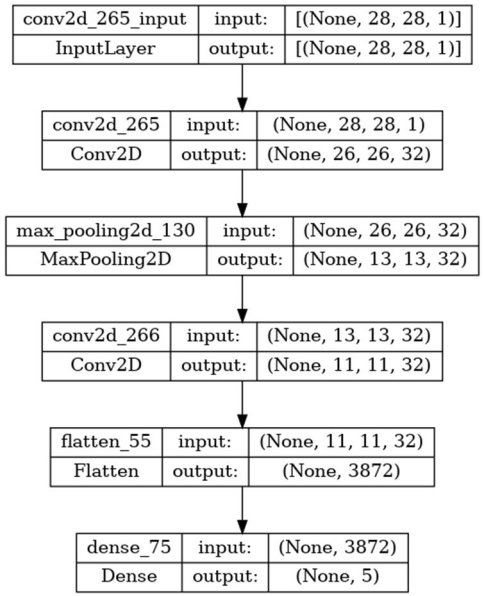
Classification with Convolutional Neural Networks

Classify the data using a Convolutional Neural Network with the following architecture:
• input features x • convolutional layer with 32, 3x3 filters, stride 1, padding 1x1 • max pooling layer 2,2 • convolutional layer with 32, 3x3 filters, stride 1, padding 1x1 • flatten the output • output layer: one fully connected layer with five output values • a SoftMax layer to transform the outputs into a multi-class probability distribution for classification • activation functions: internal layers all use ReLU activation • optimizer: Stochastic Gradient Descent

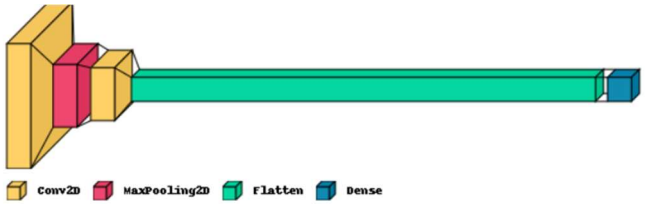
Model Summary

```
Model: "sequential_55"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_265 (Conv2D)         (None, 26, 26, 32)        320

 max_pooling2d_130 (MaxPooli  (None, 13, 13, 32)       0
 ng2D)

 conv2d_266 (Conv2D)         (None, 11, 11, 32)        9248

 flatten_55 (Flatten)        (None, 3872)              0

 dense_75 (Dense)            (None, 5)                 19365

=================================================================
Total params: 28,933
Trainable params: 28,933
Non-trainable params: 0
_________________________________________________________________
```

Model Flow



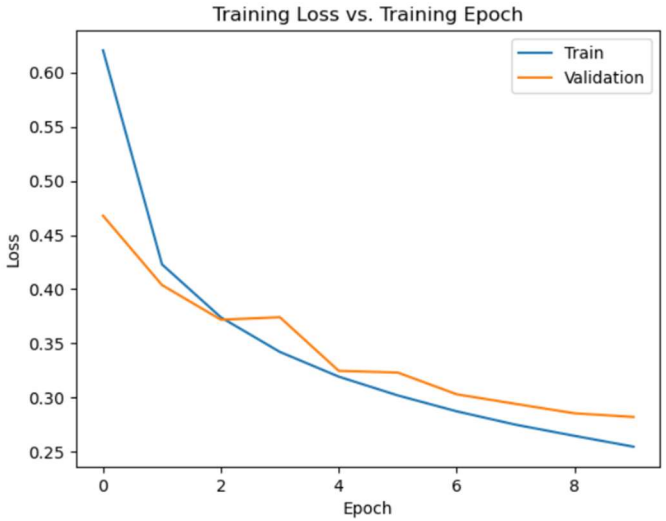
Model Architecture

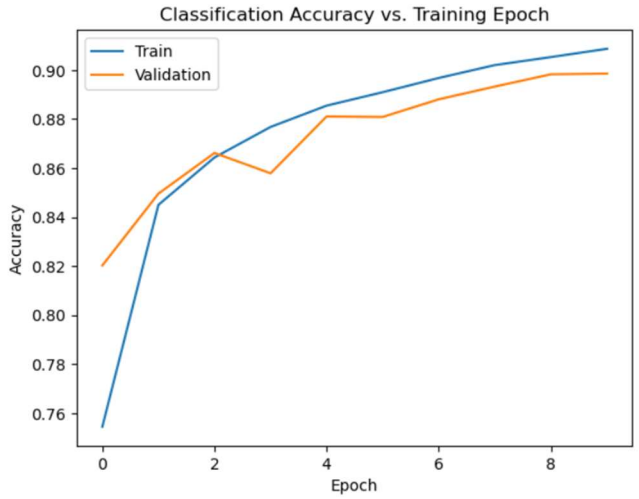


Runtime Information (Epochs, Loss, Accuracy)

```
Epoch 1/10 1875/1875 [==============================] - 8s 4ms/step - loss: 0.6315 - accuracy: 0.7481 - val_loss: 0.5119 - val_accuracy: 0.8027
Epoch 2/10 1875/1875 [==============================] - 7s 4ms/step - loss: 0.4331 - accuracy: 0.8402 - val_loss: 0.4117 - val_accuracy: 0.8482
Epoch 3/10 1875/1875 [==============================] - 7s 4ms/step - loss: 0.3821 - accuracy: 0.8620 - val_loss: 0.3914 - val_accuracy: 0.8579
Epoch 4/10 1875/1875 [==============================] - 7s 4ms/step - loss: 0.3483 - accuracy: 0.8751 - val_loss: 0.3452 - val_accuracy: 0.8760
Epoch 5/10 1875/1875 [==============================] - 7s 4ms/step - loss: 0.3240 - accuracy: 0.8845 - val_loss: 0.3234 - val_accuracy: 0.8842
Epoch 6/10 1875/1875 [==============================] - 7s 4ms/step - loss: 0.3057 - accuracy: 0.8909 - val_loss: 0.3166 - val_accuracy: 0.8838
Epoch 7/10 1875/1875 [==============================] - 8s 4ms/step - loss: 0.2893 - accuracy: 0.8970 - val_loss: 0.3058 - val_accuracy: 0.8866
Epoch 8/10 1875/1875 [==============================] - 7s 4ms/step - loss: 0.2765 - accuracy: 0.9018 - val_loss: 0.2880 - val_accuracy: 0.8969
Epoch 9/10 1875/1875 [==============================] - 7s 4ms/step - loss: 0.2650 - accuracy: 0.9051 - val_loss: 0.2773 - val_accuracy: 0.9012
Epoch 10/10 1875/1875 [==============================] - 7s 4ms/step - loss: 0.2549 - accuracy: 0.9093 - val_loss: 0.2692 - val_accuracy: 0.9039
```

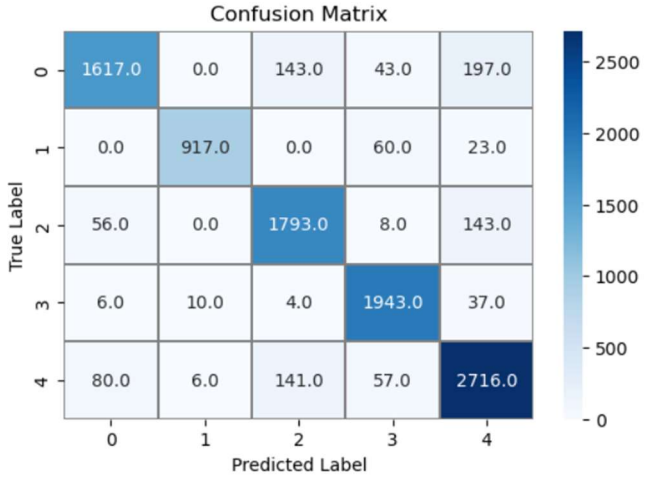
Evaluation of Model and Performance Metrics





Classification Report

	precision	recall	f1-score	support
0	0.92	0.81	0.86	2000
1	0.98	0.92	0.95	1000
2	0.86	0.90	0.88	2000
3	0.92	0.97	0.95	2000
4	0.87	0.91	0.89	3000
accuracy			0.90	10000
macro avg	0.91	0.90	0.90	10000
weighted avg	0.90	0.90	0.90	10000



Using Default Network with the given layers and hyperparameters, we observed **90.93 % Train Accuracy and 90.39 % Test Accuracy** with **10 epochs** and with the **default Batch Size**.
Observations:

- From the **Training Loss vs Training Epoch Plot**, Loss value for Train went down for every epoch. The similar pattern we observed for Validation Set.
- From the **Classification Accuracy vs Training Epoch Plot**, Accuracy value for Train went up for every epoch. The similar pattern we observed for Validation Set.
- we don't observe overfitting within these 10 epochs for both the plots.
- From the **classification report**,
    - **Precision** for the five classes ranges from 86% to 98%, meaning that 86% to 98%, of Predicted positive classes were truly positive.
    - **Recall** for the five classes ranges from 81% to 97%, meaning that 81% to 97% of Actual positive classes were truly positive.
    - **F1 Score** for the five classes is above 86% on an average, meaning that it is correctly identifying the positive cases and avoiding false positives.

