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ASSIGNMENT - 4

ML REPORT

SECTION - A

Ques - (a)

- An input image of dimensions $M \times N$ with P channels.
- A kernel of size K x K.
- A stride of 1 and no padding.

For a convolution operation with a stride of 1 and no padding, the dimensions of the resulting feature map can be determined by:

Output Height $= M - K + 1$

Output Width $= N - K + 1$

Thus, the dimensions of the output feature map will be:

$(M - K + 1) \times (N - K + 1)$

Ques - (b)
To compute the number of elementary operations needed for a single output pixel of the feature map:

1. Multiplications: Each element of the $K \times K$ kernel is multiplied by a corresponding element in the input image's $K \times K$ patch. Since the input image has P channels, and the kernel must apply to each channel, this results in: $K \times K \times P$ multiplications for each output pixel.

2. Additions: After the multiplications, the products are summed together to compute the output value. Each channel's $K \times K$ patch results in $K \times K - 1$ additions per channel, and since there are P such channels: $(K \times K - 1) \times P$ Additionally, after summing within the channels, the sums from each of the P channels need to be added together to get a single output value. This would add: $P - 1$ more additions.

Thus, the total number of additions is: $(K \times K - 1) \times P + (P - 1)$

Therefore, the total number of elementary operations (multiplications and additions) required to compute a single output pixel is:
$K \times K \times P$(multiplications) + $((K \times K - 1) \times P + P - 1)$(additions)

Ques - (c)

General Time Complexity: The total number of operations for the forward pass is proportional to the number of output pixels times the number of operations per pixel. Therefore, the computational time complexity is:
$O((M - K + 1)(N - K + 1) \times (Q \times K^2 \times P)$

2. **Assuming min (M,N)$\gg$K**: When K is much smaller than M and N, $(M-K+1)\approx M$ and $(N-K+1)\approx N$. The time complexity simplifies to:
$\mathbf{O(MN \times Q \times K^2 \times P)}$

Part (B)

K-Means Algorithm: Key Steps

1. Assignment Step: Each data point is assigned to the nearest cluster centroid based on Euclidean distance.

2. Update Step: Recalculate each cluster's centroid by taking the mean of all data points assigned to that cluster.

Determining Optimal Number of Clusters: Elbow Method

- Elbow Method: Plot the total within-cluster sum of squares (WCSS) against different numbers of clusters (k) and look for the 'elbow' where the reduction in WCSS slows down, indicating the optimal k.

Random Assignment of Cluster Centroids:

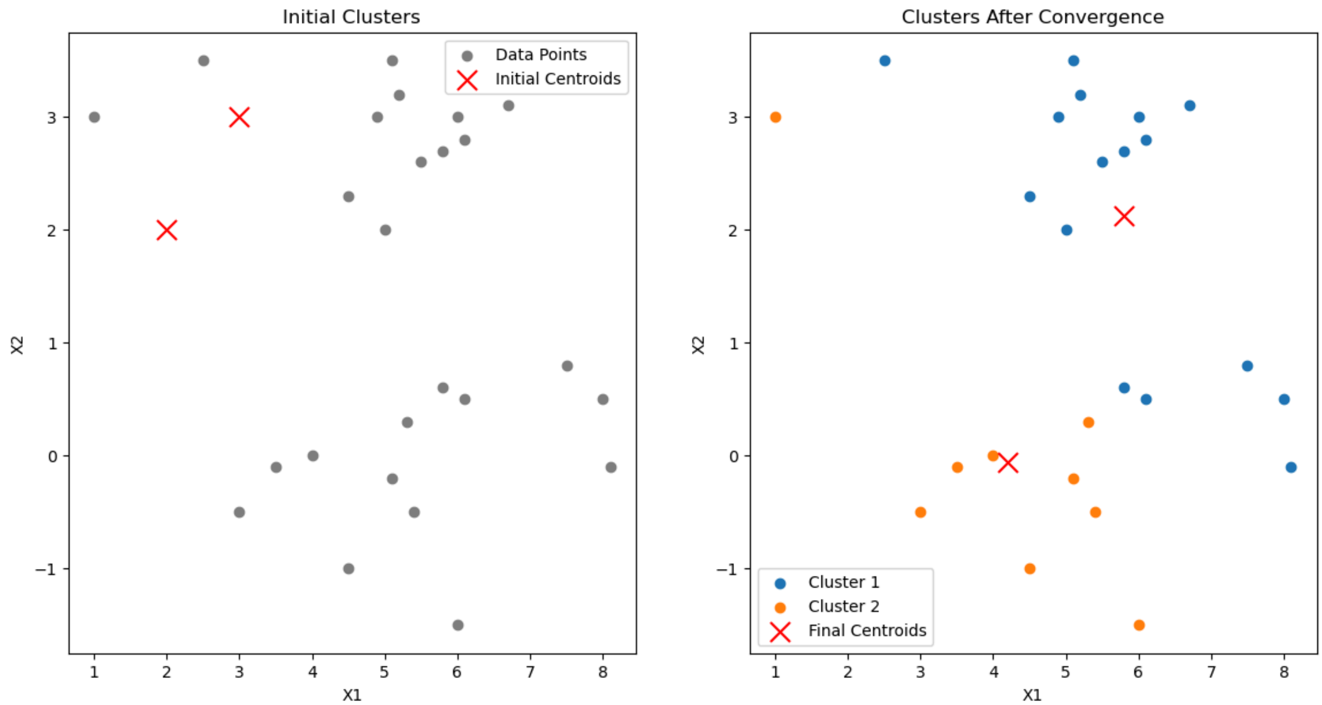
- Random Assignment: Starting centroids are placed randomly.

