Import Libraries

In [607]:
```
import os
import csv
import torch
import torchvision.transforms as transforms
from tqdm.notebook import tqdm
import pandas as pd
import numpy as np
from torch.utils.data import Dataset, DataLoader
from PIL import Image
import matplotlib.pyplot as plt
from tqdm.notebook import tqdm
import torch.nn.functional as F
import torch.nn as nn
import seaborn as sns
%matplotlib inline
```

Transforming Data to Tensors

In [562]:
```
DATA_DIR = '/content/drive/MyDrive/Colab Notebooks/Emotion_Detect/new_Fer2013.csv
```

In [563]:
```
data_df=pd.read_csv(DATA_DIR)
data_df.head()
```

Out[563]:

	emotion	pixels	Usage	label
0	0	77 78 79 79 78 75 60 55 47 48 58 73 77 79 57 5...	Training	Happy
1	0	85 84 90 121 101 102 133 153 153 169 177 189 1...	Training	Happy
2	0	4 2 13 41 56 62 67 87 95 62 65 70 80 107 127 1...	Training	Happy
3	0	14 14 18 28 27 22 21 30 42 61 77 86 88 95 100 ...	Training	Happy
4	0	252 250 246 229 182 140 98 72 53 44 67 95 95 8...	Training	Happy

In [564]:
```
classes = ['Happy', 'Sad', 'Neutral']
```

In [565]:
```
class DataSet(torch.utils.data.Dataset):

    def __init__(self,transform=None, images=None, emotions=None):
        self.transform = transform
        self.images = images
        self.emotions = emotions

    def __getitem__(self, index):
        image = self.images[index]
        emotion = self.emotions[index]
        if self.transform is not None:
            image = self.transform(image)
        return image, emotion

    def __len__(self):
        return len(self.images)
```

In [566]:
```
class DataSetFactory:

    def __init__(self):
        images = list()
        emotions = list()
        val_images = list()
        val_emotions = list()
        test_images = list()
        test_emotions = list()

        with open(DATA_DIR, 'r') as file:
            data = csv.reader(file)
            next(data)
            for row in data:
                face = [int(pixel) for pixel in row[1].split()]
                face = np.asarray(face).reshape(48, 48)
                face = face.astype('uint8')

                if row[-2] == 'Training':
                    emotions.append(int(row[0]))
                    images.append(Image.fromarray(face))
                if row[-2] == "PrivateTest":
                    val_emotions.append(int(row[0]))
                    val_images.append(Image.fromarray(face))
                if row[-2]=="PublicTest":
                    test_emotions.append(int(row[0]))
                    test_images.append(Image.fromarray(face))


        print('training size %d : val size %d : test_size %d'%(len(images), len(v
        train_transform = transforms.Compose([
            transforms.RandomHorizontalFlip(),
            transforms.RandomRotation(10),
            transforms.ToTensor(),
        ])
        val_transform = transforms.Compose([
            transforms.ToTensor()
        ])

        self.training = DataSet(transform=train_transform, images=images, emotior
        self.validation = DataSet(transform=val_transform, images=val_images, emc
        self.testing = DataSet(transform=val_transform, images=test_images, emoti
```

In [567]:
```
train_tfms = transforms.Compose([
    transforms.RandomHorizontalFlip(),
    transforms.RandomRotation(10),
    transforms.ToTensor()
])

valid_tfms = transforms.Compose([
    transforms.ToTensor(),
])
```

In [569]:
```
batch_size=128
factory = DataSetFactory()
training_loader = DataLoader(factory.training, batch_size=batch_size, shuffle=Tru
validation_loader = DataLoader(factory.validation, batch_size=batch_size, shuffle
testing_loader=DataLoader(factory.testing, batch_size=64, shuffle=True, num_worke
```

```
training size 17010 : val size 2099 : test_size 2155
```

In [570]:
```
def decode_target(target, text_labels=False):
    result = list()
    if text_labels:
        result.append(classes[target] + "(" + str(target) + ")")
        return ' '.join(result)
    for i, x in enumerate(target):
        if (x == torch.max(target)):
          # result.append(classes[i] + "(" + str(i) + ")")
          # return ' '.join(result)
          return int(i)
```

In [571]:
```
def show_sample(img, target, predict = False):
    img=img.squeeze(0)
    if predict:
      return decode_target(target)
    else:
      print('Labels:',decode_target(target,text_labels=True))
```

