Report for Assignment 2

COMP338

1) My deep neural network for image classification consists of batch normalisation, Leaky ReLU activation, fully connected layer, dropout layers and convolutional layers. It's a Convolutional Neural Network architecture.

   The following model is the architecture used:

   'nn.Module' is used for image classification which is inherited by the class Model,then I initialize the neural network layers:

```
class Model(nn.Module):
    def __init__(self):
        super(Model, self).__init__()
```

   I then introduced the convolutional layers with batch normalisation, 2D dropout layer and two fully connected layers

```
self.c1 = nn.Conv2d(1, 32, kernel_size=(3, 3), padding=1)
        self.b1 = nn.BatchNorm2d(32)
        self.c2 = nn.Conv2d(32, 64, kernel_size=(3, 3), padding=1)
        self.b2 = nn.BatchNorm2d(64)
        self.c3 = nn.Conv2d(64, 128, kernel_size=(3, 3), padding=1)
        self.b3 = nn.BatchNorm2d(128)
        self.drop_2d = nn.Dropout2d(p=0.25)
        self.fc_1 = nn.Linear(128 * 3 * 3, 512)
        self.drop = nn.Dropout(p=0.5)
        self.fc_2 = nn.Linear(512, 10)
```

I made another method that forwards the pass of the network, dropout is applied after the first connected layer and max-pooling layer.

Also, After every convolutional layer, leaky ReLU activations are used.

```
def forward(self, x):
        x = F.leaky_relu(self.b1(self.c1(x)), negative_slope=0.01)
        x = self.drop_2d(F.max_pool2d(x, kernel_size=2))
        x = F.leaky_relu(self.b2(self.c2(x)), negative_slope=0.01)
        x = self.drop_2d(F.max_pool2d(x, kernel_size=2))
        x = F.leaky_relu(self.b3(self.c3(x)), negative_slope=0.01)
        x = self.drop_2d(F.max_pool2d(x, kernel_size=2))
        x = x.view(-1, 128 * 3 * 3)
        x = F.leaky_relu(self.fc_1(x), negative_slope=0.01)
        x = self.drop(x)
        x = self.fc_2(x)
        return F.log_softmax(x, dim=1)
```

The ‘reset_parameters’ method useful for reinitializing the model's weights before training, it resets the parameters of the fully connected and convolutional layers