- Global Minima: Random starting points typically lead to convergence to a local minimum rather than a global minimum. Multiple runs with different initializations are recommended to approach the global minimum more closely.

SECTION - B

Part (a) In the notebook

Part (b)

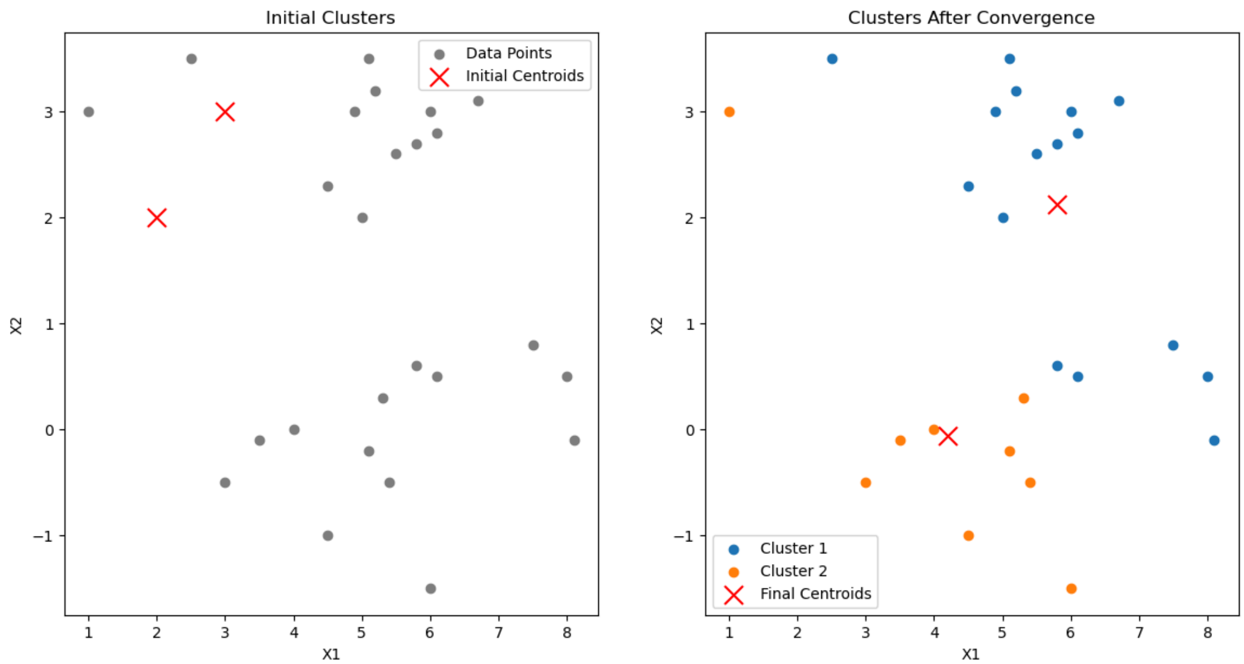


Final centroids:

[[5.8 2.125]
[4.2 -0.05555556]]

