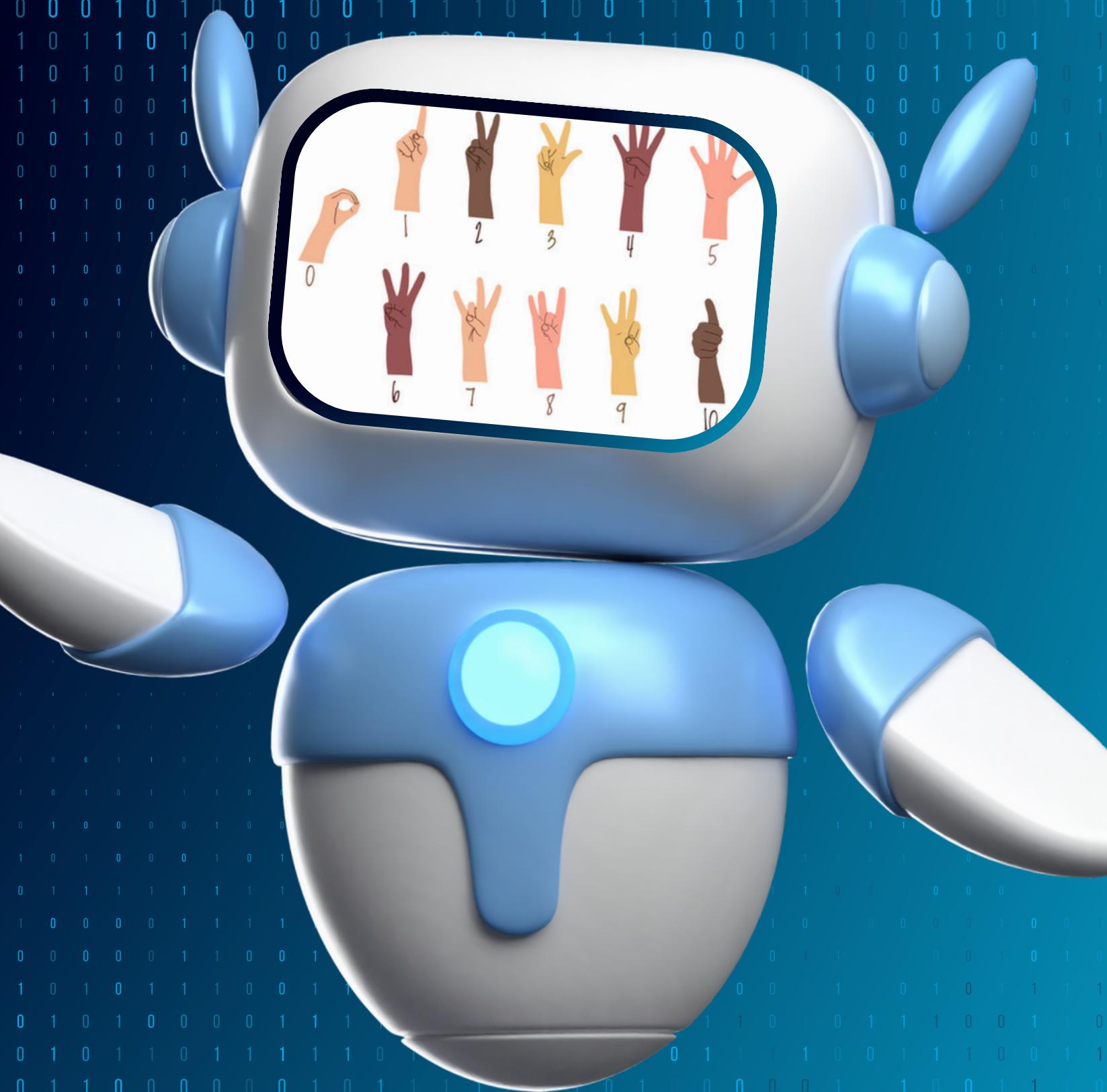


IDENTIFICATION OF DIGITS FROM SIGN LANGUAGE IMAGES

Tópicos de Aprendizagem Automática
2023/2024

Hugo Correia, 108215
Joaquim Rosa, 109089



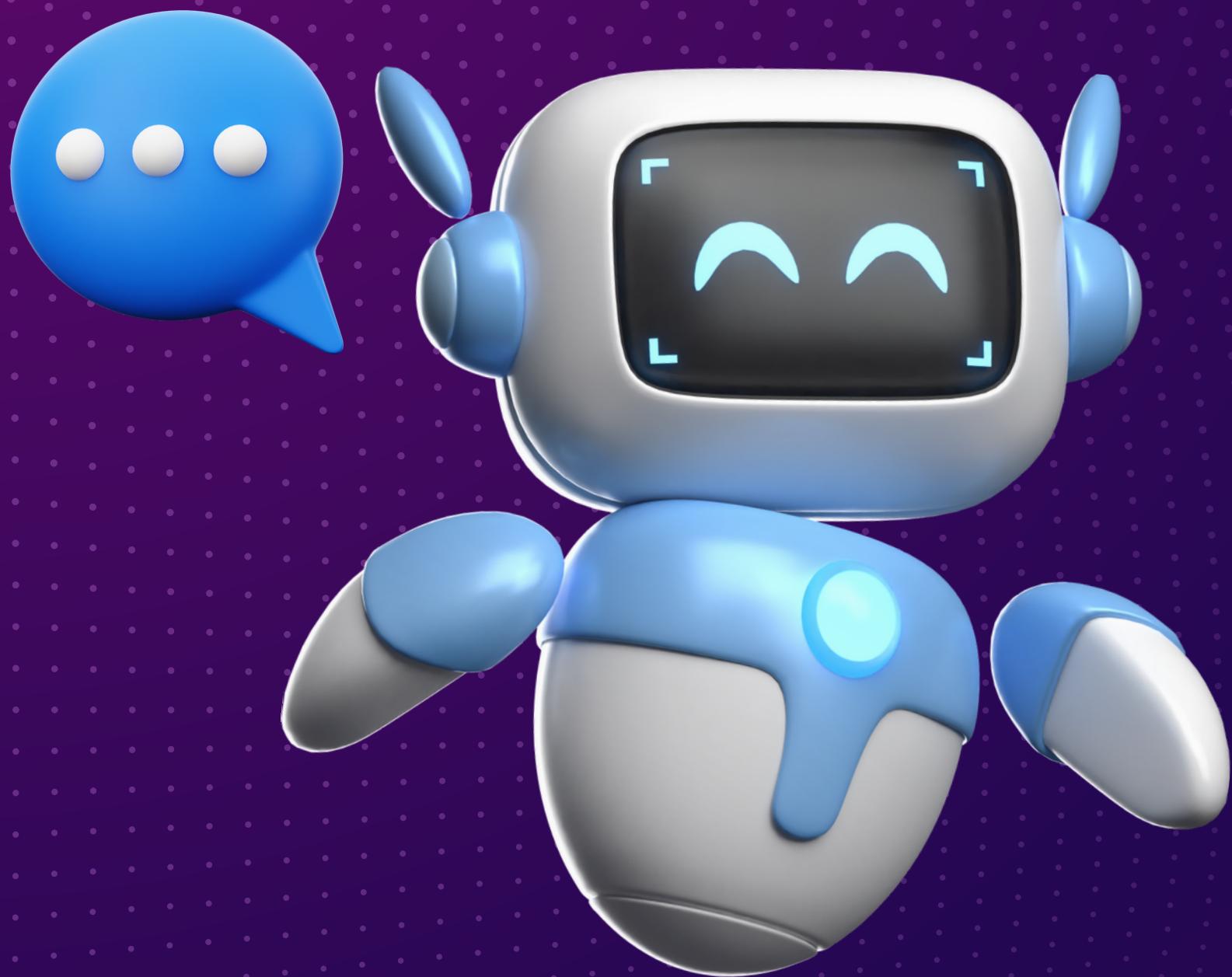
CONTENTS



- ① Introduction
- ② Dataset Description
- ③ Models Evaluation
- ④ Model Comparison
- ⑤ Conclusion

1

INTRODUCTION



COMMUNICATION GAP IN SIGN LANGUAGE

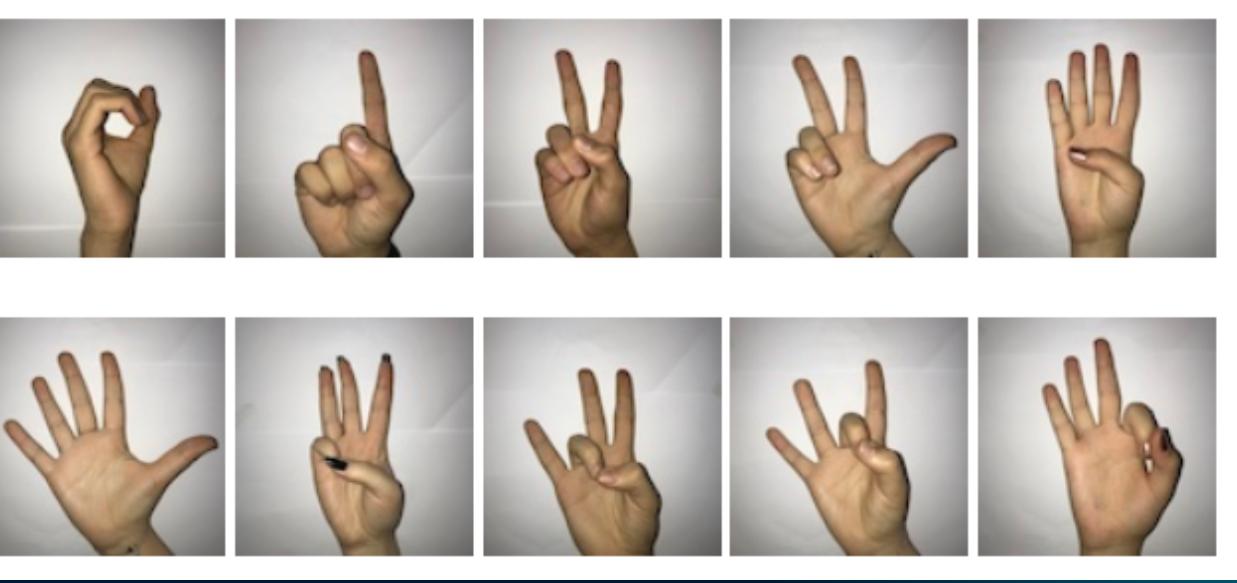
TRAINING OF DIFFERENT MODULES

RELATED WORK

2

DATASET DESCRIPTION

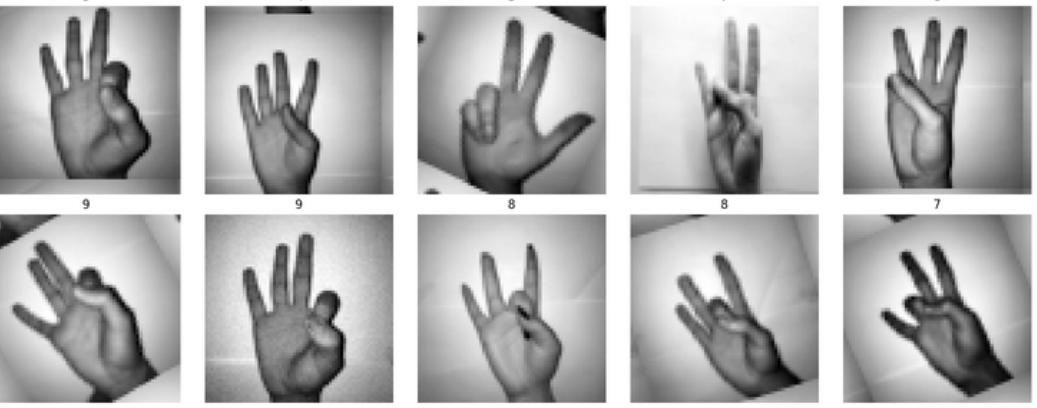
- 2062 images of digits represented in sign language, each with dimensions of 64x64 pixels
- images representing digits from 0 to 9 in sign language
- dataset was already balanced, with each label having a similar number of examples



2

DATASET PREPROCESSING

- Rotation: Rotate the image by a random angle between -30 and 30 degrees.
- Gaussian Noise: Add gaussian noise with a variance of 0.012.
- Gamma Contrast: Change the contrast of the image by a random factor between 0.8 and 1.2.
- Translation: Translate the image by a random value between -5 and 5 in both the x and y directions.