MODEL 1 - Variation of filters with more convolution layers

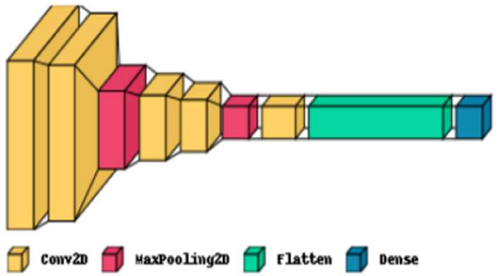
Model – 1 Summary

```
Model: "sequential_56"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_267 (Conv2D)         (None, 26, 26, 64)        640

 conv2d_268 (Conv2D)         (None, 24, 24, 64)        36928

 max_pooling2d_131 (MaxPooli  (None, 12, 12, 64)       0
 ng2D)

 conv2d_269 (Conv2D)         (None, 10, 10, 128)       73856

 conv2d_270 (Conv2D)         (None, 8, 8, 128)         147584

 max_pooling2d_132 (MaxPooli  (None, 4, 4, 128)        0
 ng2D)

 conv2d_271 (Conv2D)         (None, 2, 2, 256)         295168

 flatten_56 (Flatten)        (None, 1024)              0

 dense_76 (Dense)            (None, 5)                 5125

=================================================================
Total params: 559,301
Trainable params: 559,301
Non-trainable params: 0
```

Runtime Information (Epochs, Loss, Accuracy)

```
Epoch 1/25 235/235 [==============================] - 4s 15ms/step - loss: 1.4099 - accuracy: 0.3638 - val_loss: 1.1075 - val_accuracy: 0.5659
Epoch 2/25 235/235 [==============================] - 3s 14ms/step - loss: 0.8947 - accuracy: 0.6245 - val_loss: 0.7563 - val_accuracy: 0.7063
Epoch 3/25 235/235 [==============================] - 3s 14ms/step - loss: 0.7004 - accuracy: 0.7138 - val_loss: 0.6214 - val_accuracy: 0.7530
Epoch 4/25 235/235 [==============================] - 3s 14ms/step - loss: 0.5931 - accuracy: 0.7595 - val_loss: 0.5579 - val_accuracy: 0.7768
Epoch 5/25 235/235 [==============================] - 3s 15ms/step - loss: 0.5279 - accuracy: 0.7879 - val_loss: 0.5118 - val_accuracy: 0.7978
Epoch 6/25 235/235 [==============================] - 3s 14ms/step - loss: 0.4811 - accuracy: 0.8098 - val_loss: 0.4843 - val_accuracy: 0.8023
Epoch 7/25 235/235 [==============================] - 3s 14ms/step - loss: 0.4472 - accuracy: 0.8239 - val_loss: 0.4776 - val_accuracy: 0.8105
Epoch 8/25 235/235 [==============================] - 3s 14ms/step - loss: 0.4195 - accuracy: 0.8374 - val_loss: 0.4436 - val_accuracy: 0.8260
Epoch 9/25 235/235 [==============================] - 3s 14ms/step - loss: 0.3953 - accuracy: 0.8502 - val_loss: 0.4028 - val_accuracy: 0.8514
Epoch 10/25 235/235 [==============================] - 3s 14ms/step - loss: 0.3807 - accuracy: 0.8556 - val_loss: 0.4038 - val_accuracy: 0.8459
Epoch 11/25 235/235 [==============================] - 3s 14ms/step - loss: 0.3666 - accuracy: 0.8629 - val_loss: 0.3949 - val_accuracy: 0.8507
Epoch 12/25 235/235 [==============================] - 3s 15ms/step - loss: 0.3551 - accuracy: 0.8667 - val_loss: 0.4026 - val_accuracy: 0.8395
Epoch 13/25 235/235 [==============================] - 3s 14ms/step - loss: 0.3452 - accuracy: 0.8731 - val_loss: 0.4053 - val_accuracy: 0.8451
Epoch 14/25 235/235 [==============================] - 3s 14ms/step - loss: 0.3356 - accuracy: 0.8769 - val_loss: 0.4392 - val_accuracy: 0.8195
Epoch 15/25 235/235 [==============================] - 3s 14ms/step - loss: 0.3291 - accuracy: 0.8792 - val_loss: 0.3637 - val_accuracy: 0.8650
Epoch 16/25 235/235 [==============================] - 3s 14ms/step - loss: 0.3209 - accuracy: 0.8825 - val_loss: 0.4104 - val_accuracy: 0.8433
Epoch 17/25 235/235 [==============================] - 3s 14ms/step - loss: 0.3138 - accuracy: 0.8862 - val_loss: 0.3656 - val_accuracy: 0.8617
Epoch 18/25 235/235 [==============================] - 3s 14ms/step - loss: 0.3056 - accuracy: 0.8889 - val_loss: 0.3467 - val_accuracy: 0.8741
Epoch 19/25 235/235 [==============================] - 3s 14ms/step - loss: 0.2994 - accuracy: 0.8925 - val_loss: 0.3581 - val_accuracy: 0.8661
Epoch 20/25 235/235 [==============================] - 3s 14ms/step - loss: 0.2952 - accuracy: 0.8928 - val_loss: 0.3440 - val_accuracy: 0.8708
Epoch 21/25 235/235 [==============================] - 3s 14ms/step - loss: 0.2909 - accuracy: 0.8945 - val_loss: 0.3094 - val_accuracy: 0.8883
Epoch 22/25 235/235 [==============================] - 3s 15ms/step - loss: 0.2848 - accuracy: 0.8977 - val_loss: 0.3161 - val_accuracy: 0.8840
Epoch 23/25 235/235 [==============================] - 3s 15ms/step - loss: 0.2796 - accuracy: 0.8994 - val_loss: 0.3211 - val_accuracy: 0.8823
Epoch 24/25 235/235 [==============================] - 3s 14ms/step - loss: 0.2764 - accuracy: 0.8998 - val_loss: 0.3371 - val_accuracy: 0.8777
Epoch 25/25 235/235 [==============================] - 3s 15ms/step - loss: 0.2721 - accuracy: 0.9015 - val_loss: 0.3384 - val_accuracy: 0.8762
```

Model Architecture



MODEL 2 - With activation function - LeakyReLU & addition of Dropout

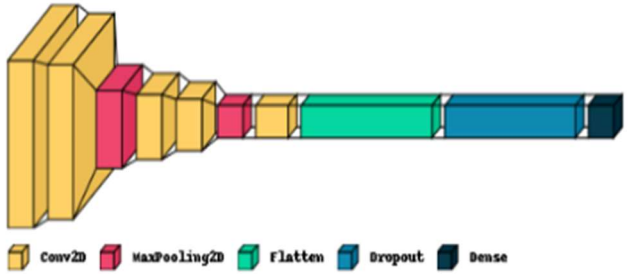
Model – 2 Summary

```
Model: "sequential_57"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_272 (Conv2D)         (None, 26, 26, 64)        640

 conv2d_273 (Conv2D)         (None, 24, 24, 64)        36928

 max_pooling2d_133 (MaxPooli  (None, 12, 12, 64)       0
 ng2D)

 conv2d_274 (Conv2D)         (None, 10, 10, 128)       73856

 conv2d_275 (Conv2D)         (None, 8, 8, 128)         147584

 max_pooling2d_134 (MaxPooli  (None, 4, 4, 128)        0
 ng2D)

 conv2d_276 (Conv2D)         (None, 2, 2, 256)         295168

 flatten_57 (Flatten)        (None, 1024)              0

 dropout_45 (Dropout)        (None, 1024)              0

 dense_77 (Dense)            (None, 5)                 5125

=================================================================
Total params: 559,301
Trainable params: 559,301
Non-trainable params: 0
_________________________________________________________________
```

Runtime Information (Epochs, Loss, Accuracy)

```
Epoch 1/25 235/235 [==============================] - 5s 17ms/step - loss: 1.3761 - accuracy: 0.3769 - val_loss: 0.9540 - val_accuracy: 0.6105
Epoch 2/25 235/235 [==============================] - 4s 15ms/step - loss: 0.8604 - accuracy: 0.6432 - val_loss: 0.7233 - val_accuracy: 0.6978
Epoch 3/25 235/235 [==============================] - 4s 15ms/step - loss: 0.6841 - accuracy: 0.7210 - val_loss: 0.6134 - val_accuracy: 0.7577
Epoch 4/25 235/235 [==============================] - 4s 16ms/step - loss: 0.5876 - accuracy: 0.7617 - val_loss: 0.5716 - val_accuracy: 0.7716
Epoch 5/25 235/235 [==============================] - 4s 16ms/step - loss: 0.5327 - accuracy: 0.7855 - val_loss: 0.5310 - val_accuracy: 0.7875
Epoch 6/25 235/235 [==============================] - 4s 16ms/step - loss: 0.4927 - accuracy: 0.8012 - val_loss: 0.4699 - val_accuracy: 0.8131
Epoch 7/25 235/235 [==============================] - 4s 15ms/step - loss: 0.4611 - accuracy: 0.8172 - val_loss: 0.4890 - val_accuracy: 0.8117
Epoch 8/25 235/235 [==============================] - 4s 15ms/step - loss: 0.4382 - accuracy: 0.8278 - val_loss: 0.4420 - val_accuracy: 0.8261
Epoch 9/25 235/235 [==============================] - 4s 16ms/step - loss: 0.4198 - accuracy: 0.8360 - val_loss: 0.4335 - val_accuracy: 0.8301
Epoch 10/25 235/235 [==============================] - 4s 15ms/step - loss: 0.4044 - accuracy: 0.8446 - val_loss: 0.4447 - val_accuracy: 0.8216
Epoch 11/25 235/235 [==============================] - 4s 15ms/step - loss: 0.3908 - accuracy: 0.8522 - val_loss: 0.4039 - val_accuracy: 0.8415
Epoch 12/25 235/235 [==============================] - 4s 16ms/step - loss: 0.3810 - accuracy: 0.8558 - val_loss: 0.3779 - val_accuracy: 0.8555
Epoch 13/25 235/235 [==============================] - 4s 16ms/step - loss: 0.3693 - accuracy: 0.8614 - val_loss: 0.3738 - val_accuracy: 0.8613
Epoch 14/25 235/235 [==============================] - 4s 15ms/step - loss: 0.3604 - accuracy: 0.8645 - val_loss: 0.3752 - val_accuracy: 0.8578
Epoch 15/25 235/235 [==============================] - 4s 16ms/step - loss: 0.3539 - accuracy: 0.8692 - val_loss: 0.3578 - val_accuracy: 0.8702
Epoch 16/25 235/235 [==============================] - 4s 16ms/step - loss: 0.3458 - accuracy: 0.8721 - val_loss: 0.3657 - val_accuracy: 0.8649
Epoch 17/25 235/235 [==============================] - 4s 16ms/step - loss: 0.3412 - accuracy: 0.8735 - val_loss: 0.3589 - val_accuracy: 0.8653
Epoch 18/25 235/235 [==============================] - 4s 15ms/step - loss: 0.3339 - accuracy: 0.8766 - val_loss: 0.3372 - val_accuracy: 0.8783
Epoch 19/25 235/235 [==============================] - 4s 15ms/step - loss: 0.3274 - accuracy: 0.8800 - val_loss: 0.3607 - val_accuracy: 0.8676
Epoch 20/25 235/235 [==============================] - 4s 16ms/step - loss: 0.3221 - accuracy: 0.8816 - val_loss: 0.3345 - val_accuracy: 0.8775
Epoch 21/25 235/235 [==============================] - 4s 15ms/step - loss: 0.3173 - accuracy: 0.8842 - val_loss: 0.3429 - val_accuracy: 0.8731
Epoch 22/25 235/235 [==============================] - 4s 16ms/step - loss: 0.3125 - accuracy: 0.8853 - val_loss: 0.3364 - val_accuracy: 0.8763
Epoch 23/25 235/235 [==============================] - 4s 15ms/step - loss: 0.3079 - accuracy: 0.8871 - val_loss: 0.3143 - val_accuracy: 0.8854
Epoch 24/25 235/235 [==============================] - 4s 16ms/step - loss: 0.3022 - accuracy: 0.8897 - val_loss: 0.3228 - val_accuracy: 0.8858
Epoch 25/25 235/235 [==============================] - 4s 16ms/step - loss: 0.3014 - accuracy: 0.8897 - val_loss: 0.3605 - val_accuracy: 0.8585
```