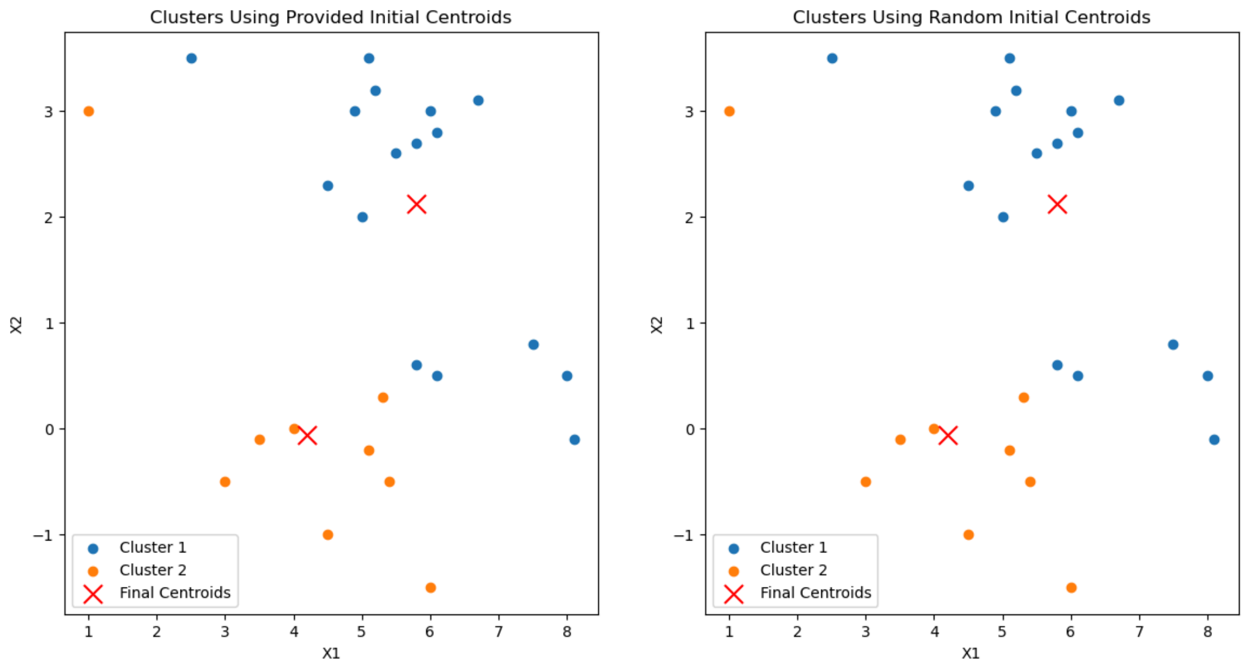
Cluster assignments:

[0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 1. 1. 1. 1. 1. 1. 0. 1. 1.
0.]