In [572]:
```
if torch.cuda.is_available():
  device = torch.device('cuda')
device
```

Out[572]:
```
device(type='cuda')
```

In [573]:
```
def to_device(data, device):
    """Move tensor(s) to chosen device"""
    if isinstance(data, (list,tuple)):
        return [to_device(x, device) for x in data]
    return data.to(device, non_blocking=True)

class DeviceDataLoader():
    """Wrap a dataloader to move data to a device"""
    def __init__(self, dl, device):
        self.dl = dl
        self.device = device

    def __iter__(self):
        """Yield a batch of data after moving it to device"""
        for b in self.dl:
            yield to_device(b, self.device)

    def __len__(self):
        """Number of batches"""
        return len(self.dl)
```

In [574]:
```
def accuracy(outputs, labels):
    _, preds = torch.max(outputs, dim=1)
    return torch.tensor(torch.sum(preds == labels).item() / len(preds))
```

In [575]:
```
training_loader = DeviceDataLoader(training_loader, device)
validation_loader = DeviceDataLoader(validation_loader, device)
testing_loader = DeviceDataLoader(testing_loader, device)
```

Building Model CNN

In [576]:
```
class Face(nn.Module):
    def training_step(self, batch):
        images, labels = batch
        out = self(images)                  # Generate predictions
        loss = F.cross_entropy(out, labels) # Calculate loss
        return loss

    def validation_step(self, batch):
        images, labels = batch
        out = self(images)                    # Generate predictions
        loss = F.cross_entropy(out, labels)   # Calculate loss
        acc = accuracy(out, labels)           # Calculate accuracy
        return {'val_loss': loss, 'val_acc': acc}

    def validation_epoch_end(self, outputs):
        batch_losses = [x['val_loss'] for x in outputs]
        epoch_loss = torch.stack(batch_losses).mean()   # Combine losses
        batch_accs = [x['val_acc'] for x in outputs]
        epoch_acc = torch.stack(batch_accs).mean()      # Combine accuracies
        return {'val_loss': epoch_loss.item(), 'val_acc': epoch_acc.item()}

    def epoch_end(self, epoch, result):
        print("Epoch [{}],last_lr: {:.4f}, val_loss: {:.4f}, val_acc: {:.4f}".for
```

In [577]:
```
class SeparableConv2d(nn.Module):

    def __init__(self, in_channels, out_channels, kernel_size=1, stride=1, paddi
        super(SeparableConv2d, self).__init__()
        self.depthwise = nn.Conv2d(in_channels, in_channels, kernel_size, stride,
                                   bias=bias)
        self.pointwise = nn.Conv2d(in_channels, out_channels, 1, 1, 0, 1, 1, bias

    def forward(self, x):
        x = self.depthwise(x)
        x = self.pointwise(x)
        return x


class ResidualBlock(nn.Module):

    def __init__(self, in_channeld, out_channels):
        super(ResidualBlock, self).__init__()

        self.residual_conv = nn.Conv2d(in_channels=in_channeld, out_channels=out_
                                       bias=False)
        self.residual_bn = nn.BatchNorm2d(out_channels, momentum=0.99, eps=1e-3)

        self.sepConv1 = SeparableConv2d(in_channels=in_channeld, out_channels=out
                                        padding=1)
        self.bn1 = nn.BatchNorm2d(out_channels, momentum=0.99, eps=1e-3)
        self.relu = nn.ReLU()

        self.sepConv2 = SeparableConv2d(in_channels=out_channels, out_channels=ou
                                        padding=1)
        self.bn2 = nn.BatchNorm2d(out_channels, momentum=0.99, eps=1e-3)
        self.maxp = nn.MaxPool2d(kernel_size=3, stride=2, padding=1)

    def forward(self, x):
        res = self.residual_conv(x)
        res = self.residual_bn(res)
        x = self.sepConv1(x)
        x = self.bn1(x)
        x = self.relu(x)
        x = self.sepConv2(x)
        x = self.bn2(x)
        x = self.maxp(x)
        return res + x


class FaceCnnModel(Face):

    def __init__(self):
        super(FaceCnnModel, self).__init__()

        self.conv1 = nn.Conv2d(in_channels=1, out_channels=8, kernel_size=3, stri
        self.bn1 = nn.BatchNorm2d(8, affine=True, momentum=0.99, eps=1e-3)
        self.relu1 = nn.ReLU()
        self.conv2 = nn.Conv2d(in_channels=8, out_channels=8, kernel_size=3, stri
        self.bn2 = nn.BatchNorm2d(8, momentum=0.99, eps=1e-3)
        self.relu2 = nn.ReLU()
```

```
        self.module1 = ResidualBlock(in_channeld=8, out_channels=16)
        self.module2 = ResidualBlock(in_channeld=16, out_channels=32)
        self.module3 = ResidualBlock(in_channeld=32, out_channels=64)
        self.module4 = ResidualBlock(in_channeld=64, out_channels=128)

        self.last_conv = nn.Conv2d(in_channels=128, out_channels=7, kernel_size=3
        self.avgp = nn.AdaptiveAvgPool2d((1, 1))

    def forward(self, input):
        x = input
        x = self.conv1(x)
        x = self.bn1(x)
        x = self.relu1(x)
        x = self.conv2(x)
        x = self.bn2(x)
        x = self.relu2(x)
        x = self.module1(x)
        x = self.module2(x)
        x = self.module3(x)
        x = self.module4(x)
        x = self.last_conv(x)
        x = self.avgp(x)
        x = x.view((x.shape[0], -1))
        return x
```