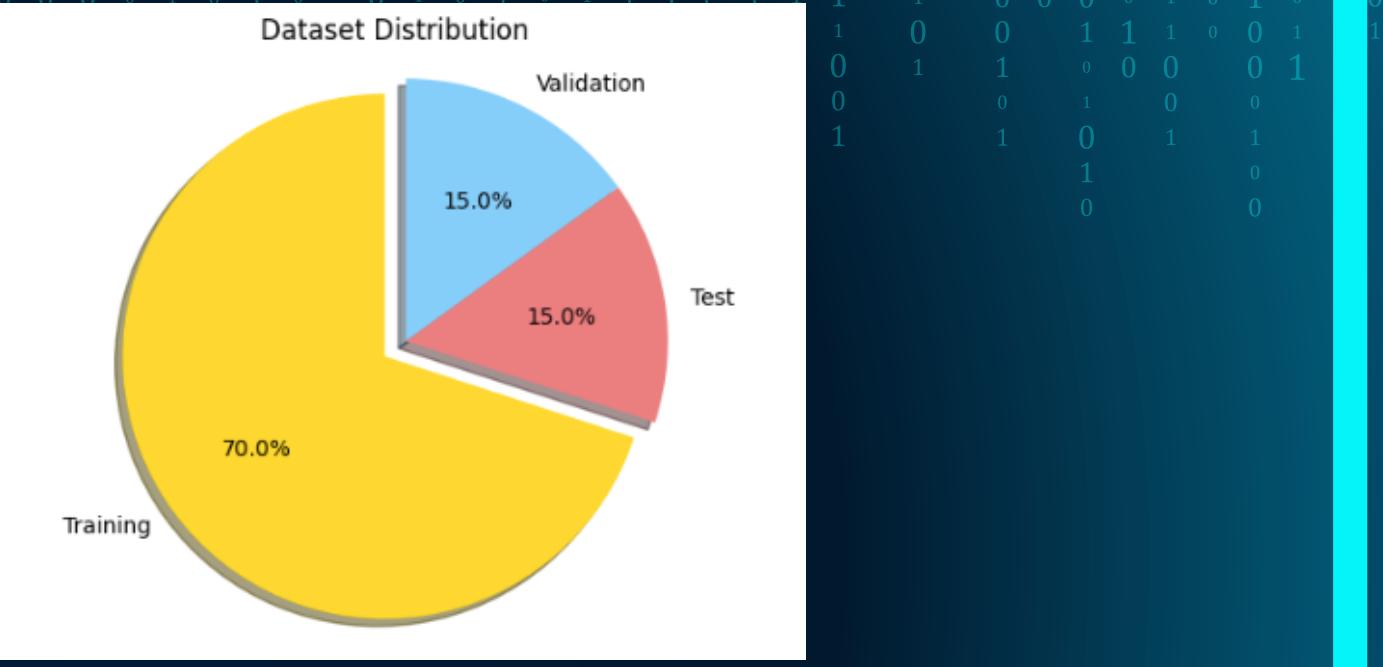


2

DATASET SPLITTING

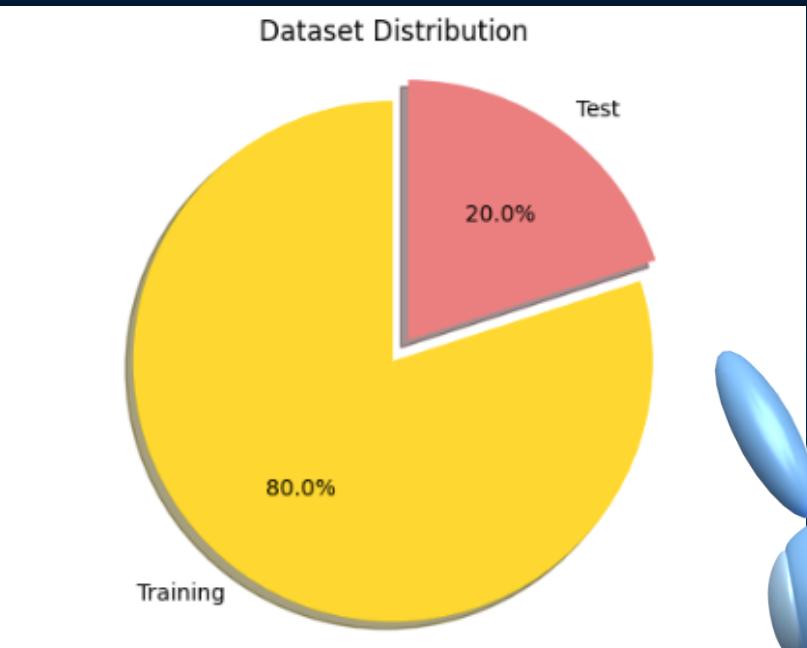
Training and Testing Data

- Training Data: 70% of the dataset
- Validation Data: 15% of the dataset
- Testing Data: 20% of the dataset



Training and Testing Data (SVM)

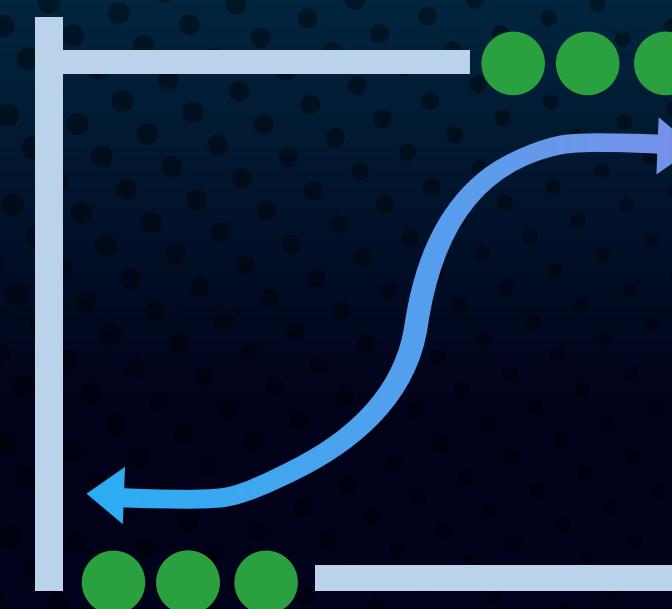
- Training Data: 80% of the dataset
- Testing Data: 20% of the dataset



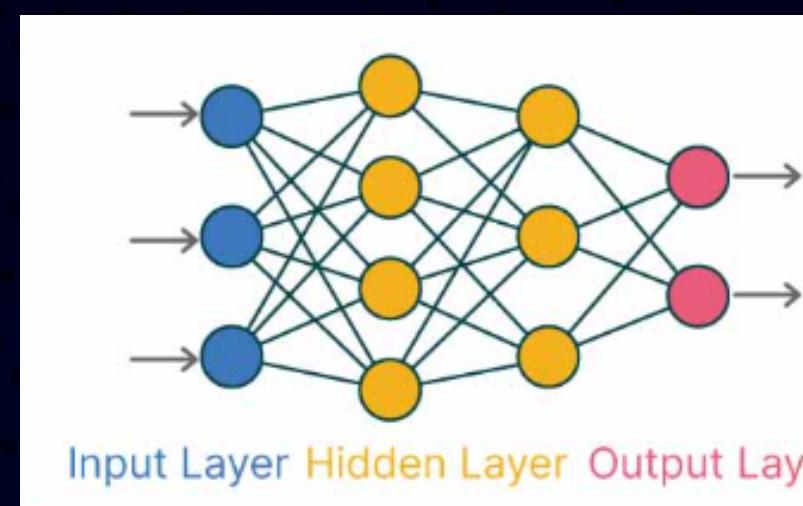
3

MODELS

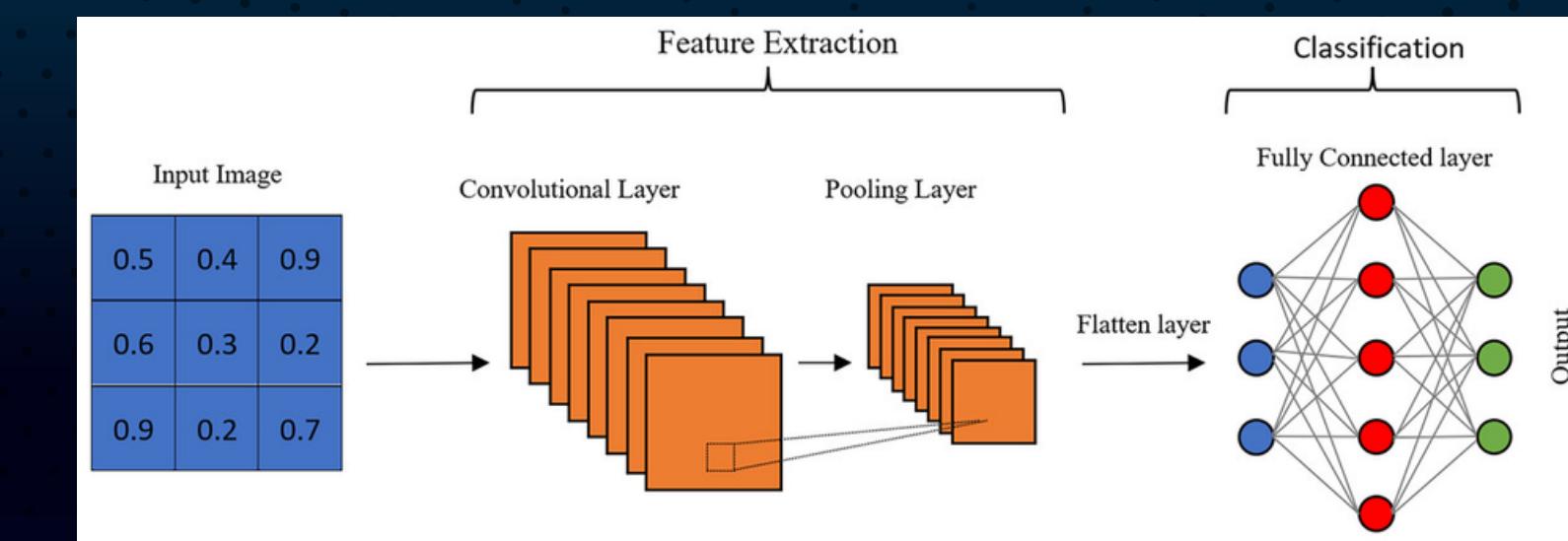
LOGISTIC REGRESSION MULTICLASS



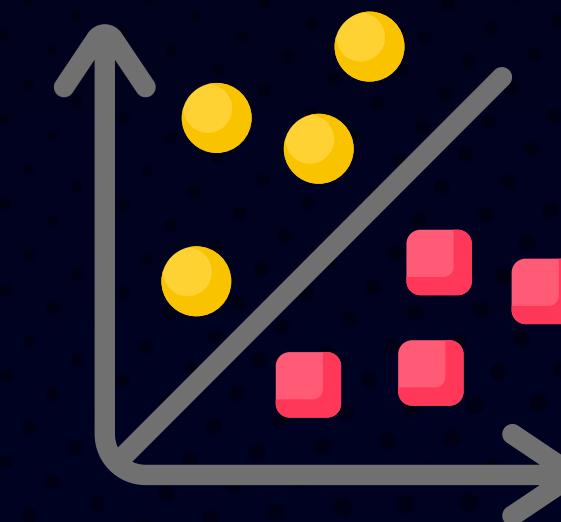
ARTIFICIAL NEURAL NETWORK



CONVOLUTIONAL NEURAL NETWORK



SUPPORT VECTOR MACHINE



3

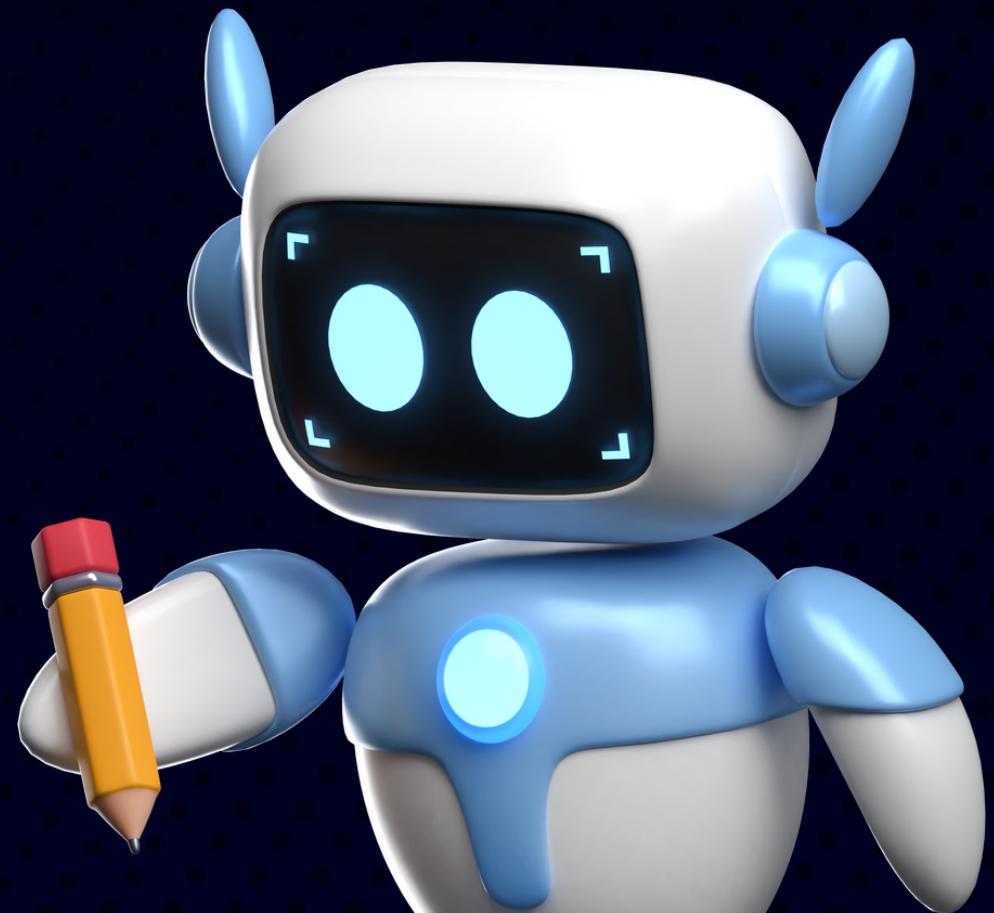
TECHNIQUES APPLIED TO INCREASE PERFORMANCE