2) I have trained and tested my network on Fashion MNIST dataset various times but the following is my final result, I have used the Lab 8[1] code for training my model on Fashion MNIST.

```
                                                                  >  c:; cd
'c:\Users\akter\OneDrive\Documents\Uni\Year 3\Comp338\A2'; &
'C:\Users\akter\AppData\Local\Programs\Python\Python311\python.exe'
'c:\Users\akter\.vscode\extensions\ms-python.python-
2023.22.1\pythonFiles\lib\python\debugpy\adapter/../..\debugpy\launcher
' '60181' '--' 'C:\Users\akter\OneDrive\Documents\Uni\Year
3\Comp338\A2\A2.py'

tensor(0.2860) tensor(0.3202)

torch.Size([1, 28, 28])

9 Ankle boot

tensor([[-1.8597, -3.1746, -2.3972, -2.2888, -2.8400, -2.7798, -1.9814,
-2.2189,

         -1.8049, -2.5444]], grad_fn=<LogSoftmaxBackward0>)

Step 0, current LR: 0.000100, loss 2.367362

Step 1, current LR: 0.010099, loss 2.177195

Step 2, current LR: 0.020098, loss 1.644790

Step 3, current LR: 0.030097, loss 1.226809

Step 4, current LR: 0.040096, loss 1.056518

Step 5, current LR: 0.050095, loss 0.968560

Step 6, current LR: 0.060094, loss 0.987204

Step 7, current LR: 0.070093, loss 0.811682

Step 8, current LR: 0.080092, loss 0.878750

Step 9, current LR: 0.090091, loss 0.882271

Step 10, current LR: 0.100090, loss 0.867876

Step 11, current LR: 0.110089, loss 0.799723

Step 12, current LR: 0.120088, loss 0.783197

Step 13, current LR: 0.130087, loss 0.762974

Step 14, current LR: 0.140086, loss 0.744828

Step 15, current LR: 0.150085, loss 0.837485

Step 16, current LR: 0.160084, loss 0.754406

Step 17, current LR: 0.170083, loss 0.791676
```

```
Step 18, current LR: 0.180082, loss 0.726336
Step 19, current LR: 0.190081, loss 0.774911
Step 20, current LR: 0.200080, loss 0.610797
Step 21, current LR: 0.210079, loss 0.680883
Step 22, current LR: 0.220078, loss 0.648943
Step 23, current LR: 0.230077, loss 0.699219
Step 24, current LR: 0.240076, loss 0.648218
Step 25, current LR: 0.250075, loss 0.614649
Step 26, current LR: 0.260074, loss 0.625982
Step 27, current LR: 0.270073, loss 0.672118
Step 28, current LR: 0.280072, loss 0.670602
Step 29, current LR: 0.290071, loss 0.581754
Step 30, current LR: 0.300070, loss 0.605485
Step 31, current LR: 0.310069, loss 0.543179
Step 32, current LR: 0.320068, loss 0.565057
Step 33, current LR: 0.330067, loss 0.569663
Step 34, current LR: 0.340066, loss 0.540360
Step 35, current LR: 0.350065, loss 0.510972
Step 36, current LR: 0.360064, loss 0.542620
Step 37, current LR: 0.370063, loss 0.582890
Step 38, current LR: 0.380062, loss 0.580740
Step 39, current LR: 0.390061, loss 0.539078
Step 40, current LR: 0.400060, loss 0.532968
Step 41, current LR: 0.410059, loss 0.528239
Step 42, current LR: 0.420058, loss 0.503957
Step 43, current LR: 0.430057, loss 0.487498
Step 44, current LR: 0.440056, loss 0.509289
Step 45, current LR: 0.450055, loss 0.494630
Step 46, current LR: 0.460054, loss 0.496604
Step 47, current LR: 0.470053, loss 0.482492
Step 48, current LR: 0.480052, loss 0.511084
Step 49, current LR: 0.490051, loss 0.534057
```

```
Step 50, current LR: 0.500050, loss 0.529274
Step 51, current LR: 0.510049, loss 0.549977
Step 52, current LR: 0.520048, loss 0.508406
Step 53, current LR: 0.530047, loss 0.484863
Step 54, current LR: 0.540046, loss 0.447664
Step 55, current LR: 0.550045, loss 0.544953
Step 56, current LR: 0.560044, loss 0.510531
Step 57, current LR: 0.570043, loss 0.507150
Step 58, current LR: 0.580042, loss 0.545038
Step 59, current LR: 0.590041, loss 0.501610
Step 60, current LR: 0.600040, loss 0.540597
Step 61, current LR: 0.610039, loss 0.450064
Step 62, current LR: 0.620038, loss 0.402151
Step 63, current LR: 0.630037, loss 0.439261
Step 64, current LR: 0.640036, loss 0.523732
Step 65, current LR: 0.650035, loss 0.478338
Step 66, current LR: 0.660034, loss 0.537907
Step 67, current LR: 0.670033, loss 0.446739
Step 68, current LR: 0.680032, loss 0.471001
Step 69, current LR: 0.690031, loss 0.459456
Step 70, current LR: 0.700030, loss 0.469187
Step 71, current LR: 0.710029, loss 0.502816
Step 72, current LR: 0.720028, loss 0.452961
Step 73, current LR: 0.730027, loss 0.485690
Step 74, current LR: 0.740026, loss 0.498849
Step 75, current LR: 0.750025, loss 0.441921
Step 76, current LR: 0.760024, loss 0.505286
Step 77, current LR: 0.770023, loss 0.458592
Step 78, current LR: 0.780022, loss 0.505416
Step 79, current LR: 0.790021, loss 0.562281
Step 80, current LR: 0.800020, loss 0.521498
Step 81, current LR: 0.810019, loss 0.484522
```

```
Step 82, current LR: 0.820018, loss 0.526953
Step 83, current LR: 0.830017, loss 0.523590
Step 84, current LR: 0.840016, loss 0.511844
Step 85, current LR: 0.850015, loss 0.515545
Step 86, current LR: 0.860014, loss 0.582136
Step 87, current LR: 0.870013, loss 0.459326
Step 88, current LR: 0.880012, loss 0.504005
Step 89, current LR: 0.890011, loss 0.538392
Step 90, current LR: 0.900010, loss 0.486304
Step 91, current LR: 0.910009, loss 0.489360
Step 92, current LR: 0.920008, loss 0.651780
Step 93, current LR: 0.930007, loss 0.513763
Step 94, current LR: 0.940006, loss 0.545003
Step 95, current LR: 0.950005, loss 0.516291
Step 96, current LR: 0.960004, loss 0.585188
Step 97, current LR: 0.970003, loss 0.565405
