 8s 299ms/step - loss: 5.7216e-08 - accurac
y: 1.0000 - val_loss: 2.2837e-06 - val_accuracy: 1.0000
Epoch 30/50
28/28 [==============================] - 8s 298ms/step - loss: 1.0488e-06 - accurac
y: 1.0000 - val_loss: 1.9706e-06 - val_accuracy: 1.0000
Epoch 31/50
28/28 [==============================] - 8s 298ms/step - loss: 1.2385e-06 - accurac
y: 1.0000 - val_loss: 1.6653e-06 - val_accuracy: 1.0000
Epoch 32/50
28/28 [==============================] - 8s 298ms/step - loss: 3.2690e-06 - accurac
y: 1.0000 - val_loss: 1.3752e-06 - val_accuracy: 1.0000
Epoch 33/50
28/28 [==============================] - 8s 296ms/step - loss: 1.6668e-06 - accurac
y: 1.0000 - val_loss: 1.2648e-06 - val_accuracy: 1.0000
Epoch 34/50
28/28 [==============================] - 8s 296ms/step - loss: 1.9341e-06 - accurac
y: 1.0000 - val_loss: 1.3826e-06 - val_accuracy: 1.0000
```

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Epoch 35/50
28/28 [==============================] - 8s 296ms/step - loss: 4.9402e-07 - accurac
y: 1.0000 - val_loss: 1.5107e-06 - val_accuracy: 1.0000
Epoch 36/50
28/28 [==============================] - 8s 297ms/step - loss: 5.6077e-08 - accurac
y: 1.0000 - val_loss: 1.4941e-06 - val_accuracy: 1.0000
Epoch 37/50
28/28 [==============================] - 8s 296ms/step - loss: 5.4387e-07 - accurac
y: 1.0000 - val_loss: 1.6070e-06 - val_accuracy: 1.0000
Epoch 38/50
28/28 [==============================] - 8s 297ms/step - loss: 2.2213e-06 - accurac
y: 1.0000 - val_loss: 1.6398e-06 - val_accuracy: 1.0000
Epoch 39/50
28/28 [==============================] - 8s 297ms/step - loss: 3.2401e-07 - accurac
y: 1.0000 - val_loss: 1.5788e-06 - val_accuracy: 1.0000
Epoch 40/50
28/28 [==============================] - 8s 297ms/step - loss: 3.8663e-08 - accurac
y: 1.0000 - val_loss: 1.5915e-06 - val_accuracy: 1.0000
Epoch 41/50
28/28 [==============================] - 8s 298ms/step - loss: 4.2243e-08 - accurac
y: 1.0000 - val_loss: 1.5788e-06 - val_accuracy: 1.0000
Epoch 42/50
28/28 [==============================] - 8s 298ms/step - loss: 5.7679e-07 - accurac
y: 1.0000 - val_loss: 1.6016e-06 - val_accuracy: 1.0000
Epoch 43/50
28/28 [==============================] - 8s 298ms/step - loss: 3.0309e-07 - accurac
y: 1.0000 - val_loss: 1.5077e-06 - val_accuracy: 1.0000
Epoch 44/50
28/28 [==============================] - 8s 299ms/step - loss: 3.2817e-07 - accurac
y: 1.0000 - val_loss: 1.5131e-06 - val_accuracy: 1.0000
Epoch 45/50
28/28 [==============================] - 8s 298ms/step - loss: 4.5077e-07 - accurac
y: 1.0000 - val_loss: 1.5297e-06 - val_accuracy: 1.0000
Epoch 46/50
28/28 [==============================] - 8s 298ms/step - loss: 1.2148e-06 - accurac
y: 1.0000 - val_loss: 1.6189e-06 - val_accuracy: 1.0000
Epoch 47/50
28/28 [==============================] - 8s 298ms/step - loss: 7.4518e-08 - accurac
y: 1.0000 - val_loss: 1.7660e-06 - val_accuracy: 1.0000
Epoch 48/50
28/28 [==============================] - 8s 298ms/step - loss: 2.3674e-08 - accurac
y: 1.0000 - val_loss: 1.7709e-06 - val_accuracy: 1.0000
Epoch 49/50
28/28 [==============================] - 8s 297ms/step - loss: 2.2862e-07 - accurac
y: 1.0000 - val_loss: 1.7644e-06 - val_accuracy: 1.0000
Epoch 50/50
28/28 [==============================] - 8s 297ms/step - loss: 5.0731e-07 - accurac
y: 1.0000 - val_loss: 1.7253e-06 - val_accuracy: 1.0000
Done@2021-01-02T17Z
Epoch 1/50
28/28 [==============================] - 9s 304ms/step - loss: 0.0178 - accuracy: 0.
9982 - val_loss: 0.0221 - val_accuracy: 0.9954
Epoch 2/50
28/28 [==============================] - 8s 297ms/step - loss: 0.0788 - accuracy: 0.
9908 - val_loss: 0.0148 - val_accuracy: 0.9932
Epoch 3/50
28/28 [==============================] - 8s 297ms/step - loss: 0.0460 - accuracy: 0.
9949 - val_loss: 5.2296e-06 - val_accuracy: 1.0000
Epoch 4/50
28/28 [==============================] - 8s 297ms/step - loss: 1.5169e-06 - accurac
y: 1.0000 - val_loss: 8.7437e-08 - val_accuracy: 1.0000
Epoch 5/50
28/28 [==============================] - 8s 298ms/step - loss: 4.0491e-05 - accurac
y: 1.0000 - val_loss: 6.2184e-08 - val_accuracy: 1.0000
Epoch 6/50
28/28 [==============================] - 8s 299ms/step - loss: 6.7426e-06 - accurac
y: 1.0000 - val_loss: 5.2408e-08 - val_accuracy: 1.0000
Epoch 7/50
28/28 [==============================] - 8s 297ms/step - loss: 3.2602e-06 - accurac
```