HYPERPARAMETER TUNING

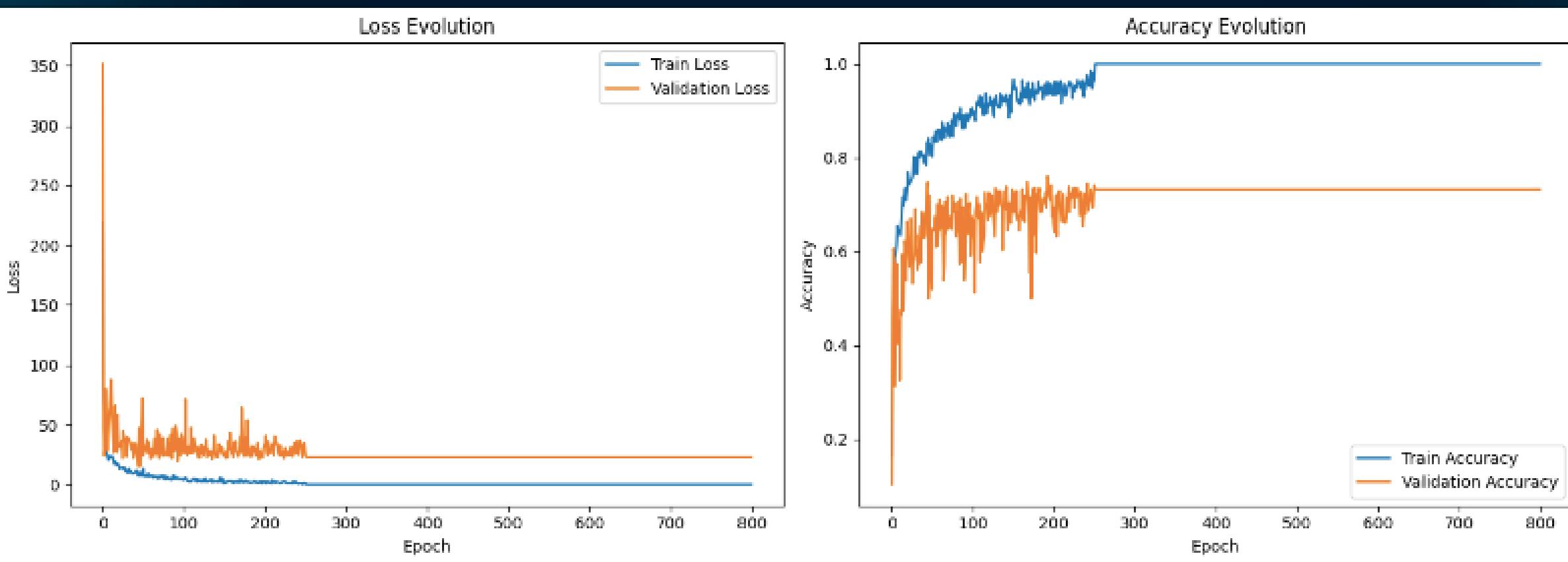
- LOGISTIC REGRESSION
- CONVOLUTIONAL NEURAL NETWORK
- ARTIFICIAL NEURAL NETWORK
- SUPPORT VECTOR MACHINE

CROSS-VALIDATION

- SUPPORT VECTOR MACHINE



LOGISTIC REGRESSION MULTICLASS



- LEARNING RATE: 0.1
 - DECAY: 1-6
 - MOMENTUM: 0.9
- NESTEROV: TRUE

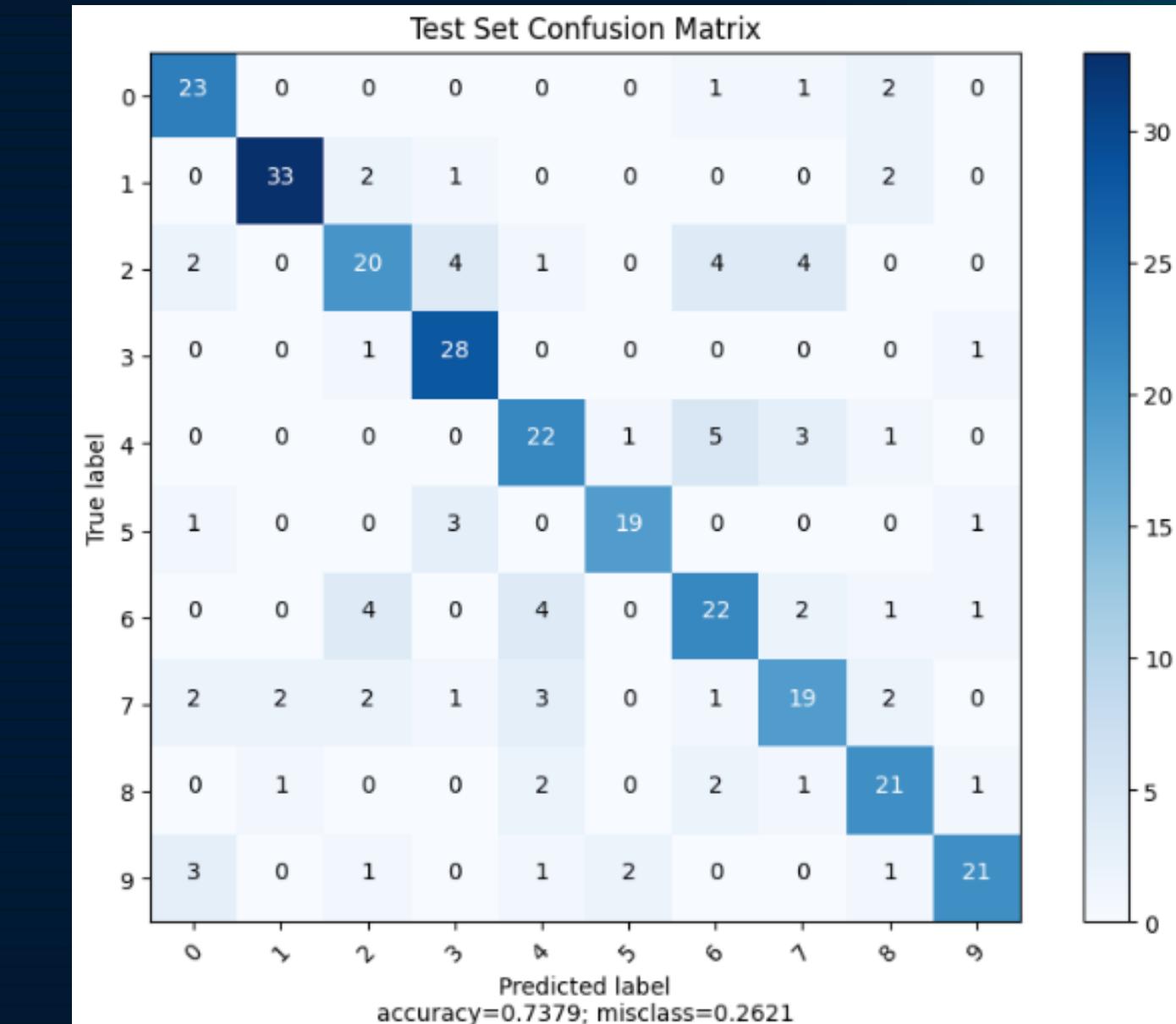
LOGISTIC REGRESSION

MULTICLASS

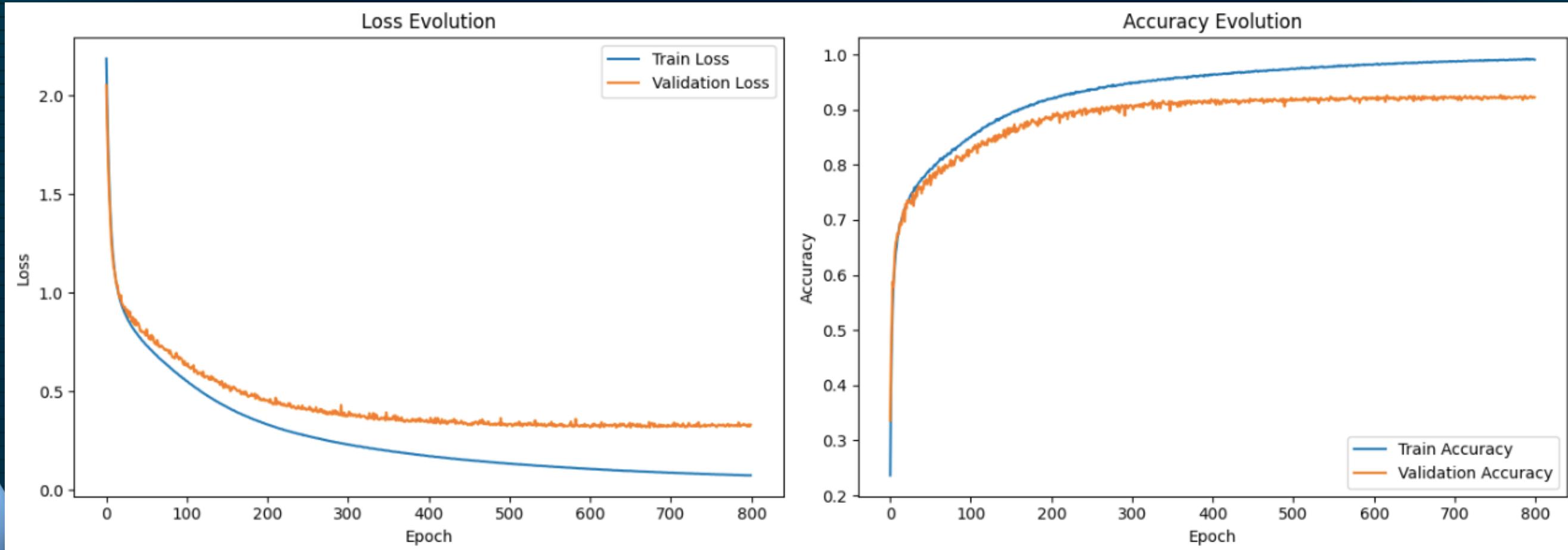
---- Test Set Analysis ----
Accuracy: 0.7378640776699029, F1 Score: 0.7363491232626245

Classification Report:

	precision	recall	f1-score	support
0	0.74	0.85	0.79	27
1	0.92	0.87	0.89	38
2	0.67	0.57	0.62	35
3	0.76	0.93	0.84	30
4	0.67	0.69	0.68	32
5	0.86	0.79	0.83	24
6	0.63	0.65	0.64	34
7	0.63	0.59	0.61	32
8	0.70	0.75	0.72	28
9	0.84	0.72	0.78	29
accuracy			0.74	309
macro avg	0.74	0.74	0.74	309
weighted avg	0.74	0.74	0.74	309



LOGISTIC REGRESSION MULTICLASS (AUGMENTED AND HYPERTUNED)



Hyperparameter	Values
learning_rate	$[1^{-4} - 1^{-1}]$
momentum	[0.8 - 0.99]
nesterov	{0, 1}

BEST HYPER-PARAMETERS

- LEARNING RATE - 0.00026
- MOMENTUM - 0.84
- NESTEROV - 1

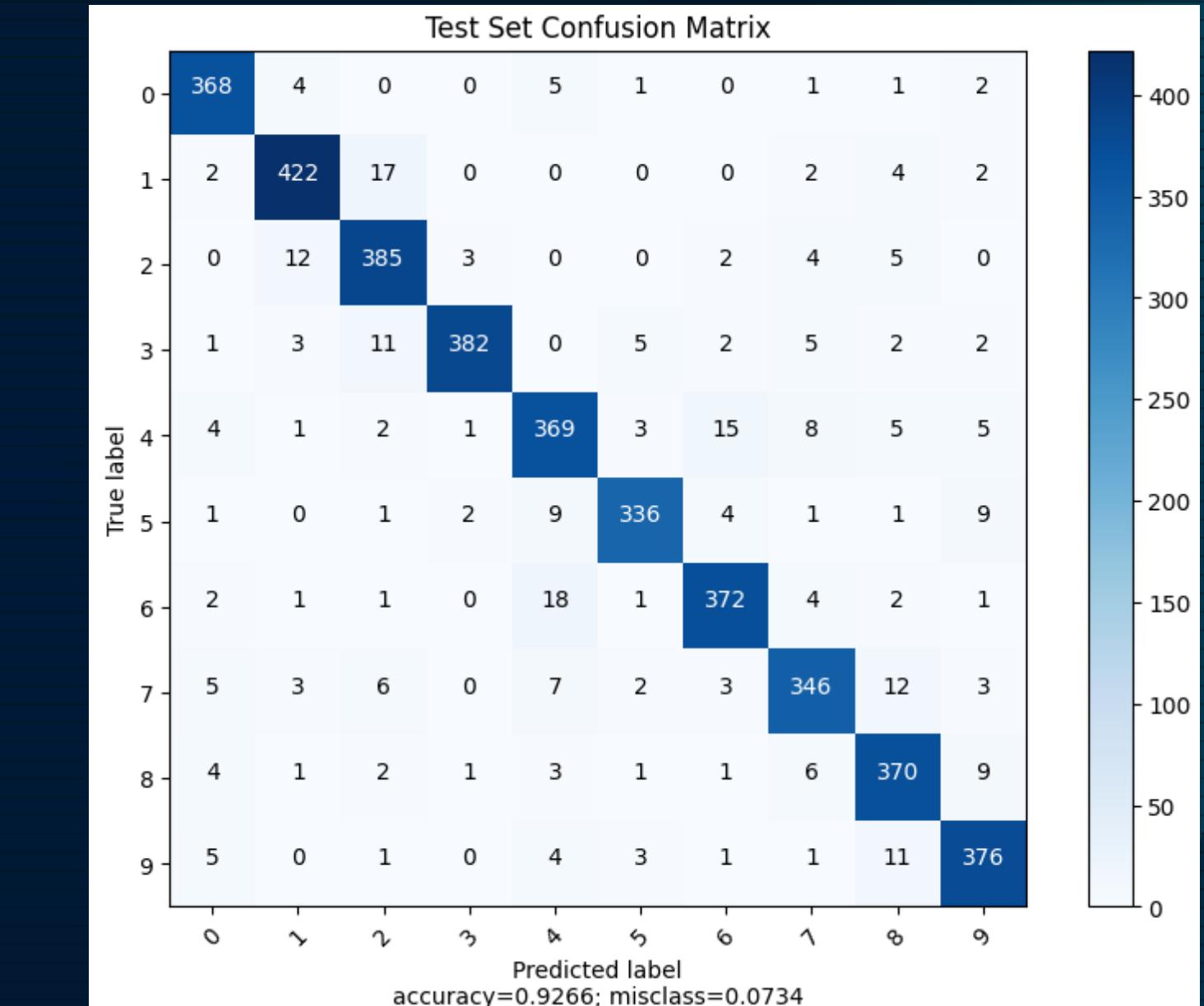
LOGISTIC REGRESSION MULTICLASS (AUGMENTED AND HYPERTUNED)

