REAL-TIME HANDWRITTEN DIGIT RECOGNITION

FasiAhmed Parvez[1] ,Md Nashrasaniya[2], J.Samika[3], M.Sai Vighna[4], M.Suryareddy[5], G.Nagatharun[6] ,J.Chaitanya[7] ,Dr.V.Ramdas[8]
[1,7,8] Assistant Professor, Department of CSE, Balaji Institute of Technology & Science, Laknepally, Warangal, India
[2,3,4,5,6] BTech Student, Department of CSE, Balaji Institute of Technology and Science, Laknepally, Warangal, India

ABSTRACT

Handwritten digit recognition is an important technology used in automation, form processing, and AI-driven applications. This project focuses on developing a real-time handwritten digit recognition system using a webcam. Unlike traditional models that rely on existing datasets like MNIST, this system uses a custom dataset (also named MNIST), which includes real-world handwriting samples. This approach makes the model more adaptable to different writing styles.

The system captures handwritten digits using a webcam and processes them in real-time. Preprocessing techniques such as grayscale conversion, noise removal, resizing, and normalization help clean the image before classification. A Convolutional Neural Network (CNN) is then used to accurately identify the digit. To make the system interactive, it includes a Graphical User Interface (GUI), where users can write a digit, and the model predicts it instantly.

This project uses OpenCV for image processing, TensorFlow/Keras for training the deep learning model, and a GUI for user interaction. The goal is to create a fast, accurate, and efficient handwritten digit recognition system that works well in real-world conditions. By building a custom dataset, the model can handle different handwriting styles better than traditional approaches.

Keywords: Handwritten Digit Recognition, Deep Learning, Convolutional Neural Networks (CNN), Image Processing, Webcam, Real-time Classification, OpenCV, TensorFlow

I. INTRODUCTION

Handwritten digit recognition is an essential technology used in various fields, including automated banking systems, postal services, and digital document processing. It allows machines to interpret handwritten numbers, making processes like form digitization and automatic number recognition more efficient. Traditional methods relied on machine learning techniques like Support Vector Machines (SVM) and K-Nearest Neighbors (KNN). However, with advancements in deep learning, models like Convolutional Neural Networks (CNNs) have greatly improved accuracy and reliability.

This project aims to develop a real-time handwritten digit recognition system using a webcam. Instead of using scanned images, the system will capture digits directly from a live camera feed, process them, and classify them using a deep learning model trained on the MNIST dataset and additional handwritten samples. The recognition process involves image

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preprocessing, feature extraction, and classification using CNNs, which are highly effective in identifying patterns in handwritten digits.

To make the system user-friendly, a Graphical User Interface (GUI) will be implemented, allowing users to write digits in front of the webcam and receive instant feedback. The project utilizes OpenCV for real-time image capture, TensorFlow/Keras for deep learning, and a GUI framework such as Tkinter or a web-based interface for interaction. The goal is to create a fast, accurate, and practical solution for recognizing handwritten digits in real-world applications[1-29].

II. Literature Survey

Several research studies have explored handwritten digit recognition. Early methods used template matching, feature extraction, and machine learning classifiers like SVM and KNN. However, these struggled with variations in handwriting and background noise.

1. Traditional Approaches

Early methods for handwritten digit recognition included:

- Template Matching – Comparing the handwritten digit with a stored set of templates.
- Feature Extraction Methods – Using edge detection, zoning, and histogram analysis to extract key features.
- Machine Learning Classifiers – Techniques such as Support Vector Machines (SVM) and K-Nearest Neighbors (KNN) for classification.

While these methods showed some success, they were limited by handwriting variations, noise, and image distortions.

2. Deep Learning-Based Approaches

With the rise of deep learning, CNNs became the dominant approach for digit recognition. CNNs are designed to automatically extract features from images, reducing the need for manual feature engineering.

Key Research Contributions in Handwritten Digit Recognition:

1. LeCun et al. (1998) introduced LeNet-5, one of the earliest CNN architectures for handwritten digit recognition, achieving high accuracy on the MNIST dataset.
2. Ciresan et al. (2012) demonstrated that deep CNNs could surpass human-level accuracy in digit classification tasks.
3. Sakhr et al. (2017) proposed a hybrid CNN-SVM approach, improving classification performance by combining deep learning with traditional machine learning.