Training Model

In [578]:
```
@torch.no_grad()
def evaluate(model, val_loader):
    model.eval()
    outputs = [model.validation_step(batch) for batch in val_loader]
    return model.validation_epoch_end(outputs)

def get_lr(optimizer):
    for param_group in optimizer.param_groups:
        return param_group['lr']

def fit_one_cycle(epochs, max_lr, model, train_loader, val_loader,
                  weight_decay=0, grad_clip=None, opt_func=torch.optim.SGD):
    torch.cuda.empty_cache()
    history = []

    # Set up cutom optimizer with weight decay
    optimizer = opt_func(model.parameters(), max_lr, weight_decay=weight_decay)
    # Set up one-cycle learning rate scheduler
    sched = torch.optim.lr_scheduler.OneCycleLR(optimizer, max_lr, epochs=epochs,
                                                steps_per_epoch=len(train_loader)

    for epoch in range(epochs):
        # Training Phase
        model.train()
        train_losses = []
        lrs = []
        for batch in tqdm(train_loader):
            loss = model.training_step(batch)
            train_losses.append(loss)
            loss.backward()

            # Gradient clipping
            if grad_clip:
                nn.utils.clip_grad_value_(model.parameters(), grad_clip)

            optimizer.step()
            optimizer.zero_grad()

            # Record & update learning rate
            lrs.append(get_lr(optimizer))
            sched.step()

        # Validation phase
        result = evaluate(model, val_loader)
        result['train_loss'] = torch.stack(train_losses).mean().item()
        result['lrs'] = lrs
        model.epoch_end(epoch, result)
        history.append(result)
    return history
```

In [579]:
```
model = to_device(FaceCnnModel(), device)
```

In [580]:
```
max_lr=0.01
grad_clip = 0.1
weight_decay = 1e-4
epochs=10
opt_func = torch.optim.Adam
```