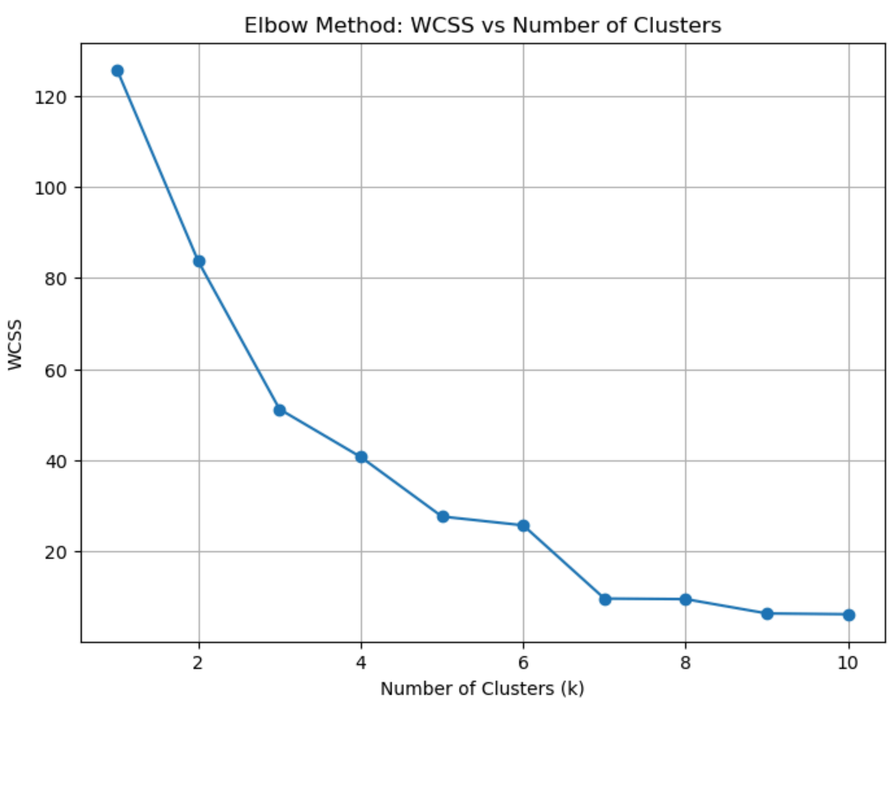


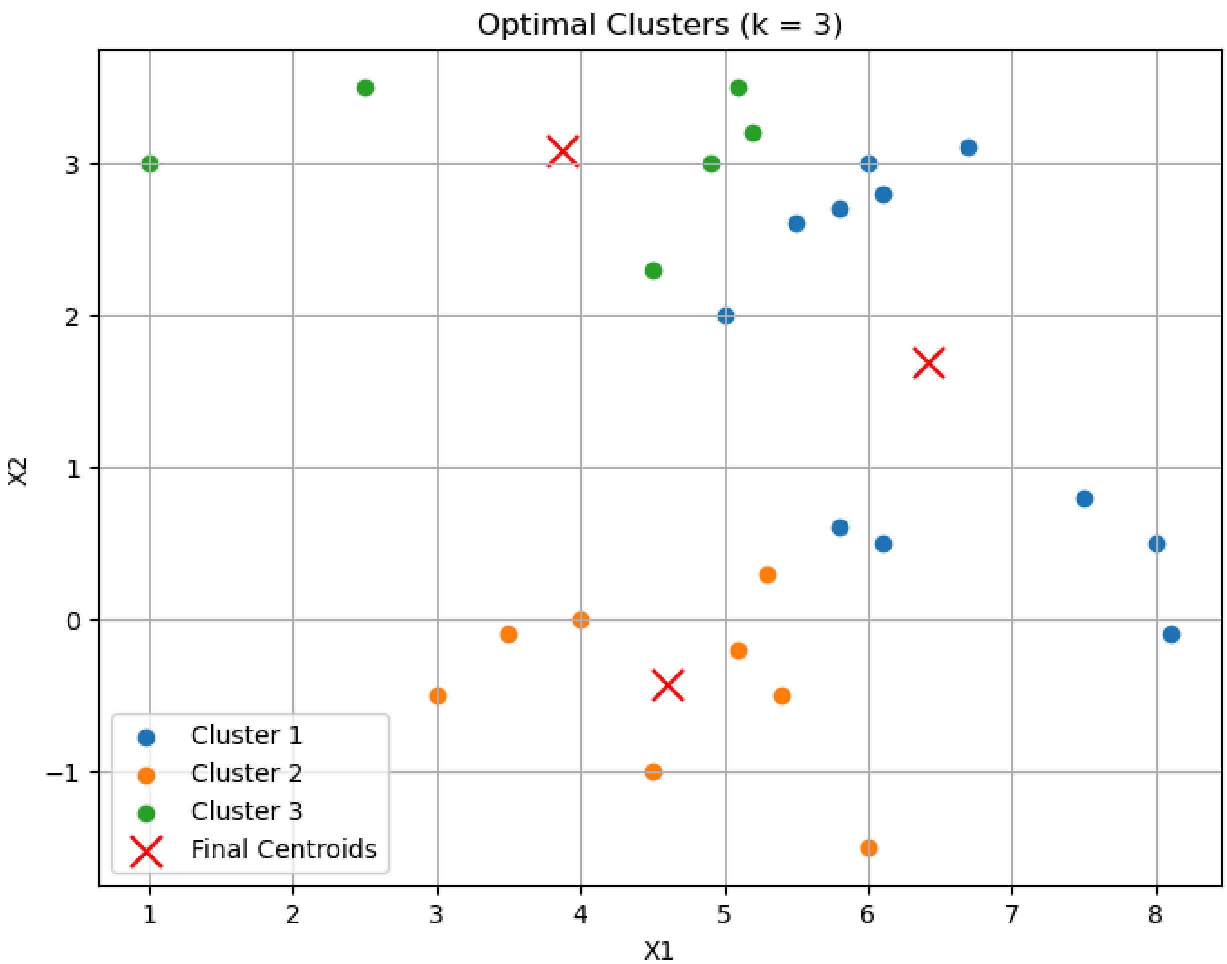

```
(array([[ 5.8       ,  2.125     ],
        [ 4.2       , -0.05555556]]),
 array([[ 5.8       ,  2.125     ],
        [ 4.2       , -0.05555556]]))
```

Part (c)


Clusters Using Provided Initial Centroids
Cluster 1
Cluster 2
Final Centroids
X1
X2
Clusters Using Random Initial Centroids
Cluster 1
Cluster 2
Final Centroids
X1
X2

Part (d)


Elbow Method: WCSS vs Number of Clusters
WCSS
Number of Clusters (k)