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y: 1.0000 - val_loss: 5.9468e-08 - val_accuracy: 1.0000
Epoch 8/50
28/28 [==============================] - 8s 298ms/step - loss: 9.6487e-07 - accurac
y: 1.0000 - val_loss: 6.0283e-08 - val_accuracy: 1.0000
Epoch 9/50
28/28 [==============================] - 8s 298ms/step - loss: 3.4765e-05 - accurac
y: 1.0000 - val_loss: 5.3494e-08 - val_accuracy: 1.0000
Epoch 10/50
28/28 [==============================] - 8s 299ms/step - loss: 3.4408e-06 - accurac
y: 1.0000 - val_loss: 4.8335e-08 - val_accuracy: 1.0000
Epoch 11/50
28/28 [==============================] - 8s 297ms/step - loss: 1.3448e-06 - accurac
y: 1.0000 - val_loss: 3.7202e-08 - val_accuracy: 1.0000
Epoch 12/50
28/28 [==============================] - 8s 297ms/step - loss: 2.2064e-07 - accurac
y: 1.0000 - val_loss: 3.3400e-08 - val_accuracy: 1.0000
Epoch 13/50
28/28 [==============================] - 8s 298ms/step - loss: 1.1782e-06 - accurac
y: 1.0000 - val_loss: 3.3129e-08 - val_accuracy: 1.0000
Epoch 14/50
28/28 [==============================] - 8s 297ms/step - loss: 5.1583e-07 - accurac
y: 1.0000 - val_loss: 3.3129e-08 - val_accuracy: 1.0000
Epoch 15/50
28/28 [==============================] - 8s 298ms/step - loss: 1.9941e-08 - accurac
y: 1.0000 - val_loss: 3.3129e-08 - val_accuracy: 1.0000
Epoch 16/50
28/28 [==============================] - 8s 298ms/step - loss: 1.1029e-06 - accurac
y: 1.0000 - val_loss: 3.0413e-08 - val_accuracy: 1.0000
Epoch 17/50
28/28 [==============================] - 8s 296ms/step - loss: 1.0742e-06 - accurac
y: 1.0000 - val_loss: 2.9599e-08 - val_accuracy: 1.0000
Epoch 18/50
28/28 [==============================] - 8s 297ms/step - loss: 4.3372e-06 - accurac
y: 1.0000 - val_loss: 2.9599e-08 - val_accuracy: 1.0000
Epoch 19/50
28/28 [==============================] - 8s 298ms/step - loss: 1.0243e-06 - accurac
y: 1.0000 - val_loss: 2.9055e-08 - val_accuracy: 1.0000
Epoch 20/50
28/28 [==============================] - 8s 298ms/step - loss: 5.8657e-06 - accurac
y: 1.0000 - val_loss: 2.0638e-08 - val_accuracy: 1.0000
Epoch 21/50
28/28 [==============================] - 8s 297ms/step - loss: 3.6396e-07 - accurac
y: 1.0000 - val_loss: 1.9008e-08 - val_accuracy: 1.0000
Epoch 22/50
28/28 [==============================] - 8s 298ms/step - loss: 1.3041e-06 - accurac
y: 1.0000 - val_loss: 1.8465e-08 - val_accuracy: 1.0000
Epoch 23/50
28/28 [==============================] - 8s 298ms/step - loss: 1.9496e-07 - accurac