In [581]:
```
history = [evaluate(model, validation_loader)]
```

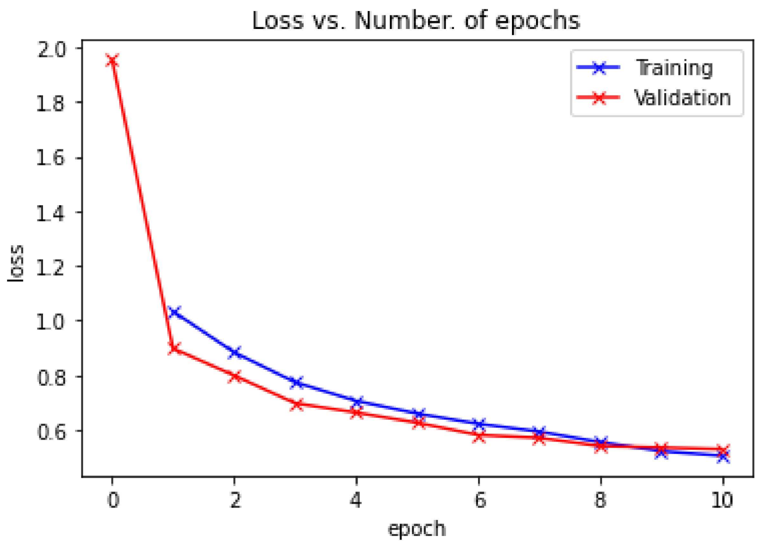
In [582]:
```
history += fit_one_cycle(epochs, max_lr, model, training_loader, validation_loade
                         grad_clip=grad_clip,
                         weight_decay=weight_decay,
                         opt_func=opt_func)
```

```
HBox(children=(FloatProgress(value=0.0, max=133.0), HTML(value='')))


Epoch [0],last_lr: 0.0028, val_loss: 0.8980, val_acc: 0.5700

HBox(children=(FloatProgress(value=0.0, max=133.0), HTML(value='')))


Epoch [1],last_lr: 0.0076, val_loss: 0.7991, val_acc: 0.6394

HBox(children=(FloatProgress(value=0.0, max=133.0), HTML(value='')))


Epoch [2],last_lr: 0.0100, val_loss: 0.6972, val_acc: 0.6778

HBox(children=(FloatProgress(value=0.0, max=133.0), HTML(value='')))


Epoch [3],last_lr: 0.0095, val_loss: 0.6632, val_acc: 0.7049

HBox(children=(FloatProgress(value=0.0, max=133.0), HTML(value='')))


Epoch [4],last_lr: 0.0081, val_loss: 0.6258, val_acc: 0.7281

HBox(children=(FloatProgress(value=0.0, max=133.0), HTML(value='')))


Epoch [5],last_lr: 0.0061, val_loss: 0.5811, val_acc: 0.7371

HBox(children=(FloatProgress(value=0.0, max=133.0), HTML(value='')))


Epoch [6],last_lr: 0.0039, val_loss: 0.5704, val_acc: 0.7527

HBox(children=(FloatProgress(value=0.0, max=133.0), HTML(value='')))


Epoch [7],last_lr: 0.0019, val_loss: 0.5406, val_acc: 0.7663

HBox(children=(FloatProgress(value=0.0, max=133.0), HTML(value='')))


Epoch [8],last_lr: 0.0005, val_loss: 0.5353, val_acc: 0.7695

HBox(children=(FloatProgress(value=0.0, max=133.0), HTML(value='')))


Epoch [9],last_lr: 0.0000, val_loss: 0.5291, val_acc: 0.7780
```

Plotting and Comparisions

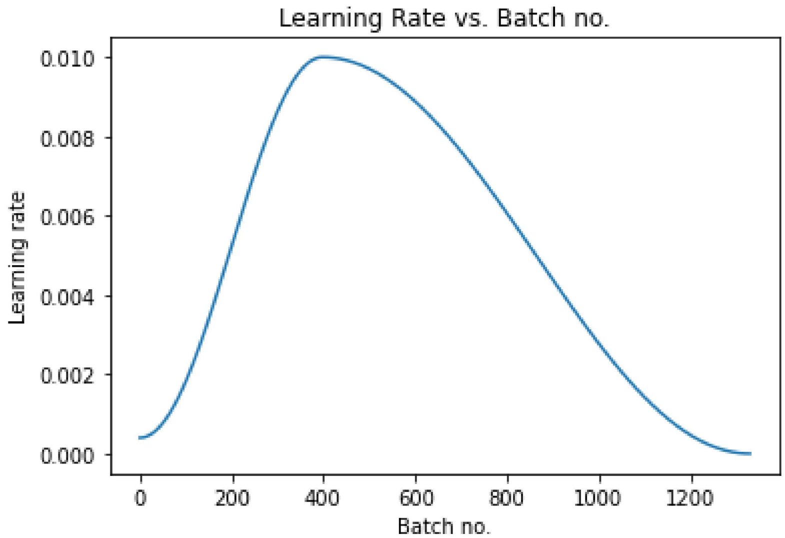
In [583]:
```
def plot_losses(history):
    train_losses = [x.get('train_loss') for x in history]
    val_losses = [x['val_loss'] for x in history]
    plt.plot(train_losses, '-bx')
    plt.plot(val_losses, '-rx')
    plt.xlabel('epoch')
    plt.ylabel('loss')
    plt.legend(['Training', 'Validation'])
    plt.title('Loss vs. Number. of epochs');
```