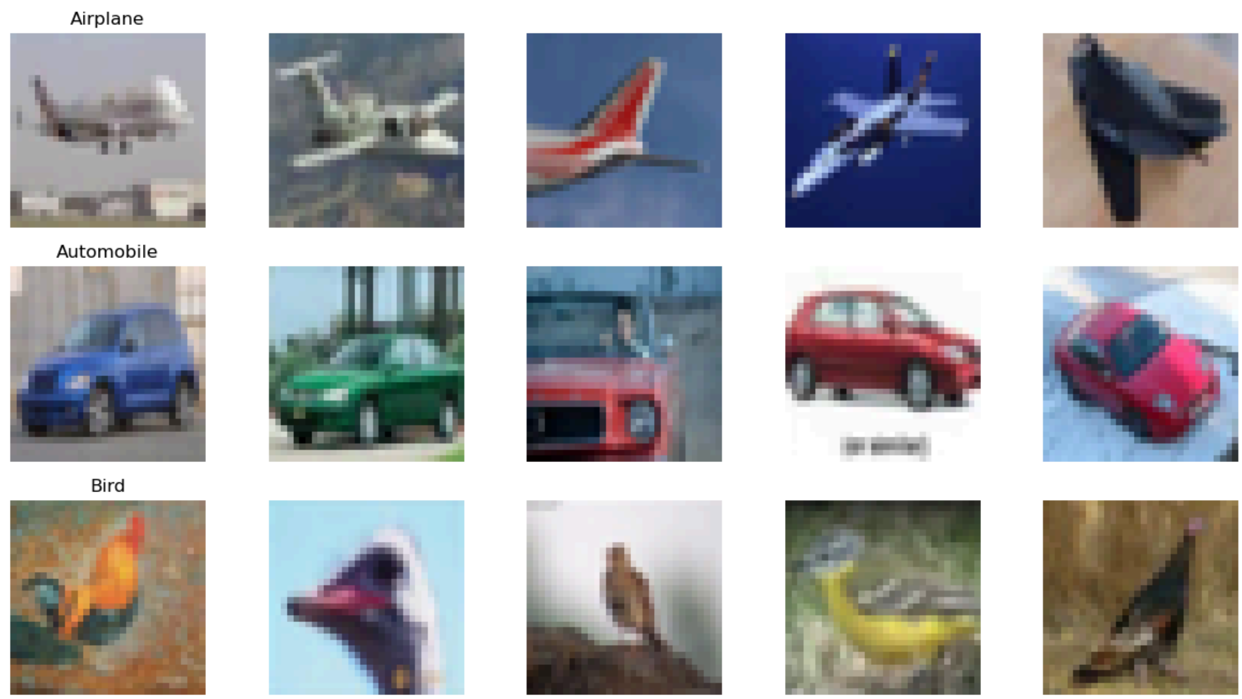

Optimal Clusters (k = 3)
X1
X2
1
2
3
4
5
6
7
8
−1
0
1
2
3
Cluster 1
Cluster 2
Cluster 3
Final Centroids

SECTION - C

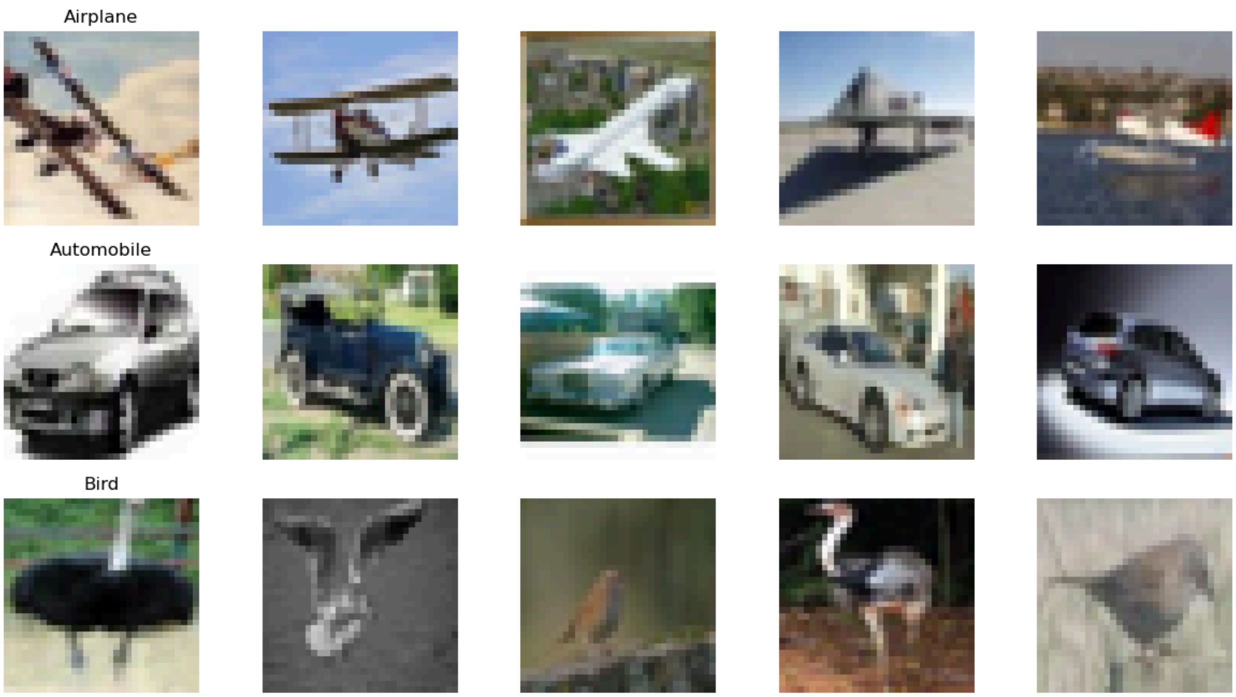
Dataset :

Train dataset: Total images = 12000
Validation dataset: Total images = 3000
Test dataset: Total images = 3000