y: 1.0000 - val_loss: 1.8465e-08 - val_accuracy: 1.0000
Epoch 24/50
28/28 [==============================] - 8s 298ms/step - loss: 3.8715e-07 - accurac
y: 1.0000 - val_loss: 1.8465e-08 - val_accuracy: 1.0000
Epoch 25/50
28/28 [==============================] - 8s 298ms/step - loss: 5.9269e-05 - accurac
y: 1.0000 - val_loss: 1.8737e-08 - val_accuracy: 1.0000
Epoch 26/50
28/28 [==============================] - 8s 298ms/step - loss: 1.2873e-07 - accurac
y: 1.0000 - val_loss: 1.8737e-08 - val_accuracy: 1.0000
Epoch 27/50
28/28 [==============================] - 8s 299ms/step - loss: 3.1918e-07 - accurac
y: 1.0000 - val_loss: 1.8737e-08 - val_accuracy: 1.0000
Epoch 28/50
28/28 [==============================] - 8s 298ms/step - loss: 9.4064e-08 - accurac
y: 1.0000 - val_loss: 1.8737e-08 - val_accuracy: 1.0000
Epoch 29/50
28/28 [==============================] - 8s 298ms/step - loss: 2.6677e-08 - accurac
y: 1.0000 - val_loss: 1.8194e-08 - val_accuracy: 1.0000
Epoch 30/50
28/28 [==============================] - 8s 298ms/step - loss: 3.9457e-07 - accurac
```

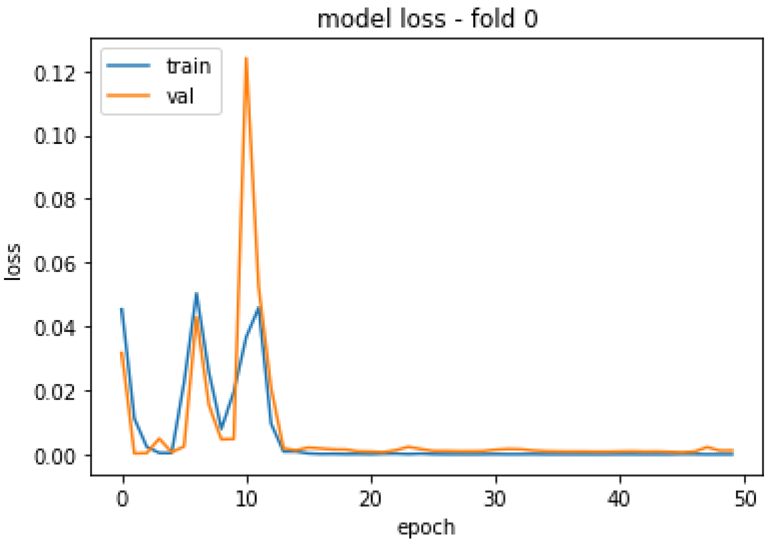
```
y: 1.0000 - val_loss: 1.7922e-08 - val_accuracy: 1.0000
Epoch 31/50
28/28 [==============================] - 8s 299ms/step - loss: 4.9760e-07 - accurac
y: 1.0000 - val_loss: 1.7651e-08 - val_accuracy: 1.0000
Epoch 32/50
28/28 [==============================] - 8s 297ms/step - loss: 1.8744e-07 - accurac
y: 1.0000 - val_loss: 1.7651e-08 - val_accuracy: 1.0000
Epoch 33/50
28/28 [==============================] - 8s 303ms/step - loss: 1.0492e-07 - accurac
y: 1.0000 - val_loss: 1.7379e-08 - val_accuracy: 1.0000
Epoch 34/50
28/28 [==============================] - 8s 298ms/step - loss: 5.8915e-08 - accurac
y: 1.0000 - val_loss: 1.6021e-08 - val_accuracy: 1.0000
Epoch 35/50
28/28 [==============================] - 8s 298ms/step - loss: 1.0978e-06 - accurac
y: 1.0000 - val_loss: 1.5207e-08 - val_accuracy: 1.0000
Epoch 36/50
28/28 [==============================] - 8s 298ms/step - loss: 1.2429e-07 - accurac
y: 1.0000 - val_loss: 1.1677e-08 - val_accuracy: 1.0000
Epoch 37/50
28/28 [==============================] - 8s 298ms/step - loss: 3.0620e-07 - accurac
y: 1.0000 - val_loss: 1.1405e-08 - val_accuracy: 1.0000
Epoch 38/50
28/28 [==============================] - 8s 298ms/step - loss: 3.1477e-07 - accurac
y: 1.0000 - val_loss: 1.1133e-08 - val_accuracy: 1.0000
Epoch 39/50
28/28 [==============================] - 8s 299ms/step - loss: 7.0173e-07 - accurac