In [584]:
```
plot_losses(history)
```



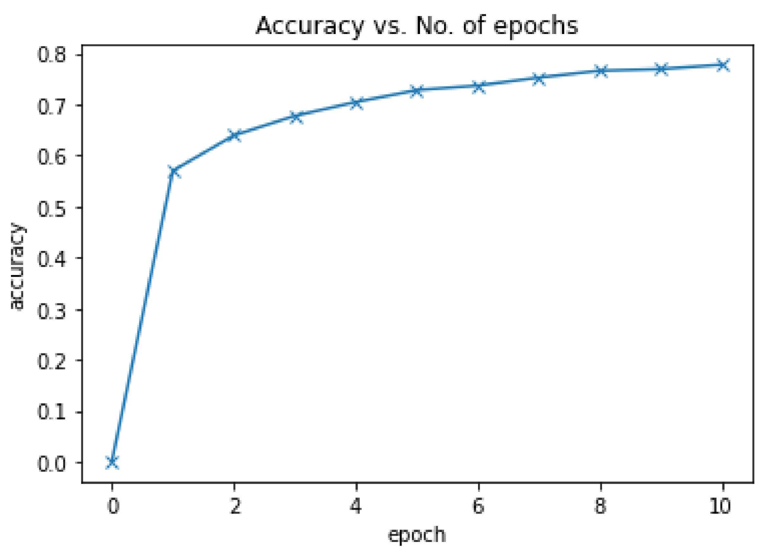
In [585]:
```
def plot_lrs(history):
    lrs = np.concatenate([x.get('lrs', []) for x in history])
    plt.plot(lrs)
    plt.xlabel('Batch no.')
    plt.ylabel('Learning rate')
    plt.title('Learning Rate vs. Batch no.');
```

In [586]:
```
plot_lrs(history)
```



In [587]:
```
def plot_accuracies(history):
    accuracies = [x['val_acc'] for x in history]
    plt.plot(accuracies, '-x')
    plt.xlabel('epoch')
    plt.ylabel('accuracy')
    plt.title('Accuracy vs. No. of epochs');
```

In [588]:
```
plot_accuracies(history)
```

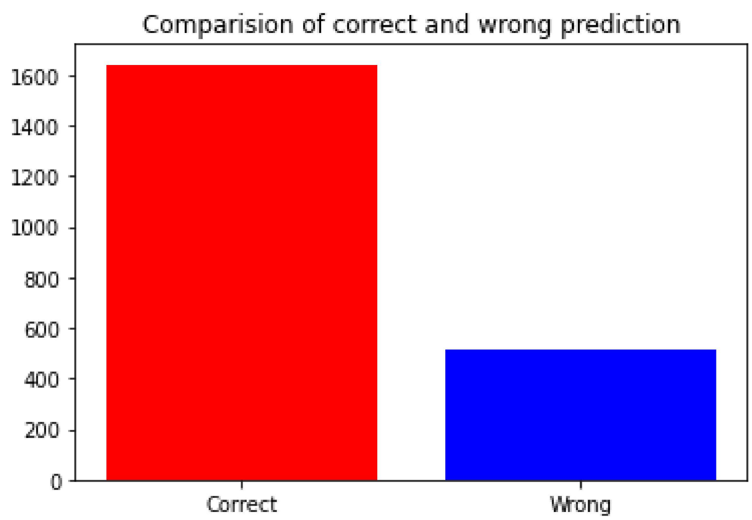


In [589]:
```
def predict_single(image):
    xb = image.unsqueeze(0)
    xb = to_device(xb, device)
    preds = model(xb)
    prediction = preds[0]
#     test=torch.max(prediction)
#     # print(test)
#     index = prediction.cpu().data.numpy().argmax()
#     # print("Prediction: ", prediction)
    return show_sample(image, prediction, predict = True)
```

In [590]:
```
prediction_list = []
for i in range(len(factory.testing)):
  prediction_list.append(predict_single(factory.testing[i][0]) == int(factory.tes
```

In [591]:
```
correct = prediction_list.count(True)
wrong = prediction_list.count(False)
height = [correct,wrong]
bars = ("Correct","Wrong")
x_pos = np.arange(len(bars))

# Create bars with different colors
plt.bar(x_pos, height, color=['red','blue'])

# Create names on the x-axis
plt.xticks(x_pos, bars)
plt.title("Comparision of correct and wrong prediction")
# Show graph
```