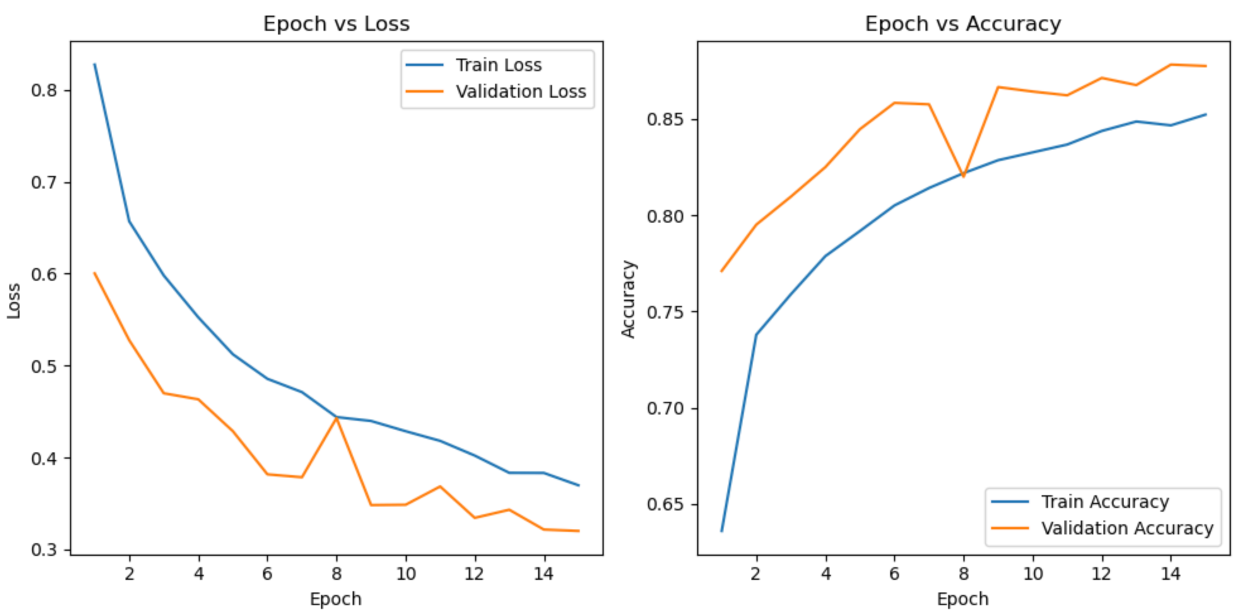
Training Dataset Images:



Validation Dataset Images:

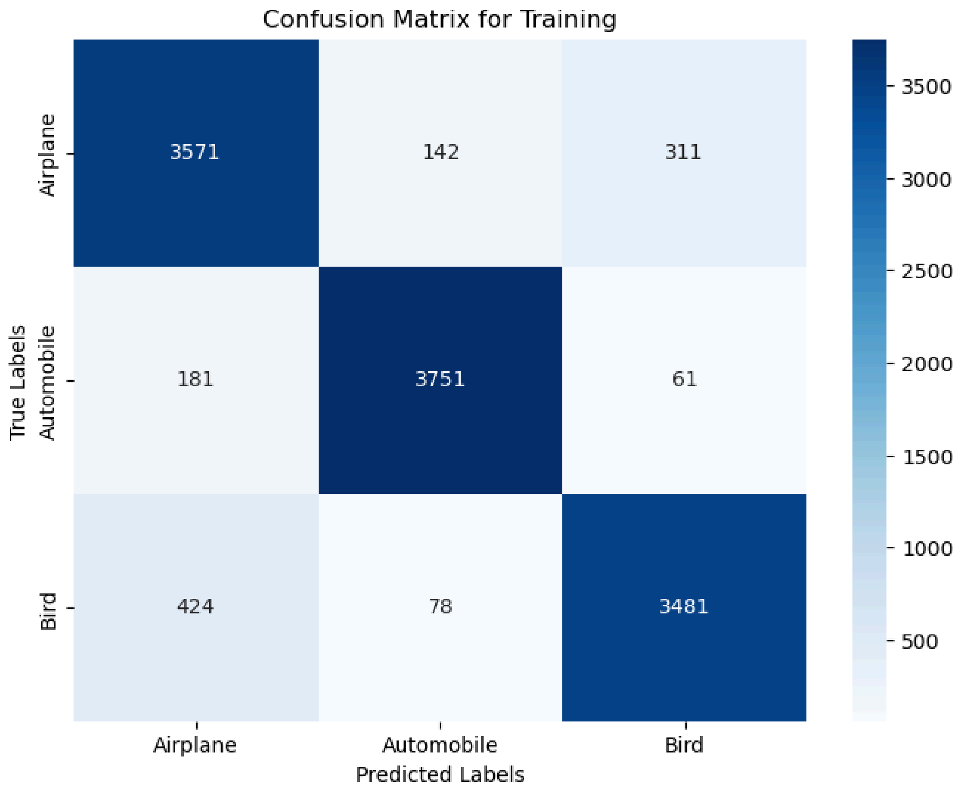


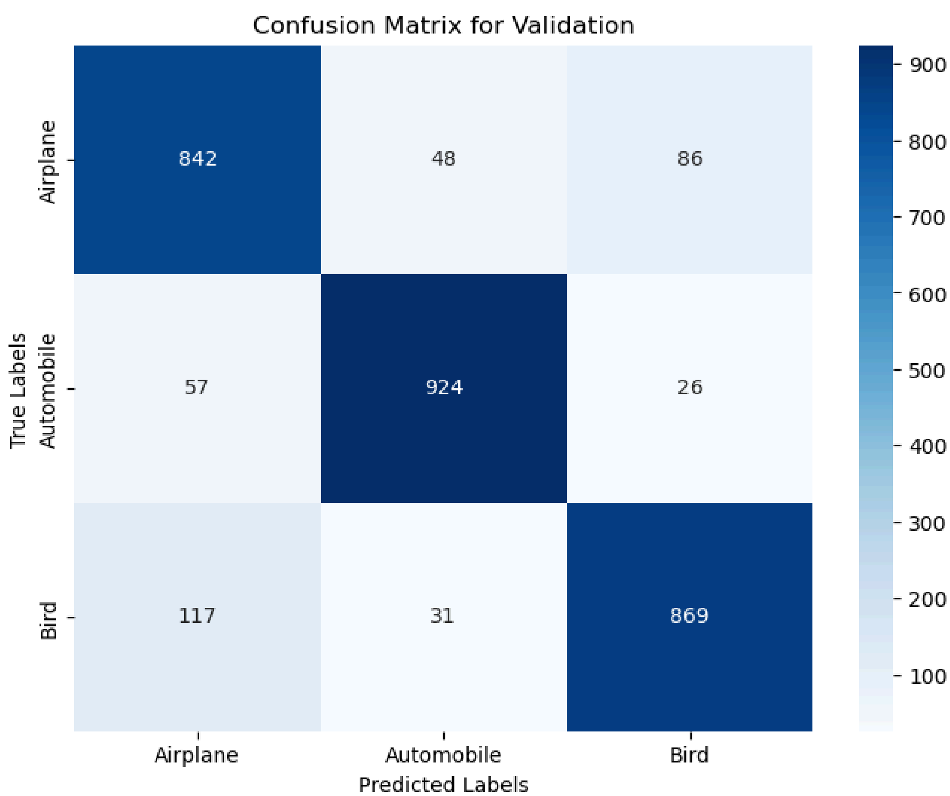
4.

