**Phase-2**

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**Github Repository Link:** [Update the project source code to your Github Repository]

### **1. Problem Statement**

* *Recognizing handwritten digits accurately is essential for applications such as postal mail sorting, bank check processing, and digitizing handwritten forms. We aim to develop a deep learning-based solution that can correctly classify handwritten digits from 0 to 9.*

### **2. Project Objectives**

* Build a robust deep learning model capable of recognizing handwritten digits.
* Achieve high accuracy (> 98%) on test data.
* Ensure the model generalizes well and can be integrated into real-world applications.

### **3. Flowchart of the Project Workflow**

Dataset Collection → Data Preprocessing → Exploratory Data Analysis (EDA) → Feature Engineering → Model Building → Model Evaluation → Results Visualization → Conclusion and Deployment Plan

### **4. Data Description**

* *Dataset Name: MNIST Handwritten Digits Dataset*
* *Origin: Available on Kaggle and official sources like Yann LeCun's website.*
* *Type of Data: Image data (grayscale images).*
* *Number of Records and Features:*
* *60,000 training images*
* *10,000 testing images*
* *Each image: 28x28 pixels (flattened as 784 features when needed).*
* *Static or Dynamic: Static dataset.*
* *Target Variable: The digit (0 to 9) corresponding to each image.*

### **5. Data Preprocessing**

Missing Values: No missing values.

Duplicate Records: Checked and none found.

Outliers:

Visual inspection — no major outliers (images are well standardized).

Data Types:

Converted pixel values to float32.

Normalization:

Scaled pixel values from [0, 255] to [0, 1] by dividing by 255.

Encoding:

Labels one-hot encoded for neural network training.

Code Example:

X\_train = X\_train / 255.0

X\_test = X\_test / 255.0

y\_train = to\_categorical(y\_train, 10)

y\_test = to\_categorical(y\_test, 10)

### **6. Exploratory Data Analysis (EDA)**

* *Univariate Analysis:*
  + *Distribution of digits is approximately uniform.*
  + *Sample digit images visualized using matplotlib.*
* *Bivariate/Multivariate Analysis:*
  + *Not much feature correlation since each pixel is independent.*
  + *Used t-SNE plots to visualize high-dimensional clustering..*
* *Insights Summary:*
* *Digits are well-separated in latent space.*
* *Some digits like 4 and 9, or 3 and 5 may visually overlap.*

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### **7. Feature Engineering**

*Techniques Used:*

*Reshaped data to (28, 28, 1) to feed into CNN.*

*Augmented images with small rotations, zooms, and shifts to improve model robustness.*

*Example:*

*datagen = ImageDataGenerator(*

*rotation\_range=10,*

*zoom\_range=0.1,*

*width\_shift\_range=0.1,*

*height\_shift\_range=0.1*

*)*

*datagen.fit(X\_train)*

### **8. Model Building**

### *Models Implemented:*

### *1. Convolutional Neural Network (CNN)*

### *2. Fully Connected Neural Network (MLP)*

### *Model Justification:*

### *CNNs are highly effective for image data.*

### *MLP used as a baseline for comparison.*

### *Data Split:*

### *80% training, 20% validation (Stratified Split).*

### *Evaluation Metrics:*

### *Accuracy*

### *Precision*

### *Recall*

### *F1-score*

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### **9. Visualization of Results & Model Insights**

*Confusion Matrix:*

* *Visualized confusion matrix to see which digits were confused.*
* *Accuracy and Loss Plots:*
* *Plotted training vs validation accuracy and loss.*

### **10. Tools and Technologies Used**

*Programming Language: Python*

*IDE/Notebook: Google Colab, Jupyter Notebook*

*Libraries:*

* *pandas*
* *numpy*
* *matplotlib*
* *seaborn*
* *scikit-learn*
* *TensorFlow/Keras*

*Visualization Tools:*

* *matplotlib*
* *seaborn*
* *plotly*

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### **11. Team Members and Contributions**

* + *Data cleaning : Kiruthika .D*
  + *EDA : Janani. B*
  + *Feature engineering:Gokulavani.E*
  + *Model development : Kiruthika.D*
  + *Documentation and reporting : Janani .B*