Step 98, current LR: 0.980002, loss 0.562153
Step 99, current LR: 0.990001, loss 0.544502
Best LR 0.15500949999999986
Train Epoch: 1 [0/60000 (0%)]   Loss: 2.284818
Train Epoch: 1 [3200/60000 (5%)]        Loss: 0.669529
Train Epoch: 1 [6400/60000 (11%)]       Loss: 0.700049
Train Epoch: 1 [9600/60000 (16%)]       Loss: 0.565863
Train Epoch: 1 [12800/60000 (21%)]      Loss: 0.401261
Train Epoch: 1 [16000/60000 (27%)]      Loss: 0.499787
Train Epoch: 1 [19200/60000 (32%)]      Loss: 0.551861
Train Epoch: 1 [22400/60000 (37%)]      Loss: 0.369242
Train Epoch: 1 [25600/60000 (43%)]      Loss: 0.477346
Train Epoch: 1 [28800/60000 (48%)]      Loss: 0.257523
Train Epoch: 1 [32000/60000 (53%)]      Loss: 0.518233
Train Epoch: 1 [35200/60000 (59%)]      Loss: 0.307784
Train Epoch: 1 [38400/60000 (64%)]      Loss: 0.353217
```

```
Train Epoch: 1 [41600/60000 (69%)]      Loss: 0.327703

Train Epoch: 1 [44800/60000 (75%)]      Loss: 0.398024

Train Epoch: 1 [48000/60000 (80%)]      Loss: 0.601247

Train Epoch: 1 [51200/60000 (85%)]      Loss: 0.387848

Train Epoch: 1 [54400/60000 (91%)]      Loss: 0.751706

Train Epoch: 1 [57600/60000 (96%)]      Loss: 0.460450

C:\Users\akter\AppData\Local\Programs\Python\Python311\Lib\site-
packages\torch\nn\_reduction.py:42: UserWarning: size_average and
reduce args will be deprecated, please use reduction='sum' instead.

  warnings.warn(warning.format(ret))


Test set: Average loss: 0.3445, Accuracy: 8736/10000 (87%)


C:\Users\akter\AppData\Local\Programs\Python\Python311\Lib\site-
packages\torch\optim\lr_scheduler.py:149: UserWarning: The epoch
parameter in `scheduler.step()` was not necessary and is being
deprecated where possible. Please use `scheduler.step()` to step the
scheduler. During the deprecation, if epoch is different from None, the
closed form is used instead of the new chainable form, where available.
Please open an issue if you are unable to replicate your use case:
https://github.com/pytorch/pytorch/issues/new/choose.

  warnings.warn(EPOCH_DEPRECATION_WARNING, UserWarning)

Train Epoch: 2 [0/60000 (0%)]   Loss: 0.147087

Train Epoch: 2 [3200/60000 (5%)]        Loss: 0.242825

Train Epoch: 2 [6400/60000 (11%)]       Loss: 0.511084

Train Epoch: 2 [9600/60000 (16%)]       Loss: 0.482474

Train Epoch: 2 [12800/60000 (21%)]      Loss: 0.248904

Train Epoch: 2 [16000/60000 (27%)]      Loss: 0.505841

Train Epoch: 2 [19200/60000 (32%)]      Loss: 0.507763

Train Epoch: 2 [22400/60000 (37%)]      Loss: 0.203072

Train Epoch: 2 [25600/60000 (43%)]      Loss: 0.404112

Train Epoch: 2 [28800/60000 (48%)]      Loss: 0.333338

Train Epoch: 2 [32000/60000 (53%)]      Loss: 0.285990

Train Epoch: 2 [35200/60000 (59%)]      Loss: 0.389168

Train Epoch: 2 [38400/60000 (64%)]      Loss: 0.590697
```

```
Train Epoch: 2 [41600/60000 (69%)]      Loss: 0.529820
Train Epoch: 2 [44800/60000 (75%)]      Loss: 0.210139
Train Epoch: 2 [48000/60000 (80%)]      Loss: 0.276648
Train Epoch: 2 [51200/60000 (85%)]      Loss: 0.295714
Train Epoch: 2 [54400/60000 (91%)]      Loss: 0.414928
Train Epoch: 2 [57600/60000 (96%)]      Loss: 0.213051

Test set: Average loss: 0.2976, Accuracy: 8862/10000 (89%)

Train Epoch: 3 [0/60000 (0%)]   Loss: 0.353808
Train Epoch: 3 [3200/60000 (5%)]        Loss: 0.120168
Train Epoch: 3 [6400/60000 (11%)]       Loss: 0.175571
Train Epoch: 3 [9600/60000 (16%)]       Loss: 0.148384
Train Epoch: 3 [12800/60000 (21%)]      Loss: 0.408646
Train Epoch: 3 [16000/60000 (27%)]      Loss: 0.383682
Train Epoch: 3 [19200/60000 (32%)]      Loss: 0.177019
Train Epoch: 3 [22400/60000 (37%)]      Loss: 0.218066
Train Epoch: 3 [25600/60000 (43%)]      Loss: 0.233183
Train Epoch: 3 [28800/60000 (48%)]      Loss: 0.394906
Train Epoch: 3 [32000/60000 (53%)]      Loss: 0.290600
Train Epoch: 3 [35200/60000 (59%)]      Loss: 0.194964
Train Epoch: 3 [38400/60000 (64%)]      Loss: 0.189315
Train Epoch: 3 [41600/60000 (69%)]      Loss: 0.222278
Train Epoch: 3 [44800/60000 (75%)]      Loss: 0.176076
Train Epoch: 3 [48000/60000 (80%)]      Loss: 0.127407
Train Epoch: 3 [51200/60000 (85%)]      Loss: 0.238179
Train Epoch: 3 [54400/60000 (91%)]      Loss: 0.226442
Train Epoch: 3 [57600/60000 (96%)]      Loss: 0.181935

Test set: Average loss: 0.2783, Accuracy: 8959/10000 (90%)

Train Epoch: 4 [0/60000 (0%)]   Loss: 0.334824
```

```
Train Epoch: 4 [3200/60000 (5%)]        Loss: 0.250964
Train Epoch: 4 [6400/60000 (11%)]       Loss: 0.126519
Train Epoch: 4 [9600/60000 (16%)]       Loss: 0.352087
Train Epoch: 4 [12800/60000 (21%)]      Loss: 0.366425
Train Epoch: 4 [16000/60000 (27%)]      Loss: 0.304416
Train Epoch: 4 [19200/60000 (32%)]      Loss: 0.381255
Train Epoch: 4 [22400/60000 (37%)]      Loss: 0.422339
Train Epoch: 4 [25600/60000 (43%)]      Loss: 0.083914
Train Epoch: 4 [28800/60000 (48%)]      Loss: 0.278738
Train Epoch: 4 [32000/60000 (53%)]      Loss: 0.103549
Train Epoch: 4 [35200/60000 (59%)]      Loss: 0.506841
Train Epoch: 4 [38400/60000 (64%)]      Loss: 0.305666
Train Epoch: 4 [41600/60000 (69%)]      Loss: 0.279692
Train Epoch: 4 [44800/60000 (75%)]      Loss: 0.457645
Train Epoch: 4 [48000/60000 (80%)]      Loss: 0.131175
Train Epoch: 4 [51200/60000 (85%)]      Loss: 0.444106
Train Epoch: 4 [54400/60000 (91%)]      Loss: 0.191257