3. Real-Time Handwritten Digit Recognition Using Webcam

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While most research focuses on static image recognition, recent studies have explored realtime digit recognition using webcams. Key advancements include:

- Live Image Preprocessing – Converting webcam frames to grayscale, thresholding, and noise reduction.
- CNN-Based Recognition – Using real-time frame-by-frame classification for digit recognition.
- Edge Detection and Segmentation – Techniques such as Canny edge detection and adaptive thresholding to isolate the digit from the background.

Notable Works in Webcam-Based Digit Recognition

1. Jia et al. (2019) developed a real-time handwritten digit recognition system using OpenCV and TensorFlow, achieving 97% accuracy.
2. Patel et al. (2021) implemented a real-time digit classification model that integrates a CNN with OpenCV, demonstrating a fast and accurate recognition system.
3. Kumar et al. (2022) explored gesture-based digit input using a webcam, allowing users to write digits in the air for recognition.

III . Existing System

Handwritten digit recognition using a webcam has been widely researched, with several systems developed using traditional image processing and machine learning techniques. These systems follow a standard approach where a webcam captures an image of a

handwritten digit, processes it, and classifies it using different recognition methods.

However, despite their structured approach, many existing systems face accuracy and efficiency challenges when applied in real-world scenarios.A typical handwritten digit recognition system operates through multiple steps. First, the webcam captures the handwritten digit, which is then processed to enhance its quality. Preprocessing techniques such as grayscale conversion, noise reduction, and resizing ensure that the image is clear and standardized before further analysis. After preprocessing, the system extracts key features like edges, contours, and shape patterns, which are crucial for identifying the digit. Once the features are extracted, classification is performed using machine learning algorithms, including Support Vector Machines (SVM), K-Nearest Neighbors (KNN), or Artificial Neural Networks (ANN). Finally, the system displays the predicted digit on the screen, allowing the user to verify the result.

Most of these recognition systems utilize OpenCV for image capturing and preprocessing, along with NumPy and Scikit-Learn for mathematical computations and traditional machine learning. One of the biggest challenges is low accuracy in real-world conditions, as different handwriting styles make it difficult for the system to generalize. Due to these limitations, there is a need for a more advanced and robust system that leverages deep learning

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techniques, specifically Convolutional Neural Networks (CNNs). CNN-based models can automatically learn important features from handwritten digits without requiring manual feature extraction, improving accuracy, speed, and adaptability. A deep learning-based handwritten digit recognition system would enhance the reliability of real-time recognition, making it more suitable for practical applications.

IV. Proposed System

This project presents a real-time handwritten digit recognition system using deep learning and a webcam. The system utilizes a Convolutional Neural Network (CNN) trained on both the MNIST dataset and real-world handwritten samples, allowing it to recognize diverse handwriting styles accurately.

The system follows a structured workflow. First, a webcam captures the handwritten digit. The image is then pre-processed using grayscale conversion, noise removal, and normalization. After preprocessing, the CNN model classifies the digit, and the result is displayed on a Graphical User Interface (GUI) in real-time.To implement this system, OpenCV is used for image processing, TensorFlow/Keras for training the CNN model, and Tkinter/Web GUI for interactive display. This system provides a fast, accurate, and efficient solution for automated form processing, digital handwriting analysis, and AI-powered recognition applications**.**

V. Problem Statement

Handwritten digit recognition presents a significant challenge due to variations in individual handwriting styles, distortions, and noise in captured images. When using a webcam, additional factors such as lighting conditions and background interference further impact accuracy of recognition. Traditional machine learning models like Support Vector Machines (SVM) and K-Nearest Neighbors (KNN) often struggle with real-time performance and fail to adapt effectively to different handwriting styles. Furthermore, conventional feature extraction techniques may not generalize well across varying digit structures, leading to frequent misclassifications.

The key challenge in real-time handwritten digit recognition is to capture clear images under different environmental conditions while ensuring fast and accurate classification. The system needs to process raw webcam images, remove noise, extract relevant features, and classify digits efficiently. This project aims to develop a deep learning-based solution using Convolutional Neural Networks (CNNs) to improve accuracy and enhance real-time recognition. Such a system will be highly beneficial for applications like document processing, automatedform filling, and interactive learning tools.