y: 1.0000 - val_loss: 1.1133e-08 - val_accuracy: 1.0000
Epoch 40/50
28/28 [==============================] - 8s 299ms/step - loss: 1.3838e-08 - accurac
y: 1.0000 - val_loss: 1.1133e-08 - val_accuracy: 1.0000
Epoch 41/50
28/28 [==============================] - 8s 299ms/step - loss: 3.2727e-07 - accurac
y: 1.0000 - val_loss: 1.0047e-08 - val_accuracy: 1.0000
Epoch 42/50
28/28 [==============================] - 8s 298ms/step - loss: 9.7589e-06 - accurac
y: 1.0000 - val_loss: 9.5041e-09 - val_accuracy: 1.0000
Epoch 43/50
28/28 [==============================] - 8s 299ms/step - loss: 3.6033e-06 - accurac
y: 1.0000 - val_loss: 8.4180e-09 - val_accuracy: 1.0000
Epoch 44/50
28/28 [==============================] - 8s 299ms/step - loss: 1.2770e-07 - accurac
y: 1.0000 - val_loss: 1.5750e-08 - val_accuracy: 1.0000
Epoch 45/50
28/28 [==============================] - 8s 299ms/step - loss: 6.6112e-07 - accurac
y: 1.0000 - val_loss: 1.9280e-08 - val_accuracy: 1.0000
Epoch 46/50
28/28 [==============================] - 8s 298ms/step - loss: 1.2364e-06 - accurac
y: 1.0000 - val_loss: 1.7379e-08 - val_accuracy: 1.0000
Epoch 47/50
28/28 [==============================] - 8s 298ms/step - loss: 8.4793e-07 - accurac
y: 1.0000 - val_loss: 1.7922e-08 - val_accuracy: 1.0000
Epoch 48/50
28/28 [==============================] - 8s 299ms/step - loss: 3.2907e-07 - accurac
y: 1.0000 - val_loss: 1.7107e-08 - val_accuracy: 1.0000
Epoch 49/50
28/28 [==============================] - 8s 298ms/step - loss: 3.8344e-06 - accurac
y: 1.0000 - val_loss: 1.4664e-08 - val_accuracy: 1.0000
Epoch 50/50
28/28 [==============================] - 8s 298ms/step - loss: 4.5036e-08 - accurac
y: 1.0000 - val_loss: 1.3306e-08 - val_accuracy: 1.0000
Done@2021-01-02T17Z
```

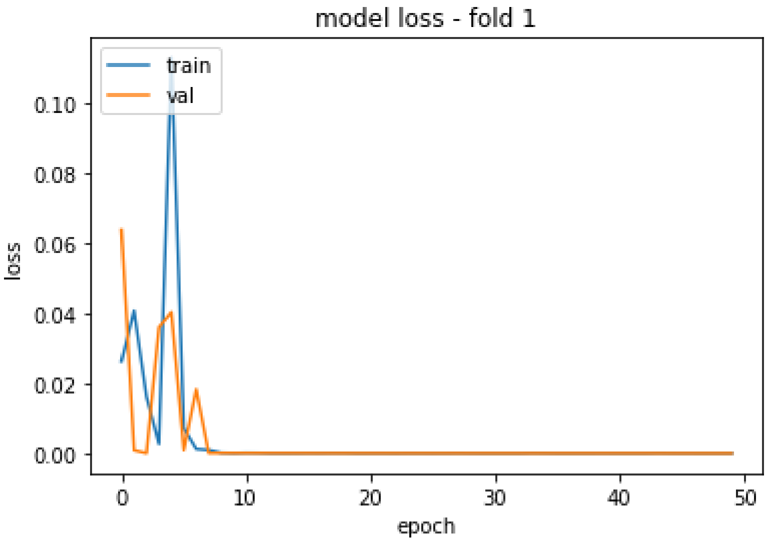
Draw train loss, val loss

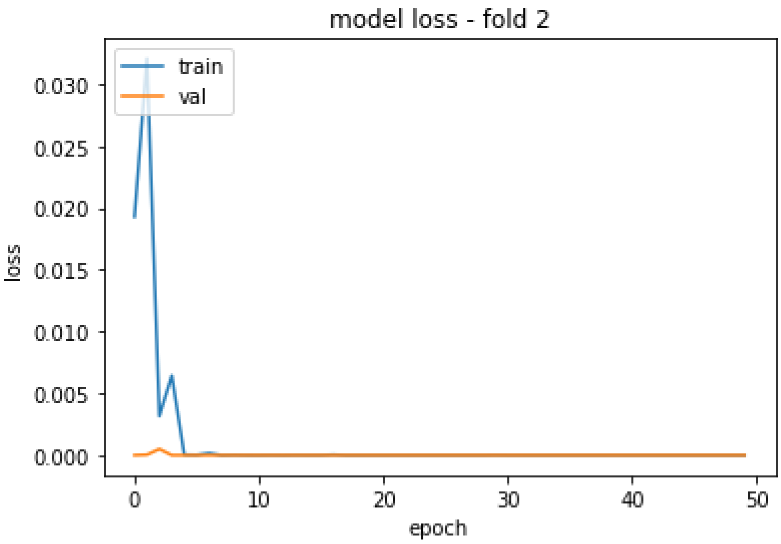
K-Fold's

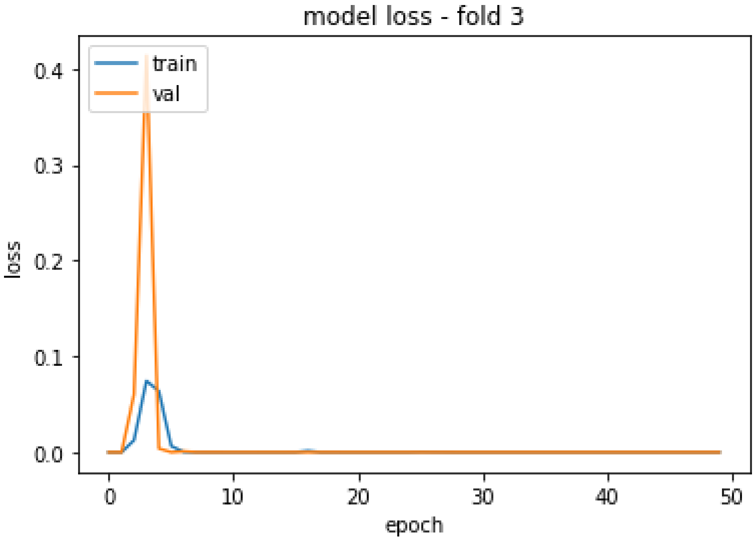
In [72]:

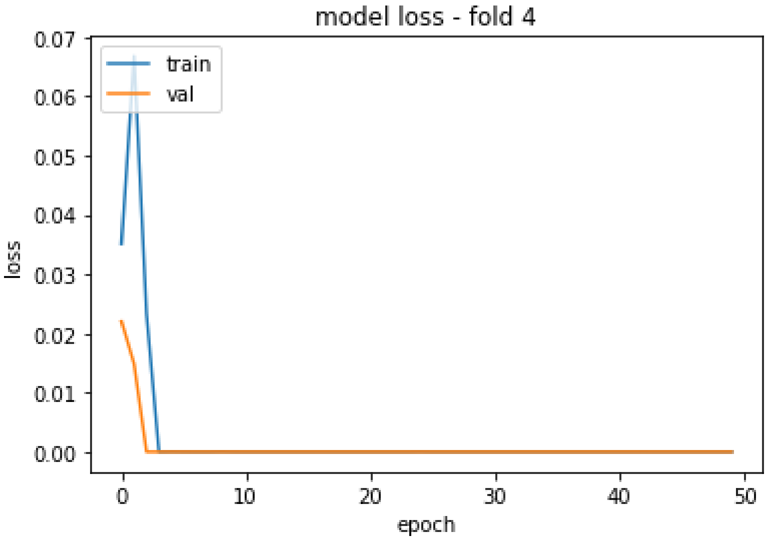
```
for i in range(5):
  # retrieve:
  f_k = open(RootFolder + 'history/history_final' + str(i) + '.pckl', 'rb')
  history_k = pickle.load(f_k)
  f_k.close()
  # plot
  plt.plot(history_k['loss'])
  plt.plot(history_k['val_loss'])
  plt.title('model loss - fold ' + str(i))
  plt.xlabel('epoch')
  plt.ylabel('loss')
  plt.legend(['train', 'val'], loc='upper left')
  plt.show()
print("Done@" + datetime.datetime.now().strftime("%Y-%m-%dT%HZ"))
```