Model Architecture



MODEL 3 - With activation function - Sigmoid & addition of Dropout

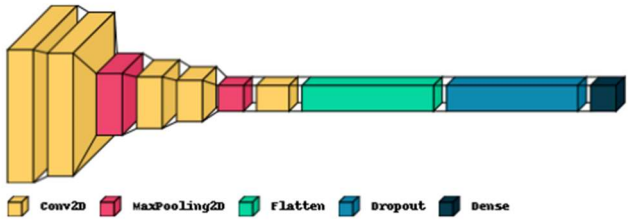
Model – 3 Summary

```
Model: "sequential_58"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_277 (Conv2D)         (None, 26, 26, 64)        640

 conv2d_278 (Conv2D)         (None, 24, 24, 64)        36928

 max_pooling2d_135 (MaxPooli  (None, 12, 12, 64)       0
 ng2D)

 conv2d_279 (Conv2D)         (None, 10, 10, 128)       73856

 conv2d_280 (Conv2D)         (None, 8, 8, 128)         147584

 max_pooling2d_136 (MaxPooli  (None, 4, 4, 128)        0
 ng2D)

 conv2d_281 (Conv2D)         (None, 2, 2, 256)         295168

 flatten_58 (Flatten)        (None, 1024)              0

 dropout_46 (Dropout)        (None, 1024)              0

 dense_78 (Dense)            (None, 5)                 5125

=================================================================
Total params: 559,301
Trainable params: 559,301
Non-trainable params: 0
```

Runtime Information (Epochs, Loss, Accuracy)

```
Epoch 1/25 235/235 [==============================] - 5s 16ms/step - loss: 1.6333 - accuracy: 0.2542 - val_loss: 1.5642 - val_accuracy: 0.3000
Epoch 2/25 235/235 [==============================] - 4s 16ms/step - loss: 1.6139 - accuracy: 0.2592 - val_loss: 1.5632 - val_accuracy: 0.3000
Epoch 3/25 235/235 [==============================] - 4s 15ms/step - loss: 1.5993 - accuracy: 0.2615 - val_loss: 1.5579 - val_accuracy: 0.3000
Epoch 4/25 235/235 [==============================] - 4s 16ms/step - loss: 1.5881 - accuracy: 0.2696 - val_loss: 1.5621 - val_accuracy: 0.3000
Epoch 5/25 235/235 [==============================] - 4s 15ms/step - loss: 1.5827 - accuracy: 0.2729 - val_loss: 1.5582 - val_accuracy: 0.3000
Epoch 6/25 235/235 [==============================] - 4s 15ms/step - loss: 1.5781 - accuracy: 0.2795 - val_loss: 1.5572 - val_accuracy: 0.3000
Epoch 7/25 235/235 [==============================] - 4s 16ms/step - loss: 1.5752 - accuracy: 0.2811 - val_loss: 1.5579 - val_accuracy: 0.3000
Epoch 8/25 235/235 [==============================] - 4s 15ms/step - loss: 1.5723 - accuracy: 0.2858 - val_loss: 1.5575 - val_accuracy: 0.3000
Epoch 9/25 235/235 [==============================] - 4s 15ms/step - loss: 1.5689 - accuracy: 0.2894 - val_loss: 1.5582 - val_accuracy: 0.3000
Epoch 10/25 235/235 [==============================] - 4s 16ms/step - loss: 1.5673 - accuracy: 0.2913 - val_loss: 1.5572 - val_accuracy: 0.3000
Epoch 11/25 235/235 [==============================] - 4s 16ms/step - loss: 1.5655 - accuracy: 0.2937 - val_loss: 1.5582 - val_accuracy: 0.3000
Epoch 12/25 235/235 [==============================] - 4s 16ms/step - loss: 1.5652 - accuracy: 0.2946 - val_loss: 1.5573 - val_accuracy: 0.3000
Epoch 13/25 235/235 [==============================] - 4s 16ms/step - loss: 1.5640 - accuracy: 0.2973 - val_loss: 1.5572 - val_accuracy: 0.3000
Epoch 14/25 235/235 [==============================] - 4s 16ms/step - loss: 1.5634 - accuracy: 0.2969 - val_loss: 1.5573 - val_accuracy: 0.3000
Epoch 15/25 235/235 [==============================] - 4s 15ms/step - loss: 1.5627 - accuracy: 0.2979 - val_loss: 1.5574 - val_accuracy: 0.3000
Epoch 16/25 235/235 [==============================] - 4s 15ms/step - loss: 1.5630 - accuracy: 0.2987 - val_loss: 1.5574 - val_accuracy: 0.3000
Epoch 17/25 235/235 [==============================] - 4s 16ms/step - loss: 1.5622 - accuracy: 0.2990 - val_loss: 1.5574 - val_accuracy: 0.3000
Epoch 18/25 235/235 [==============================] - 4s 16ms/step - loss: 1.5617 - accuracy: 0.2995 - val_loss: 1.5573 - val_accuracy: 0.3000
Epoch 19/25 235/235 [==============================] - 4s 16ms/step - loss: 1.5608 - accuracy: 0.2993 - val_loss: 1.5572 - val_accuracy: 0.3000
Epoch 20/25 235/235 [==============================] - 4s 15ms/step - loss: 1.5610 - accuracy: 0.2998 - val_loss: 1.5572 - val_accuracy: 0.3000
Epoch 21/25 235/235 [==============================] - 4s 16ms/step - loss: 1.5608 - accuracy: 0.2998 - val_loss: 1.5575 - val_accuracy: 0.3000
Epoch 22/25 235/235 [==============================] - 4s 16ms/step - loss: 1.5605 - accuracy: 0.3002 - val_loss: 1.5575 - val_accuracy: 0.3000
Epoch 23/25 235/235 [==============================] - 4s 16ms/step - loss: 1.5601 - accuracy: 0.3000 - val_loss: 1.5574 - val_accuracy: 0.3000
Epoch 24/25 235/235 [==============================] - 4s 16ms/step - loss: 1.5604 - accuracy: 0.2999 - val_loss: 1.5572 - val_accuracy: 0.3000
Epoch 25/25 235/235 [==============================] - 4s 15ms/step - loss: 1.5597 - accuracy: 0.3000 - val_loss: 1.5573 - val_accuracy: 0.3000
```

Model Architecture



MODEL 4 - With activation function - tanh & addition of Dropout

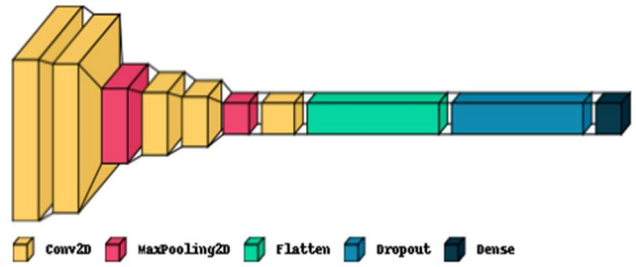
Model – 4 Summary

```
Model: "sequential_59"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_282 (Conv2D)         (None, 26, 26, 64)        640

 conv2d_283 (Conv2D)         (None, 24, 24, 64)        36928

 max_pooling2d_137 (MaxPooli  (None, 12, 12, 64)       0
 ng2D)

 conv2d_284 (Conv2D)         (None, 10, 10, 128)       73856

 conv2d_285 (Conv2D)         (None, 8, 8, 128)         147584

 max_pooling2d_138 (MaxPooli  (None, 4, 4, 128)        0
 ng2D)

 conv2d_286 (Conv2D)         (None, 2, 2, 256)         295168

 flatten_59 (Flatten)        (None, 1024)              0

 dropout_47 (Dropout)        (None, 1024)              0

 dense_79 (Dense)            (None, 5)                 5125

=================================================================
Total params: 559,301
Trainable params: 559,301
Non-trainable params: 0
_________________________________________________________________
```