VI. Methodology

The methodology for this handwritten digit recognition system involves several key steps to ensure accurate and real-time classification of handwritten digits using deep learning. The system follows the following approach:

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1. **Data Collection and Preprocessing**:
    - The project leverages the MNIST dataset, which contains a large collection of handwritten digits (0-9) in grayscale images. This dataset serves as the foundation for training the Convolutional Neural Network (CNN).
    - Images captured by the webcam undergo preprocessing steps, including:
        - Grayscale conversion to simplify the image and reduce computational load.
2. **Model Training**:
    - A CNN is used for its ability to efficiently learn spatial hierarchies of features from images.
    - The CNN model is trained using the MNIST dataset. It typically consists of multiple layers, such as convolutional layers for feature extraction, pooling layers for dimensionality reduction, and fully connected layers for classification.
3. **Webcam Integration**:
    - OpenCV is employed to interface with the webcam, allowing the system to capture real-time images of handwritten digits.
4. **Real-Time Image Processing**:
    - The captured frame undergoes the same preprocessing steps as the training dataset (grayscale conversion, resizing, normalization) to ensure consistency.
    - The preprocessed image is passed through the trained CNN model to classify the digit.
5. **Digit Classification and Output**:
    - The CNN model outputs a prediction for the handwritten digit. The system then displays the predicted digit on the GUI for user feedback.
    - The output is presented in real time, allowing users to immediately see the result of their input.
6. **User Interface**:
    - A GUI is designed using Tkinter (for a desktop application) or a web-based framework (for a web application). The interface provides features like capturing images, displaying predictions, and possibly allowing users to reset or clear the input field.

Vll.BLOCK DIAGRAM AND WORKFLOW

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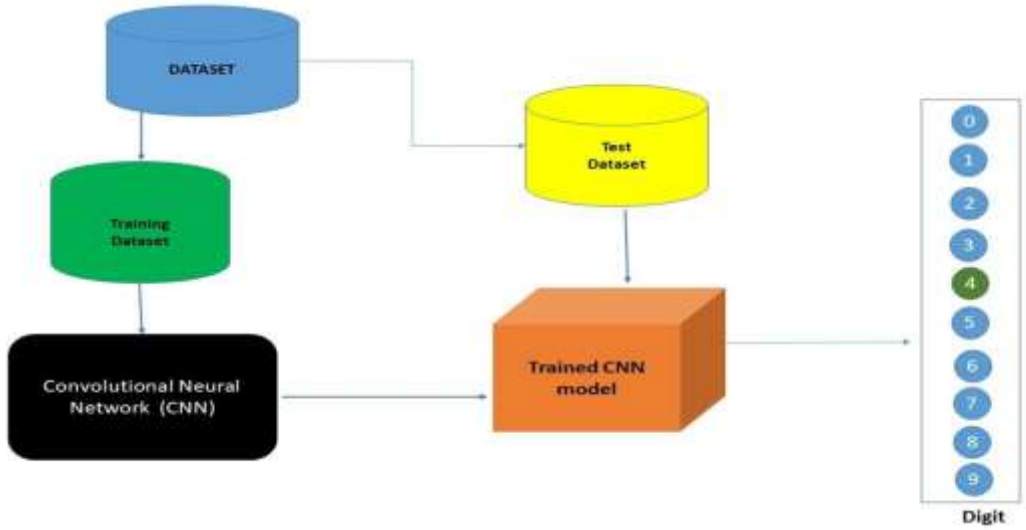

Fig1:CNN WorkFlow

Fig 1 represents Convolutional Neural Network workflow. Handwritten Digits Dataset is created and then Dataset will be trained and tested from training dataset it will go to cnn model. Test dataset is sent to Trained CNN model from that digits were classified and predicted.

