**<HANDWRITTEN DIGIT CLASSIFIER >**

**Submitted for**

**CSET211 - Statistical Machine Learning**

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**Abstract:**

Handwritten digit classification is a key application in machine learning, aimed at recognizing and categorizing handwritten digits (0–9). This project employs a Convolutional Neural Network (CNN) to achieve digit recognition using the MNIST dataset, a benchmark collection of 70,000 grayscale images of handwritten digits. The dataset is preprocessed through normalization, reshaping, and one-hot encoding to ensure compatibility with the CNN architecture.

The proposed CNN comprises convolutional layers for feature extraction, max-pooling for dimensionality reduction, dropout layers for overfitting prevention, and dense layers for classification. Performance evaluation demonstrates excellent results, achieving 99.2% accuracy on both validation and test datasets. The system shows strong generalization, as evidenced by accurate predictions on unseen data.

Future directions include exploring advanced architectures like ResNet, expanding datasets for greater robustness, and deploying the model in real-world applications, including web and mobile platforms. This project highlights the effectiveness of CNNs for handwritten digit recognition and sets the stage for further enhancements and practical implementation

1. **Introduction**

* A handwritten digit classifier is a machine learning system designed to accurately recognize and classify handwritten digits, ranging from 0 to 9. This technology plays a vital role in various practical applications, such as postal mail sorting, bank check processing, and automated form digitization, where efficient and precise recognition of numeric inputs is critical.
* This project utilizes a Convolutional Neural Network (CNN), a specialized deep learning model designed to process image data, to perform digit recognition tasks. The chosen dataset for this project is the MNIST dataset, a well-established benchmark in the field of machine learning. MNIST comprises a collection of 70,000 labeled grayscale images of handwritten digits, with 60,000 images designated for training and 10,000 for testing.
* The classifier is meticulously trained to identify digits from input images by learning intricate patterns and features inherent to handwritten numerals. CNNs excel in such tasks due to their ability to extract spatial hierarchies of features from images, making them particularly suitable for image-based classification problems. Leveraging the power of deep learning, the proposed system achieves remarkable accuracy and demonstrates robustness in digit recognition, paving the way for deployment in real-world scenarios.

1. **Related Survey**

Handwritten digit recognition has been a prominent topic in machine learning and computer vision. Some key advancements include:

* **LeNet-5 (1998):** One of the first CNN architectures, proposed by Yann LeCun, specifically designed for handwritten digit recognition using the MNIST dataset.
* **Deep Learning:** Advances in deep neural networks, like CNNs, have significantly improved the performance of digit recognition models.
* **Applications:** Handwritten digit classifiers have found applications in postal address digitization, check processing in banks, and form digitization tasks.

The MNIST dataset has become the benchmark for evaluating these models, offering a large corpus of 70,000 labeled images of digits for training and testing.

1. **Datasets**

The dataset used is the **MNIST dataset**, which contains:

* **Training set:** 60,000 grayscale images of handwritten digits (28x28 pixels each).
* **Testing set:** 10,000 grayscale images for evaluation.

#### 3.1 Data Preprocessing

Steps for preprocessing:

1. **Normalization:** The pixel values (0–255) are scaled to a range of 0 to 1.
2. **Reshaping:** Images are reshaped to include a channel dimension (28x28x1) for compatibility with CNNs.
3. **One-hot Encoding:** Labels are converted into a categorical format with 10 classes (0–9).
4. **Methodology**

The model employs a Convolutional Neural Network (CNN) with the following architecture:

1. **Convolutional Layers:** Extract spatial features from input images.
2. **Max-Pooling Layers:** Reduce dimensionality and computation.
3. **Dropout:** Prevent overfitting during training.
4. **Dense Layers:** Classify features into the appropriate digit class.

#### 4.1 Hardware and Software Requirements

* **Hardware:** A system with a GPU is recommended for faster training.
* **Software:**
  + TensorFlow/Keras for model development.
  + Python for coding.
  + Libraries: NumPy, Matplotlib, PIL for preprocessing and visualization.
  1. **Performance Metrics**

1.  **Accuracy:** Percentage of correctly classified images.
2.  **Loss:** Quantifies the difference between predictions and actual label
3. **Results and Analysis :**

 **Training Accuracy:** Consistently increased over epochs, indicating effective learning.

 **Validation Accuracy:** Approximately 99.2% after 10 epochs, suggesting excellent generalization.

 **Test Accuracy:** Achieved 99.2%, indicating strong performance on unseen data.

 **Visualization:** Example predictions of test images demonstrate accurate recognition with high confidence.

#### Conclusions

* The CNN-based handwritten digit classifier achieved a high test accuracy of 99.2%.
* The MNIST dataset proved effective for training and testing the model.

#### Future Work

* **Enhanced Architectures:** Explore advanced models like ResNet or MobileNet for even higher accuracy.
* **Dataset Expansion:** Incorporate additional datasets (e.g., EMNIST) to make the model more robust.
* **Real-World Deployment:** Integrate the model into web or mobile applications for digit recognition.
* **Edge Computing:** Optimize the model for low-power devices for on-device digit recognition.
* This project demonstrates the potential of CNNs in practical handwritten digit classification and lays the groundwork for further exploration.

**\*\* Include the GitHub link as the last sentence of the Abstract for easy access to supplementary materials.**

<https://github.com/yashthakur234/SMLPROJECT/tree/main>

\*Above link contain code of my project/Model and Screenshots of output.