Project Report

on

HandWritten-Digit-Recognition

submitted in partial fulfillment of the requirements

for the award of the degree

of

Bachelor of Technology

in

Computer Science and Engineering

By

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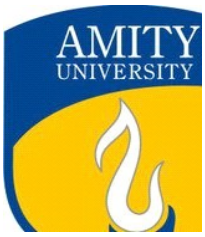

Computer Science and Engineering
Amity School of Engineering & Technology
Amity University Madhya Pradesh, Gwalior
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DECLARATION

I, **Ananya Jain**, student of Bachelor of Technology in Computer Science and Engineering hereby declare that the Project report entitled **"HandWritten-Digit-Recognition"** which is submitted by me to Department of Computer Science and Engineering, Amity School of Engineering & Technology, Amity University Madhya Pradesh, in partial fulfillment of the requirement for the award of the Degree of Bachelor of Technology in Computer Science and Engineering, has not been previously formed the basis for the award of any degree, diploma or other similar title or recognition. Our supervisor, HOD and the Institute should not be held for full or partial violation of copyrights if found at any stage of our degree.

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CERTIFICATE

This is to certify that the major project entitled "**HandWritten-Digit-Recognition**" by **Ananya Jain (Enrolment No A60205222153)** is a Bonafide record of project carried out by her under my supervision and guidance in partial fulfillment of the requirements for the award of the Degree of Bachelor of Technology in Computer Science and Engineering in the Department of Computer Science and Engineering, Amity School of Engineering and Technology, Amity University Madhya Pradesh, Gwalior. Neither this project nor any part of it has been submitted for any degree or academic award elsewhere.

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Head of the Department

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ABSTRACT

Handwritten digit recognition is a classic problem in the field of pattern recognition and machine learning, with wide-ranging real-world applications such as postal code detection, bank cheque processing, and automated form digitization. This project presents a system that can accurately recognize handwritten digits using a combination of image processing techniques and machine learning algorithms.

The dataset used is the MNIST dataset, which consists of 70,000 grayscale images of handwritten digits (0–9). Feature extraction is performed using the Histogram of Oriented Gradients (HOG) technique to capture the shape and structure of each digit. These features are then standardized using StandardScaler and fed into a Linear Support Vector Machine (SVM) classifier, which is trained to distinguish between the digits.

This project showcases the practical implementation of computer vision and machine learning concepts and serves as a foundation for more advanced recognition systems, including those based on deep learning architectures.

Keywords: HOG Features, Support Vector Machine (SVM), MNIST Dataset.

LIST OF FIGURES

LIST OF ABBREVIATIONS

S. No.	Terms	Expanded Form
1	HOG	Histogram of Oriented Gradients
2	SVM	Support Vector Machine
3	MNIST	Modified National Institute of Standards and Technology
4	ROI	Region of Interest
5	GUI	Graphical User Interface
6	AI	Artificial Intelligence
7	ML	Machine Learning
8	CV	Computer Vision
9	BGR	Blue-Green-Red
10	CNN	Convolutional Neural Network
11	API	Application Programming Interface
12	Scikit-learn	Scientific Kit
13	OpenCV	Open Source Computer Vision Library
14	Pkl	Pickle File
15	JPEG/JPG	Joint Photographic Experts Group
16	PCA	Principal Component Analysis
17	SGD	Stochastic Gradient Descent
18	HCI	Human-Computer Interaction
19	OCR	Optical Character Recognition
20	TPR	True Positive Rate
21	AUROC	Area Under the Receiver Operating Characteristic Curve *(if evaluation metrics are discussed)*

CONTENTS

Chapter 1

INTRODUCTION TO HDR

1.1 Introduction

Handwritten Digit Recognition (HDR) is one of the most compelling applications of machine learning and computer vision, offering an effective means to convert human-written characters into digital form. It forms the foundational technology behind many real-world systems including postal code readers, banking cheque verification systems, and digitized form processing.

In this project, we implement an HDR system using the MNIST dataset, Histogram of Oriented Gradients (HOG) for feature extraction, and a Support Vector Machine (SVM) classifier for recognition. This combination yields a lightweight and efficient solution that achieves reliable accuracy in recognizing digits from grayscale images.

1.2 Background and Motivation

The increasing need to process handwritten data efficiently has accelerated the development of intelligent systems capable of automatic recognition. With the surge in digitization efforts across sectors, there is a growing emphasis on converting paper-based data into digital text. Manual transcription is time-consuming, error-prone, and expensive. Automating the recognition of handwritten digits significantly enhances speed, accuracy, and operational efficiency.

Digit recognition, particularly with the availability of benchmark datasets such as MNIST, serves as an excellent starting point for beginners to explore machine learning, pattern recognition, and deep learning. It also has far-reaching implications in advanced research in artificial intelligence, including natural handwriting understanding and document analysis.

1.3 Problem Statement

Despite the development of high-accuracy models using deep learning, not all real-world applications require or can support the computational overhead of complex neural networks. This project focuses on building a computationally efficient handwritten digit recognizer using conventional machine learning methods.

The objective is to design a system that:

- Accepts a user-provided image containing digits.
- Preprocesses the image using standard image processing techniques.
- Extracts meaningful features using HOG descriptors.
- Classifies each digit using a trained Linear SVM model.

This pipeline aims to balance performance and resource efficiency, making it suitable for deployment in constrained environments such as embedded systems.