---- Test Set Analysis ----

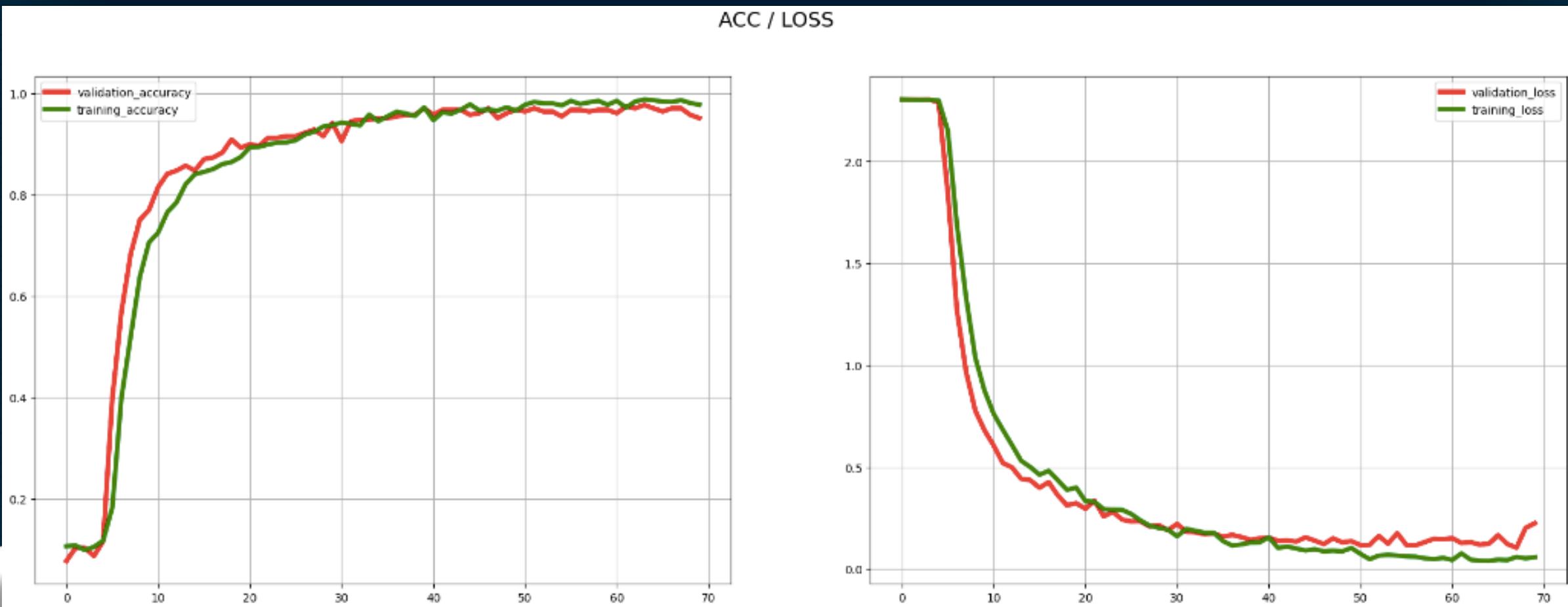
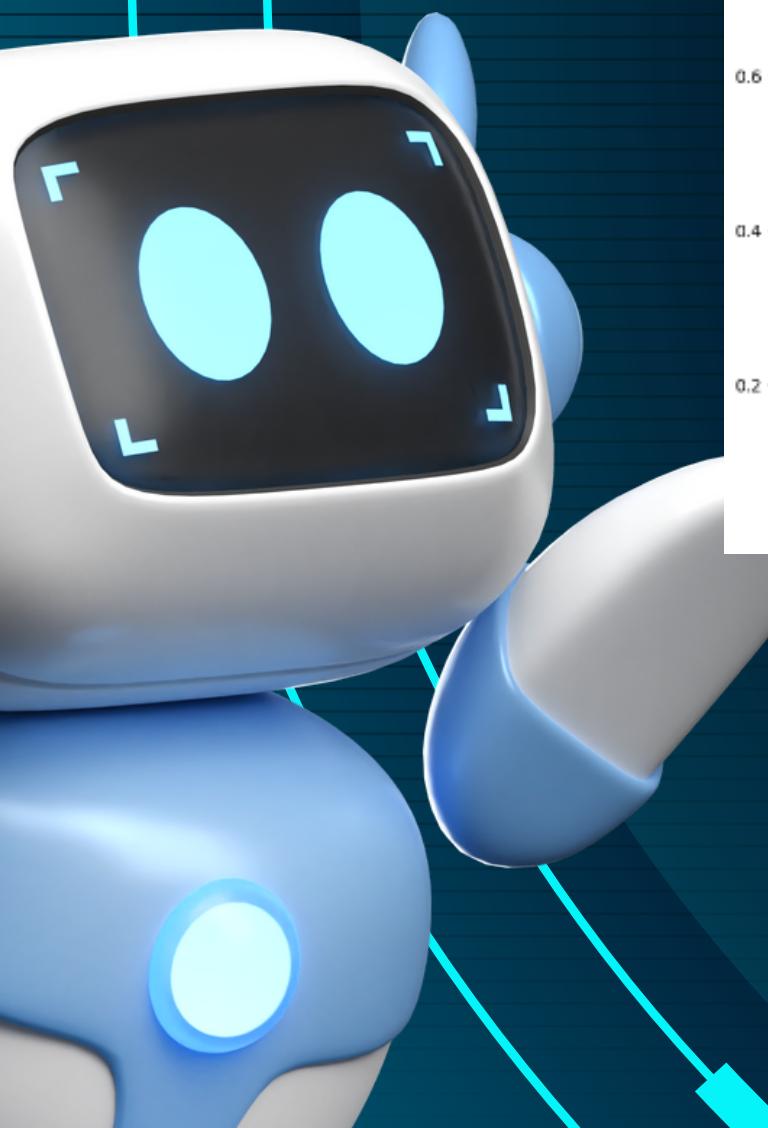
Accuracy: 0.9266351653817458, F1 Score: 0.9267268571270962

Classification Report:

	precision	recall	f1-score	support
0	0.94	0.96	0.95	382
1	0.94	0.94	0.94	449
2	0.90	0.94	0.92	411
3	0.98	0.92	0.95	413
4	0.89	0.89	0.89	413
5	0.95	0.92	0.94	364
6	0.93	0.93	0.93	402
7	0.92	0.89	0.90	387
8	0.90	0.93	0.91	398
9	0.92	0.94	0.93	402
accuracy			0.93	4021
macro avg	0.93	0.93	0.93	4021
weighted avg	0.93	0.93	0.93	4021