Runtime Information (Epochs, Loss, Accuracy)

```
Epoch 1/25 235/235 [==============================] - 5s 17ms/step - loss: 1.1087 - accuracy: 0.5365 - val_loss: 0.7554 - val_accuracy: 0.6963
Epoch 2/25 235/235 [==============================] - 4s 16ms/step - loss: 0.6830 - accuracy: 0.7221 - val_loss: 0.6231 - val_accuracy: 0.7372
Epoch 3/25 235/235 [==============================] - 4s 16ms/step - loss: 0.5853 - accuracy: 0.7625 - val_loss: 0.6046 - val_accuracy: 0.7500
Epoch 4/25 235/235 [==============================] - 4s 16ms/step - loss: 0.5359 - accuracy: 0.7832 - val_loss: 0.5305 - val_accuracy: 0.7753
Epoch 5/25 235/235 [==============================] - 4s 15ms/step - loss: 0.5018 - accuracy: 0.7957 - val_loss: 0.4852 - val_accuracy: 0.8073
Epoch 6/25 235/235 [==============================] - 4s 15ms/step - loss: 0.4727 - accuracy: 0.8108 - val_loss: 0.4657 - val_accuracy: 0.8155
Epoch 7/25 235/235 [==============================] - 4s 15ms/step - loss: 0.4525 - accuracy: 0.8196 - val_loss: 0.4538 - val_accuracy: 0.8172
Epoch 8/25 235/235 [==============================] - 4s 16ms/step - loss: 0.4353 - accuracy: 0.8280 - val_loss: 0.4451 - val_accuracy: 0.8203
Epoch 9/25 235/235 [==============================] - 4s 15ms/step - loss: 0.4202 - accuracy: 0.8353 - val_loss: 0.4186 - val_accuracy: 0.8385
Epoch 10/25 235/235 [==============================] - 4s 16ms/step - loss: 0.4070 - accuracy: 0.8442 - val_loss: 0.4111 - val_accuracy: 0.8419
Epoch 11/25 235/235 [==============================] - 4s 15ms/step - loss: 0.3955 - accuracy: 0.8494 - val_loss: 0.3958 - val_accuracy: 0.8514
Epoch 12/25 235/235 [==============================] - 4s 16ms/step - loss: 0.3833 - accuracy: 0.8559 - val_loss: 0.3876 - val_accuracy: 0.8537
Epoch 13/25 235/235 [==============================] - 4s 15ms/step - loss: 0.3753 - accuracy: 0.8584 - val_loss: 0.3955 - val_accuracy: 0.8470
Epoch 14/25 235/235 [==============================] - 4s 16ms/step - loss: 0.3649 - accuracy: 0.8642 - val_loss: 0.3863 - val_accuracy: 0.8522
Epoch 15/25 235/235 [==============================] - 4s 16ms/step - loss: 0.3570 - accuracy: 0.8676 - val_loss: 0.3640 - val_accuracy: 0.8659
Epoch 16/25 235/235 [==============================] - 4s 15ms/step - loss: 0.3499 - accuracy: 0.8709 - val_loss: 0.3504 - val_accuracy: 0.8726
Epoch 17/25 235/235 [==============================] - 4s 16ms/step - loss: 0.3420 - accuracy: 0.8739 - val_loss: 0.3669 - val_accuracy: 0.8609
Epoch 18/25 235/235 [==============================] - 4s 15ms/step - loss: 0.3360 - accuracy: 0.8765 - val_loss: 0.3450 - val_accuracy: 0.8730
Epoch 19/25 235/235 [==============================] - 4s 15ms/step - loss: 0.3284 - accuracy: 0.8801 - val_loss: 0.3691 - val_accuracy: 0.8579
Epoch 20/25 235/235 [==============================] - 4s 16ms/step - loss: 0.3237 - accuracy: 0.8822 - val_loss: 0.3467 - val_accuracy: 0.8699
Epoch 21/25 235/235 [==============================] - 4s 16ms/step - loss: 0.3178 - accuracy: 0.8852 - val_loss: 0.3207 - val_accuracy: 0.8858
Epoch 22/25 235/235 [==============================] - 4s 16ms/step - loss: 0.3114 - accuracy: 0.8868 - val_loss: 0.3213 - val_accuracy: 0.8848
Epoch 23/25 235/235 [==============================] - 4s 15ms/step - loss: 0.3064 - accuracy: 0.8885 - val_loss: 0.3179 - val_accuracy: 0.8846
Epoch 24/25 235/235 [==============================] - 4s 16ms/step - loss: 0.3030 - accuracy: 0.8899 - val_loss: 0.3172 - val_accuracy: 0.8826
Epoch 25/25 235/235 [==============================] - 4s 16ms/step - loss: 0.2972 - accuracy: 0.8925 - val_loss: 0.3119 - val_accuracy: 0.8895
```

Model Architecture



MODEL 5 - With activation function - tanh & using Adam optimizer

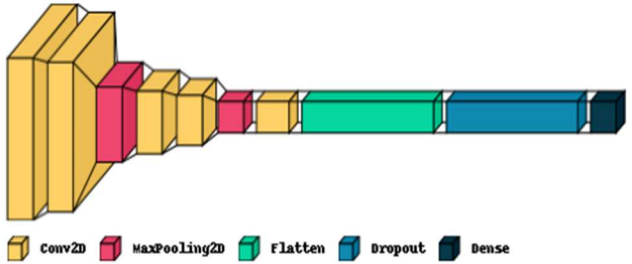
Model – 5 Summary

```
Model: "sequential_60"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_287 (Conv2D)         (None, 26, 26, 64)        640

 conv2d_288 (Conv2D)         (None, 24, 24, 64)        36928

 max_pooling2d_139 (MaxPooli  (None, 12, 12, 64)       0
 ng2D)

 conv2d_289 (Conv2D)         (None, 10, 10, 128)       73856

 conv2d_290 (Conv2D)         (None, 8, 8, 128)         147584

 max_pooling2d_140 (MaxPooli  (None, 4, 4, 128)        0
 ng2D)

 conv2d_291 (Conv2D)         (None, 2, 2, 256)         295168

 flatten_60 (Flatten)        (None, 1024)              0

 dropout_48 (Dropout)        (None, 1024)              0

 dense_80 (Dense)            (None, 5)                 5125

=================================================================
Total params: 559,301
Trainable params: 559,301
Non-trainable params: 0
_________________________________________________________________
```

Runtime Information (Epochs, Loss, Accuracy)

```
Epoch 1/25 469/469 [==============================] - 7s 10ms/step - loss: 0.4291 - accuracy: 0.8391 - val_loss: 0.2953 - val_accuracy: 0.8941
Epoch 2/25 469/469 [==============================] - 5s 10ms/step - loss: 0.2890 - accuracy: 0.8963 - val_loss: 0.2820 - val_accuracy: 0.8977
Epoch 3/25 469/469 [==============================] - 4s 10ms/step - loss: 0.2474 - accuracy: 0.9118 - val_loss: 0.2469 - val_accuracy: 0.9116
Epoch 4/25 469/469 [==============================] - 4s 9ms/step - loss: 0.2216 - accuracy: 0.9214 - val_loss: 0.2407 - val_accuracy: 0.9142
Epoch 5/25 469/469 [==============================] - 4s 10ms/step - loss: 0.1984 - accuracy: 0.9283 - val_loss: 0.2340 - val_accuracy: 0.9180
Epoch 6/25 469/469 [==============================] - 4s 9ms/step - loss: 0.1796 - accuracy: 0.9366 - val_loss: 0.2301 - val_accuracy: 0.9186
Epoch 7/25 469/469 [==============================] - 5s 10ms/step - loss: 0.1627 - accuracy: 0.9416 - val_loss: 0.2608 - val_accuracy: 0.9130
Epoch 8/25 469/469 [==============================] - 4s 9ms/step - loss: 0.1492 - accuracy: 0.9476 - val_loss: 0.2337 - val_accuracy: 0.9227
Epoch 9/25 469/469 [==============================] - 5s 10ms/step - loss: 0.1412 - accuracy: 0.9495 - val_loss: 0.2359 - val_accuracy: 0.9231
```

Model Architecture



MODEL 6 - With activation function - LeakyReLU & using Adam optimizer

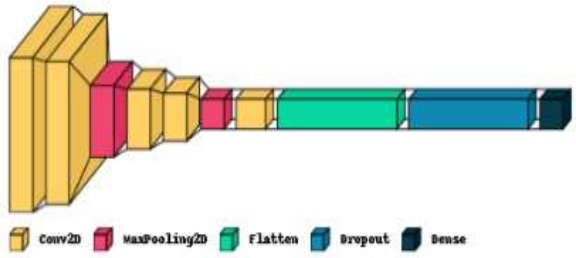
Model – 6 Summary

```
Model: "sequential_61"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_292 (Conv2D)         (None, 26, 26, 64)        640

 conv2d_293 (Conv2D)         (None, 24, 24, 64)        36928

 max_pooling2d_141 (MaxPooli  (None, 12, 12, 64)       0
 ng2D)

 conv2d_294 (Conv2D)         (None, 10, 10, 128)       73856

 conv2d_295 (Conv2D)         (None, 8, 8, 128)         147584

 max_pooling2d_142 (MaxPooli  (None, 4, 4, 128)        0
 ng2D)

 conv2d_296 (Conv2D)         (None, 2, 2, 256)         295168

 flatten_61 (Flatten)        (None, 1024)              0

 dropout_49 (Dropout)        (None, 1024)              0

 dense_81 (Dense)            (None, 5)                 5125

=================================================================
Total params: 559,301
Trainable params: 559,301
Non-trainable params: 0
_________________________________________________________________
```