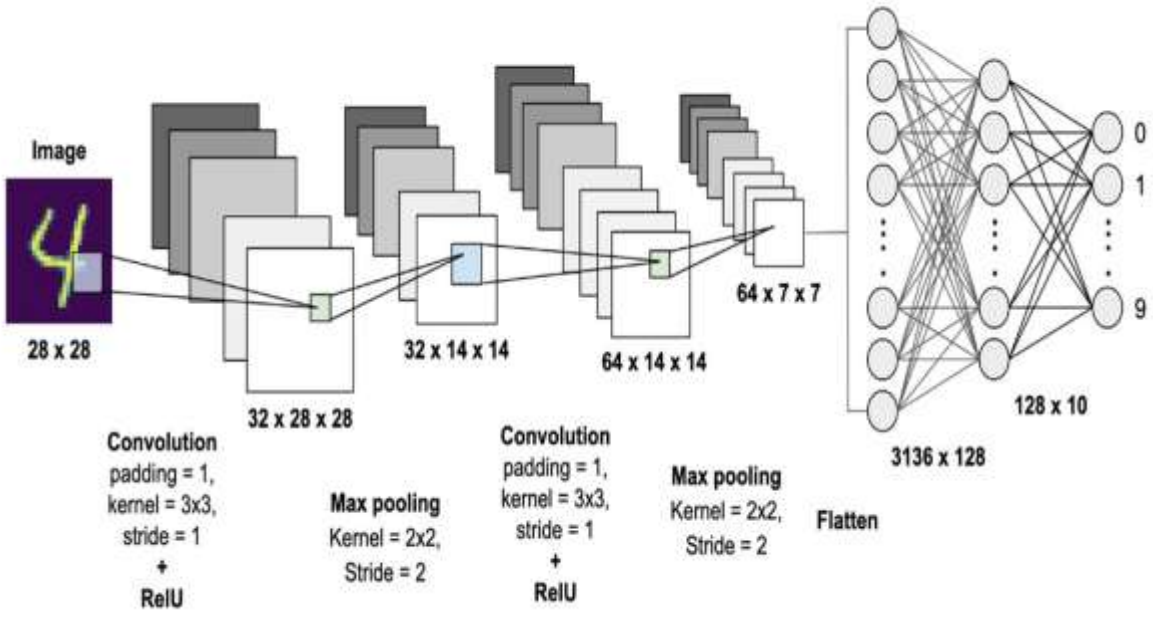

Fig 2:CNN Block Diagram

Fig 2 shows CNN Block Diagram.From 28 x 28 pixel Image using convolution and max pooling and relu techniques images are predicted and classified**.**

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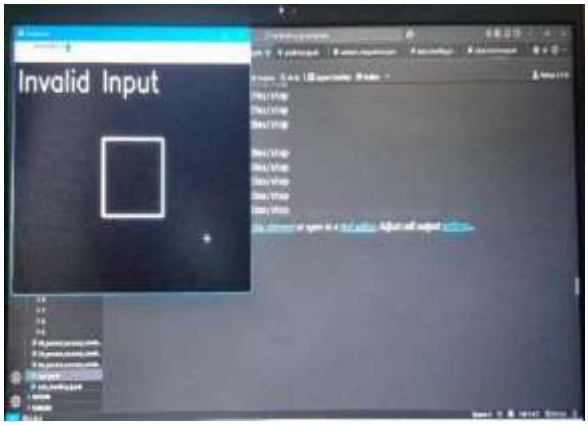
VIII .Future Scope

Handwritten digit recognition system can be improved in several ways to enhance its accuracy and usability. One of the key advancements would be training the model on a more diverse dataset that includes different handwriting styles, sizes, and real-world variations. This would help the system recognize digits more accurately across different users.Another potential improvement is integrating transformer-based models, which have shown great success in image recognition tasks. These models could improve classification accuracy and make the system more robust. Additionally, deploying the system on mobile devices would allow users to recognize handwritten digits on the go, making the application more accessible and practical. Beyond digit recognition, the system could be extended to handwritten word recognition, enabling real-time text transcription. This would be highly beneficial for applications such as automated note-taking, document processing, and assistive technologies for visually impaired users.

OUTPUT SCREENS:



Real Time Handwritten Digit Prediction Using Web Camera

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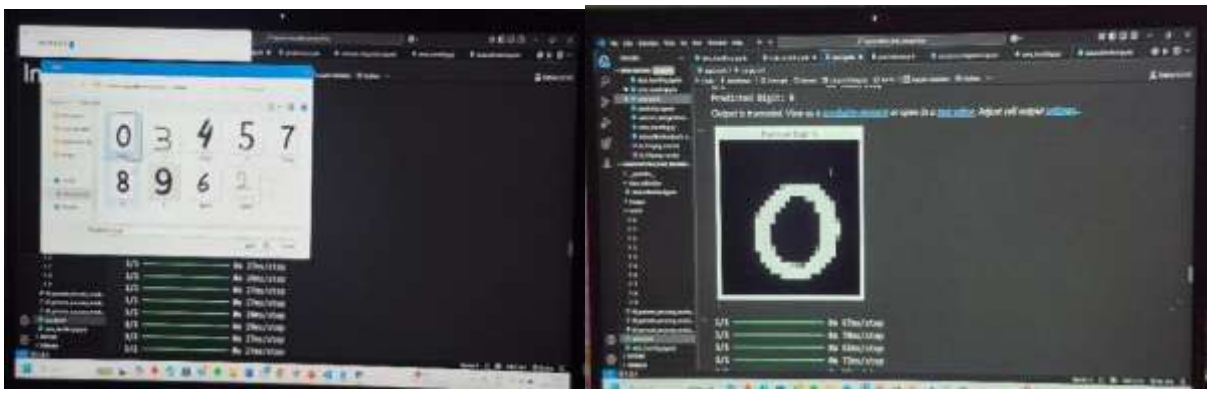
Uploading Image for Handwritten Digit Prediction

Prediction of Digit 5



Prediction of Digit 0

IX. Conclusion

Handwritten digit recognition using deep learning and a webcam offers an efficient and interactive solution for digit classification. Traditional machine learning methods struggle with handwriting variations and real-time processing, whereas Convolutional Neural Networks (CNNs) provide a more reliable approach by automatically extracting important features and improving classification accuracy.This project successfully integrates real-time image capture with a deep learning model, allowing for accurate recognition of handwritten digits. The system applies preprocessing techniques such as grayscale conversion, noise reduction, and adaptive thresholding to standardize images before classification. The CNN model, trained on the MNIST dataset, accurately recognizes digits and provides instant feedback through a Graphical User Interface (GUI).This implementation highlights the effectiveness of deep learning in real-time image recognition and paves the way for advancements in handwritten text recognition, document automation, and AI-driven human-computer interaction. Future improvements can further enhance its usability in practical applications.

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Mr. FASI AHMED PARVEZ is Associate Professor and Head of the Department in Balaji Institute of Technology & Science. He is pursuing his Ph.D in data mining. He has more than 16 years of experience in the field of teaching students at various levels in Engineering colleges. He already wrote a book on “DATA STRUCTURE using C”. He has published more than 20 papers in International Journals. He has presented 6 research papers at various National/International conferences.

Miss. Mohammed Nashra saniya Pursuing B. Tech in department of Computer Science and Engineering at Balaji Institute of Technology and Science, Narsampet. My research interest in AI&ML, DevOps, HTML and Certified as SAP Trainer and also researched on various ML and DL Algorithms and created “Real-time Handwritten digit recognition using Deep learning”,

Miss. J.SamikaPursuing B. Tech in department of Computer Science and Engineering at Balaji Institute of Technology and Science, Narsampet. My research interest in Machine learning Algorithm and understanding Training

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flow and also researched on various ML Algorithm DL Algorithms and created “Real-time Handwritten digit recognition using Deep learning”,

Miss. M Sai vignhaPursuing B. Tech in department of Computer Science and Engineering at Balaji Institute of Technology and Science, Narsampet. My research interest in Machine learning Algorithm and understanding Testing flow of project and also researched on various Webcam Integration and created “Real-time Handwritten digit recognition using Deep learning”,

Mr.M.Surya Reddy Pursuing B. Tech in department of Computer Science and Engineering at Balaji Institute of Technology and Science, Narsampet. My research interest in ML Algorithms and AI&ML and also researched on various Dataset mining and created “Real-time Handwritten digit recognition using Deep learning”.

Mr.G.NagaTharunPursuing B. Tech in department of Computer Science and Engineering at Balaji Institute of Technology and Science, Narsampet. My research interest in ML Algorithms and also researched on various ML and DL Threshold Adjustments and created “Real-time Handwritten digit recognition using Deep learning”.

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