Train Epoch: 4 [57600/60000 (96%)]      Loss: 0.275416

Test set: Average loss: 0.2540, Accuracy: 9071/10000 (91%)

Train Epoch: 5 [0/60000 (0%)]   Loss: 0.269519
Train Epoch: 5 [3200/60000 (5%)]        Loss: 0.117834
Train Epoch: 5 [6400/60000 (11%)]       Loss: 0.204048
Train Epoch: 5 [9600/60000 (16%)]       Loss: 0.201575
Train Epoch: 5 [12800/60000 (21%)]      Loss: 0.324231
Train Epoch: 5 [16000/60000 (27%)]      Loss: 0.183858
Train Epoch: 5 [19200/60000 (32%)]      Loss: 0.570320
Train Epoch: 5 [22400/60000 (37%)]      Loss: 0.151579
Train Epoch: 5 [25600/60000 (43%)]      Loss: 0.116057
Train Epoch: 5 [28800/60000 (48%)]      Loss: 0.096191
Train Epoch: 5 [32000/60000 (53%)]      Loss: 0.138877
```

```
Train Epoch: 5 [35200/60000 (59%)]      Loss: 0.300690
Train Epoch: 5 [38400/60000 (64%)]      Loss: 0.235336
Train Epoch: 5 [41600/60000 (69%)]      Loss: 0.115381
Train Epoch: 5 [44800/60000 (75%)]      Loss: 0.220713
Train Epoch: 5 [48000/60000 (80%)]      Loss: 0.260003
Train Epoch: 5 [51200/60000 (85%)]      Loss: 0.249519
Train Epoch: 5 [54400/60000 (91%)]      Loss: 0.259438
Train Epoch: 5 [57600/60000 (96%)]      Loss: 0.377515

Test set: Average loss: 0.2544, Accuracy: 9066/10000 (91%)

Train Epoch: 6 [0/60000 (0%)]   Loss: 0.221382
Train Epoch: 6 [3200/60000 (5%)]        Loss: 0.135301
Train Epoch: 6 [6400/60000 (11%)]       Loss: 0.354989
Train Epoch: 6 [9600/60000 (16%)]       Loss: 0.148672
Train Epoch: 6 [12800/60000 (21%)]      Loss: 0.170225
Train Epoch: 6 [16000/60000 (27%)]      Loss: 0.310208
Train Epoch: 6 [19200/60000 (32%)]      Loss: 0.346885
Train Epoch: 6 [22400/60000 (37%)]      Loss: 0.431055
Train Epoch: 6 [25600/60000 (43%)]      Loss: 0.283916
Train Epoch: 6 [28800/60000 (48%)]      Loss: 0.219890
Train Epoch: 6 [32000/60000 (53%)]      Loss: 0.269138
Train Epoch: 6 [35200/60000 (59%)]      Loss: 0.458967
Train Epoch: 6 [38400/60000 (64%)]      Loss: 0.243867
Train Epoch: 6 [41600/60000 (69%)]      Loss: 0.344873
Train Epoch: 6 [44800/60000 (75%)]      Loss: 0.136298
Train Epoch: 6 [48000/60000 (80%)]      Loss: 0.107845
Train Epoch: 6 [51200/60000 (85%)]      Loss: 0.082719
Train Epoch: 6 [54400/60000 (91%)]      Loss: 0.157060
Train Epoch: 6 [57600/60000 (96%)]      Loss: 0.361737

Test set: Average loss: 0.2474, Accuracy: 9102/10000 (91%)
```

```
Train Epoch: 7 [0/60000 (0%)]   Loss: 0.247690
Train Epoch: 7 [3200/60000 (5%)]        Loss: 0.317258
Train Epoch: 7 [6400/60000 (11%)]       Loss: 0.328935
Train Epoch: 7 [9600/60000 (16%)]       Loss: 0.209821
Train Epoch: 7 [12800/60000 (21%)]      Loss: 0.315075
Train Epoch: 7 [16000/60000 (27%)]      Loss: 0.153562
Train Epoch: 7 [19200/60000 (32%)]      Loss: 0.260912
Train Epoch: 7 [22400/60000 (37%)]      Loss: 0.404386
Train Epoch: 7 [25600/60000 (43%)]      Loss: 0.129358
Train Epoch: 7 [28800/60000 (48%)]      Loss: 0.358716
Train Epoch: 7 [32000/60000 (53%)]      Loss: 0.397293
Train Epoch: 7 [35200/60000 (59%)]      Loss: 0.550251
Train Epoch: 7 [38400/60000 (64%)]      Loss: 0.152387
Train Epoch: 7 [41600/60000 (69%)]      Loss: 0.314585
Train Epoch: 7 [44800/60000 (75%)]      Loss: 0.049652
Train Epoch: 7 [48000/60000 (80%)]      Loss: 0.489659
Train Epoch: 7 [51200/60000 (85%)]      Loss: 0.336331
Train Epoch: 7 [54400/60000 (91%)]      Loss: 0.213662
Train Epoch: 7 [57600/60000 (96%)]      Loss: 0.255660

Test set: Average loss: 0.2542, Accuracy: 9058/10000 (91%)

Train Epoch: 8 [0/60000 (0%)]   Loss: 0.127633
Train Epoch: 8 [3200/60000 (5%)]        Loss: 0.131552
Train Epoch: 8 [6400/60000 (11%)]       Loss: 0.322923
Train Epoch: 8 [9600/60000 (16%)]       Loss: 0.328242
Train Epoch: 8 [12800/60000 (21%)]      Loss: 0.213035
Train Epoch: 8 [16000/60000 (27%)]      Loss: 0.164457
Train Epoch: 8 [19200/60000 (32%)]      Loss: 0.459046
Train Epoch: 8 [22400/60000 (37%)]      Loss: 0.292276
Train Epoch: 8 [25600/60000 (43%)]      Loss: 0.192200
```

```
Train Epoch: 8 [28800/60000 (48%)]      Loss: 0.194468
Train Epoch: 8 [32000/60000 (53%)]      Loss: 0.248349
Train Epoch: 8 [35200/60000 (59%)]      Loss: 0.478862
Train Epoch: 8 [38400/60000 (64%)]      Loss: 0.112020
Train Epoch: 8 [41600/60000 (69%)]      Loss: 0.258259
Train Epoch: 8 [44800/60000 (75%)]      Loss: 0.758875
Train Epoch: 8 [48000/60000 (80%)]      Loss: 0.129911
Train Epoch: 8 [51200/60000 (85%)]      Loss: 0.091921
Train Epoch: 8 [54400/60000 (91%)]      Loss: 0.218471
Train Epoch: 8 [57600/60000 (96%)]      Loss: 0.196154

Test set: Average loss: 0.2580, Accuracy: 9050/10000 (90%)

Train Epoch: 9 [0/60000 (0%)]   Loss: 0.162212
Train Epoch: 9 [3200/60000 (5%)]        Loss: 0.259033
Train Epoch: 9 [6400/60000 (11%)]       Loss: 0.550702
Train Epoch: 9 [9600/60000 (16%)]       Loss: 0.138305
Train Epoch: 9 [12800/60000 (21%)]      Loss: 0.149227
Train Epoch: 9 [16000/60000 (27%)]      Loss: 0.272030
Train Epoch: 9 [19200/60000 (32%)]      Loss: 0.162374
Train Epoch: 9 [22400/60000 (37%)]      Loss: 0.218032
Train Epoch: 9 [25600/60000 (43%)]      Loss: 0.258348
Train Epoch: 9 [28800/60000 (48%)]      Loss: 0.107854
Train Epoch: 9 [32000/60000 (53%)]      Loss: 0.433166
Train Epoch: 9 [35200/60000 (59%)]      Loss: 0.233859
Train Epoch: 9 [38400/60000 (64%)]      Loss: 0.293387
Train Epoch: 9 [41600/60000 (69%)]      Loss: 0.150888