Runtime Information (Epochs, Loss, Accuracy)

```
Epoch 1/25 469/469 [==============================] - 6s 10ms/step - loss: 0.4068 - accuracy: 0.8436 - val_loss: 0.2564 - val_accuracy: 0.9082
Epoch 2/25 469/469 [==============================] - 5s 10ms/step - loss: 0.2464 - accuracy: 0.9108 - val_loss: 0.2260 - val_accuracy: 0.9206
Epoch 3/25 469/469 [==============================] - 4s 9ms/step - loss: 0.2065 - accuracy: 0.9262 - val_loss: 0.2083 - val_accuracy: 0.9239
Epoch 4/25 469/469 [==============================] - 4s 9ms/step - loss: 0.1852 - accuracy: 0.9336 - val_loss: 0.2213 - val_accuracy: 0.9220
Epoch 5/25 469/469 [==============================] - 5s 10ms/step - loss: 0.1641 - accuracy: 0.9412 - val_loss: 0.2026 - val_accuracy: 0.9301
Epoch 6/25 469/469 [==============================] - 5s 10ms/step - loss: 0.1505 - accuracy: 0.9455 - val_loss: 0.1913 - val_accuracy: 0.9365
Epoch 7/25 469/469 [==============================] - 5s 10ms/step - loss: 0.1368 - accuracy: 0.9509 - val_loss: 0.1909 - val_accuracy: 0.9346
Epoch 8/25 469/469 [==============================] - 4s 9ms/step - loss: 0.1233 - accuracy: 0.9561 - val_loss: 0.2047 - val_accuracy: 0.9318
Epoch 9/25 469/469 [==============================] - 5s 10ms/step - loss: 0.1127 - accuracy: 0.9593 - val_loss: 0.2072 - val_accuracy: 0.9311
Epoch 10/25 469/469 [==============================] - 4s 9ms/step - loss: 0.1046 - accuracy: 0.9620 - val_loss: 0.2076 - val_accuracy: 0.9330
```

Model Architecture



MODEL 7 - With activation function - LeakyReLU & variation of kernel size

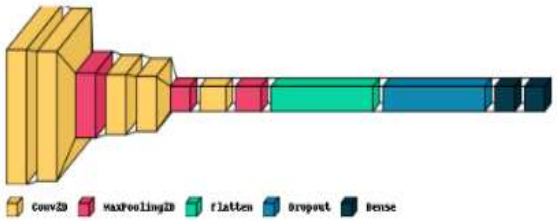
Model – 7 Summary

```
Model: "sequential_62"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_297 (Conv2D)         (None, 27, 27, 64)        320

 conv2d_298 (Conv2D)         (None, 26, 26, 64)        16448

 max_pooling2d_143 (MaxPooli  (None, 13, 13, 64)       0
 ng2D)

 conv2d_299 (Conv2D)         (None, 12, 12, 128)       32896

 conv2d_300 (Conv2D)         (None, 11, 11, 128)       65664

 max_pooling2d_144 (MaxPooli  (None, 5, 5, 128)        0
 ng2D)

 conv2d_301 (Conv2D)         (None, 4, 4, 256)         131328

 max_pooling2d_145 (MaxPooli  (None, 2, 2, 256)        0
 ng2D)

 flatten_62 (Flatten)        (None, 1024)              0

 dropout_50 (Dropout)        (None, 1024)              0

 dense_82 (Dense)            (None, 5)                 5125

 dense_83 (Dense)            (None, 5)                 30

=================================================================
Total params: 251,811
Trainable params: 251,811
Non-trainable params: 0
_________________________________________________________________
```

Runtime Information (Epochs, Loss, Accuracy)

```
Epoch 1/25 469/469 [==============================] - 8s 12ms/step - loss: 0.5219 - accuracy: 0.7979 - val_loss: 0.3837 - val_accuracy: 0.8515
Epoch 2/25 469/469 [==============================] - 5s 11ms/step - loss: 0.3228 - accuracy: 0.8804 - val_loss: 0.2888 - val_accuracy: 0.8901
Epoch 3/25 469/469 [==============================] - 5s 11ms/step - loss: 0.2674 - accuracy: 0.9027 - val_loss: 0.2387 - val_accuracy: 0.9141
Epoch 4/25 469/469 [==============================] - 5s 11ms/step - loss: 0.2395 - accuracy: 0.9130 - val_loss: 0.2346 - val_accuracy: 0.9157
Epoch 5/25 469/469 [==============================] - 5s 11ms/step - loss: 0.2186 - accuracy: 0.9220 - val_loss: 0.2315 - val_accuracy: 0.9181
Epoch 6/25 469/469 [==============================] - 5s 11ms/step - loss: 0.2055 - accuracy: 0.9261 - val_loss: 0.2026 - val_accuracy: 0.9288
Epoch 7/25 469/469 [==============================] - 5s 11ms/step - loss: 0.1918 - accuracy: 0.9311 - val_loss: 0.1987 - val_accuracy: 0.9306
Epoch 8/25 469/469 [==============================] - 5s 11ms/step - loss: 0.1795 - accuracy: 0.9341 - val_loss: 0.1935 - val_accuracy: 0.9328
Epoch 9/25 469/469 [==============================] - 5s 12ms/step - loss: 0.1723 - accuracy: 0.9376 - val_loss: 0.1912 - val_accuracy: 0.9332
Epoch 10/25 469/469 [==============================] - 5s 11ms/step - loss: 0.1609 - accuracy: 0.9417 - val_loss: 0.1985 - val_accuracy: 0.9292
Epoch 11/25 469/469 [==============================] - 5s 11ms/step - loss: 0.1534 - accuracy: 0.9443 - val_loss: 0.1946 - val_accuracy: 0.9346
Epoch 12/25 469/469 [==============================] - 5s 11ms/step - loss: 0.1460 - accuracy: 0.9463 - val_loss: 0.1879 - val_accuracy: 0.9350
Epoch 13/25 469/469 [==============================] - 5s 11ms/step - loss: 0.1393 - accuracy: 0.9498 - val_loss: 0.1813 - val_accuracy: 0.9384
Epoch 14/25 469/469 [==============================] - 5s 11ms/step - loss: 0.1333 - accuracy: 0.9519 - val_loss: 0.1906 - val_accuracy: 0.9369
Epoch 15/25 469/469 [==============================] - 5s 11ms/step - loss: 0.1270 - accuracy: 0.9536 - val_loss: 0.1894 - val_accuracy: 0.9379
Epoch 16/25 469/469 [==============================] - 5s 11ms/step - loss: 0.1191 - accuracy: 0.9558 - val_loss: 0.1849 - val_accuracy: 0.9386
```

Model Architecture



MODEL 8 - With activation function - LeakyReLU & variation of kernel size & addition of Early Stopping

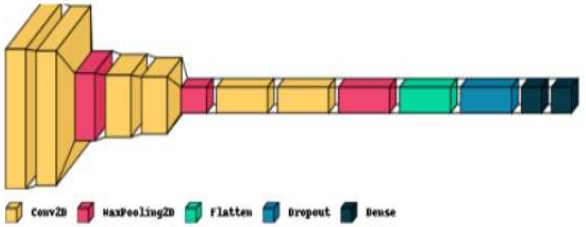
Model – 8 Summary

```
Model: "sequential_63"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_302 (Conv2D)         (None, 27, 27, 128)       640

 conv2d_303 (Conv2D)         (None, 26, 26, 128)       65664

 max_pooling2d_146 (MaxPooli  (None, 13, 13, 128)      0
 ng2D)

 conv2d_304 (Conv2D)         (None, 12, 12, 256)       131328

 conv2d_305 (Conv2D)         (None, 11, 11, 256)       262400

 max_pooling2d_147 (MaxPooli  (None, 5, 5, 256)        0
 ng2D)

 conv2d_306 (Conv2D)         (None, 4, 4, 512)         524800

 conv2d_307 (Conv2D)         (None, 3, 3, 512)         1049088

 max_pooling2d_148 (MaxPooli  (None, 1, 1, 512)        0
 ng2D)

 flatten_63 (Flatten)        (None, 512)               0

 dropout_51 (Dropout)        (None, 512)               0

 dense_84 (Dense)            (None, 5)                 2565

 dense_85 (Dense)            (None, 5)                 30

=================================================================
Total params: 2,036,515
Trainable params: 2,036,515
Non-trainable params: 0
_________________________________________________________________
```

Runtime Information (Epochs, Loss, Accuracy)

```
Epoch 1/25 469/469 [==============================] - 14s 25ms/step - loss: 0.5497 - accuracy: 0.7807 - val_loss: 0.3808 - val_accuracy: 0.8508
Epoch 2/25 469/469 [==============================] - 11s 24ms/step - loss: 0.3359 - accuracy: 0.8752 - val_loss: 0.3467 - val_accuracy: 0.8674
Epoch 3/25 469/469 [==============================] - 11s 24ms/step - loss: 0.2741 - accuracy: 0.8976 - val_loss: 0.2680 - val_accuracy: 0.9031
Epoch 4/25 469/469 [==============================] - 11s 24ms/step - loss: 0.2392 - accuracy: 0.9113 - val_loss: 0.2373 - val_accuracy: 0.9114
Epoch 5/25 469/469 [==============================] - 11s 24ms/step - loss: 0.2156 - accuracy: 0.9214 - val_loss: 0.2344 - val_accuracy: 0.9145
Epoch 6/25 469/469 [==============================] - 11s 24ms/step - loss: 0.1996 - accuracy: 0.9263 - val_loss: 0.2786 - val_accuracy: 0.9025
Epoch 7/25 469/469 [==============================] - 11s 24ms/step - loss: 0.1845 - accuracy: 0.9321 - val_loss: 0.2141 - val_accuracy: 0.9237
Epoch 8/25 469/469 [==============================] - 11s 24ms/step - loss: 0.1677 - accuracy: 0.9386 - val_loss: 0.2139 - val_accuracy: 0.9273
Epoch 9/25 469/469 [==============================] - 11s 24ms/step - loss: 0.1500 - accuracy: 0.9458 - val_loss: 0.2218 - val_accuracy: 0.9223
Epoch 10/25 469/469 [==============================] - 11s 24ms/step - loss: 0.1413 - accuracy: 0.9484 - val_loss: 0.2196 - val_accuracy: 0.9268
Epoch 11/25 469/469 [==============================] - 11s 24ms/step - loss: 0.1269 - accuracy: 0.9538 - val_loss: 0.2212 - val_accuracy: 0.9296
```