```
Done@2021-01-02T17Z
```

In [73]:

```
f_0 = open(RootFolder + 'history/history_final0.pckl', 'rb')
history_0 = pickle.load(f_0)
f_0.close()
f_1 = open(RootFolder + 'history/history_final1.pckl', 'rb')
history_1 = pickle.load(f_1)
f_1.close()
f_2 = open(RootFolder + 'history/history_final2.pckl', 'rb')
history_2 = pickle.load(f_2)
f_2.close()
```

```
f_3 = open(RootFolder + 'history/history_final3.pckl', 'rb')
history_3 = pickle.load(f_3)
f_3.close()
f_4 = open(RootFolder + 'history/history_final4.pckl', 'rb')
history_4 = pickle.load(f_4)
f_4.close()
```

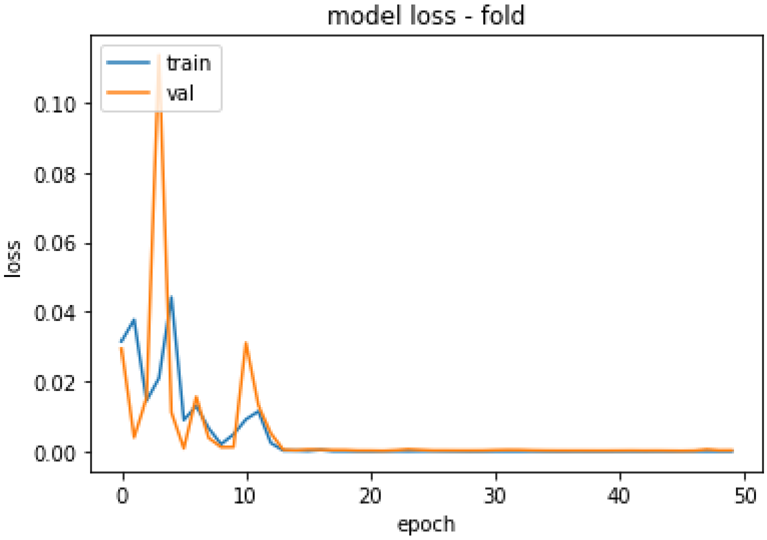
In [64]:

```
print(np.array(history_0['loss']).flatten().shape)
```

```
(24,)
```

In [74]:

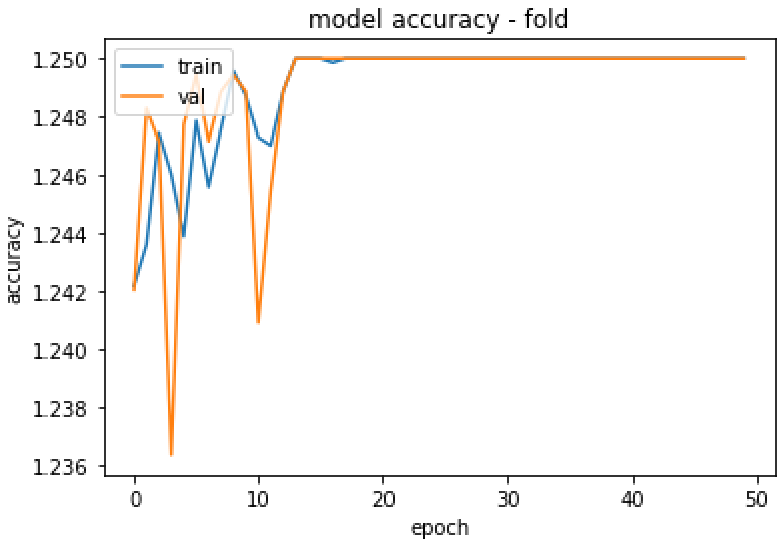
```
# plot loss line
plt.plot((np.array(history_0['loss']) + np.array(history_1['loss']) + \
          np.array(history_2['loss']) + np.array(history_3['loss']) + \
          np.array(history_4['loss'])) / 4)
plt.plot((np.array(history_0['val_loss']) + np.array(history_1['val_loss']) + \
          np.array(history_2['val_loss']) + np.array(history_3['val_loss']) + \
          np.array(history_4['val_loss'])) / 4)
plt.title('model loss - fold')
plt.xlabel('epoch')
plt.ylabel('loss')
plt.legend(['train', 'val'], loc='upper left')
plt.show()
print("Done@" + datetime.datetime.now().strftime("%Y-%m-%dT%HZ"))
```



```
Done@2021-01-02T17Z
```

In [75]:

```
# plot accuracy line
plt.plot((np.array(history_0['accuracy']) + np.array(history_1['accuracy']) + np.arr
plt.plot((np.array(history_0['val_accuracy']) + np.array(history_1['val_accuracy'])
plt.title('model accuracy - fold')
plt.xlabel('epoch')
plt.ylabel('accuracy')
plt.legend(['train', 'val'], loc='upper left')
plt.show()
print("Done@" + datetime.datetime.now().strftime("%Y-%m-%dT%HZ"))
```



```
Done@2021-01-02T17Z
```

Final Model

In [80]:

```
# Final model
early_stopping = EarlyStopping(monitor='accuracy',
                               min_delta=0,
                               patience=10,
                               verbose=1,
                               mode='auto',
                               restore_best_weights=True)
model.compile(optimizer='Adam', loss='categorical_crossentropy', metrics=['accuracy'
hist = model.fit(X_train, y_train, epochs=30, batch_size=64, verbose=1) # epoch cho
# save history to file
f = open(RootFolder + 'history/history_final.pckl', 'wb')
pickle.dump(hist.history, f)
f.close()
print("Done@" + datetime.datetime.now().strftime("%Y-%m-%dT%HZ"))
```

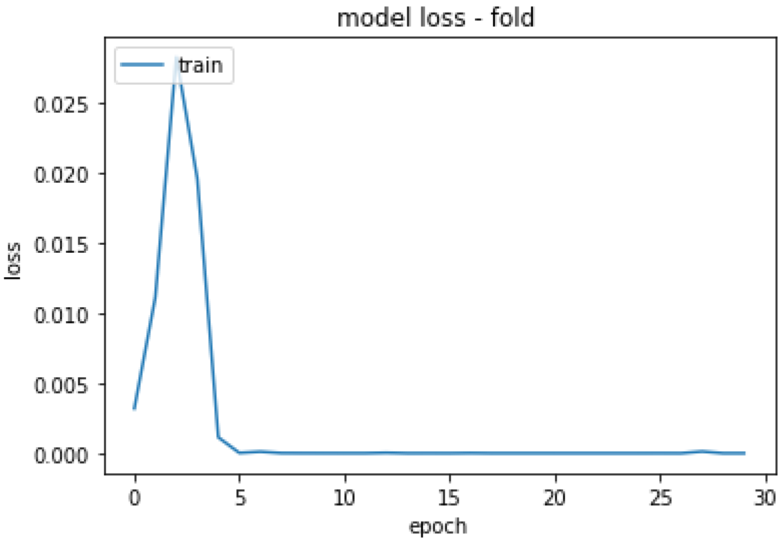
```
Epoch 1/30
35/35 [==============================] - 9s 228ms/step - loss: 0.0035 - accuracy: 0.
9989
Epoch 2/30
35/35 [==============================] - 8s 231ms/step - loss: 0.0084 - accuracy: 0.
9980
Epoch 3/30
35/35 [==============================] - 8s 236ms/step - loss: 0.0139 - accuracy: 0.
9977
Epoch 4/30
35/35 [==============================] - 8s 239ms/step - loss: 0.0375 - accuracy: 0.
9946
Epoch 5/30
35/35 [==============================] - 8s 240ms/step - loss: 0.0012 - accuracy: 0.
9991
Epoch 6/30
35/35 [==============================] - 8s 240ms/step - loss: 4.6425e-05 - accurac
y: 1.0000
Epoch 7/30
35/35 [==============================] - 8s 238ms/step - loss: 1.1111e-04 - accurac
y: 1.0000
Epoch 8/30
35/35 [==============================] - 8s 235ms/step - loss: 1.0563e-05 - accurac
y: 1.0000
Epoch 9/30
35/35 [==============================] - 8s 233ms/step - loss: 5.9517e-06 - accurac
y: 1.0000
```

