Import libraries

```
from __future__ import print_function
import torch
import torch.nn as nn
import torch.nn.functional as F
import torch.optim as optim
from torchvision import datasets, transforms
```

```
from google.colab import drive
drive.mount('/content/drive', force_remount = True)
```

```
Mounted at /content/drive
```

```
%cd 'drive/MyDrive/EVA8/Session 5 - Assignment'
```

```
/content/drive/MyDrive/EVA8/Session 5 - Assignment
```

```
from model import NetWithGN, NetWithLN, NetWithBN
```

Data Transformations (without normalization)

```
# Train Phase transformations
train_transforms = transforms.Compose([
                                      transforms.RandomRotation((-7.0, 7.0), fill=(1,)),
                                      transforms.ToTensor()
                                       ])

# Test Phase transformations
                                   ose([
                                      transforms.ToTensor()
                                       ])
```


Dataset and Creating Train/Test Split (without normalization)

```
train = datasets.MNIST('./data', train=True, download=True, transform=train_transforms)
test = datasets.MNIST('./data', train=False, download=True, transform=test_transforms)
```

Dataloader Arguments & Test/Train Dataloaders (without normalization)

```
SEED = 1

# CUDA?
cuda = torch.cuda.is_available()
print("CUDA Available?", cuda)

# For reproducibility
torch.manual_seed(SEED)

if cuda:
    torch.cuda.manual_seed(SEED)

# dataloader arguments - something you'll fetch these from cmdprmt
dataloader_args = dict(shuffle=True, batch_size=128, num_workers=4, pin_memory=True) if cuda else dict(shuffle=True, batch

# train dataloader
train_loader = torch.utils.data.DataLoader(train, **dataloader_args)

# test dataloader
test_loader = torch.utils.data.DataLoader(test, **dataloader_args)
```

```
CUDA Available? True
/usr/local/lib/python3.8/dist-packages/torch/utils/data/dataloader.py:554: UserWarning: This DataLoader will create 4
  warnings.warn(_create_warning_msg(
```

Data Transformations (with normalization)

```
# Train Phase transformations
train_transforms = transforms.Compose([
                                      transforms.RandomRotation((-7.0, 7.0), fill=(1,)),
                                      transforms.ToTensor(),
                                      transforms.Normalize((0.1307,), (0.3081,))
                                       ])

# Test Phase transformations
test_transforms = transforms.Compose([
                                      transforms.ToTensor(),
                                      transforms.Normalize((0.1307,), (0.3081,))
                                       ])
```

Dataset and Creating Train/Test Split (with normalization)

```
train = datasets.MNIST('./data', train=True, download=True, transform=train_transforms)
test = datasets.MNIST('./data', train=False, download=True, transform=test_transforms)
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Dataloader Arguments & Test/Train Dataloaders (with normalization)

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cuda = torch.cuda.is_available()
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# dataloader arguments - something you'll fetch these from cmdprmt
dataloader_args = dict(shuffle=True, batch_size=128, num_workers=4, pin_memory=True) if cuda else dict(shuffle=True, batch

# train dataloader
train_loader = torch.utils.data.DataLoader(train, **dataloader_args)

# test dataloader
test_loader = torch.utils.data.DataLoader(test, **dataloader_args)
```

```
    CUDA Available? True
```

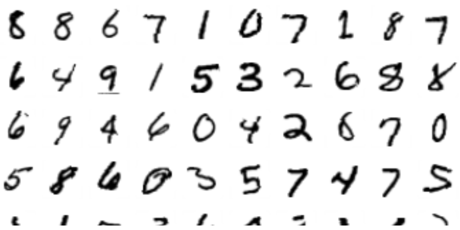
plot some images to see which image augmentation to use (with normalization)

We will plot some images to see which image augmentation technique we can use

```
dataiter = iter(train_loader)
images, labels = next(dataiter)

# Let's visualize some of the images
%matplotlib inline
import matplotlib.pyplot as plt

figure = plt.figure()
num_of_images = 60
for index in range(1, num_of_images + 1):
    plt.subplot(6, 10, index)
    plt.axis('off')
    plt.imshow(images[index].numpy().squeeze(), cmap='gray_r')
```