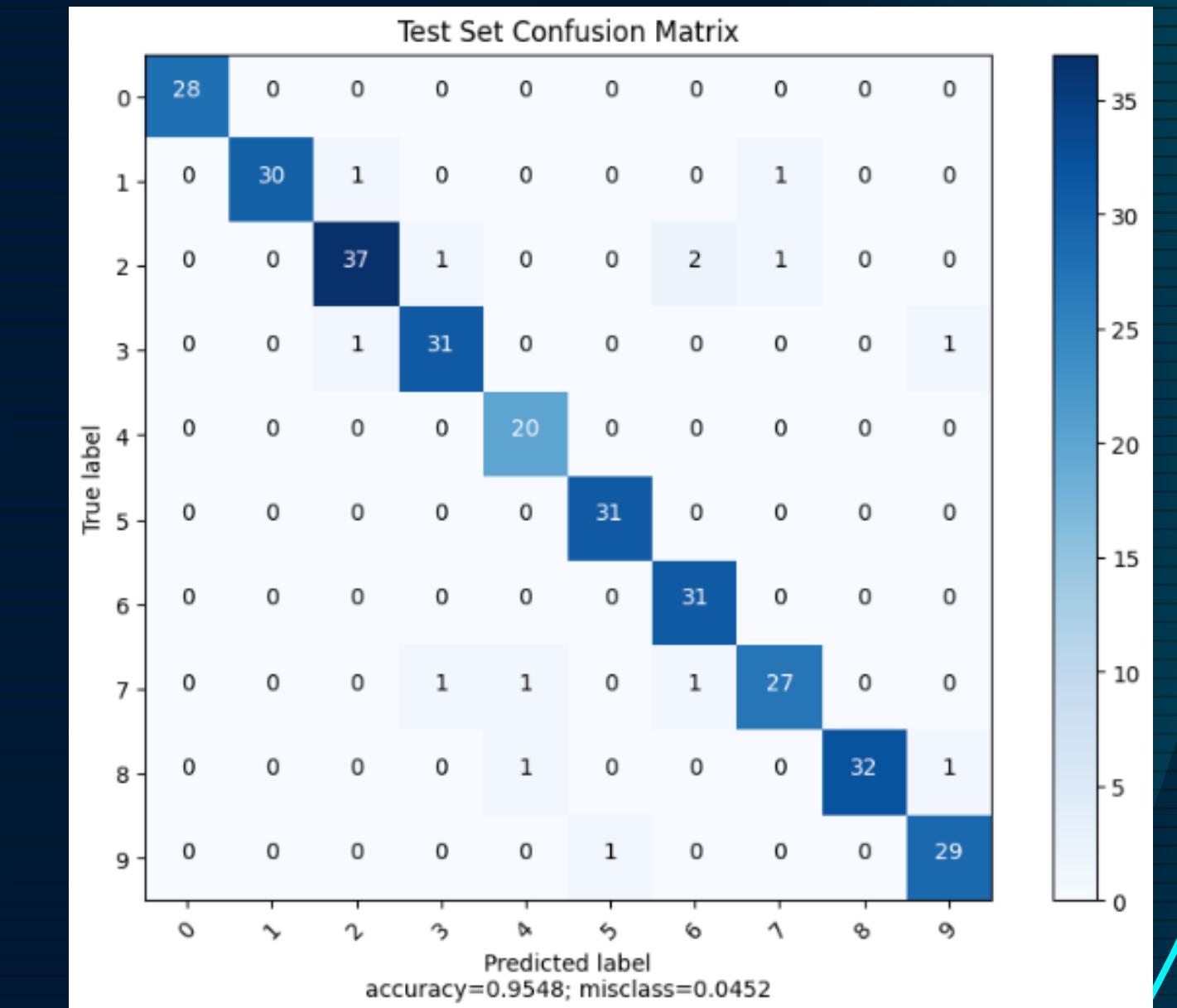


CONVOLUTIONAL NEURAL NETWORK

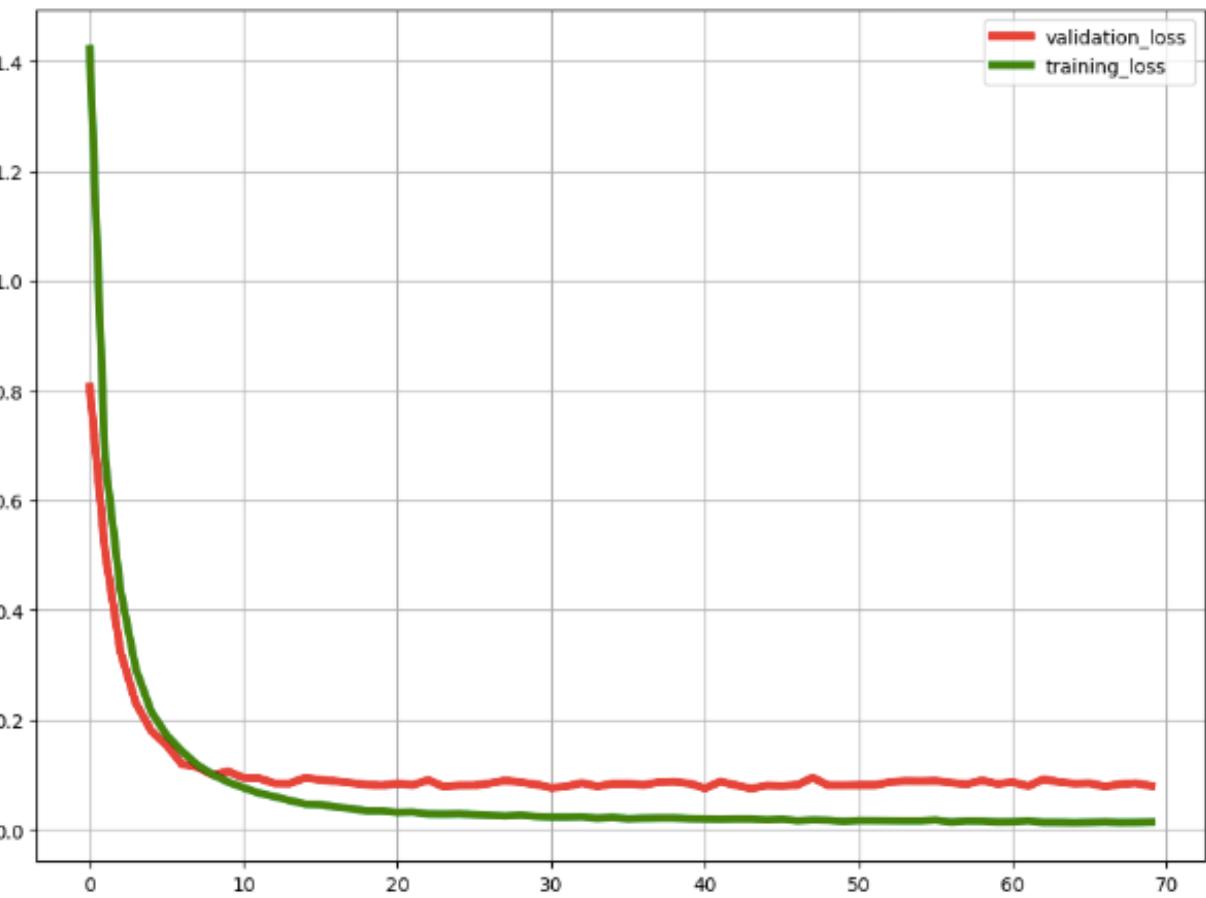
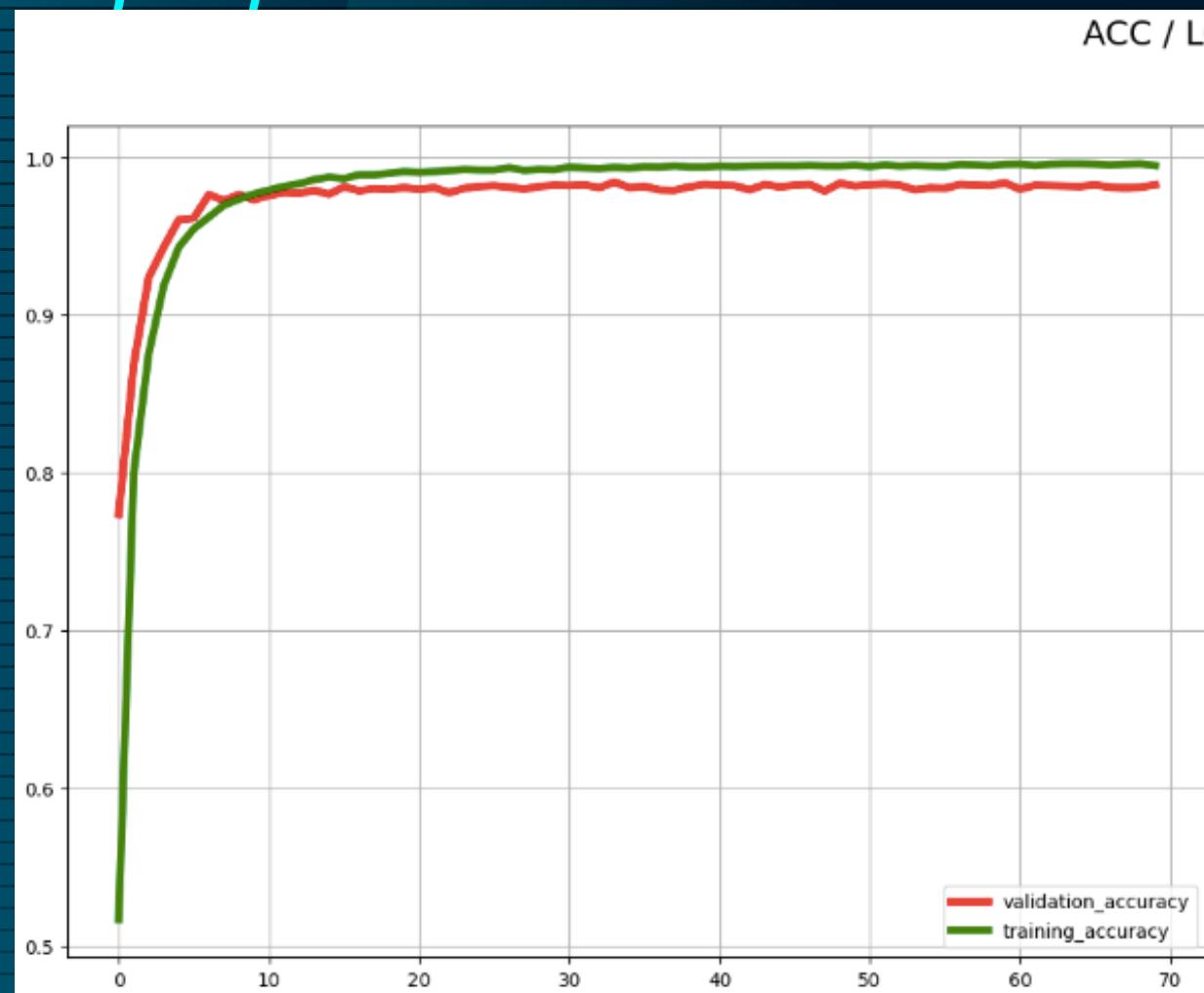


CONVOLUTIONAL NEURAL NETWORK

Results for Test set				
precision recall f1-score support				
0	1.00	1.00	1.00	28
1	1.00	0.94	0.97	32
2	0.95	0.90	0.93	41
3	0.94	0.94	0.94	33
4	0.91	1.00	0.95	20
5	0.97	1.00	0.98	31
6	0.91	1.00	0.95	31
7	0.93	0.90	0.92	30
8	1.00	0.94	0.97	34
9	0.94	0.97	0.95	30
accuracy			0.95	310
macro avg	0.95	0.96	0.96	310
weighted avg	0.96	0.95	0.95	310



CONVOLUTIONAL NEURAL NETWORK (AUGMENTED AND HYPERTUNED)

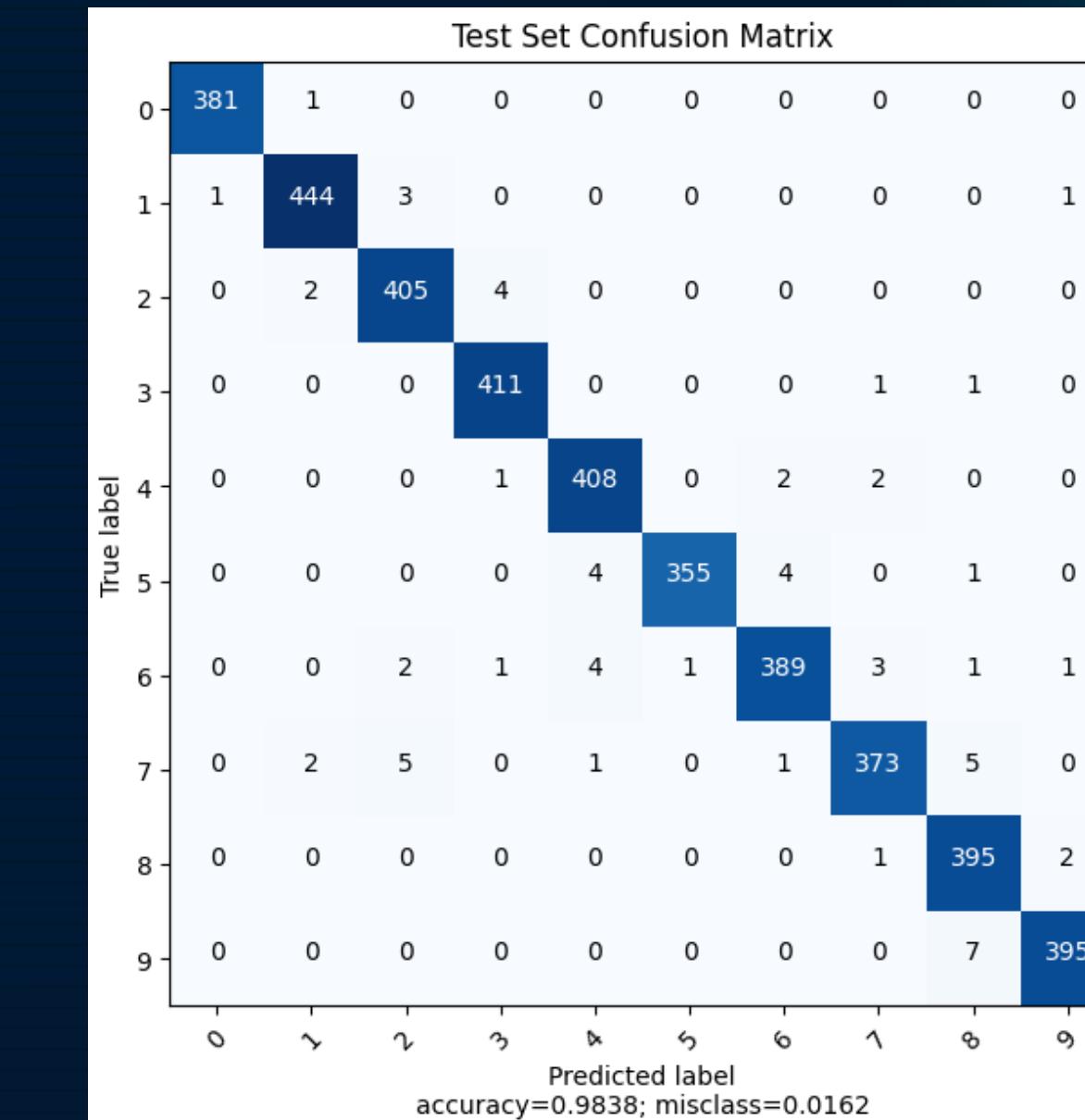


Hyperparameter	Values
conv_1_filters	{16, 32, 48, 64}
conv_2_filters	{16, 32, 48, 64}
conv_3_filters	{16, 32, 48, 64}
conv_4_filters	{16, 32, 48, 64}
conv_5_filters	{16, 32, 48, 64}
conv_6_filters	{32, 64, 96, 128}
conv_7_filters	{16, 32, 48, 64}
dropout_1	[0.1 - 0.5]
dropout_2	[0.1 - 0.5]
dropout_3	[0.1 - 0.5]
dense_1_units	{64, 128, 192 e 256}
dense_2_units	{32, 64, 96 e 128}
dense_3_units	{16, 32, 48 e 64}
learning_rate	[1 ⁻⁵ - 1 ⁻²]

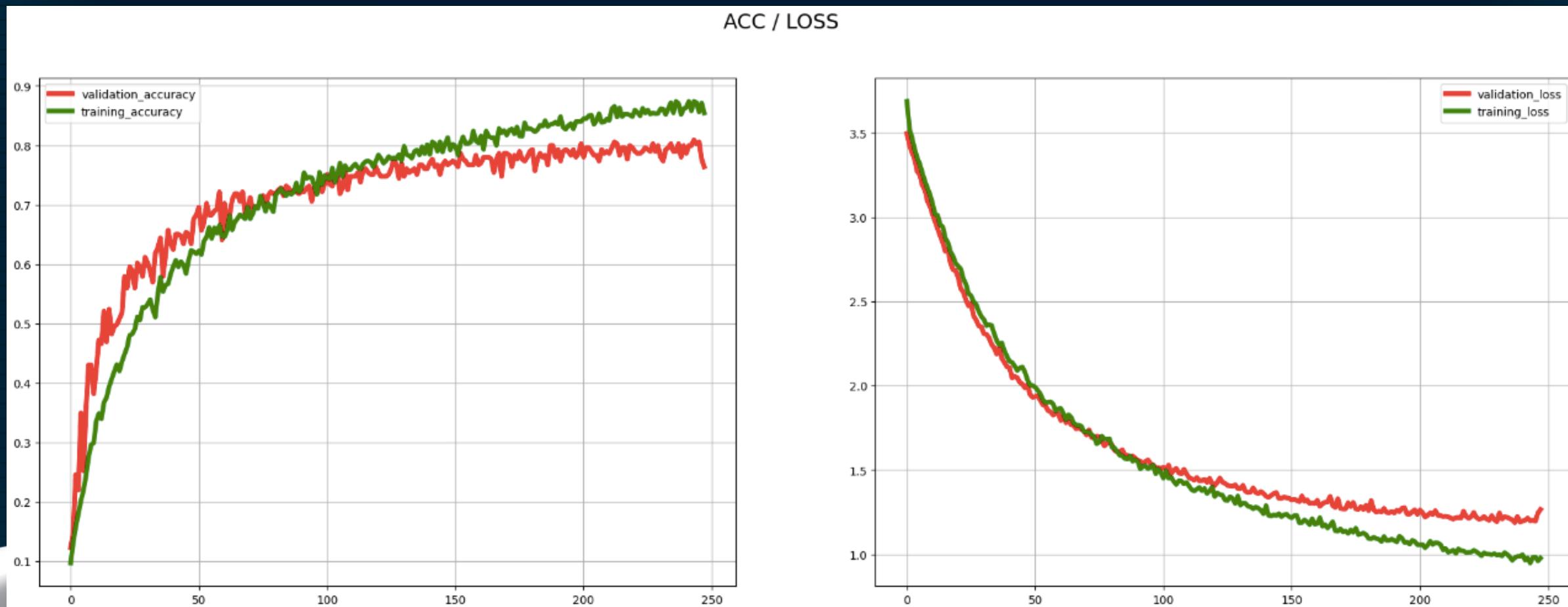
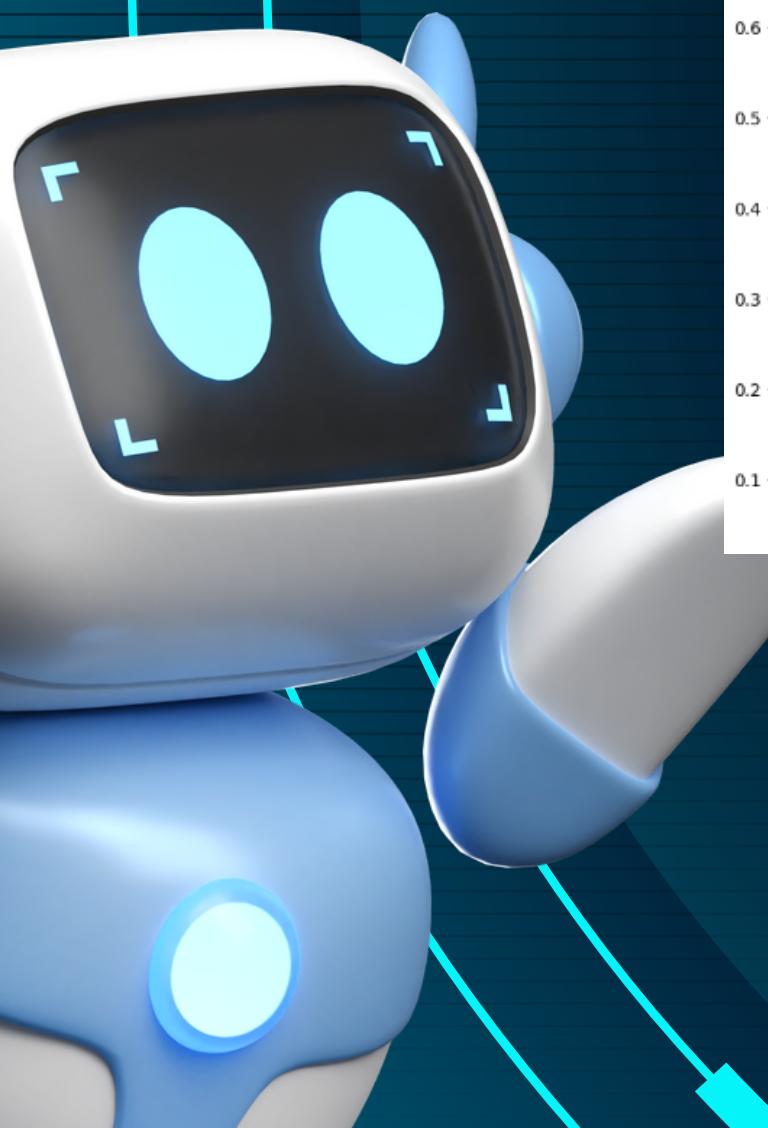
- CONV 1 FILTERS - 64
- CONV 2 FILTERS - 48
- CONV 3 FILTERS - 48
- CONV 4 FILTERS - 64
- CONV 5 FILTERS - 32
- CONV 6 FILTERS - 128
- CONV 7 FILTERS - 32
- DROPOUT 1 - 0.5
- DROPOUT 2 - 0.5
- DROPOUT 3 - 0.4
- DENSE 1 UNITS - 256
- DENSE 2 UNITS - 64
- DENSE 3 UNITS - 16
- LEARNING RATE - 0.000287