Model Architecture



MODEL 9 - Multiple activation functions - relu, LeakyReLU & tanh

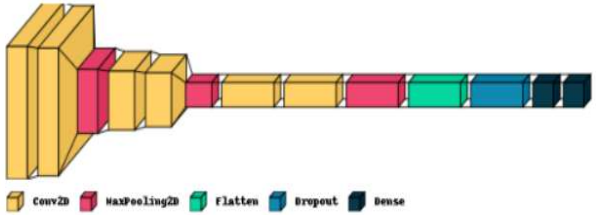
Model –9 Summary

```
Model: "sequential_64"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_308 (Conv2D)         (None, 27, 27, 128)       640

 conv2d_309 (Conv2D)         (None, 26, 26, 128)       65664

 max_pooling2d_149 (MaxPooli  (None, 13, 13, 128)      0
 ng2D)

 conv2d_310 (Conv2D)         (None, 12, 12, 256)       131328

 conv2d_311 (Conv2D)         (None, 11, 11, 256)       262400

 max_pooling2d_150 (MaxPooli  (None, 5, 5, 256)        0
 ng2D)

 conv2d_312 (Conv2D)         (None, 4, 4, 512)         524800

 conv2d_313 (Conv2D)         (None, 3, 3, 512)         1049088

 max_pooling2d_151 (MaxPooli  (None, 1, 1, 512)        0
 ng2D)

 flatten_64 (Flatten)        (None, 512)               0

 dropout_52 (Dropout)        (None, 512)               0

 dense_86 (Dense)            (None, 5)                 2565

 dense_87 (Dense)            (None, 5)                 30

=================================================================
Total params: 2,036,515
Trainable params: 2,036,515
Non-trainable params: 0
_________________________________________________________________
```

Runtime Information (Epochs, Loss, Accuracy)

```
Epoch 1/25 469/469 [==============================] - 13s 23ms/step - loss: 0.5152 - accuracy: 0.7936 - val_loss: 0.3606 - val_accuracy: 0.8598
Epoch 2/25 469/469 [==============================] - 11s 23ms/step - loss: 0.3322 - accuracy: 0.8740 - val_loss: 0.3130 - val_accuracy: 0.8850
Epoch 3/25 469/469 [==============================] - 11s 23ms/step - loss: 0.2715 - accuracy: 0.8988 - val_loss: 0.2582 - val_accuracy: 0.9071
Epoch 4/25 469/469 [==============================] - 11s 23ms/step - loss: 0.2390 - accuracy: 0.9112 - val_loss: 0.2461 - val_accuracy: 0.9097
Epoch 5/25 469/469 [==============================] - 11s 23ms/step - loss: 0.2201 - accuracy: 0.9189 - val_loss: 0.2352 - val_accuracy: 0.9127
Epoch 6/25 469/469 [==============================] - 11s 23ms/step - loss: 0.2063 - accuracy: 0.9228 - val_loss: 0.2273 - val_accuracy: 0.9160
Epoch 7/25 469/469 [==============================] - 11s 23ms/step - loss: 0.1944 - accuracy: 0.9275 - val_loss: 0.2412 - val_accuracy: 0.9108
Epoch 8/25 469/469 [==============================] - 11s 23ms/step - loss: 0.1852 - accuracy: 0.9320 - val_loss: 0.2148 - val_accuracy: 0.9202
Epoch 9/25 469/469 [==============================] - 11s 23ms/step - loss: 0.1736 - accuracy: 0.9360 - val_loss: 0.2086 - val_accuracy: 0.9256
Epoch 10/25 469/469 [==============================] - 11s 23ms/step - loss: 0.1660 - accuracy: 0.9395 - val_loss: 0.2124 - val_accuracy: 0.9255
Epoch 11/25 469/469 [==============================] - 11s 23ms/step - loss: 0.1576 - accuracy: 0.9431 - val_loss: 0.2052 - val_accuracy: 0.9297
Epoch 12/25 469/469 [==============================] - 11s 23ms/step - loss: 0.1459 - accuracy: 0.9455 - val_loss: 0.2145 - val_accuracy: 0.9236
Epoch 13/25 469/469 [==============================] - 11s 23ms/step - loss: 0.1363 - accuracy: 0.9498 - val_loss: 0.2094 - val_accuracy: 0.9291
Epoch 14/25 469/469 [==============================] - 11s 23ms/step - loss: 0.1282 - accuracy: 0.9531 - val_loss: 0.2282 - val_accuracy: 0.9203
```

Model Architecture



MODEL 10 - With activation function - LeakyReLU & varying the order of layers

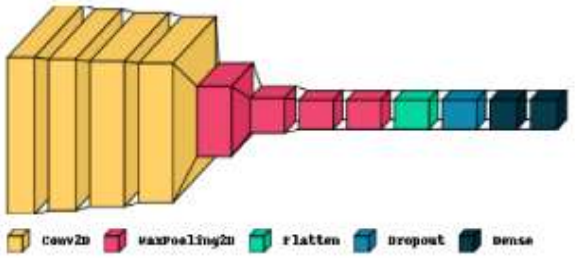
Model – 10 Summary

```
Model: "sequential_65"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_314 (Conv2D)         (None, 27, 27, 128)       640

 conv2d_315 (Conv2D)         (None, 26, 26, 128)       65664

 conv2d_316 (Conv2D)         (None, 25, 25, 256)       131328

 conv2d_317 (Conv2D)         (None, 24, 24, 256)       262400

 max_pooling2d_152 (MaxPooli  (None, 12, 12, 256)      0
 ng2D)

 max_pooling2d_153 (MaxPooli  (None, 6, 6, 256)        0
 ng2D)

 max_pooling2d_154 (MaxPooli  (None, 3, 3, 256)        0
 ng2D)

 max_pooling2d_155 (MaxPooli  (None, 1, 1, 256)        0
 ng2D)

 flatten_65 (Flatten)        (None, 256)               0

 dropout_53 (Dropout)        (None, 256)               0

 dense_88 (Dense)            (None, 5)                 1285

 dense_89 (Dense)            (None, 5)                 30

=================================================================
Total params: 461,347
Trainable params: 461,347
Non-trainable params: 0
_________________________________________________________________
```

Runtime Information (Epochs, Loss, Accuracy)

```
Epoch 1/25 469/469 [==============================] - 22s 42ms/step - loss: 0.7582 - accuracy: 0.6976 - val_loss: 0.5347 - val_accuracy: 0.7872
Epoch 2/25 469/469 [==============================] - 20s 42ms/step - loss: 0.5376 - accuracy: 0.7930 - val_loss: 0.4691 - val_accuracy: 0.8187
Epoch 3/25 469/469 [==============================] - 20s 42ms/step - loss: 0.4886 - accuracy: 0.8123 - val_loss: 0.4278 - val_accuracy: 0.8337
Epoch 4/25 469/469 [==============================] - 20s 42ms/step - loss: 0.4606 - accuracy: 0.8234 - val_loss: 0.4321 - val_accuracy: 0.8358
Epoch 5/25 469/469 [==============================] - 20s 42ms/step - loss: 0.4404 - accuracy: 0.8322 - val_loss: 0.4098 - val_accuracy: 0.8469
Epoch 6/25 469/469 [==============================] - 19s 41ms/step - loss: 0.4314 - accuracy: 0.8345 - val_loss: 0.4119 - val_accuracy: 0.8448
Epoch 7/25 469/469 [==============================] - 19s 41ms/step - loss: 0.4185 - accuracy: 0.8406 - val_loss: 0.3918 - val_accuracy: 0.8512
Epoch 8/25 469/469 [==============================] - 20s 42ms/step - loss: 0.4068 - accuracy: 0.8449 - val_loss: 0.3736 - val_accuracy: 0.8548
Epoch 9/25 469/469 [==============================] - 20s 42ms/step - loss: 0.3959 - accuracy: 0.8498 - val_loss: 0.3954 - val_accuracy: 0.8471
Epoch 10/25 469/469 [==============================] - 20s 42ms/step - loss: 0.3895 - accuracy: 0.8524 - val_loss: 0.3800 - val_accuracy: 0.8559
Epoch 11/25 469/469 [==============================] - 20s 42ms/step - loss: 0.3858 - accuracy: 0.8522 - val_loss: 0.3540 - val_accuracy: 0.8643
Epoch 12/25 469/469 [==============================] - 20s 42ms/step - loss: 0.3776 - accuracy: 0.8553 - val_loss: 0.3708 - val_accuracy: 0.8589
Epoch 13/25 469/469 [==============================] - 19s 41ms/step - loss: 0.3738 - accuracy: 0.8573 - val_loss: 0.3578 - val_accuracy: 0.8630
Epoch 14/25 469/469 [==============================] - 19s 41ms/step - loss: 0.3660 - accuracy: 0.8597 - val_loss: 0.3557 - val_accuracy: 0.8616
```

Model Architecture



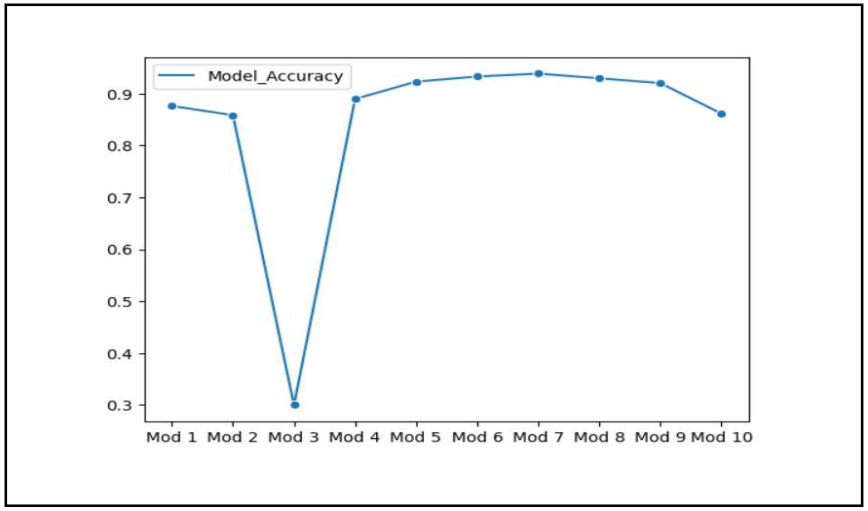
Observations from All 10 models:

- We tried creating multiple networks by increasing the number of layers and tried varying the sequence of layers. Increasing the number of layers and varying the sequence of layers can potentially improve a neural network's ability to learn complex patterns and features from input data
- We tried different optimizers like Adam and SGD. It adapts the learning rate for each parameter based on estimates of the first and second moments of the gradients, which can help it converge faster and more reliably
- We tried Early Stopping to overcome the overfitting. The idea is to stop the training process before the model starts to overfit the training data. This is done by monitoring the validation loss during training and stopping the training process when the validation loss stops improving.
- We tried Dropout function for regularization. This can help prevent the model from relying too much on any single feature or neuron and can force the model to learn more robust and generalizable representations of the data.
- We tried Varying Activation Functions Like Sigmoid, LeakyReLU, ReLU, tanH. They introduce non-linearity into the model and enable it to learn complex patterns in the data
- We tried using different size of filters in Convolutional layers and Max Pooling Layers. By varying the size of the filters and pooling windows, we can explore different trade-offs between model complexity and performance
- We varied kernel Size for the convolutional layers to ensure that our model is able to capture the relevant patterns in the data and generalize well to new data.

Best Model:

We evaluated all models with the test data. Here is the table of accuracy comparison and plot of accuracy for all models.

	Model_Accuracy
Mod 1	0.8762
Mod 2	0.8585
Mod 3	0.3000
Mod 4	0.8895
Mod 5	0.9231
Mod 6	0.9330
Mod 7	0.9386
Mod 8	0.9296
Mod 9	0.9203
Mod 10	0.8616



When comparing the accuracy of all models we developed, Model 7 gave the best accuracy.

Possibly because We used leaky ReLU as Activation function which is more effective when comparing with other activation functions we used. Besides we used drop out and early stopping to avoid overfitting. Adam optimizer also helped this model to learn optimally.

From the Models we created, we finalized the Model 7 in terms of accuracy. It provides the effective accuracy when comparing with the other models we created.

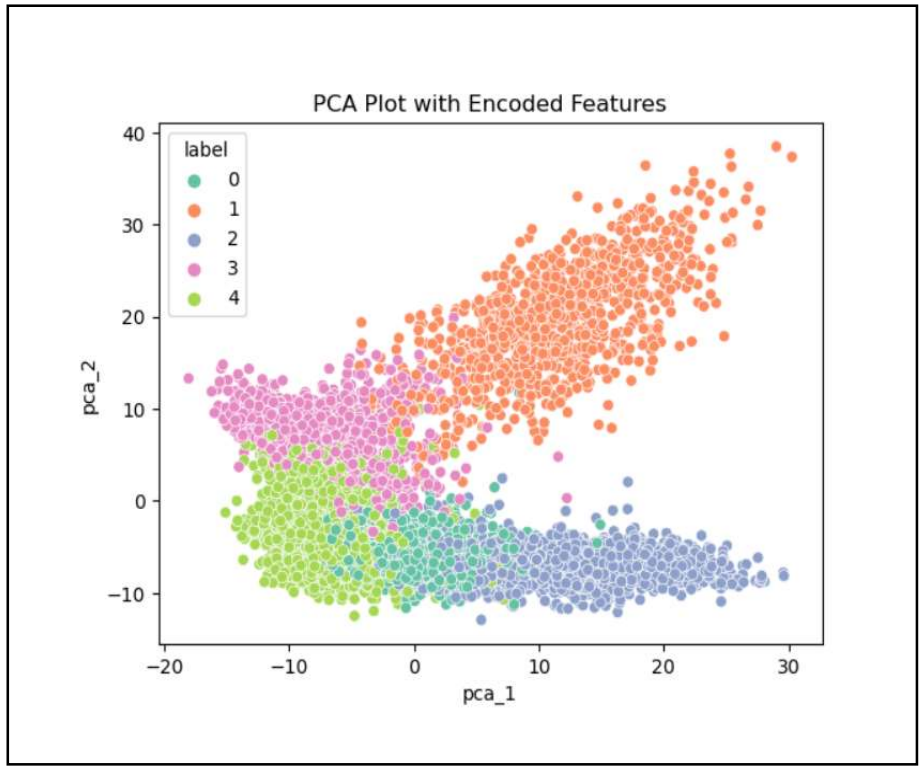
Model 7 has the accuracy of 93.86 %.

We defined an intermediate layer model and we extracted the train encoding sets and Test encoding sets.

Activity 1: PCA - Visualizing encoding with the first two components

We used test encoding data to extract the PCA components and we plotted for the two components.

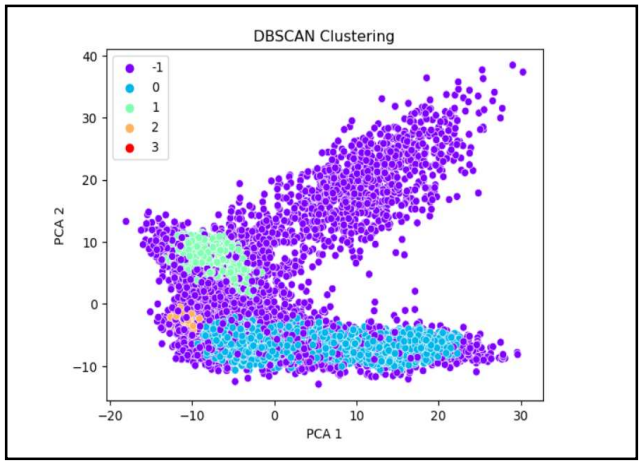
we observed that the different clothing categories are clustered together in certain regions of the plot, indicating that the encoding is effective at capturing the visual similarities between different types of clothing.

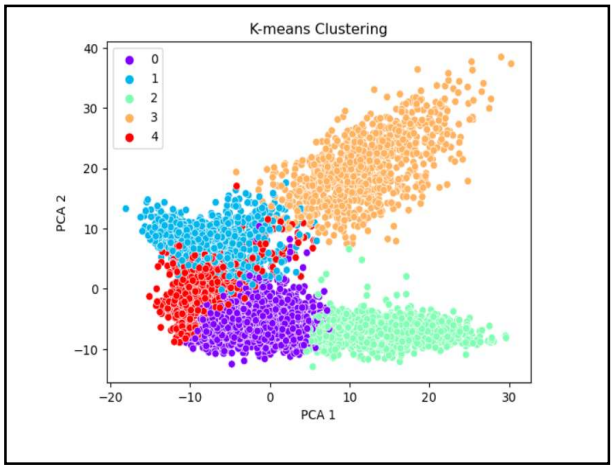


Activity 2: DBSCAN and K means for Clustering and Visualization.

We used test encoding data to perform DBSCAN and K Means and we generated the DB Scan predicted labels and K Means Predicted labels.

From the Graph we observed that for DBSCAN, the labels are filled with outliers (-1) and it clustered very bad but in the case of K Means it clustered effectively and it's really helpful for the prediction of Mystery Labels.

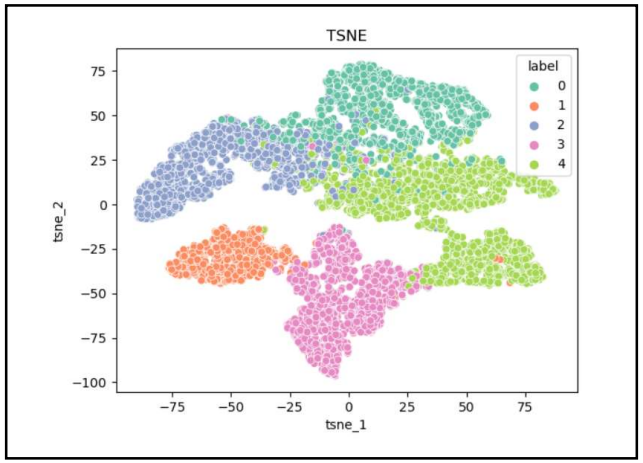


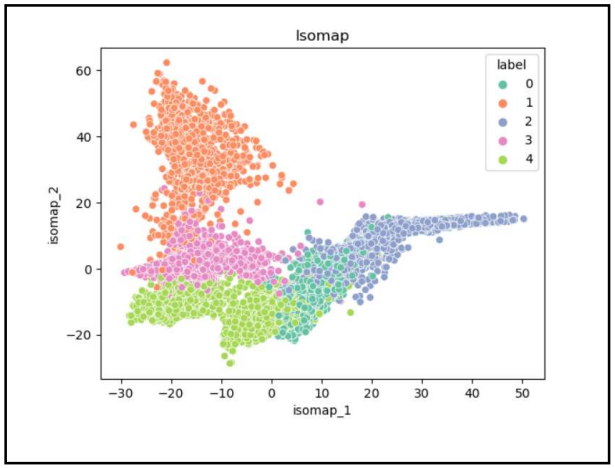


K Means performed well for clustering as it grouped the different classes properly and it has very less outliers but in the case of DBSCAN, it underperformed both in Clustering of classes and outliers.

Activity 3: t-SNE and ISOMAP for Clustering and Visualization.