Training and Testing

```
from tqdm import tqdm

class TrainAndTest:
  def __init__(self):
    self.train_losses = []
    self.test_losses = []
    self.train_acc = []
    self.test_acc = []
    self.misclassified_images = []

  def train(self, model, device, train_loader, optimizer, epoch, task):
    """
    this function will train the model
    params model: model to be used for training
    params devide: can be GPU or CPu
    params train_loader: traininig data
    optimiser: optimiser to be used
    epoch: epoch number
    task: task for which training will be performed (can be 'GN' for Group normalisation, 'LN' for Layer normalisation or
          If this is 'BN' then only we will do L1 regularisation)
    returns: train_acc, train_losses
    """
    model.train()
    pbar = tqdm(train_loader)
    correct = 0

A Google Drive error has occurred.   in enumerate(pbar):

      data, target = data.to(device), target.to(device)

      # Init
      optimizer.zero_grad()
      # In PyTorch, we need to set the gradients to zero before starting to do backpropragation because PyTorch accumulate
      # Because of this, when you start your training loop, ideally you should zero out the gradients so that you do the p

      # Predict
      y_pred = model(data)

      # Calculate loss
      loss = F.nll_loss(y_pred, target)

      # Calculate 'L1' regularization loss if task == 'BN'
      if(task=='BN'):
        lambda_l1 = 0.01
        l1_reg = 0
        for param in model.parameters():
            l1_reg += torch.norm(param, p=1)
        l1_loss = lambda_l1 * l1_reg
        loss += l1_loss

      self.train_losses.append(loss)

      # Backpropagation
      loss.backward()
      optimizer.step()

      # Update pbar-tqdm

      pred = y_pred.argmax(dim=1, keepdim=True)  # get the index of the max log-probability
      correct += pred.eq(target.view_as(pred)).sum().item()
      processed += len(data)

      pbar.set_description(desc= f'Loss={loss.item()} Batch_id={batch_idx} Accuracy={100*correct/processed:0.2f}')
      self.train_acc.append(100*correct/processed)
    return self.train_acc, self.train_losses

  def test(self, model, device, test_loader):
```

```
    """
    this function will test the model in test data
    params model: model to be tested
    params devide: can be GPU or CPU
    params test_loader: test data
    returns: test_acc, test_losses and misclassified_images
    """
    model.eval()
    test_loss = 0
    correct = 0
    with torch.no_grad():
        for data, target in test_loader:
            data, target = data.to(device), target.to(device)
            output = model(data)
            test_loss += F.nll_loss(output, target, reduction='sum').item()  # sum up batch loss
            pred = output.argmax(dim=1, keepdim=True)  # get the index of the max log-probability
            indices = [item[0] for item in (pred.eq(target.view_as(pred)) == False).nonzero().tolist()]
            mis_imgs = data[indices, :, :, :]
            self.misclassified_images.extend(mis_imgs)
            correct += pred.eq(target.view_as(pred)).sum().item()

    test_loss /= len(test_loader.dataset)
    self.test_losses.append(test_loss)

    print('\nTest set: Average loss: {:.4f}, Accuracy: {}/{} ({:.2f}%)\n'.format(
        test_loss, correct, len(test_loader.dataset),
        100. * correct / len(test_loader.dataset)))

    self.test_acc.append(100. * correct / len(test_loader.dataset))
    return self.test_acc, self.test_losses, self.misclassified_images

use_cuda = torch.cuda.is_available()
device = torch.device("cuda" if use_cuda else "cpu")


def get_model(task_name):
  """
  this function will return the model based on the task_name
                                   'BN'
```



```
  if (task_name=='GN'):
    print("You have chosen GN, Now we will perform Group Normalisation")
    model =  NetWithGN().to(device)
  elif(task_name=='LN'):
    print("You have chosen LN, Now we will perform Layer Normalisation")
    model =  NetWithLN().to(device)
  elif(task_name=='BN'):
    print("You have chosen BN, Now we will perform Batch Normalisation with L1 regularisation")
    model =  NetWithBN().to(device)
  return model


from torch.optim.lr_scheduler import StepLR
def perform_tasks(task_name):
  """
  performs the train and test on the data
  params task_name: (GN, LN, BN)
  returns: train_acc, train_losses, test_acc, test_losses, misclassified_images
  """
  model = get_model(task_name) #get the model based on the task name (GN, LN, BN)
  optimizer = optim.SGD(model.parameters(), lr=0.01, momentum=0.9) #declare optimiser
  scheduler = StepLR(optimizer, step_size=6, gamma=0.1) #learning rate scheduler
  train_test_obj = TrainAndTest() #create the obejct of TrainAndTest class
  EPOCHS = 20
  for epoch in range(EPOCHS): #for each epoch
      print("EPOCH:", epoch)
      train_acc, train_losses = train_test_obj.train(model, device, train_loader, optimizer, epoch, task_name) #model trai
      scheduler.step() #update weights
      test_acc, test_losses, misclassified_images = train_test_obj.test(model, device, test_loader) #test model using test
  return train_acc, train_losses, test_acc, test_losses, misclassified_images


import random
def show_misclassified_images(misclassified_images, task_name):
  """
  show 10 misclassified images
  """
  misclassified_images = random.sample(misclassified_images, 10)
  fig, axs = plt.subplots(nrows=5, ncols=2, figsize=(8, 12))
  axs = axs.ravel()
```

```
  for i, ax in enumerate(axs):
      if i < 10:
          ax.imshow(misclassified_images[i].cpu().numpy().squeeze(), cmap='gray')
          ax.set_title('Image ' + str(i))

  plt.tight_layout()
  plt.suptitle(f'Misclassified images using {task_name}', y=1.02)
  plt.show()
```

Group Normalisation

```
task_name = 'GN'
train_acc_GN, train_losses_GN, test_acc_GN, test_losses_GN, misclassified_images_GN = perform_tasks(task_name)
train_losses_GN = [i.item() for i in train_losses_GN]
```

```
Test set: Average loss: 0.0212, Accuracy: 9921/10000 (99.21%)

EPOCH: 9
Loss=0.05961877107620239 Batch_id=468 Accuracy=97.69: 100%|██████████| 469/469 [00:18<00:00, 25.92it/s]

Test set: Average loss: 0.0198, Accuracy: 9921/10000 (99.21%)

EPOCH: 10
Loss=0.04525679349899292 Batch_id=468 Accuracy=97.66: 100%|██████████| 469/469 [00:18<00:00, 25.96it/s]

Test set: Average loss: 0.0205, Accuracy: 9927/10000 (99.27%)

EPOCH: 11
Loss=0.04970937967300415 Batch_id=468 Accuracy=97.52: 100%|██████████| 469/469 [00:18<00:00, 25.47it/s]

Test set: Average loss: 0.0187, Accuracy: 9922/10000 (99.22%)

EPOCH: 12
Loss=0.06041562557220459 Batch_id=468 Accuracy=97.67: 100%|██████████| 469/469 [00:18<00:00, 25.88it/s]

Test set: Average loss: 0.0187, Accuracy: 9928/10000 (99.28%)

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Test set: Average loss: 0.0186, Accuracy: 9930/10000 (99.30%)

EPOCH: 14
Loss=0.08620817214250565 Batch_id=468 Accuracy=97.74: 100%|██████████| 469/469 [00:18<00:00, 25.99it/s]

Test set: Average loss: 0.0188, Accuracy: 9928/10000 (99.28%)

EPOCH: 15
Loss=0.05799892917275429 Batch_id=468 Accuracy=97.73: 100%|██████████| 469/469 [00:18<00:00, 26.00it/s]

Test set: Average loss: 0.0187, Accuracy: 9925/10000 (99.25%)

EPOCH: 16
Loss=0.06123394891619682 Batch_id=468 Accuracy=97.65: 100%|██████████| 469/469 [00:18<00:00, 26.02it/s]

Test set: Average loss: 0.0186, Accuracy: 9926/10000 (99.26%)

EPOCH: 17
Loss=0.04270932078361511 Batch_id=468 Accuracy=97.71: 100%|██████████| 469/469 [00:18<00:00, 25.69it/s]

Test set: Average loss: 0.0187, Accuracy: 9926/10000 (99.26%)

EPOCH: 18
Loss=0.06956575065851212 Batch_id=468 Accuracy=97.74: 100%|██████████| 469/469 [00:17<00:00, 26.15it/s]

Test set: Average loss: 0.0186, Accuracy: 9926/10000 (99.26%)

EPOCH: 19
Loss=0.07965157181024551 Batch_id=468 Accuracy=97.72: 100%|██████████| 469/469 [00:17<00:00, 26.13it/s]

Test set: Average loss: 0.0186, Accuracy: 9926/10000 (99.26%)
```
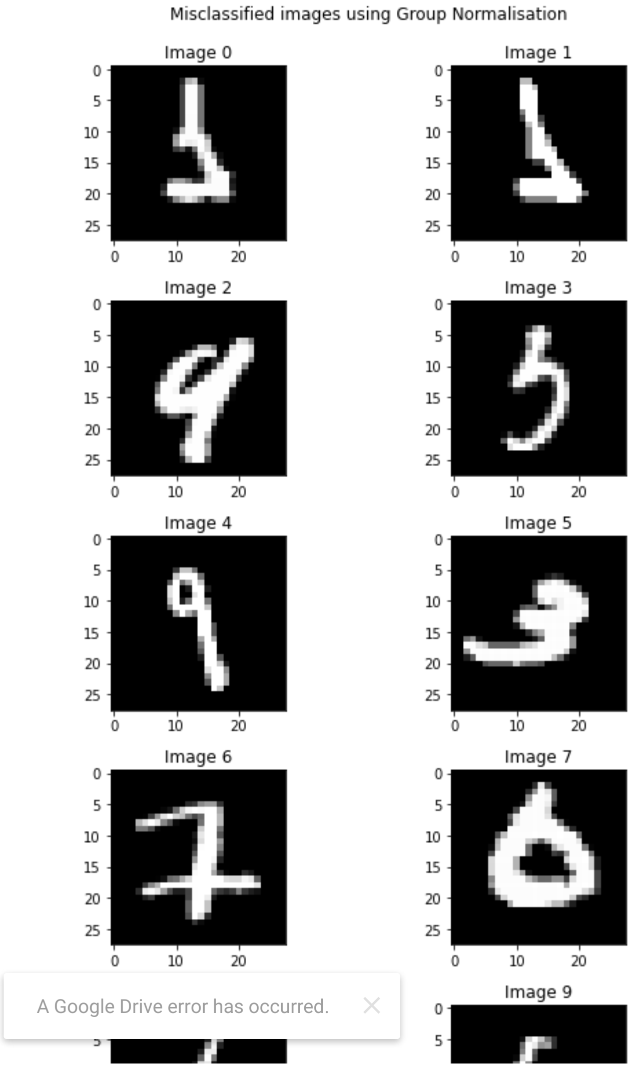

```
show_misclassified_images(misclassified_images_GN, 'Group Normalisation')
```

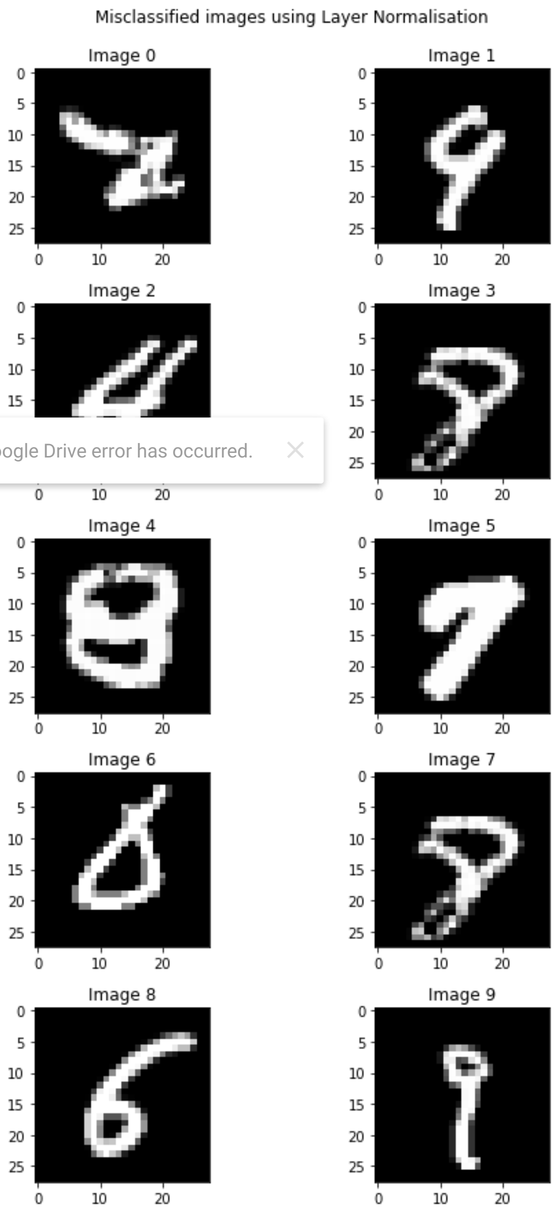



```
task_name = 'LN'
train_acc_LN, train_losses_LN, test_acc_LN, test_losses_LN, misclassified_images_LN = perform_tasks(task_name)
train_losses_LN = [i.item() for i in train_losses_LN]
```

```
You have chosen LN, Now we will perform Layer Normalisation
EPOCH: 0
Loss=0.20948584377765656 Batch_id=468 Accuracy=82.77: 100%|██████████| 469/469 [00:19<00:00, 24.66it/s]

Test set: Average loss: 0.1382, Accuracy: 9667/10000 (96.67%)

EPOCH: 1
Loss=0.16525419056415558 Batch_id=468 Accuracy=94.24: 100%|██████████| 469/469 [00:19<00:00, 24.57it/s]

Test set: Average loss: 0.0946, Accuracy: 9731/10000 (97.31%)

EPOCH: 2
Loss=0.09798494726419449 Batch_id=468 Accuracy=95.23: 100%|██████████| 469/469 [00:18<00:00, 24.76it/s]

Test set: Average loss: 0.0731, Accuracy: 9785/10000 (97.85%)

EPOCH: 3
Loss=0.06869831681251526 Batch_id=468 Accuracy=95.89: 100%|██████████| 469/469 [00:18<00:00, 25.01it/s]

Test set: Average loss: 0.0609, Accuracy: 9827/10000 (98.27%)

EPOCH: 4
Loss=0.14128398895263672 Batch_id=468 Accuracy=96.20: 100%|██████████| 469/469 [00:18<00:00, 24.88it/s]

Test set: Average loss: 0.0583, Accuracy: 9834/10000 (98.34%)

EPOCH: 5
Loss=0.13747243583202362 Batch_id=468 Accuracy=96.43: 100%|██████████| 469/469 [00:18<00:00, 24.99it/s]

Test set: Average loss: 0.0540, Accuracy: 9830/10000 (98.30%)

EPOCH: 6
Loss=0.0532214492559433 Batch_id=468 Accuracy=96.82: 100%|██████████| 469/469 [00:19<00:00, 24.65it/s]

Test set: Average loss: 0.0468, Accuracy: 9858/10000 (98.58%)

EPOCH: 7
```

```
Loss=0.12967424094676971 Batch_id=468 Accuracy=96.71: 100%|██████████| 469/469 [00:19<00:00, 24.45it/s]

Test set: Average loss: 0.0455, Accuracy: 9868/10000 (98.68%)

EPOCH: 8
Loss=0.25995495915412903 Batch_id=468 Accuracy=96.91: 100%|██████████| 469/469 [00:18<00:00, 24.79it/s]

Test set: Average loss: 0.0451, Accuracy: 9875/10000 (98.75%)

EPOCH: 9
Loss=0.04723837599158287 Batch_id=468 Accuracy=96.86: 100%|██████████| 469/469 [00:18<00:00, 24.98it/s]

Test set: Average loss: 0.0451, Accuracy: 9856/10000 (98.56%)

EPOCH: 10
Loss=0.055987898260354996 Batch_id=468 Accuracy=96.93: 100%|██████████| 469/469 [00:18<00:00, 25.10it/s]

Test set: Average loss: 0.0450, Accuracy: 9863/10000 (98.63%)

EPOCH: 11
```

```
show_misclassified_images(misclassified_images_LN, 'Layer Normalisation')
```



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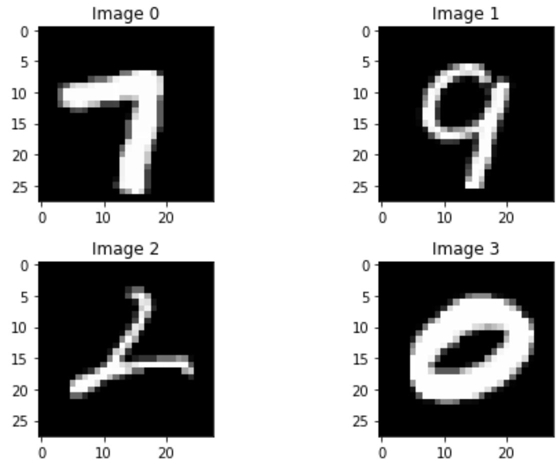
Bacth Normalisation with L1 regularisation

```
task_name = 'BN'
train_acc_BN, train_losses_BN, test_acc_BN, test_losses_BN, misclassified_images_BN = perform_tasks(task_name)
train_losses_BN = [i.item() for i in train_losses_BN]
```

```
EPOCH: 1
Loss=1.1470924615859985 Batch_id=468 Accuracy=89.70: 100%|██████████| 469/469 [00:19<00:00, 24.39it/s]

Test set: Average loss: 0.9903, Accuracy: 6651/10000 (66.51%)

EPOCH: 2
Loss=1.0104014873504639 Batch_id=468 Accuracy=90.13: 100%|██████████| 469/469 [00:19<00:00, 24.20it/s]

Test set: Average loss: 0.6918, Accuracy: 7792/10000 (77.92%)

EPOCH: 3
Loss=1.466449499130249 Batch_id=468 Accuracy=89.86: 100%|██████████| 469/469 [00:19<00:00, 23.92it/s]

Test set: Average loss: 5.0010, Accuracy: 3986/10000 (39.86%)

EPOCH: 4
Loss=1.0603042840957642 Batch_id=468 Accuracy=88.52: 100%|██████████| 469/469 [00:19<00:00, 23.90it/s]

Test set: Average loss: 0.9016, Accuracy: 6894/10000 (68.94%)

EPOCH: 5
Loss=0.9505712985992432 Batch_id=468 Accuracy=89.60: 100%|██████████| 469/469 [00:19<00:00, 23.71it/s]

Test set: Average loss: 0.5401, Accuracy: 8736/10000 (87.36%)

EPOCH: 6
Loss=0.7473505735397339 Batch_id=468 Accuracy=92.27: 100%|██████████| 469/469 [00:19<00:00, 23.50it/s]

Test set: Average loss: 0.1856, Accuracy: 9609/10000 (96.09%)

EPOCH: 7
Loss=0.8415389657020569 Batch_id=468 Accuracy=92.08: 100%|██████████| 469/469 [00:19<00:00, 23.80it/s]

Test set: Average loss: 0.1889, Accuracy: 9511/10000 (95.11%)

EPOCH: 8
Loss=0.721432089805603 Batch_id=468 Accuracy=92.04: 100%|██████████| 469/469 [00:19<00:00, 23.84it/s]

Test set: Average loss: 0.2357, Accuracy: 9407/10000 (94.07%)

EPOCH: 9
Loss=0.7655919790267944 Batch_id=468 Accuracy=91.95: 100%|██████████| 469/469 [00:20<00:00, 23.42it/s]
A Google Drive error has occurred.  ×  78, Accuracy: 8989/10000 (89.89%)

EPOCH: 10
Loss=0.8030099868774414 Batch_id=468 Accuracy=91.96: 100%|██████████| 469/469 [00:19<00:00, 23.83it/s]

Test set: Average loss: 0.1611, Accuracy: 9645/10000 (96.45%)

EPOCH: 11
Loss=0.7599208354949951 Batch_id=468 Accuracy=91.95: 100%|██████████| 469/469 [00:19<00:00, 23.93it/s]

Test set: Average loss: 0.1932, Accuracy: 9636/10000 (96.36%)
```

```
show_misclassified_images(misclassified_images_BN, 'Batch Normalisation with L1 regularisation')
```

Misclassified images using Batch Normalisation with L1 regularisation



Comparing loses and accuracies

```
fig, axs = plt.subplots(1,2,figsize=(15,5))
axs[0].plot(test_losses_GN, label='Group Normalisation')
axs[0].plot(test_losses_LN, label = 'Layer Normalisation')
axs[0].plot(test_losses_BN, label = 'Batch Normalisation + L1')
axs[0].set_title("Test Loss")
axs[0].set_xlabel('Epochs')
axs[0].set_ylabel('Loss')
axs[0].legend()

axs[1].plot(test_acc_GN, label='Group Normalisation')
axs[1].plot(test_acc_LN, label = 'Layer Normalisation')
axs[1].plot(test_acc_BN, label = 'Batch Normalisation + L1')
axs[1].set_title("Test Accuracy")
axs[0].set_xlabel('Epochs')
```

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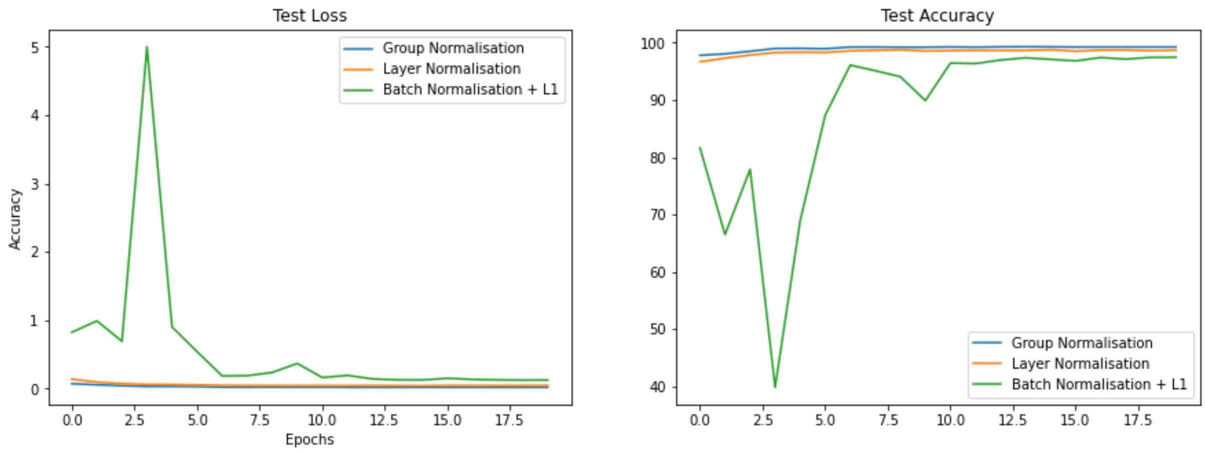
```
<matplotlib.legend.Legend at 0x7f769e06ff40>
```



✓ 2s completed at 23:19

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