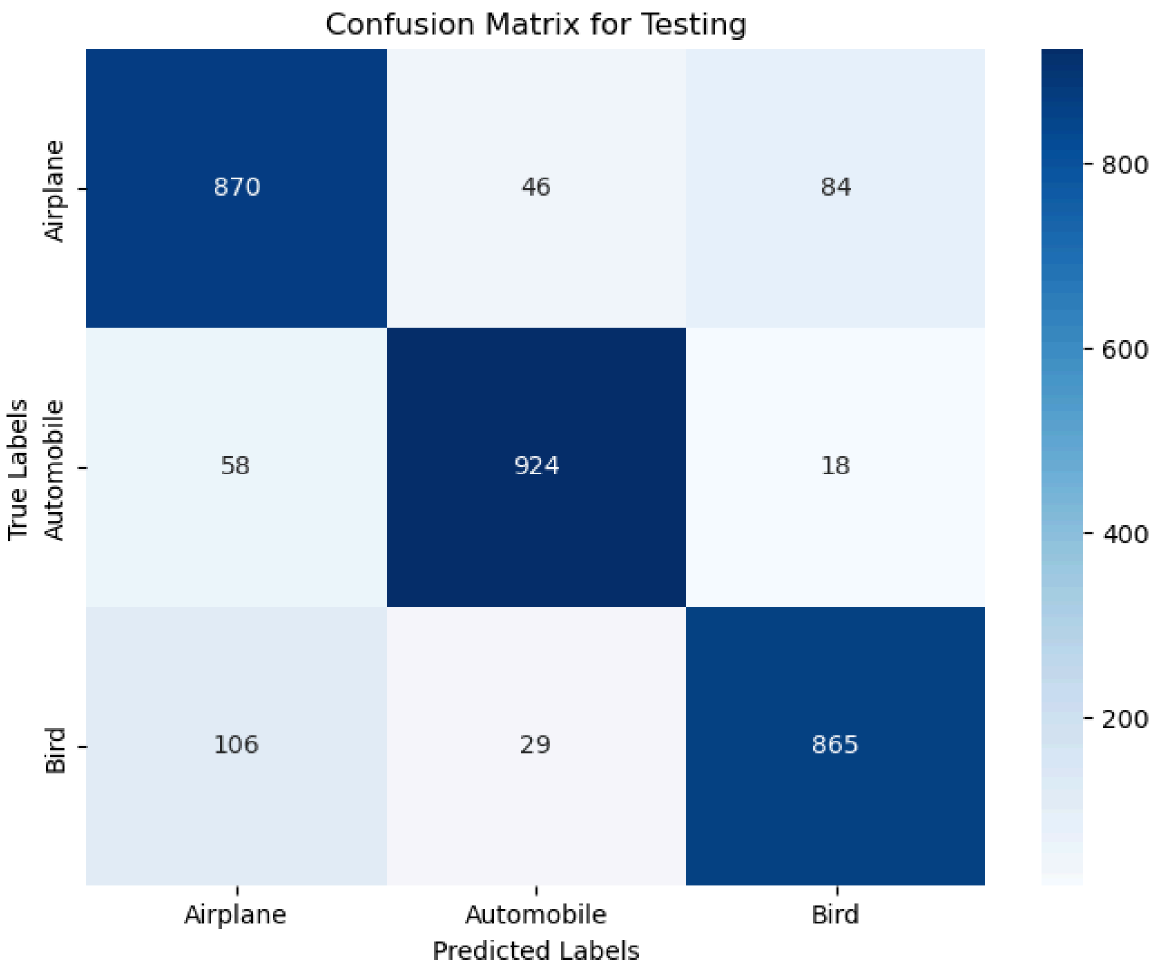


5.
Best Model Path: models/model_epoch_14.pth with Validation Accuracy: 0.8783

Test Accuracy: 0.8863
Test F1 Score: 0.8865


Confusion Matrix for Training
Airplane
Automobile
Bird
True Labels
Predicted Labels
3571
142
311
181
3751
61
424
78
3481
3500
3000
2500
2000
1500
1000
500


Confusion Matrix for Validation
Airplane
Automobile
Bird
True Labels
Predicted Labels
842
48
86
57
924
26
117
31
869
900
800
700
600
500
400
300
200
100

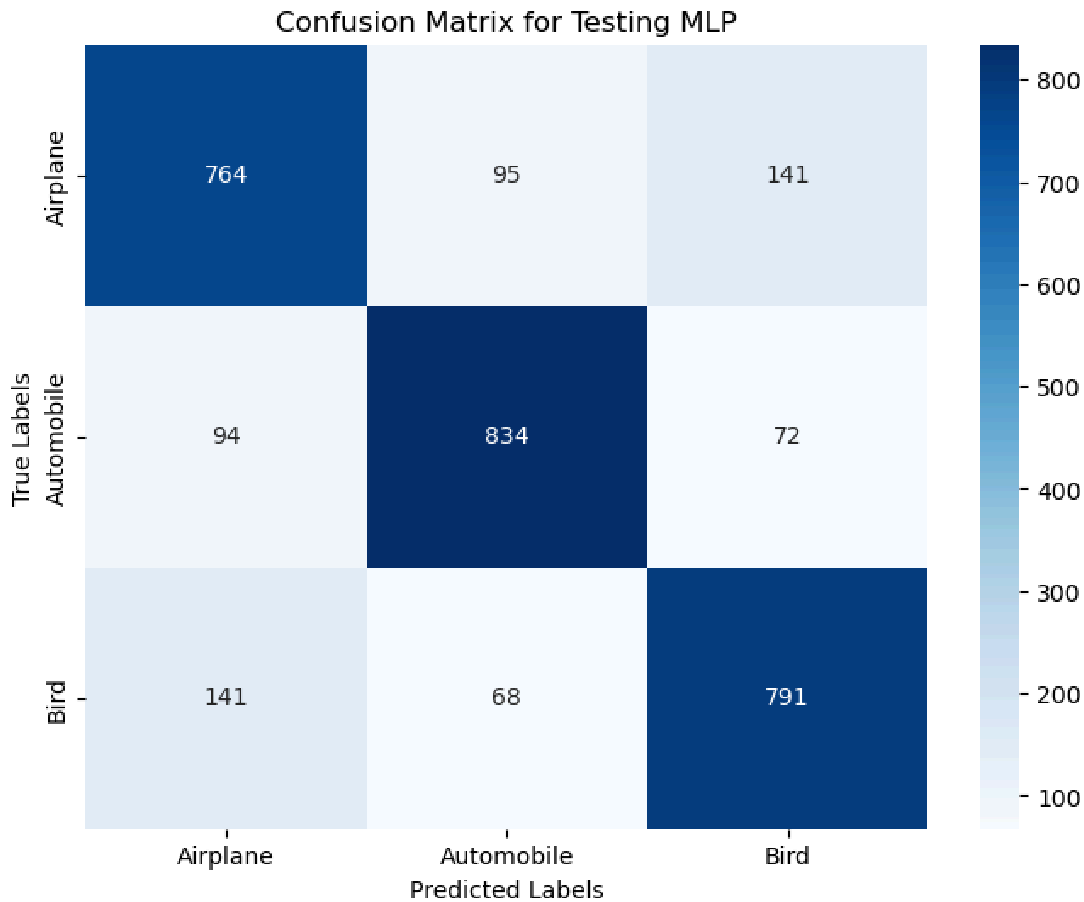

Confusion Matrix for Testing
True Labels
Predicted Labels
Airplane
Automobile
Bird
870
46
84
58
924
18
106
29
865
800
600
400
200

6.

7.

```
Best MLP Model: Epoch 15 with Validation Accuracy: 0.7835

MLP Test Accuracy: 0.7963
MLP Test F1 Score: 0.7964
```




```
Comparison Results:
Accuracy - CNN: 0.8500, MLP: 0.7963
F1 Score - CNN: 0.8400, MLP: 0.7964
```