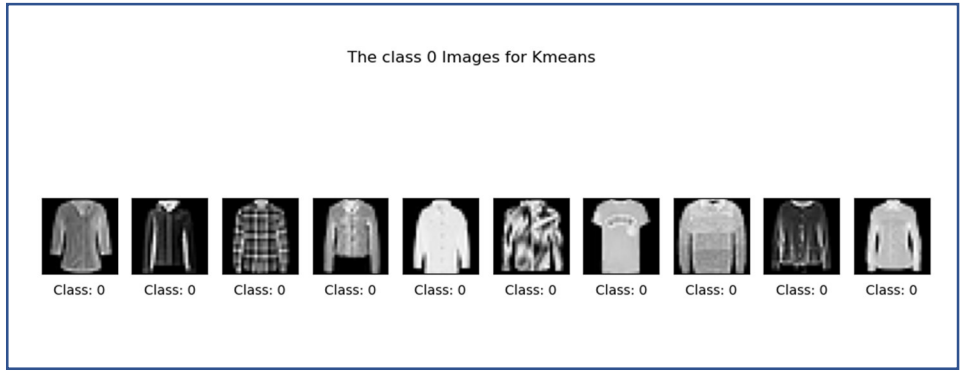
We have tried T-SNE and Isomap (Dimensionality Reduction Techniques) for the visualization to predict the mystery labels. The features extracted from this two techniques helped us effectively to distinguish between the different types of classes (clothing's)

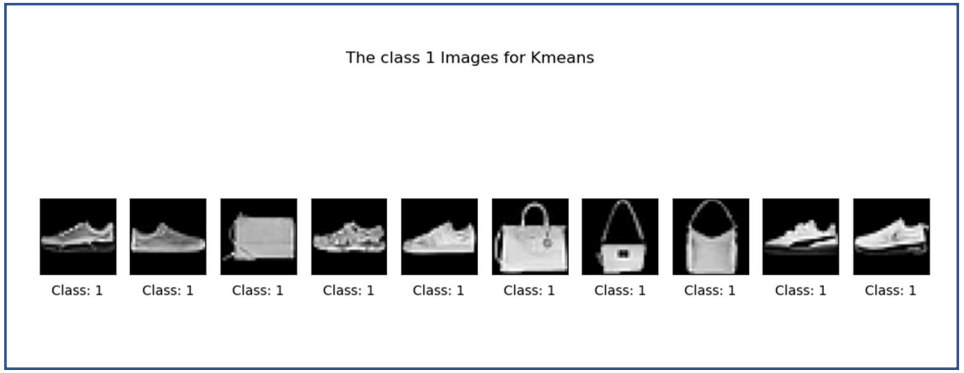


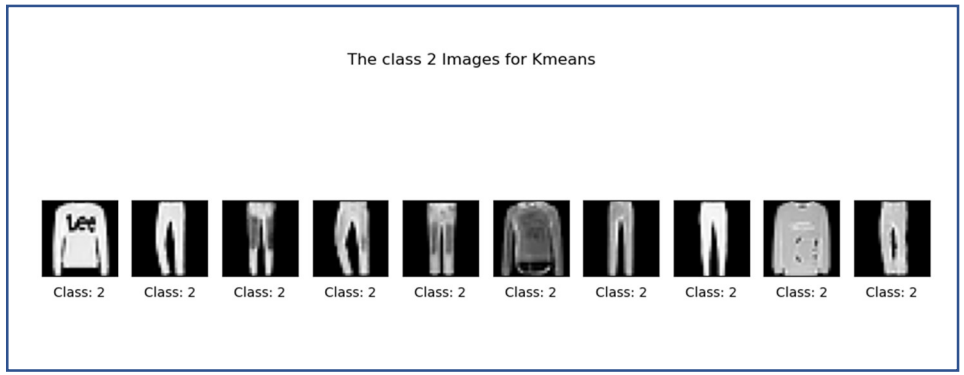


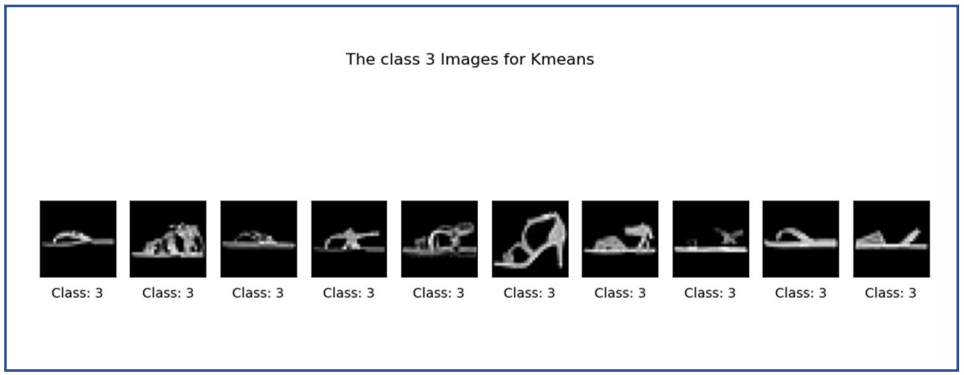
Activity 4: Prediction of Mystery Labels.

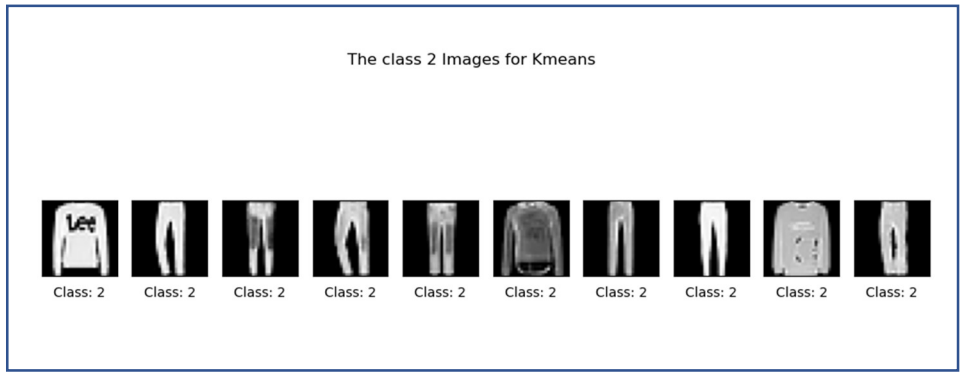
We used K means Labels to identify the Mystery Labels.











From the Images, we predicted the mystery labels for all 5 classes.

Class 0 - Shoes and Bags

Class 1 - Casual shirts, T-shirts and Skirts

Class 2 - Lounge Pants and Sweatshirts

Class 3 - Sandals and Flip-flops

Class 4 - Boots and Formal wear

Activity 5: Using this Encoding in a Creative Way.

We used Encoded data of Model 7 as an Input to the Autoencoders.

Reasons to use Auto Encoders:

- During training, the input to the autoencoder is the noisy data, and the output is the corresponding clean data. The autoencoder learns to encode the noisy input into a latent space representation, and then decode this representation to reconstruct the clean data.
- Autoencoders can learn to extract meaningful features from high-dimensional data. These features can be used for various tasks, such as image recognition, classification, and clustering.

We have used three encoder layers and three decoded layers with activation function as LeakyReLU with Dropout and early stopping for regularization and to avoid overfitting respectively.

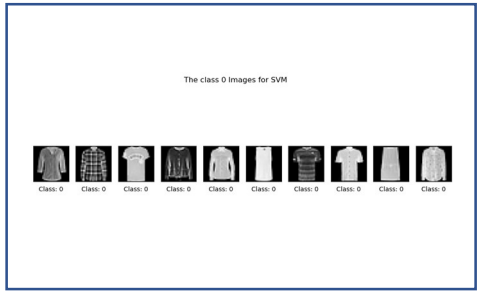
We tried with Adam optimizer and loss function as Mean Squared Error with 20 Epochs.
As we applied early stopping, we got Accuracy as 99.45% in the 12th Epoch.

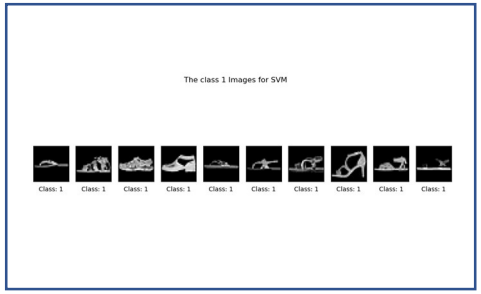
With this Auto encoder models, we extracted the train and test datasets.

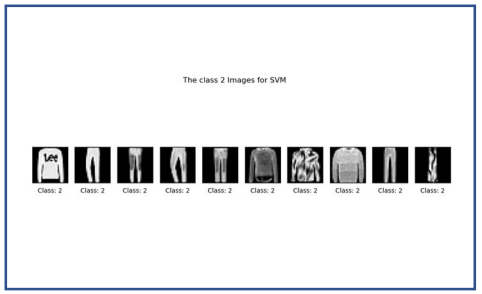
We used it in SVM Classifier which is considered to be the most efficient image classification model in terms of handling high dimensional spaces and robustness to noise when comparing with other Classification Algorithms like Decision trees and Logistic Regression.

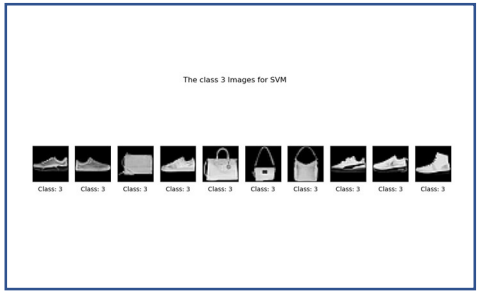
We got the test Accuracy of 94.06 % using SVM.

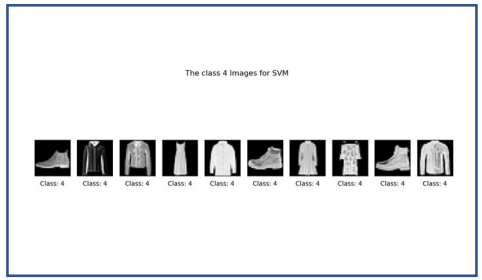
With the Labels predicted using SVM we found the Mystery Labels.











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