Train Epoch: 9 [44800/60000 (75%)]      Loss: 0.208071
Train Epoch: 9 [48000/60000 (80%)]      Loss: 0.285518
Train Epoch: 9 [51200/60000 (85%)]      Loss: 0.154989
Train Epoch: 9 [54400/60000 (91%)]      Loss: 0.071917
Train Epoch: 9 [57600/60000 (96%)]      Loss: 0.193569
```

```
Test set: Average loss: 0.2413, Accuracy: 9100/10000 (91%)

Train Epoch: 10 [0/60000 (0%)]  Loss: 0.258336
Train Epoch: 10 [3200/60000 (5%)]       Loss: 0.372819
Train Epoch: 10 [6400/60000 (11%)]      Loss: 0.431715
Train Epoch: 10 [9600/60000 (16%)]      Loss: 0.162497
Train Epoch: 10 [12800/60000 (21%)]     Loss: 0.324251
Train Epoch: 10 [16000/60000 (27%)]     Loss: 0.055974
Train Epoch: 10 [19200/60000 (32%)]     Loss: 0.111387
Train Epoch: 10 [22400/60000 (37%)]     Loss: 0.344210
Train Epoch: 10 [25600/60000 (43%)]     Loss: 0.090062
Train Epoch: 10 [28800/60000 (48%)]     Loss: 0.189000
Train Epoch: 10 [32000/60000 (53%)]     Loss: 0.438991
Train Epoch: 10 [35200/60000 (59%)]     Loss: 0.223389
Train Epoch: 10 [38400/60000 (64%)]     Loss: 0.350007
Train Epoch: 10 [41600/60000 (69%)]     Loss: 0.100897
Train Epoch: 10 [44800/60000 (75%)]     Loss: 0.371671
Train Epoch: 10 [48000/60000 (80%)]     Loss: 0.065494
Train Epoch: 10 [51200/60000 (85%)]     Loss: 0.199656
Train Epoch: 10 [54400/60000 (91%)]     Loss: 0.521232
Train Epoch: 10 [57600/60000 (96%)]     Loss: 0.353044

Test set: Average loss: 0.2281, Accuracy: 9183/10000 (92%)

Train Epoch: 11 [0/60000 (0%)]  Loss: 0.266851
Train Epoch: 11 [3200/60000 (5%)]       Loss: 0.096388
Train Epoch: 11 [6400/60000 (11%)]      Loss: 0.242638
Train Epoch: 11 [9600/60000 (16%)]      Loss: 0.125699
Train Epoch: 11 [12800/60000 (21%)]     Loss: 0.107887
Train Epoch: 11 [16000/60000 (27%)]     Loss: 0.147439
Train Epoch: 11 [19200/60000 (32%)]     Loss: 0.133625
```

```
Train Epoch: 11 [22400/60000 (37%)]     Loss: 0.121648
Train Epoch: 11 [25600/60000 (43%)]     Loss: 0.039231
Train Epoch: 11 [28800/60000 (48%)]     Loss: 0.418295
Train Epoch: 11 [32000/60000 (53%)]     Loss: 0.059303
Train Epoch: 11 [35200/60000 (59%)]     Loss: 0.158304
Train Epoch: 11 [38400/60000 (64%)]     Loss: 0.235332
Train Epoch: 11 [41600/60000 (69%)]     Loss: 0.087018
Train Epoch: 11 [44800/60000 (75%)]     Loss: 0.510702
Train Epoch: 11 [48000/60000 (80%)]     Loss: 0.085632
Train Epoch: 11 [51200/60000 (85%)]     Loss: 0.135293
Train Epoch: 11 [54400/60000 (91%)]     Loss: 0.136916
Train Epoch: 11 [57600/60000 (96%)]     Loss: 0.131132

Test set: Average loss: 0.2278, Accuracy: 9184/10000 (92%)

Train Epoch: 12 [0/60000 (0%)]  Loss: 0.140254
Train Epoch: 12 [3200/60000 (5%)]       Loss: 0.194500
Train Epoch: 12 [6400/60000 (11%)]      Loss: 0.237094
Train Epoch: 12 [9600/60000 (16%)]      Loss: 0.229096
Train Epoch: 12 [12800/60000 (21%)]     Loss: 0.087347
Train Epoch: 12 [16000/60000 (27%)]     Loss: 0.237802
Train Epoch: 12 [19200/60000 (32%)]     Loss: 0.102381
Train Epoch: 12 [22400/60000 (37%)]     Loss: 0.353462
Train Epoch: 12 [25600/60000 (43%)]     Loss: 0.168221
Train Epoch: 12 [28800/60000 (48%)]     Loss: 0.231476
Train Epoch: 12 [32000/60000 (53%)]     Loss: 0.346666
Train Epoch: 12 [35200/60000 (59%)]     Loss: 0.128028
Train Epoch: 12 [38400/60000 (64%)]     Loss: 0.232141
Train Epoch: 12 [41600/60000 (69%)]     Loss: 0.114252
Train Epoch: 12 [44800/60000 (75%)]     Loss: 0.196243
Train Epoch: 12 [48000/60000 (80%)]     Loss: 0.172571
Train Epoch: 12 [51200/60000 (85%)]     Loss: 0.231232
```

```
Train Epoch: 12 [54400/60000 (91%)]     Loss: 0.408616
Train Epoch: 12 [57600/60000 (96%)]     Loss: 0.259723

Test set: Average loss: 0.2294, Accuracy: 9164/10000 (92%)

Train Epoch: 13 [0/60000 (0%)]  Loss: 0.141668
Train Epoch: 13 [3200/60000 (5%)]       Loss: 0.241525
Train Epoch: 13 [6400/60000 (11%)]      Loss: 0.084475
Train Epoch: 13 [9600/60000 (16%)]      Loss: 0.114124
Train Epoch: 13 [12800/60000 (21%)]     Loss: 0.080732
Train Epoch: 13 [16000/60000 (27%)]     Loss: 0.368501
Train Epoch: 13 [19200/60000 (32%)]     Loss: 0.456996
Train Epoch: 13 [22400/60000 (37%)]     Loss: 0.226210
Train Epoch: 13 [25600/60000 (43%)]     Loss: 0.207762
Train Epoch: 13 [28800/60000 (48%)]     Loss: 0.121362
Train Epoch: 13 [32000/60000 (53%)]     Loss: 0.228537
Train Epoch: 13 [35200/60000 (59%)]     Loss: 0.119864
Train Epoch: 13 [38400/60000 (64%)]     Loss: 0.103579
Train Epoch: 13 [41600/60000 (69%)]     Loss: 0.639782
Train Epoch: 13 [44800/60000 (75%)]     Loss: 0.204730
Train Epoch: 13 [48000/60000 (80%)]     Loss: 0.113923
Train Epoch: 13 [51200/60000 (85%)]     Loss: 0.177870
Train Epoch: 13 [54400/60000 (91%)]     Loss: 0.174485
Train Epoch: 13 [57600/60000 (96%)]     Loss: 0.228979

Test set: Average loss: 0.2392, Accuracy: 9110/10000 (91%)

Train Epoch: 14 [0/60000 (0%)]  Loss: 0.093956
Train Epoch: 14 [3200/60000 (5%)]       Loss: 0.261350
Train Epoch: 14 [6400/60000 (11%)]      Loss: 0.178673
Train Epoch: 14 [9600/60000 (16%)]      Loss: 0.350368
Train Epoch: 14 [12800/60000 (21%)]     Loss: 0.098180
```

```
Train Epoch: 14 [16000/60000 (27%)]     Loss: 0.563507
Train Epoch: 14 [19200/60000 (32%)]     Loss: 0.177621
Train Epoch: 14 [22400/60000 (37%)]     Loss: 0.211035
Train Epoch: 14 [25600/60000 (43%)]     Loss: 0.225930
Train Epoch: 14 [28800/60000 (48%)]     Loss: 0.192950
Train Epoch: 14 [32000/60000 (53%)]     Loss: 0.148077
Train Epoch: 14 [35200/60000 (59%)]     Loss: 0.218732
Train Epoch: 14 [38400/60000 (64%)]     Loss: 0.546368
Train Epoch: 14 [41600/60000 (69%)]     Loss: 0.311532
Train Epoch: 14 [44800/60000 (75%)]     Loss: 0.262348
Train Epoch: 14 [48000/60000 (80%)]     Loss: 0.192662
Train Epoch: 14 [51200/60000 (85%)]     Loss: 0.225981
Train Epoch: 14 [54400/60000 (91%)]     Loss: 0.145885
Train Epoch: 14 [57600/60000 (96%)]     Loss: 0.068899

Test set: Average loss: 0.2336, Accuracy: 9154/10000 (92%)

Train Epoch: 15 [0/60000 (0%)]  Loss: 0.217917
Train Epoch: 15 [3200/60000 (5%)]       Loss: 0.183640
Train Epoch: 15 [6400/60000 (11%)]      Loss: 0.310900
Train Epoch: 15 [9600/60000 (16%)]      Loss: 0.243404
Train Epoch: 15 [12800/60000 (21%)]     Loss: 0.027050
Train Epoch: 15 [16000/60000 (27%)]     Loss: 0.294297
Train Epoch: 15 [19200/60000 (32%)]     Loss: 0.573549
Train Epoch: 15 [22400/60000 (37%)]     Loss: 0.111196
Train Epoch: 15 [25600/60000 (43%)]     Loss: 0.268351
Train Epoch: 15 [28800/60000 (48%)]     Loss: 0.067472
Train Epoch: 15 [32000/60000 (53%)]     Loss: 0.139042
Train Epoch: 15 [35200/60000 (59%)]     Loss: 0.182671
Train Epoch: 15 [38400/60000 (64%)]     Loss: 0.352957
Train Epoch: 15 [41600/60000 (69%)]     Loss: 0.264442
Train Epoch: 15 [44800/60000 (75%)]     Loss: 0.081119
```

```
Train Epoch: 15 [48000/60000 (80%)]     Loss: 0.064089
Train Epoch: 15 [51200/60000 (85%)]     Loss: 0.418650
Train Epoch: 15 [54400/60000 (91%)]     Loss: 0.350456
Train Epoch: 15 [57600/60000 (96%)]     Loss: 0.245281

Test set: Average loss: 0.2256, Accuracy: 9183/10000 (92%)

Train Epoch: 16 [0/60000 (0%)]  Loss: 0.231796
Train Epoch: 16 [3200/60000 (5%)]       Loss: 0.086664
Train Epoch: 16 [6400/60000 (11%)]      Loss: 0.269998
Train Epoch: 16 [9600/60000 (16%)]      Loss: 0.234114
Train Epoch: 16 [12800/60000 (21%)]     Loss: 0.189053
Train Epoch: 16 [16000/60000 (27%)]     Loss: 0.250320
Train Epoch: 16 [19200/60000 (32%)]     Loss: 0.229309
Train Epoch: 16 [22400/60000 (37%)]     Loss: 0.312933
Train Epoch: 16 [25600/60000 (43%)]     Loss: 0.145855
Train Epoch: 16 [28800/60000 (48%)]     Loss: 0.144862
Train Epoch: 16 [32000/60000 (53%)]     Loss: 0.193211
Train Epoch: 16 [35200/60000 (59%)]     Loss: 0.231272
Train Epoch: 16 [38400/60000 (64%)]     Loss: 0.237566
Train Epoch: 16 [41600/60000 (69%)]     Loss: 0.073902
Train Epoch: 16 [44800/60000 (75%)]     Loss: 0.039168
Train Epoch: 16 [48000/60000 (80%)]     Loss: 0.152219
Train Epoch: 16 [51200/60000 (85%)]     Loss: 0.187135
Train Epoch: 16 [54400/60000 (91%)]     Loss: 0.249443
Train Epoch: 16 [57600/60000 (96%)]     Loss: 0.348727

Test set: Average loss: 0.2152, Accuracy: 9229/10000 (92%)

Train Epoch: 17 [0/60000 (0%)]  Loss: 0.105379
Train Epoch: 17 [3200/60000 (5%)]       Loss: 0.170515
Train Epoch: 17 [6400/60000 (11%)]      Loss: 0.374534
```

```
Train Epoch: 17 [9600/60000 (16%)]      Loss: 0.042635
Train Epoch: 17 [12800/60000 (21%)]     Loss: 0.301322
Train Epoch: 17 [16000/60000 (27%)]     Loss: 0.236927
Train Epoch: 17 [19200/60000 (32%)]     Loss: 0.252912
Train Epoch: 17 [22400/60000 (37%)]     Loss: 0.151363
Train Epoch: 17 [25600/60000 (43%)]     Loss: 0.090547
Train Epoch: 17 [28800/60000 (48%)]     Loss: 0.105029
Train Epoch: 17 [32000/60000 (53%)]     Loss: 0.197586
Train Epoch: 17 [35200/60000 (59%)]     Loss: 0.224573
Train Epoch: 17 [38400/60000 (64%)]     Loss: 0.282855
Train Epoch: 17 [41600/60000 (69%)]     Loss: 0.321768
Train Epoch: 17 [44800/60000 (75%)]     Loss: 0.083824
Train Epoch: 17 [48000/60000 (80%)]     Loss: 0.363828
Train Epoch: 17 [51200/60000 (85%)]     Loss: 0.295905
Train Epoch: 17 [54400/60000 (91%)]     Loss: 0.105106
Train Epoch: 17 [57600/60000 (96%)]     Loss: 0.157616

Test set: Average loss: 0.2147, Accuracy: 9227/10000 (92%)

Train Epoch: 18 [0/60000 (0%)]  Loss: 0.182092
Train Epoch: 18 [3200/60000 (5%)]       Loss: 0.063100
Train Epoch: 18 [6400/60000 (11%)]      Loss: 0.118038
Train Epoch: 18 [9600/60000 (16%)]      Loss: 0.270264
Train Epoch: 18 [12800/60000 (21%)]     Loss: 0.156428
Train Epoch: 18 [16000/60000 (27%)]     Loss: 0.376725
Train Epoch: 18 [19200/60000 (32%)]     Loss: 0.550755
Train Epoch: 18 [22400/60000 (37%)]     Loss: 0.074650
Train Epoch: 18 [25600/60000 (43%)]     Loss: 0.359740
Train Epoch: 18 [28800/60000 (48%)]     Loss: 0.290011
Train Epoch: 18 [32000/60000 (53%)]     Loss: 0.205332
Train Epoch: 18 [35200/60000 (59%)]     Loss: 0.181072
Train Epoch: 18 [38400/60000 (64%)]     Loss: 0.108975
```

```
Train Epoch: 18 [41600/60000 (69%)]     Loss: 0.333759
Train Epoch: 18 [44800/60000 (75%)]     Loss: 0.047148
Train Epoch: 18 [48000/60000 (80%)]     Loss: 0.046085
Train Epoch: 18 [51200/60000 (85%)]     Loss: 0.062050
Train Epoch: 18 [54400/60000 (91%)]     Loss: 0.127744
Train Epoch: 18 [57600/60000 (96%)]     Loss: 0.384642

Test set: Average loss: 0.2127, Accuracy: 9232/10000 (92%)

Train Epoch: 19 [0/60000 (0%)]  Loss: 0.373279
Train Epoch: 19 [3200/60000 (5%)]       Loss: 0.432973
Train Epoch: 19 [6400/60000 (11%)]      Loss: 0.221669
Train Epoch: 19 [9600/60000 (16%)]      Loss: 0.181928
Train Epoch: 19 [12800/60000 (21%)]     Loss: 0.185661