```
Epoch 10/30
35/35 [==============================] - 8s 232ms/step - loss: 9.6270e-07 - accurac
y: 1.0000
Epoch 11/30
35/35 [==============================] - 8s 233ms/step - loss: 3.0382e-06 - accurac
y: 1.0000
Epoch 12/30
35/35 [==============================] - 8s 233ms/step - loss: 2.2676e-06 - accurac
y: 1.0000
Epoch 13/30
35/35 [==============================] - 8s 235ms/step - loss: 2.7936e-05 - accurac
y: 1.0000
Epoch 14/30
35/35 [==============================] - 8s 236ms/step - loss: 5.6407e-07 - accurac
y: 1.0000
Epoch 15/30
35/35 [==============================] - 8s 237ms/step - loss: 2.0936e-06 - accurac
y: 1.0000
Epoch 16/30
35/35 [==============================] - 8s 238ms/step - loss: 1.2605e-07 - accurac
y: 1.0000
Epoch 17/30
35/35 [==============================] - 8s 238ms/step - loss: 2.8147e-05 - accurac
y: 1.0000
Epoch 18/30
35/35 [==============================] - 8s 237ms/step - loss: 1.3857e-07 - accurac
y: 1.0000
Epoch 19/30
35/35 [==============================] - 8s 236ms/step - loss: 3.7797e-07 - accurac
y: 1.0000
Epoch 20/30
35/35 [==============================] - 8s 234ms/step - loss: 5.0182e-07 - accurac
y: 1.0000
Epoch 21/30
35/35 [==============================] - 8s 235ms/step - loss: 3.0168e-07 - accurac
y: 1.0000
Epoch 22/30
35/35 [==============================] - 8s 235ms/step - loss: 1.2584e-07 - accurac
y: 1.0000
Epoch 23/30
35/35 [==============================] - 8s 235ms/step - loss: 3.2518e-07 - accurac
y: 1.0000
Epoch 24/30
35/35 [==============================] - 8s 236ms/step - loss: 6.1521e-08 - accurac
y: 1.0000
Epoch 25/30
35/35 [==============================] - 8s 237ms/step - loss: 1.2045e-07 - accurac
y: 1.0000
Epoch 26/30
35/35 [==============================] - 8s 237ms/step - loss: 1.6570e-06 - accurac
y: 1.0000
Epoch 27/30
35/35 [==============================] - 8s 237ms/step - loss: 3.9497e-08 - accurac
y: 1.0000
Epoch 28/30
35/35 [==============================] - 8s 237ms/step - loss: 1.8838e-04 - accurac
y: 1.0000
Epoch 29/30
35/35 [==============================] - 8s 237ms/step - loss: 6.4946e-07 - accurac
y: 1.0000
Epoch 30/30
35/35 [==============================] - 8s 235ms/step - loss: 6.7920e-09 - accurac
y: 1.0000
Done@2021-01-02T17Z
```

Final Model's

In [81]:

```
  f = open(RootFolder + 'history/history_final.pckl', 'rb')
  history = pickle.load(f)
  f.close()
  # plot
  plt.plot(history['loss'])
  # plt.plot(history['val_loss'])
  plt.title('model loss - fold ')
  plt.xlabel('epoch')
  plt.ylabel('loss')
  plt.legend(['train', 'val'], loc='upper left')
  plt.show()
  print("Done@" + datetime.datetime.now().strftime("%Y-%m-%dT%HZ"))
```



```
Done@2021-01-02T17Z
```

Save final model

In [82]:

```
# Luu model da train ra file
import datetime
model.save(RootFolder + 'models/mymodel_final.h5')
print("Done@" + datetime.datetime.now().strftime("%Y-%m-%dT%HZ"))
```

```
Done@2021-01-02T17Z
```

Download file

In [ ]:

```
# download file tu colab ve
if (USE_COLAB):
    from google.colab import files
    files.download(RootFolder + 'models/mymodel_final.h5')
print("Done@" + datetime.datetime.now().strftime("%Y-%m-%dT%HZ"))
```

In [ ]:

```
if (USE_COLAB):
    from google.colab import files
    for i in range(5):
      files.download(RootFolder + 'history/history_final' + str(i) + '.pckl')
    files.download(RootFolder + 'history/history_final.pckl')
print("Done@" + datetime.datetime.now().strftime("%Y-%m-%dT%HZ"))
```

Confusion Matrix

In [83]:

```
model_trained = load_model(RootFolder + 'models/mymodel_final.h5')
print("Done@" + datetime.datetime.now().strftime("%Y-%m-%dT%HZ"))
```

```
Done@2021-01-02T17Z
```

In [84]:

```
y_pred = model_trained.predict(X_test)
print("Done@" + datetime.datetime.now().strftime("%Y-%m-%dT%HZ"))
```

```
Done@2021-01-02T17Z
```

Label y_pred and y_test

In [85]:

```
# labled y_pred
print(y_pred.shape)
y_pred_labelled = []
for i in range(0, 550):
    y_pred_labelled.append(gesture_names[np.argmax(y_pred[i])])
print("Done@" + datetime.datetime.now().strftime("%Y-%m-%dT%HZ"))
```

```
(550, 5)
Done@2021-01-02T17Z
```

In [86]:

```
# labled y_test
print(y_test.shape)
y_test_labelled = []
for i in range(0, 550):
    y_test_labelled.append(gesture_names[np.argmax(y_test[i])])
import datetime
print("Done@" + datetime.datetime.now().strftime("%Y-%m-%dT%HZ"))
```

```
(550, 5)
Done@2021-01-02T17Z
```

Confusion Matrix for Multiple Classes

Act Label\Pred Label	E	L	F	V	B
E	Pee	Pel	Pef	Pev	Pev
L	Ple	Pll	Plf	Plv	Plv
F	Pfe	Pfl	Pff	Pfv	Pfv
V	Pve	Pvl	Pvf	Pvv	Pvv
B	Pbe	Pbl	Pbf	Pbv	Pbv

In [87]:

```
conf_mat = confusion_matrix(y_test_labelled, y_pred_labelled, labels=["E", "L", "F",
table = tabulate(conf_mat, headers=["E", "L", "F", "V", "B"], tablefmt='fancy_grid')
print("Confusion Matrix")
print(table)
import datetime
print("Done@" + datetime.datetime.now().strftime("%Y-%m-%dT%HZ"))
```

```
Confusion Matrix
```

```
│   E │   L │   F │   V │   B │
╞═════╪═════╪═════╪═════╪═════╡
│ 110 │   0 │   0 │   0 │   0 │
├─────┼─────┼─────┼─────┼─────┤
│   1 │ 108 │   0 │   1 │   0 │
├─────┼─────┼─────┼─────┼─────┤
│   0 │   0 │ 110 │   0 │   0 │
├─────┼─────┼─────┼─────┼─────┤
│   0 │   0 │   0 │ 108 │   2 │
├─────┼─────┼─────┼─────┼─────┤
│   1 │   0 │   0 │   0 │ 109 │
╘═════╧═════╧═════╧═════╧═════╛
Done@2021-01-02T17Z
```

Confusion Matrix for each Label

Actual\Predict	Pred Neg	Pred Pos
Act Neg	TN	FP
Act Pos	FN	TP

In [88]:

```
mul_conf_mat = multilabel_confusion_matrix(y_test_labelled, y_pred_labelled, labels=
table = tabulate(mul_conf_mat[0], tablefmt='fancy_grid')
print("E")
print(table)
table = tabulate(mul_conf_mat[1], tablefmt='fancy_grid')
print("L")
print(table)
table = tabulate(mul_conf_mat[2], tablefmt='fancy_grid')
print("F")
print(table)
table = tabulate(mul_conf_mat[3], tablefmt='fancy_grid')
print("V")
print(table)
table = tabulate(mul_conf_mat[4], tablefmt='fancy_grid')
print("B")
print(table)
import datetime
print("Done@" + datetime.datetime.now().strftime("%Y-%m-%dT%HZ"))
```

```
E
╒═════╤═════╕
│ 438 │   2 │
├─────┼─────┤
│   0 │ 110 │
╘═════╧═════╛
L
╒═════╤═════╕
│ 440 │   0 │
├─────┼─────┤
│   2 │ 108 │
╘═════╧═════╛
F
╒═════╤═════╕
│ 440 │   0 │
├─────┼─────┤
│   0 │ 110 │
╘═════╧═════╛
V
╒═════╤═════╕
│ 439 │   1 │
├─────┼─────┤
│   2 │ 108 │
╘═════╧═════╛
```

B

438	2
1	109

Done@2021-01-02T17Z

In [89]:

```
from sklearn.metrics import accuracy_score
accuracy_score(y_test_labelled, y_pred_labelled)
```

Out[89]:

```
0.990909090909091
```

Measure Accuracy base Confusion matrix

In [90]:

```
np.sum(conf_mat)
accur = (conf_mat[0,0] + conf_mat[1,1] + conf_mat[2,2] + conf_mat[3,3] + conf_mat[4,
print(accur)
```

```
0.990909090909091
```

In [9]:

```
import tensorflow as tf
from tensorflow import keras
```

In [10]:

```
print("Num GPUs Available: ", len(tf.config.experimental.list_physical_devices('GPU'
```

```
Num GPUs Available:  1
```

In [11]:

```
tf.test.is_built_with_cuda()
```

Out[11]:

```
True
```

In [12]:

```
print(tf.version.VERSION)
```

```
2.4.0
```

In [13]:

```
import sys
sys.version
```

Out[13]:

```
'3.6.9 (default, Oct  8 2020, 12:12:24) \n[GCC 8.4.0]'
```

In [ ]: