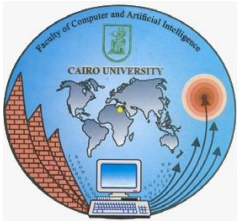

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Machine Learning Project

Implemented by

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FFNN

Experiments on NN Architecture

Model (number of hidden, number of neurons)	**Avg Accuracy**
1 hidden layer with 100 neurons	22.801697254180908
2 hidden layers with 100, 50 neurons	86.6585803382537
3 hidden layers with 100, 50, 30 neurons	85.68829508388744
4 hidden layers with 100, 70, 50, 30 neurons	87.26500851266525
5 hidden layers with 100, 90, 70, 150, 200 neurons	80.41237014181473

So we choose this model for Architecture1

Number of hidden layers: 2

- 1^{st} hidden with 100 neurons
- 2^{nd} hidden with 50 neurons

And this model for Architecture2

Number of hidden layers: 4

- 1^{st} hidden with 100 neurons
- 2^{nd} hidden with 70 neurons
- 3^{rd} hidden with 50 neurons
- 4^{th} hidden with 30 neurons

Model 1

Training:

```
Epoch 1/10
52/52 [==============================] - 1s 19ms/step - loss: 0.0420 - accuracy: 0.9927
Epoch 2/10
52/52 [==============================] - 1s 18ms/step - loss: 0.0623 - accuracy: 0.9812
Epoch 3/10
52/52 [==============================] - 1s 17ms/step - loss: 0.1008 - accuracy: 0.9648
Epoch 4/10
52/52 [==============================] - 1s 18ms/step - loss: 0.0969 - accuracy: 0.9685
Epoch 5/10
52/52 [==============================] - 2s 32ms/step - loss: 0.3921 - accuracy: 0.8866
Epoch 6/10
52/52 [==============================] - 2s 33ms/step - loss: 0.7132 - accuracy: 0.7944
Epoch 7/10
52/52 [==============================] - 1s 24ms/step - loss: 0.2092 - accuracy: 0.9260
Epoch 8/10
52/52 [==============================] - 1s 23ms/step - loss: 0.1705 - accuracy: 0.9369
Epoch 9/10
52/52 [==============================] - 1s 21ms/step - loss: 0.2355 - accuracy: 0.9236
Epoch 10/10
52/52 [==============================] - 1s 21ms/step - loss: 0.0932 - accuracy: 0.9733
```

After testing:

```
13/13 - 0s - loss: 1.3296 - accuracy: 0.7119 - 52ms/epoch - 4ms/step
7/7 [==============================] - 0s 3ms/step
              precision    recall  f1-score   support

           0       0.81      0.85      0.83        40
           1       0.62      0.90      0.74        48
           2       0.66      0.62      0.64        50
           3       0.76      0.74      0.75        35
           4       0.67      0.50      0.57        32
           5       0.84      0.82      0.83        38
           6       0.72      0.68      0.70        41
           7       0.57      0.68      0.62        38
           8       0.74      0.58      0.65        45
           9       0.82      0.72      0.77        46

    accuracy                           0.71       413
   macro avg       0.72      0.71      0.71       413
weighted avg       0.72      0.71      0.71       413
```

Model 2

Training:

```
Epoch 1/10
52/52 [==============================] - 1s 17ms/step - loss: 0.3929 - accuracy: 0.8708
Epoch 2/10
52/52 [==============================] - 1s 17ms/step - loss: 0.5932 - accuracy: 0.8011
Epoch 3/10
52/52 [==============================] - 1s 17ms/step - loss: 0.2225 - accuracy: 0.9236
Epoch 4/10
52/52 [==============================] - 1s 20ms/step - loss: 0.3082 - accuracy: 0.8939
Epoch 5/10
52/52 [==============================] - 1s 20ms/step - loss: 0.2631 - accuracy: 0.8927
Epoch 6/10
52/52 [==============================] - 1s 21ms/step - loss: 0.1735 - accuracy: 0.9448
Epoch 7/10
52/52 [==============================] - 1s 24ms/step - loss: 0.2954 - accuracy: 0.8902
Epoch 8/10
52/52 [==============================] - 1s 21ms/step - loss: 0.3654 - accuracy: 0.8636
Epoch 9/10
52/52 [==============================] - 1s 22ms/step - loss: 0.2941 - accuracy: 0.9024
Epoch 10/10
52/52 [==============================] - 1s 22ms/step - loss: 0.1856 - accuracy: 0.9369
```

After testing:

```
13/13 - 0s - loss: 1.2676 - accuracy: 0.7046 - 58ms/epoch - 4ms/step
7/7 [==============================] - 0s 4ms/step
              precision    recall  f1-score   support

           0       0.79      0.85      0.82        40
           1       0.78      0.81      0.80        48
           2       0.80      0.70      0.74        50
           3       0.65      0.74      0.69        35
           4       0.49      0.69      0.57        32
           5       0.76      0.89      0.82        38
           6       0.74      0.68      0.71        41
           7       0.63      0.63      0.63        38
           8       0.53      0.42      0.47        45
           9       0.88      0.65      0.75        46

    accuracy                           0.70       413
   macro avg       0.70      0.71      0.70       413
weighted avg       0.71      0.70      0.70       413
```

CNN

Experiments on CNN Architecture

Model (number of convolution layer, pooling layers)	**Avg Accuracy**
1 convolution layer and 1 pooling layer	97.81685857211842
2 convolution layer and 1 pooling layer	98.09035773838268
2 convolution layer and 2 pooling layer	98.1200726593242
3 convolution layer and 2 pooling layer	98.05942984188304
4 convolution layer and 2 pooling layer	99.57550027791191

So we choose this model for CNN

Number of convolution layers: 4

Number of pooling layers: 2

CNN Model:

Training:

```
Epoch 1/10
52/52 [==============================] - 7s 126ms/step - loss: 0.0647 - accuracy: 0.9854
Epoch 2/10
52/52 [==============================] - 5s 101ms/step - loss: 0.0135 - accuracy: 0.9951
Epoch 3/10
52/52 [==============================] - 5s 102ms/step - loss: 0.0142 - accuracy: 0.9951
Epoch 4/10
52/52 [==============================] - 5s 102ms/step - loss: 0.0151 - accuracy: 0.9933
Epoch 5/10
52/52 [==============================] - 5s 103ms/step - loss: 0.0210 - accuracy: 0.9927
Epoch 6/10
52/52 [==============================] - 5s 103ms/step - loss: 0.0040 - accuracy: 0.9988
Epoch 7/10
52/52 [==============================] - 5s 104ms/step - loss: 0.0041 - accuracy: 0.9982
Epoch 8/10
52/52 [==============================] - 5s 104ms/step - loss: 0.0144 - accuracy: 0.9951
Epoch 9/10
52/52 [==============================] - 5s 104ms/step - loss: 0.0186 - accuracy: 0.9939
Epoch 10/10
52/52 [==============================] - 5s 104ms/step - loss: 0.0068 - accuracy: 0.9982
```

After testing:

```
13/13 - 1s - loss: 0.0261 - accuracy: 0.9927 - 1s/epoch - 90ms/step
7/7 [==============================] - 4s 59ms/step
              precision    recall  f1-score   support

           0       1.00      1.00      1.00        40
           1       0.98      1.00      0.99        48
           2       1.00      0.98      0.99        50
           3       1.00      1.00      1.00        35
           4       0.97      1.00      0.98        32
           5       1.00      1.00      1.00        38
           6       0.98      1.00      0.99        41
           7       1.00      1.00      1.00        38
           8       1.00      1.00      1.00        45
           9       1.00      0.96      0.98        46

    accuracy                           0.99       413
   macro avg       0.99      0.99      0.99       413
weighted avg       0.99      0.99      0.99       413
```

SVM Model:

Cross Validation Experiment Result:

```
Average Accuracy :  81.50394178289875
```

After testing:

	precision	recall	f1-score	support
0	0.90	0.95	0.93	40
1	0.94	0.92	0.93	48
2	0.87	0.82	0.85	50
3	0.94	0.94	0.94	35
4	0.59	0.62	0.61	32
5	0.95	0.92	0.93	38
6	0.74	0.71	0.72	41
7	0.72	0.76	0.74	38
8	0.91	0.93	0.92	45
9	0.89	0.89	0.89	46
accuracy			0.85	413
macro avg	0.85	0.85	0.85	413
weighted avg	0.85	0.85	0.85	413

CNN Model VS SVM Model

From the above experiments it is clear that the CNN model is *much better* than the SVM model due to the testing accuracy. Since the CNN testing accuracy is 99% on the other hand the SVM testing accuracy is 85%.