CONVOLUTIONAL NEURAL NETWORK (AUGMENTED AND HYPER-TUNED)

Results for Test set				
precision recall f1-score support				
0	1.00	1.00	1.00	382
1	0.99	0.99	0.99	449
2	0.98	0.99	0.98	411
3	0.99	1.00	0.99	413
4	0.98	0.99	0.98	413
5	1.00	0.98	0.99	364
6	0.98	0.97	0.97	402
7	0.98	0.96	0.97	387
8	0.96	0.99	0.98	398
9	0.99	0.98	0.99	402
accuracy			0.98	4021
macro avg	0.98	0.98	0.98	4021
weighted avg	0.98	0.98	0.98	4021

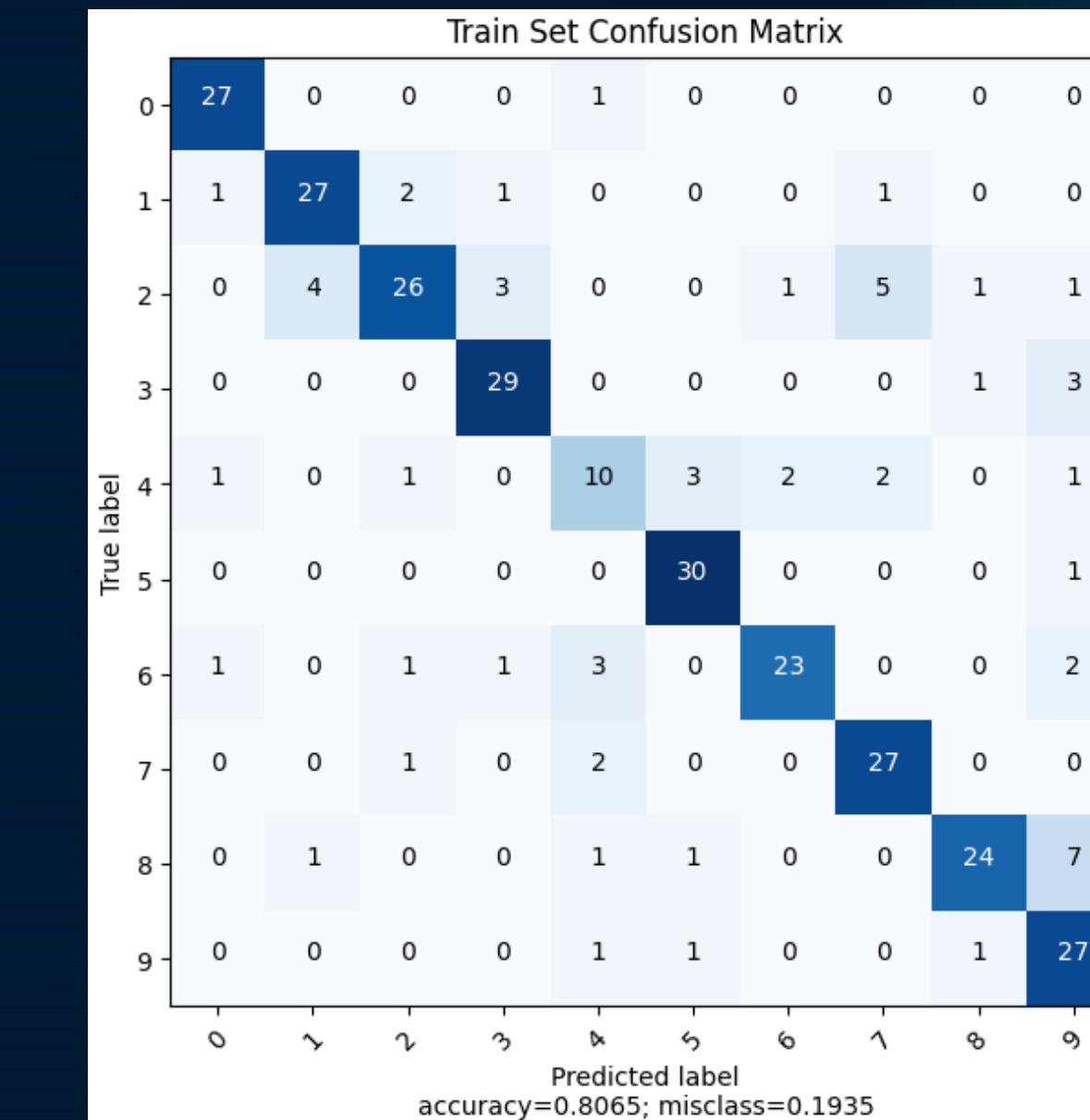


ARTIFICIAL NEURAL NETWORK

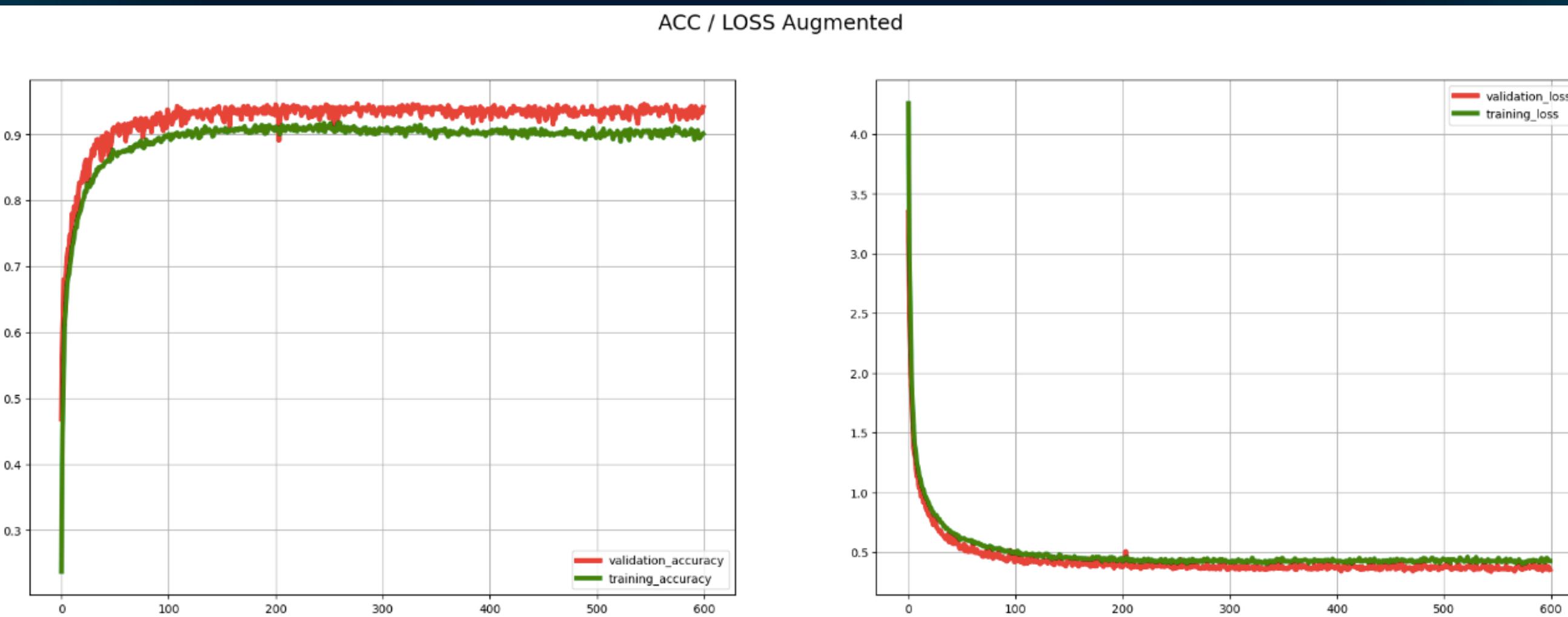


ARTIFICIAL NEURAL NETWORK

Results for Test set				
precision recall f1-score support				
0	0.90	0.96	0.93	28
1	0.84	0.84	0.84	32
2	0.84	0.63	0.72	41
3	0.85	0.88	0.87	33
4	0.56	0.50	0.53	20
5	0.86	0.97	0.91	31
6	0.88	0.74	0.81	31
7	0.77	0.90	0.83	30
8	0.89	0.71	0.79	34
9	0.64	0.90	0.75	30
accuracy			0.81	310
macro avg	0.80	0.80	0.80	310
weighted avg	0.81	0.81	0.80	310



ARTIFICIAL NEURAL NETWORK (AUGMENTED AND HYPERTUNNED)

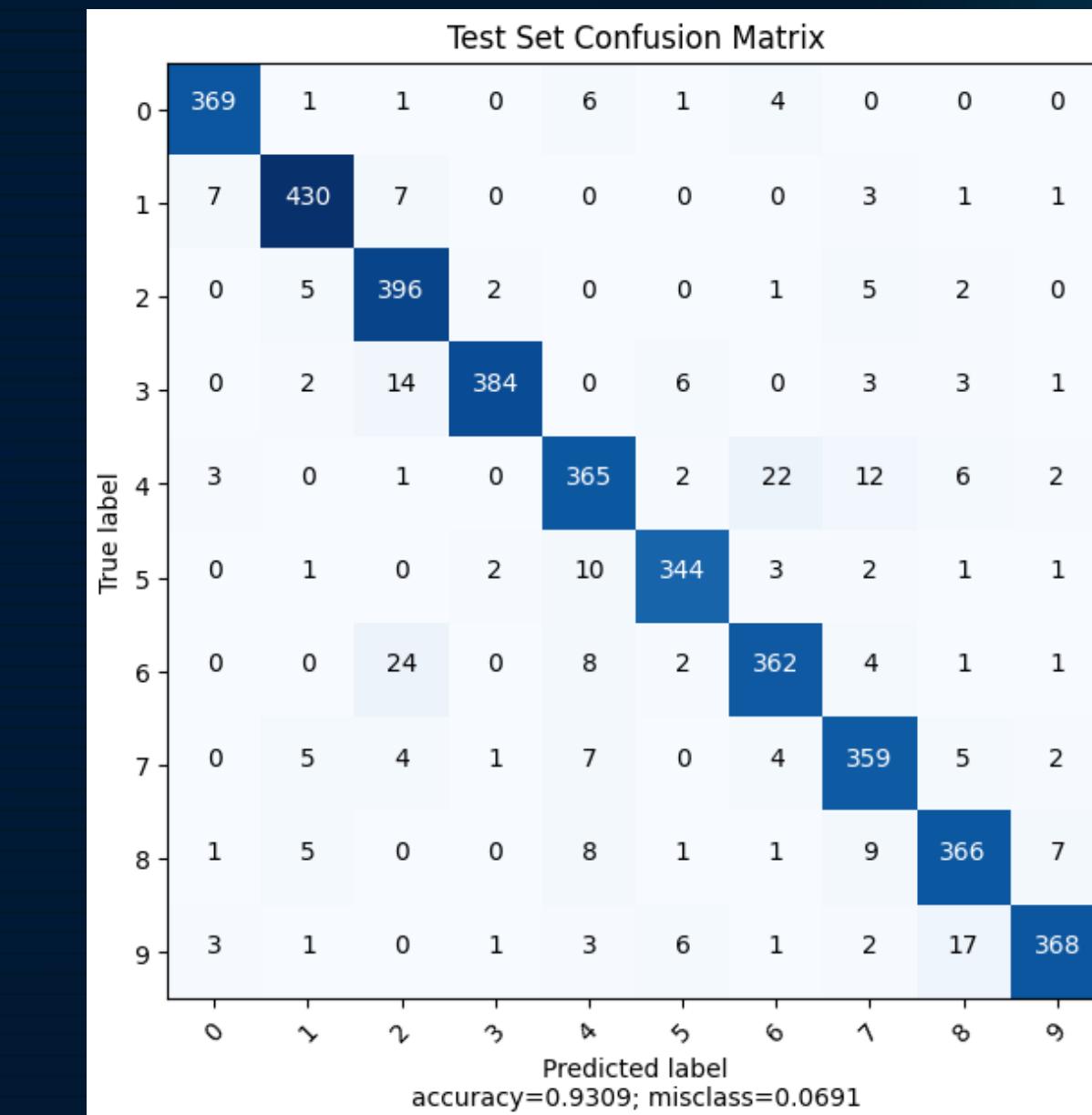


Hyperparameter	Values
units_layer_1	{256, 512, 768 e 1024}
l2_layer_1	[1^{-4} - 1^{-2}]
dropout_layer_1	[0.1 - 0.5]
units_layer_2	{128, 256, 384 e 512}
l2_layer_2	[1^{-4} - 1^{-2}]
dropout_layer_2	[0.1 - 0.5]
learning_rate	[1^{-5} - 1^{-2}]

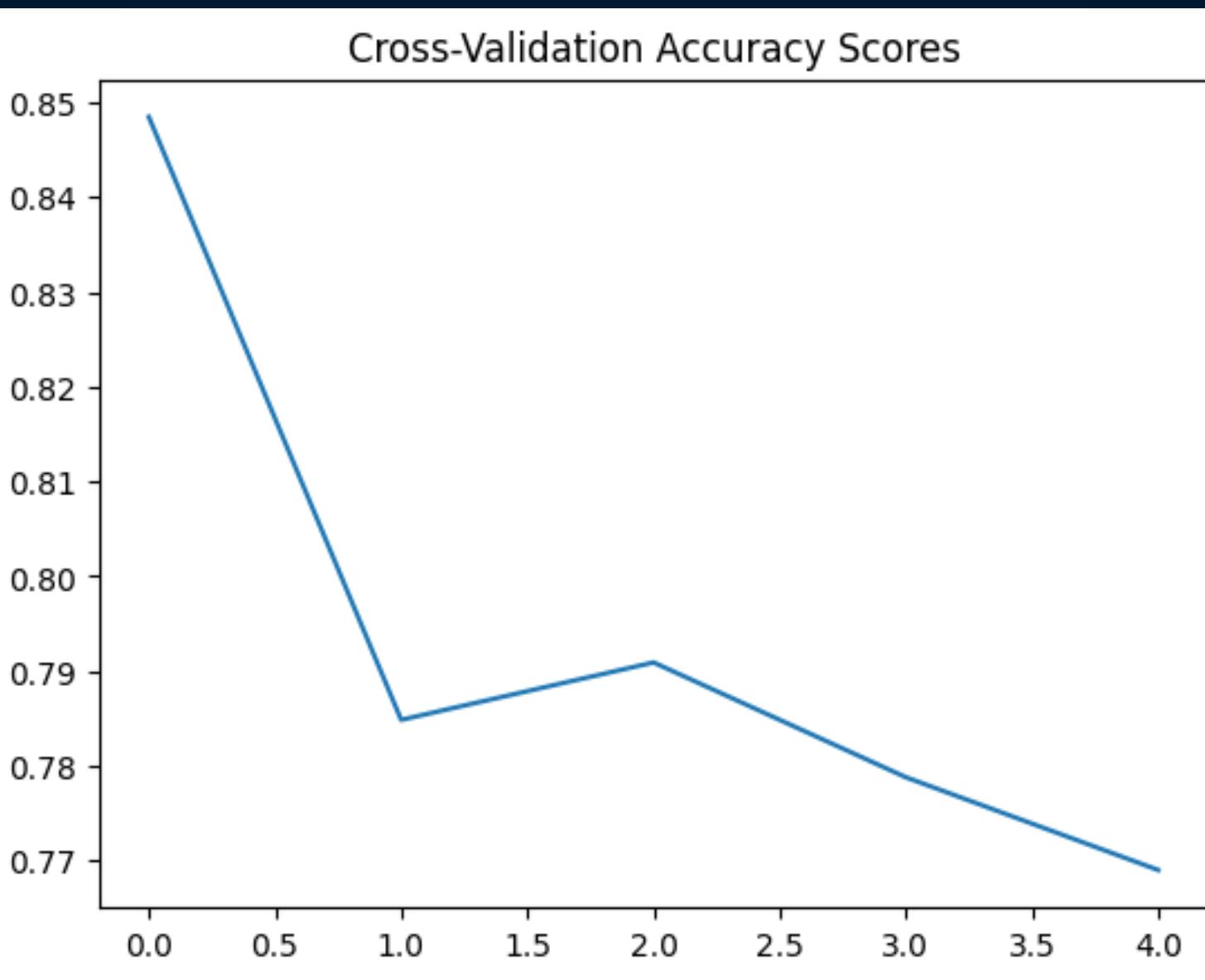
- UNITS LAYER 1 - 1024
- L2 LAYER 1 - 0.0016786
- DROPOUT LAYER 1 - 0.3
- UNITS LAYER 2 - 384
- L2 LAYER 2 - 0.0006236
- DROPOUT LAYER 2 - 0.2
- LEARNING RATE - 7.8111e-05

ARTIFICIAL NEURAL NETWORK (AUGMENTED AND HYPERTUNED)

Results for Test set				
Accuracy: 0.9308629694105944				
F1 Score: 0.9309741826235661				
	precision	recall	f1-score	support
0	0.96	0.97	0.96	382
1	0.96	0.96	0.96	449
2	0.89	0.96	0.92	411
3	0.98	0.93	0.96	413
4	0.90	0.88	0.89	413
5	0.95	0.95	0.95	364
6	0.91	0.90	0.91	402
7	0.90	0.93	0.91	387
8	0.91	0.92	0.92	398
9	0.96	0.92	0.94	402
accuracy			0.93	4021
macro avg	0.93	0.93	0.93	4021
weighted avg	0.93	0.93	0.93	4021



SUPPORT VECTOR MACHINE



THE KERNEL PARAMETER WAS SET TO LINEAR, SPECIFYING THAT THIS IS A LINEAR SVM
5 STAGES OF CROSS VALIDATION

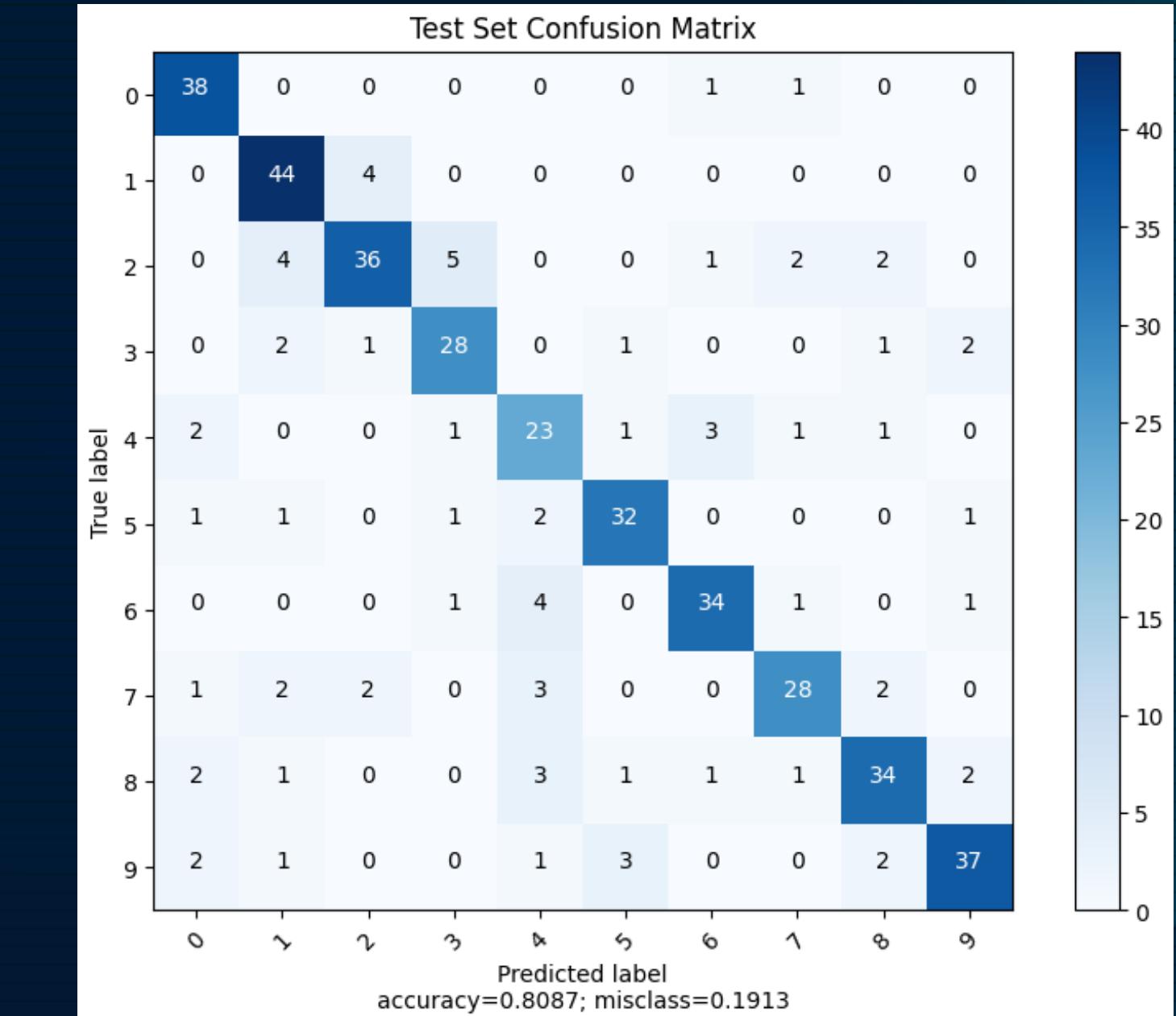
SUPPORT VECTOR MACHINE

---- Test Set ----

Accuracy: 0.8087, F1 Score: 0.8080

Classification Report:

	precision	recall	f1-score	support
0	0.83	0.95	0.88	40
1	0.80	0.92	0.85	48
2	0.84	0.72	0.77	50
3	0.78	0.80	0.79	35
4	0.64	0.72	0.68	32
5	0.84	0.84	0.84	38
6	0.85	0.83	0.84	41
7	0.82	0.74	0.78	38
8	0.81	0.76	0.78	45
9	0.86	0.80	0.83	46
accuracy			0.81	413
macro avg	0.81	0.81	0.80	413
weighted avg	0.81	0.81	0.81	413



SUPPORT VECTOR MACHINE (AUGMENTED AND HYPER-TUNED)

5 STAGES OF CROSS VALIDATION

Hyperparameter	Values
C	{0.1, 1, 10, 100}
kernel	{rbf, poly, sigmoid, linear}
gamma	{scale, auto, 0.01, 0.001}
degree	{2, 3, 4}

BEST HYPER-PARAMETERS

- C - 10
- DEGREE - 2
- KERNEL - RBF
- GAMMA - 0.01

WE TESTED ALL POSSIBLE COMBINATIONS USING THE FOLLOWING PARAMETERS, PRESENTED IN THE TABLE IV, RESULTING IN A TOTAL OF 192 COMBINATIONS. WE REPEATED THIS PROCESS 5 TIMES FOR EACH COMBINATION, RESULTING IN A TOTAL OF 960 TRAINING SETS.

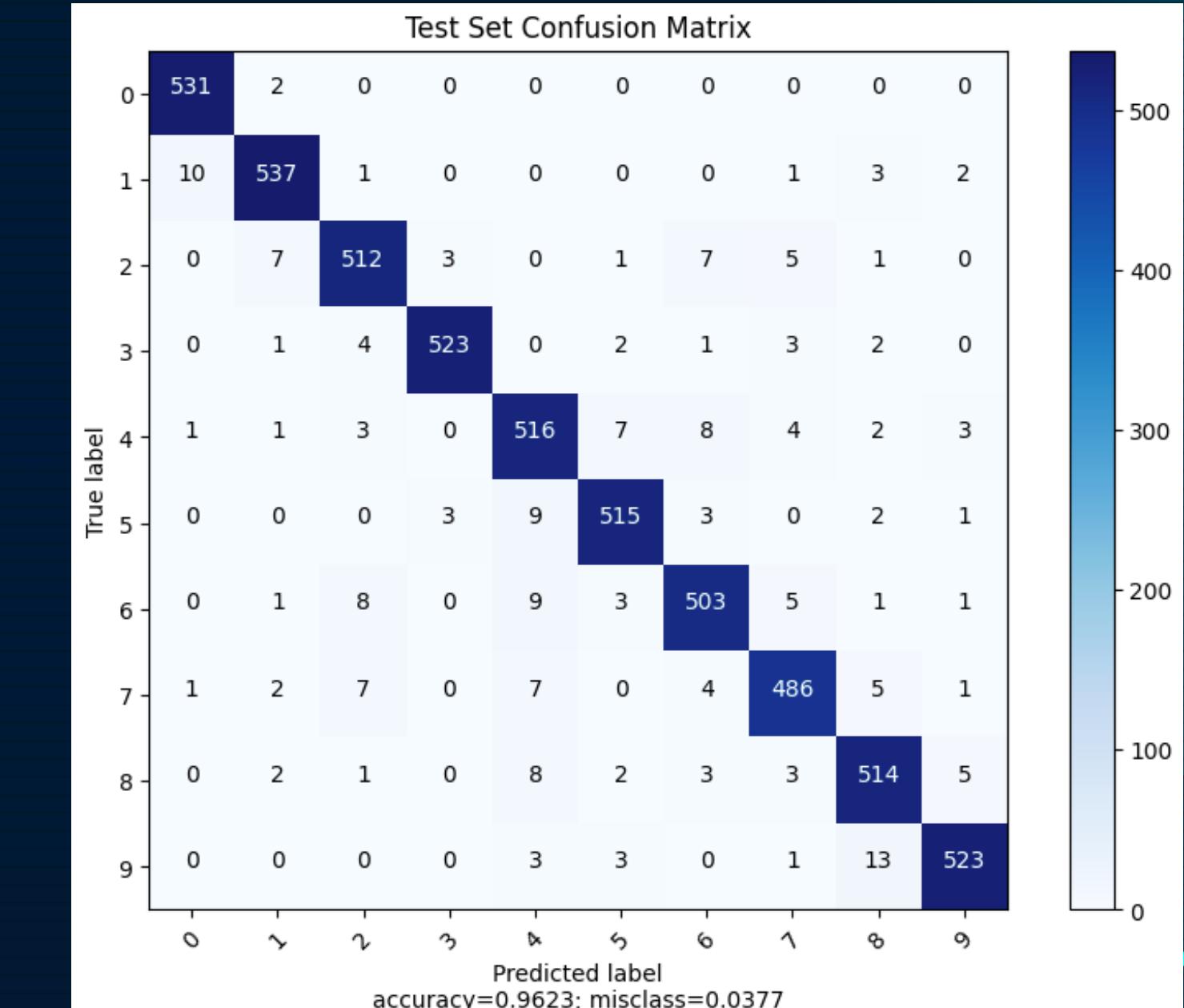
SUPPORT VECTOR MACHINE

---- Test Set ----

Accuracy: 0.9623, F1 Score: 0.9623

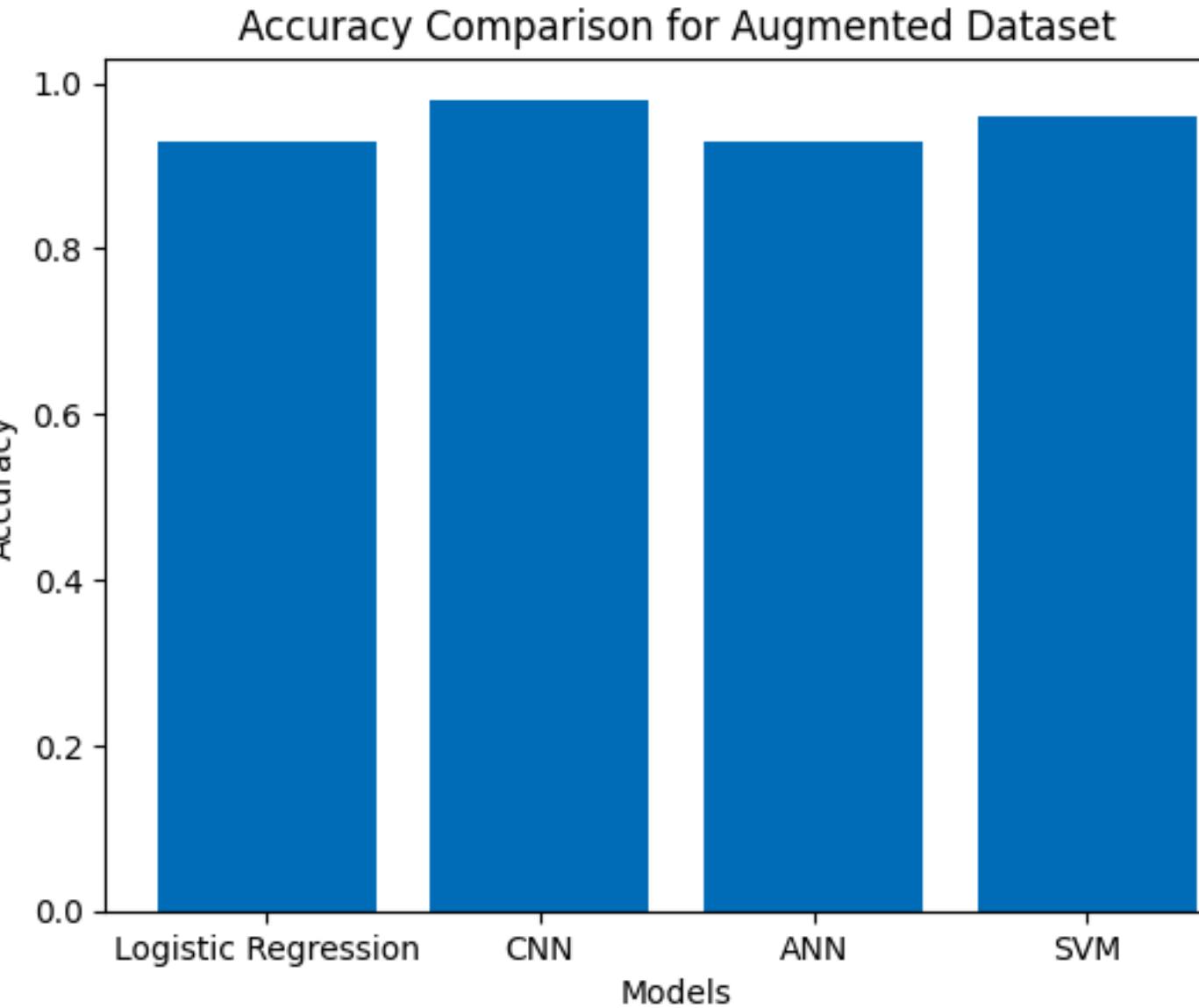
Classification Report:

	precision	recall	f1-score	support
0	0.98	1.00	0.99	533
1	0.97	0.97	0.97	554
2	0.96	0.96	0.96	536
3	0.99	0.98	0.98	536
4	0.93	0.95	0.94	545
5	0.97	0.97	0.97	533
6	0.95	0.95	0.95	531
7	0.96	0.95	0.95	513
8	0.95	0.96	0.95	538
9	0.98	0.96	0.97	543
accuracy			0.96	5362
macro avg	0.96	0.96	0.96	5362
weighted avg	0.96	0.96	0.96	5362



4

MODEL COMPARISON

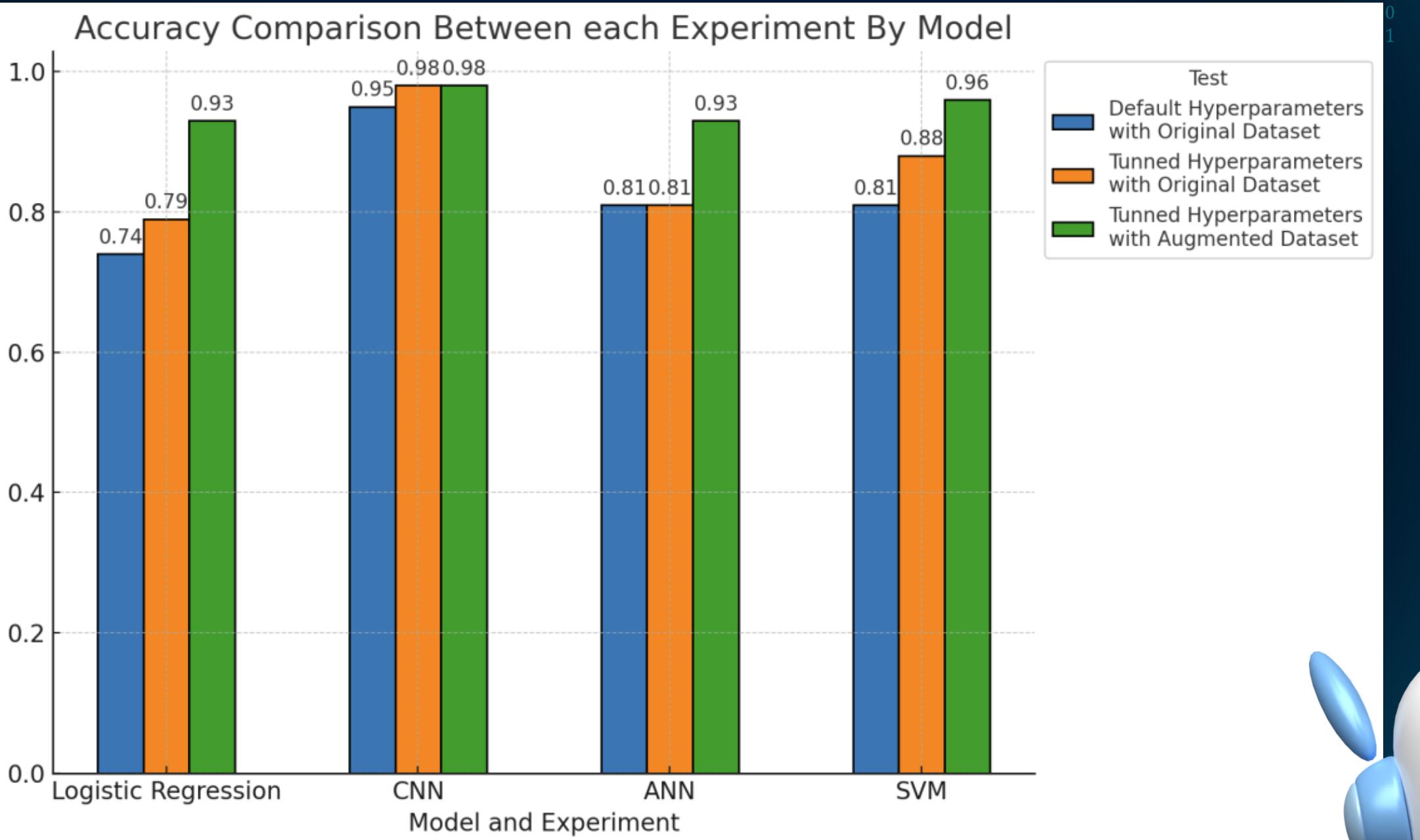


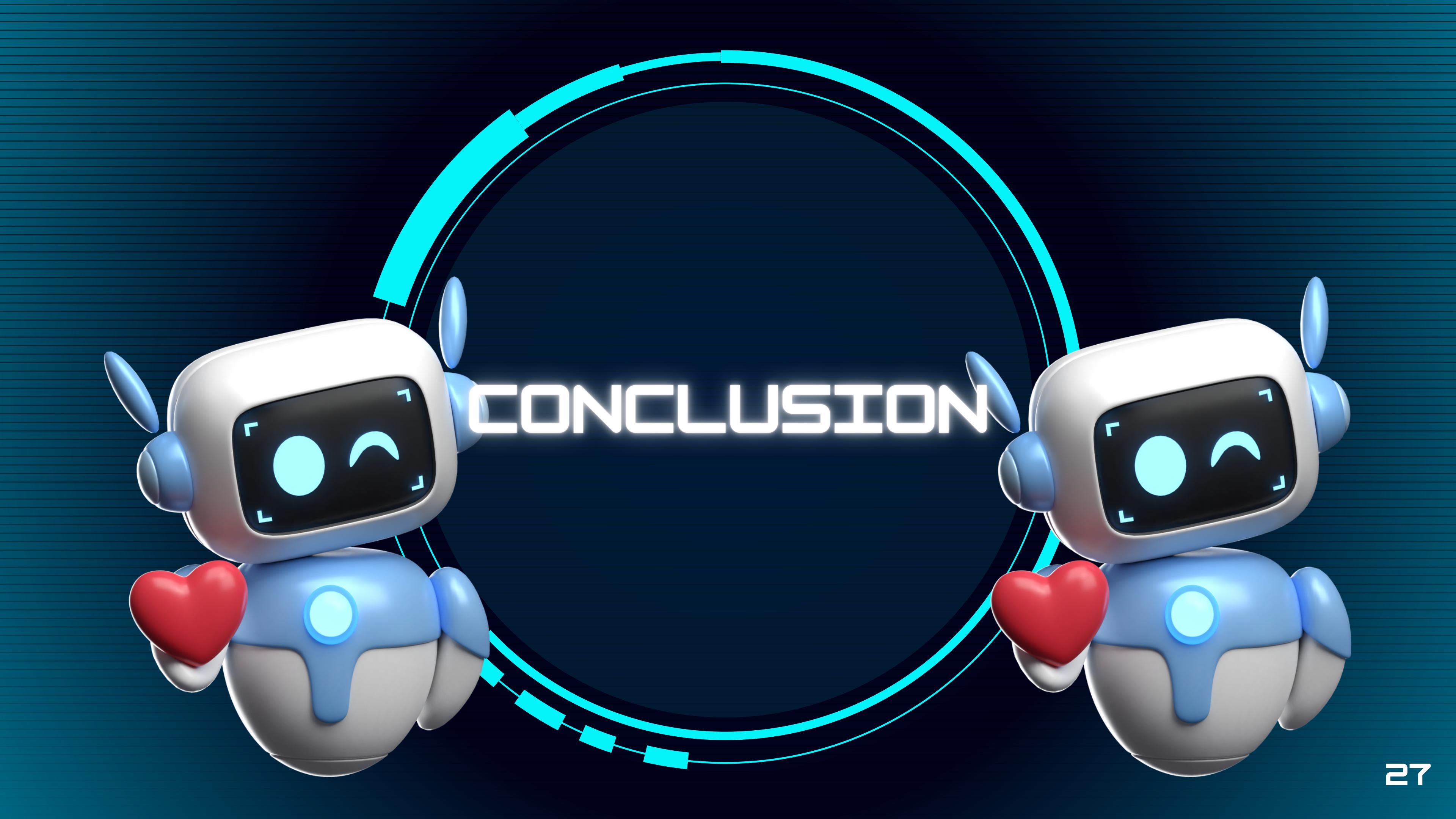
- LOGISTIC R. - 92.62%
- CNN - 98.3%
- ANN - 93.09%
- SVM - 96.23%



4

ACCURACY COMPARISON BETWEEN EACH TEST





CONCLUSION