1.4 Objectives of the Project

- To implement a system that accurately recognizes handwritten digits from grayscale images.
- To understand and apply the concepts of image preprocessing, feature extraction, and classification.
- To demonstrate the practical application of machine learning in computer vision.
- To evaluate the effectiveness of traditional machine learning algorithms in solving OCR-related problems.

Table 1.1 Components of Handwritten Digit Recognition System

Component	Description
MNIST Dataset	A widely-used dataset of handwritten digits (0-9) for training and testing
HOG (Histogram of Oriented Gradients)	Feature descriptor used to detect object edges and gradients
Linear SVM	A classification algorithm for categorizing extra
Joblib	Python library used to serialize and save the trained model

Chapter 2

Review of Literature and Definition of Problem

2.1 Review of Literature

The domain of handwritten digit recognition has been extensively explored in the fields of pattern recognition, image processing, and machine learning. Over the years, significant advancements have led to the development of increasingly accurate and efficient recognition systems.

2.1.1 Early Approaches

The earliest digit recognition systems relied on rule-based methods and geometric feature extraction. These systems typically extracted pixel-level features such as stroke direction, edge counts, or symmetry measures. Although simple, such techniques were limited by poor generalization and sensitivity to noise and variations in handwriting styles.

2.1.2 Statistical and Machine Learning Models

With the advent of statistical pattern recognition, machine learning algorithms such as K-Nearest Neighbors (KNN), Naive Bayes, and Support Vector Machines (SVMs) began to outperform earlier methods. The MNIST dataset, introduced by LeCun et al., became a standard benchmark, allowing researchers to systematically evaluate algorithmic performance.

Histogram of Oriented Gradients (HOG), a feature descriptor introduced by Dalal and Triggs, was particularly effective in capturing shape and texture information. When combined with SVMs, HOG-based methods demonstrated robust performance on character recognition tasks with significantly reduced computational overhead compared to neural networks.

2.1.3 Deep Learning Paradigm

Recent years have witnessed a surge in deep learning models, particularly Convolutional Neural Networks (CNNs), which have achieved state-of-the-art accuracy on the MNIST dataset—often exceeding 99%. However, such models come with high

computational and hardware requirements, making them less suitable for resource-constrained environments.

2.1.4 Contemporary Implementations

Recent works have emphasized hybrid models that combine traditional techniques with deep learning to leverage the strengths of both. Nonetheless, for many real-time, embedded, or educational applications, classic models like HOG+SVM still offer a compelling balance between accuracy and efficiency.

2.2 Definition of the Problem

Despite the impressive performance of deep learning models, there remains a significant gap in deploying digit recognition systems in environments with limited computational resources. The primary challenges include:

- **Variability in Handwriting Styles**: Differences in user handwriting can result in high intra-class variation, complicating the recognition process.
- **Noise and Artifacts**: Images may include noise, background clutter, or distortions that impact feature extraction.
- **Computational Overhead**: Deep models require high-end GPUs and large memory, limiting their usage in mobile and embedded systems.

Therefore, this project focuses on developing an efficient and lightweight handwritten digit recognition system using a well-engineered combination of HOG feature descriptors and a Linear Support Vector Machine (SVM) classifier.

Chapter 3

Materials and Methods

This chapter outlines the tools, libraries, datasets, and methodologies used in developing the Handwritten Digit Recognition system. The aim is to describe the complete pipeline from data acquisition to model training and evaluation, providing a clear understanding of the systematic approach adopted in the project.

3.1 Materials Used

3.1.1 Hardware Requirements

Component	Specification
Processor	Intel Core i5 / Ryzen 5 or higher
RAM	Minimum 8 GB
Storage	At least 2 GB of free disk space
Display	1366x768 or higher resolution
Operating System	Windows 10 / Linux / macOS

3.1.2 Software and Libraries

Tool / Library	Purpose
Python 3.x	Core programming language
scikit-learn	Machine learning algorithms (SVM)
scikit-image	Feature extraction using HOG
NumPy	Numerical computations
OpenCV	Image processing and visualization
Joblib	Model persistence
MNIST Dataset	Standard dataset for training

3.2 Dataset Description

The **MNIST (Modified National Institute of Standards and Technology)** dataset is a benchmark dataset in the field of pattern recognition. It consists of:

- 60,000 grayscale images for training
- 10,000 grayscale images for testing
- Each image is 28x28 pixels
- Contains digits from 0 to 9 (10 classes)

These images are centered and size-normalized, allowing for consistent preprocessing and feature extraction.

3.3 Methodology

The methodology can be divided into the following steps:

3.3.1 Image Preprocessing

- Convert the input image to grayscale.
- Apply Gaussian blur to remove noise.
- Apply binary thresholding to distinguish foreground (digit) from background.
- Detect contours and extract individual digits.

3.3.2 Feature Extraction using HOG

The **Histogram of Oriented Gradients (HOG)** method captures the structural and gradient information of digits:

- Image resized to 28x28 pixels.
- 9 orientation bins.
- Pixels per cell: 14×14
- Cells per block: 1×1

This results in a compact feature vector for each digit image that is robust to variations in handwriting style.

3.3.3 Feature Normalization

- The extracted features are standardized using the StandardScaler from scikit-learn to ensure uniformity in the data distribution.
- Normalization improves the performance of linear classifiers by standardizing the scale.

3.3.4 Classification using SVM

- A **Linear Support Vector Machine (SVM)** is trained using the normalized HOG features.
- The SVM finds the optimal hyperplane that separates digit classes with maximum margin.
- Chosen for its simplicity, efficiency, and good performance on high-dimensional data.