Train Epoch: 19 [16000/60000 (27%)]     Loss: 0.175699
Train Epoch: 19 [19200/60000 (32%)]     Loss: 0.057187
Train Epoch: 19 [22400/60000 (37%)]     Loss: 0.241681
Train Epoch: 19 [25600/60000 (43%)]     Loss: 0.190081
Train Epoch: 19 [28800/60000 (48%)]     Loss: 0.381701
Train Epoch: 19 [32000/60000 (53%)]     Loss: 0.178810
Train Epoch: 19 [35200/60000 (59%)]     Loss: 0.101957
Train Epoch: 19 [38400/60000 (64%)]     Loss: 0.070171
Train Epoch: 19 [41600/60000 (69%)]     Loss: 0.097166
Train Epoch: 19 [44800/60000 (75%)]     Loss: 0.149985
Train Epoch: 19 [48000/60000 (80%)]     Loss: 0.181670
Train Epoch: 19 [51200/60000 (85%)]     Loss: 0.167013
Train Epoch: 19 [54400/60000 (91%)]     Loss: 0.163036
Train Epoch: 19 [57600/60000 (96%)]     Loss: 0.464870

Test set: Average loss: 0.2298, Accuracy: 9154/10000 (92%)

Train Epoch: 20 [0/60000 (0%)]  Loss: 0.151015
```

```
Train Epoch: 20 [3200/60000 (5%)]       Loss: 0.074904
Train Epoch: 20 [6400/60000 (11%)]      Loss: 0.226993
Train Epoch: 20 [9600/60000 (16%)]      Loss: 0.234816
Train Epoch: 20 [12800/60000 (21%)]     Loss: 0.300222
Train Epoch: 20 [16000/60000 (27%)]     Loss: 0.102581
Train Epoch: 20 [19200/60000 (32%)]     Loss: 0.058458
Train Epoch: 20 [22400/60000 (37%)]     Loss: 0.092174
Train Epoch: 20 [25600/60000 (43%)]     Loss: 0.240170
Train Epoch: 20 [28800/60000 (48%)]     Loss: 0.365579
Train Epoch: 20 [32000/60000 (53%)]     Loss: 0.156040
Train Epoch: 20 [35200/60000 (59%)]     Loss: 0.320360
Train Epoch: 20 [38400/60000 (64%)]     Loss: 0.417951
Train Epoch: 20 [41600/60000 (69%)]     Loss: 0.089889
Train Epoch: 20 [44800/60000 (75%)]     Loss: 0.190165
Train Epoch: 20 [48000/60000 (80%)]     Loss: 0.118459
Train Epoch: 20 [51200/60000 (85%)]     Loss: 0.217849
Train Epoch: 20 [54400/60000 (91%)]     Loss: 0.160777
Train Epoch: 20 [57600/60000 (96%)]     Loss: 0.053574

Test set: Average loss: 0.2268, Accuracy: 9193/10000 (92%)

Train Epoch: 21 [0/60000 (0%)]  Loss: 0.091587
Train Epoch: 21 [3200/60000 (5%)]       Loss: 0.111735
Train Epoch: 21 [6400/60000 (11%)]      Loss: 0.230729
Train Epoch: 21 [9600/60000 (16%)]      Loss: 0.116341
Train Epoch: 21 [12800/60000 (21%)]     Loss: 0.210068
Train Epoch: 21 [16000/60000 (27%)]     Loss: 0.206757
Train Epoch: 21 [19200/60000 (32%)]     Loss: 0.089675
Train Epoch: 21 [22400/60000 (37%)]     Loss: 0.102239
Train Epoch: 21 [25600/60000 (43%)]     Loss: 0.133530
Train Epoch: 21 [28800/60000 (48%)]     Loss: 0.181349
Train Epoch: 21 [32000/60000 (53%)]     Loss: 0.225148
```

```
Train Epoch: 21 [35200/60000 (59%)]     Loss: 0.257884
Train Epoch: 21 [38400/60000 (64%)]     Loss: 0.405956
Train Epoch: 21 [41600/60000 (69%)]     Loss: 0.114115
Train Epoch: 21 [44800/60000 (75%)]     Loss: 0.272520
Train Epoch: 21 [48000/60000 (80%)]     Loss: 0.160547
Train Epoch: 21 [51200/60000 (85%)]     Loss: 0.299128
Train Epoch: 21 [54400/60000 (91%)]     Loss: 0.106102
Train Epoch: 21 [57600/60000 (96%)]     Loss: 0.139390

Test set: Average loss: 0.2143, Accuracy: 9200/10000 (92%)

Train Epoch: 22 [0/60000 (0%)]  Loss: 0.149550
Train Epoch: 22 [3200/60000 (5%)]       Loss: 0.269402
Train Epoch: 22 [6400/60000 (11%)]      Loss: 0.242133
Train Epoch: 22 [9600/60000 (16%)]      Loss: 0.267989
Train Epoch: 22 [12800/60000 (21%)]     Loss: 0.231771
Train Epoch: 22 [16000/60000 (27%)]     Loss: 0.072673
Train Epoch: 22 [19200/60000 (32%)]     Loss: 0.180050
Train Epoch: 22 [22400/60000 (37%)]     Loss: 0.067765
Train Epoch: 22 [25600/60000 (43%)]     Loss: 0.151444
Train Epoch: 22 [28800/60000 (48%)]     Loss: 0.365056
Train Epoch: 22 [32000/60000 (53%)]     Loss: 0.217065
Train Epoch: 22 [35200/60000 (59%)]     Loss: 0.224308
Train Epoch: 22 [38400/60000 (64%)]     Loss: 0.028444
Train Epoch: 22 [41600/60000 (69%)]     Loss: 0.158789
Train Epoch: 22 [44800/60000 (75%)]     Loss: 0.194917
Train Epoch: 22 [48000/60000 (80%)]     Loss: 0.167354
Train Epoch: 22 [51200/60000 (85%)]     Loss: 0.138584
Train Epoch: 22 [54400/60000 (91%)]     Loss: 0.193111
Train Epoch: 22 [57600/60000 (96%)]     Loss: 0.205879

Test set: Average loss: 0.2081, Accuracy: 9252/10000 (93%)
```

```
Train Epoch: 23 [0/60000 (0%)]  Loss: 0.115316
Train Epoch: 23 [3200/60000 (5%)]       Loss: 0.282001
Train Epoch: 23 [6400/60000 (11%)]      Loss: 0.078044
Train Epoch: 23 [9600/60000 (16%)]      Loss: 0.066080
Train Epoch: 23 [12800/60000 (21%)]     Loss: 0.127318
Train Epoch: 23 [16000/60000 (27%)]     Loss: 0.130401
Train Epoch: 23 [19200/60000 (32%)]     Loss: 0.153588
Train Epoch: 23 [22400/60000 (37%)]     Loss: 0.096067
Train Epoch: 23 [25600/60000 (43%)]     Loss: 0.214846
Train Epoch: 23 [28800/60000 (48%)]     Loss: 0.141747
Train Epoch: 23 [32000/60000 (53%)]     Loss: 0.073428
Train Epoch: 23 [35200/60000 (59%)]     Loss: 0.302874
Train Epoch: 23 [38400/60000 (64%)]     Loss: 0.167417
Train Epoch: 23 [41600/60000 (69%)]     Loss: 0.216941
Train Epoch: 23 [44800/60000 (75%)]     Loss: 0.344980
Train Epoch: 23 [48000/60000 (80%)]     Loss: 0.227247
Train Epoch: 23 [51200/60000 (85%)]     Loss: 0.249223
Train Epoch: 23 [54400/60000 (91%)]     Loss: 0.062588
Train Epoch: 23 [57600/60000 (96%)]     Loss: 0.132832

Test set: Average loss: 0.2083, Accuracy: 9254/10000 (93%)
```