Out[591]:
```
Text(0.5, 1.0, 'Comparision of correct and wrong prediction')
```

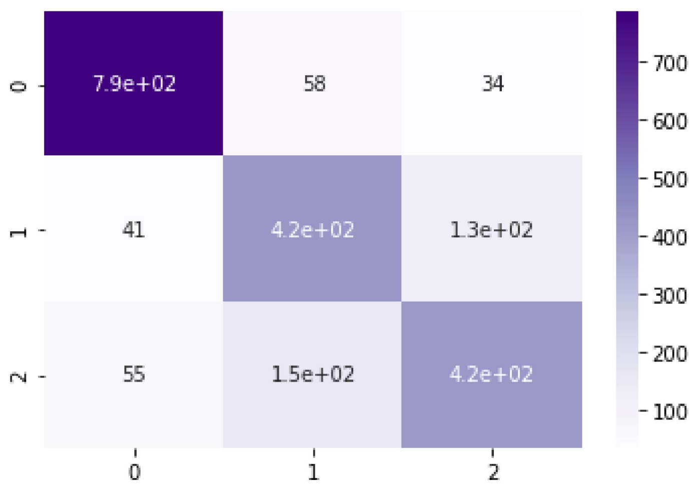


In [596]:
```
confusion_matrix = torch.zeros(3, 3)
with torch.no_grad():
    for i, (inputs, classes) in enumerate(validation_loader):
        outputs = model(inputs)
        _, preds = torch.max(outputs, 1)
        for t, p in zip(classes.view(-1), preds.view(-1)):
                confusion_matrix[t.long(), p.long()] += 1

print(confusion_matrix)
```

```
tensor([[787.,  58.,  34.],
        [ 41., 422., 131.],
        [ 55., 152., 419.]])
```

In [597]:
```
sn.heatmap(confusion_matrix,annot=True,cmap='Purples')
```

Out[597]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x7f188ea25910>
```



In [593]:
```
after = [evaluate(model, validation_loader)]
after
```

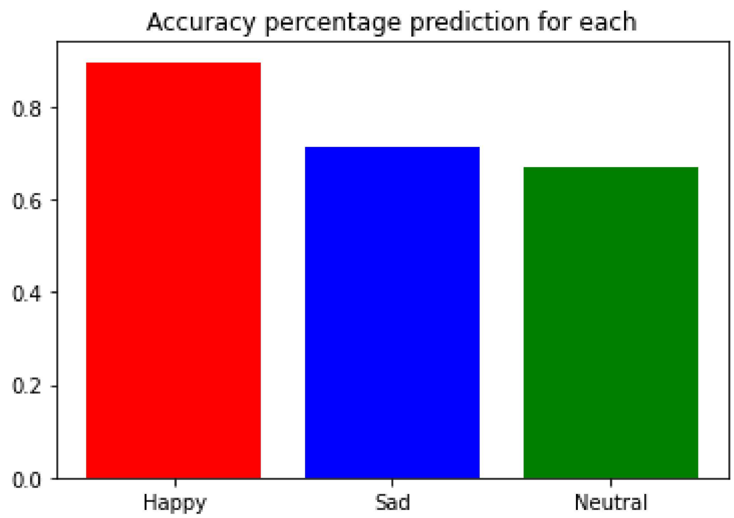
Out[593]:
```
[{'val_acc': 0.7738339900970459, 'val_loss': 0.5342395901679993}]
```

In [601]:
```
accuracy = (confusion_matrix.diag()/confusion_matrix.sum(1))
```

Out[601]:
```
[0.8953356146812439, 0.7104377150535583, 0.669329047203064]
```

In [604]:
```
height = accuracy.tolist()
bars = ("Happy","Sad","Neutral")
x_pos = np.arange(len(bars))

# Create bars with different colors
plt.bar(x_pos, height, color=['red','blue',"green"])

# Create names on the x-axis
plt.xticks(x_pos, bars)
plt.title("Accuracy percentage prediction for each")
# Show graph
```

Out[604]:
```
Text(0.5, 1.0, 'Accuracy percentage prediction for each')
```



Saving Model

In [605]:
```
torch.save(model,'Benten_CNN.pt')
```