The best accuracy I could get was 9254/10000 (93%) at Epoch 23

3)

Introduction

This report outlines the design and performance of a neural network for image classification using the Fashion MNIST dataset.

My neural network is a CNN(convolutional neural network) for image classification. It consists of three convolutional layers (c1,c2,c3) with a batch normalization (b1,b2,b3) and leaky ReLU activation function.

I introduced ReLU, as it learns complex patterns and relationships in the data. I choose the Leaky ReLU to address issues with the dead neurons and encourage better convergence during training.

To reduce spatial dimensions, max-pooling is applied after each convolution layer to reduce spatial dimensions.

To prevent overfitting, two fully connected layers (fc1 and fc2) follow the convolutional layers with dropout applied.

The final layer is for multi-class classification.

The following fine-tuning strategies have been implemented to improve the models performance:

In the class 'Model': I used convolutional layers, batch normalization, dropout, and fully connected layers. Convolutional layers extract hierarchical features, while batch normalization and dropout prevent overfitting.

```
self.c1 = nn.Conv2d(1, 32, kernel_size=(3, 3), padding=1)
        self.b1 = nn.BatchNorm2d(32)
        self.c2 = nn.Conv2d(32, 64, kernel_size=(3, 3), padding=1)
        self.b2 = nn.BatchNorm2d(64)
        self.c3 = nn.Conv2d(64, 128, kernel_size=(3, 3), padding=1)
        self.b3 = nn.BatchNorm2d(128)
        self.drop_2d = nn.Dropout2d(p=0.25)
        self.fc_1 = nn.Linear(128 * 3 * 3, 512)
        self.drop = nn.Dropout(p=0.5)
        self.fc_2 = nn.Linear(512, 10)
```

The mean and standard deviation of the training dataset are calculated to normalize the input images.

A dropout rate of 0.25 for 2D dropout and 0.5 for dropout is given. To prevent co-adaptation of hidden units dropout layers are strategically placed after convolutional layers and fully connected layers to prevent co-adaptation of hidden units.

```
self.drop_2d = nn.Dropout2d(p=0.25)
        self.fc_1 = nn.Linear(128 * 3 * 3, 512)
        self.drop = nn.Dropout(p=0.5)
```

A strict grid search is implemented to find the optimal learning rate using the 'find_lr' function. The learning rate is adjusted in small increments within a specified range, and the best learning rate that minimizes the loss is selected.

```
lr = find_lr(model, train_loader, 1e-4, 1, 100, 30)
model.reset_parameters()

print('Best LR', lr)

optimizer = torch.optim.SGD(model.parameters(), lr=lr)
```

A learning rate scheduler is used to help the model converge faster and find a better global minimum

```
scheduler = torch.optim.lr_scheduler.CosineAnnealingLR(optimizer,
                                                       T_max=3,
                                                       last_epoch=-1)
```

Batch normalisation is used to normalize the activations, its applied after each convolutional layer, helping it to accelerate and stabilize the training.

```
        self.b1 = nn.BatchNorm2d(32)
        self.c2 = nn.Conv2d(32, 64, kernel_size=(3, 3), padding=1)
        self.b2 = nn.BatchNorm2d(64)
        self.c3 = nn.Conv2d(64, 128, kernel_size=(3, 3), padding=1)
```

```
        self.b3 = nn.BatchNorm2d(128)
```

I wasn't able to implement other techniques such as 'confusion matrix', 'early stopping', and 'weight decay'.

Weight decay would have by encouraging the model to use smaller weights, early stopping would have prevented overfitting as well as saving time when testing the data as it stops when accuracy does not improve, confusion matrix would have helped me to evaluate the model's performance on the set data.

I run my deep neural network in my CPU. As I have used Lab8 source code[1], I did leave the model prediction in my final code untouched. It first produces an image and predicts.

The code then enters a training loop with epochs, where the loss and the LR are printed in each step. The learning rate gradually increases with each step, with best being 0.15500... .

The training loop then proceeds through multiple epochs, After each epoch, model is evaluated on test set, showing average loss and accuracy

The training process demonstrated effective learning, with the model achieving a final accuracy of approximately 93.00%.

In conclusion, strategies collectively contribute to the model's robustness and accuracy. However, I wasn't able to implement more fine tuning strategies as I kept getting errors or the accuracy was worse than this current one. Therefore, the designed model showcases the importance of a combination of these techniques for effective fine-tuning in image classification tasks.

Reference:

1. COMP338_Lab_08_Fashion_MNIST_Classification.ipynb