

**Thiagarajar College Of Engineering
Nalaiya Thiran - An Initiative by IBM**

Project Report

On

**A Novel Method for Handwritten Digit
Recognition System**

Submitted By

Team ID : PNT2022TMID21423

B.T. Shreya 917719D091

S. Deva Dharshini 917719D017

M. Priyadharshini 917719D065

S. Chetana 917719D115

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Chapter 1

Introduction

PROJECT OVERVIEW

Handwritten digit recognition is the ability of a computer system to recognize the handwritten inputs like digits, characters etc. from a wide variety of sources like emails, papers, images, letters etc. Handwritten digit recognition are done using Machine Learning, Deep Learning and Computer Vision algorithms. Machine Learning Algorithms like CNN- convolutional neural networks and with Deep Learning algorithm like multilayer CNN using Keras with Theano and Tensorflow

.With the use of deep learning and machine learning, human effort can be reduced in recognizing, learning, predictions and in many more areas. Handwritten Digit Recognition is the ability of computer systems to recognise handwritten digits from various sources, such as images, documents, and so

PURPOSE

Handwritten character recognition is one of the practically important issues in pattern recognition applications. The applications of digit recognition include in postal mail sorting, bank check processing, form data entry. Pattern recognition is a data analysis method that uses machine learning algorithms to automatically recognize patterns and regularities in data. This data can be anything from text and images to sounds or other definable qualities. Pattern recognition systems can recognize familiar patterns quickly and accurately.

The main purpose of this project is

- Pattern recognition solves the problem of fake biometric detection.
- It is useful for cloth pattern recognition for visually impaired blind people.
- It helps in speaker diarization.
- We can recognize particular objects from different angles.

Chapter 2

Literature Survey

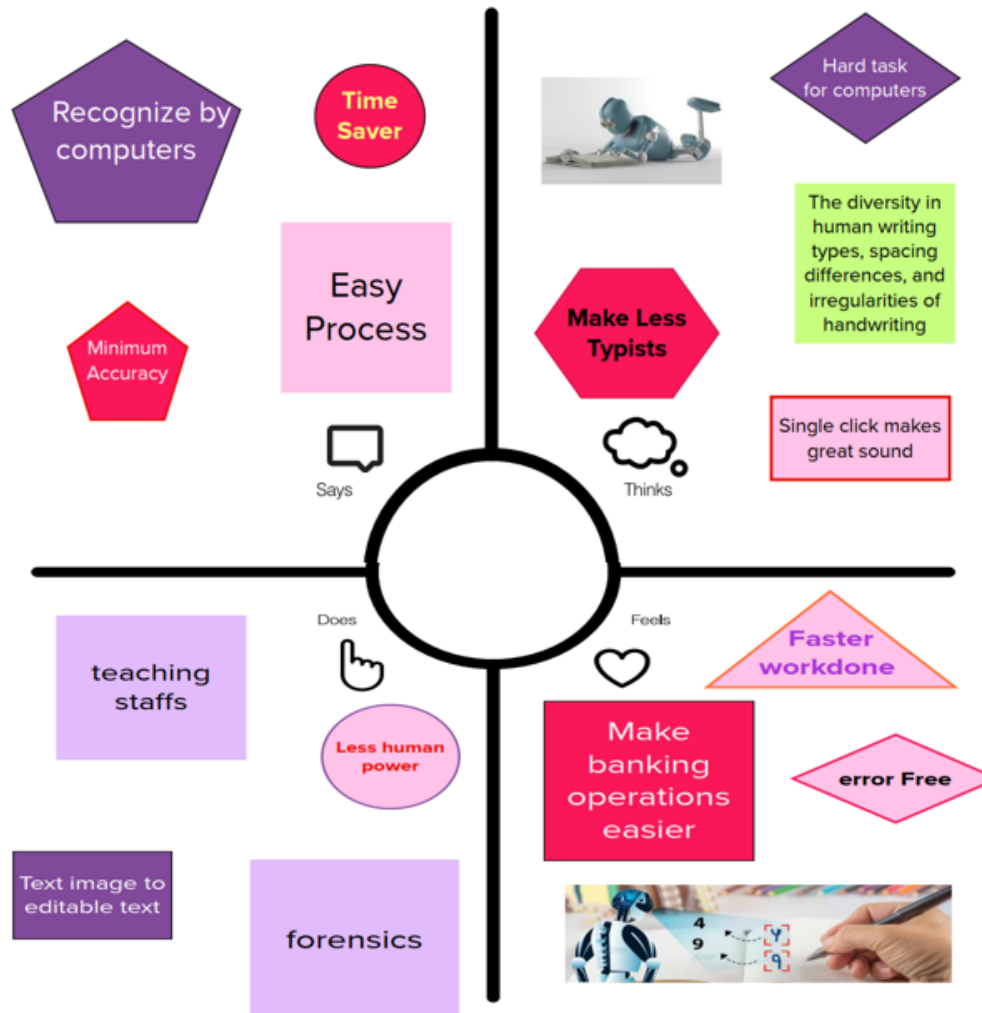
Title	Author of the paper	Abstract
Handwritten digit recognition: benchmarking of state-of-the-art techniques	Cheng-LinLiu Kazuki Nakashima Hiroshi Sako Hiromichi Fujisawa	This paper presents the results of handwritten digit recognition on well-known image databases using state-of-the-art feature extraction and classification techniques. The tested databases are CENPARMI, CEDAR, and MNIST. On the test data set of each database, 80 recognition accuracies are given by combining eight classifiers with ten feature vectors
Handwritten Digit Recognition with a Back Propagation Network	Y. LeCun, B. Boser, J. S. Denker, D. Henderson, R. E. Howard, W. Hubbard, and L. D. Jackel AT&T Bell Laboratories, Holmdel, N. J. 07733	We present an application of back-propagation networks to handwritten digit recognition. Minimal preprocessing of the data was required, but architecture of the network was highly constrained and specifically designed for the task

<p>A Novel Approach for Handwritten Character Recognition Using K-NN Classifier</p>	<p>abhay mishra,kris hnan kumar,prav een kumar</p>	<p>In this digital era, it is crucial to identify the authenticity of the words where the writer identification becomes a big challenge. This paper highlights an efficient approach to recognize the character from hand written document using k-nearest neighbor algorithm. Then, a supervised-learning algorithm is employed to recognize the character.</p>
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Chapter 3

Ideation and Proposed Solution

Empathy Map Canvas



Ideation and Brainstorming

Brainstorming provides a free and open environment that encourages everyone within a team to participate in the creative thinking process that leads to problem solving. Prioritizing volume over value, out-of-the-box ideas are welcome and built upon, and all participants are encouraged to collaborate, helping each other develop a rich amount of creative solutions.

We have formed a team of four members. We have chosen the domain of Artificial Intelligence. Artificial intelligence (AI) is intelligence demonstrated by machines, as opposed to the natural intelligence displayed by animals and humans.

All our team members are gathered through google meet to share our thoughts about the topic A NOVEL METHOD FOR HANDWRITTEN DIGIT RECOGNITION SYSTEM.

In the meeting we discussed the problem statements for this project and we decided the problem statement given below.

PROBLEM STATEMENT:

Handwritten digit recognition is very important as it will be very helpful to reduce human effort. As each individual has different handwriting for representing digits, the system should have a capability to identify every handwriting with maximum accuracy. Such a system will be useful to reduce human interventions in identification, as everything is being digitized. The main objective of this work is to ensure effective and reliable approaches for recognition of handwritten digits and make banking operations easier and error free. Handwriting recognition has gained a lot of attention in the field of pattern recognition and machine learning due to its application in various fields.

We shared our ideas through the comment section in the google meet and we also explained our ideas to the team members .

Our ideas are:

- Using sensors to find the veins and tissues action during writing and classifies the waveform obtained from that and obtaining the digits
- Handwritten digit recognition system for English alphabets
- Improvising the digit recognition with newer technologies
- Digits should be recognised with zero latency

Proposed Solution

S.No	Parameter	Description
1.	Problem Statement (Problem to be solved)	It is a hard task for the machine because handwritten digits are not perfect and can be made with many different shapes and sizes.
2.	Idea / Solution description	The handwritten digit recognition system is a way to tackle this problem which uses the image of a digit and recognizes the digit present in the image. Convolutional Neural Network model created using

		PyTorch library over the MNIST dataset to recognize handwritten digits .
3.	Novelty / Uniqueness	Number recognition has numerous operations like number plate recognition, postal correspondence sorting, bank check processing, etc . In Handwritten number recognition, we face numerous challenges . because of different styles of jotting of different peoples as it is not an optical character recognition. This exploration provides a comprehensive comparison between different machine literacy and deep literacy algorithms for the purpose of handwritten number recognition.
4.	Social Impact / Customer Satisfaction	Handwriting recognition helps to transform the writings in the papers to a text document format which can also be said as readable electronic format. By this way, historical facts can be stored, reviewed and shared easily too many people. Lastly, the advantage is textual studies.
5.	Business Model (Revenue Model)	The global Handwriting Recognition (HWR) market was valued at over 1,340.37 million in 2020 and is expected to generate a cumulative growth opportunity valued at over USD 4,291.27 million during the forecast period. The global Handwriting Recognition (HWR) industry is expected to post a lucrative CAGR of over 16.97%
6.	Scalability of the Solution	Today, OCR technology provides higher than 99% accuracy with typed characters in high-quality images. However, the diversity in human writing types, spacing differences, and irregularities of handwriting causes less accurate character recognition, as you can see in the featured image. Thus, tools that read handwriting cannot provide the same degree of accuracy that OCR systems offer on typed characters. But, our model improves its accuracy by introducing highly sophisticated algorithms designed to solve this problem

Problem Solution Fit

Project Title: A Novel Method for handwritten digit recognition system

Project Design Phase-I - Solution Fit Template

Team ID: PNT2022TMID21423

Define CS, fit into CC	1. CUSTOMER SEGMENT(S) CC Who is your customer? 1. Forensic officers 2. Police Officers 3. Intelligent division unit employees	6. CUSTOMER CONSTRAINT S CC 1. Cost limitations 2. Technology availability 3. Power supply 4. Environmental surroundings	5. AVAILABLE SOLUTIONS AS 1. Random guessing method 2. Brute force search with already available records	Explore AS, differentiate

Focus on JSP as in BE, understand CC	2. JOBS-TO-BE-DONE / PROBLEMS JSP To identify what is written on the sheet and doing it manually is a huge time consuming work.	9. PROBLEM ROOT CAUSE RC Existence of criminals that write an important message in some encoded form.	7. BEHAVIOUR BE Manual labouring work who attempts to find the message with the help from the previous records.	Focus on JSP as in BE, understand CC

Identify strong TR & E M	3. TRIGGERS TR Customers being officers, they want to identify who the criminal is and wants to prevent happening that crime again in future.	10. YOUR SOLUTION SL Our solution is to create a model system that is trained with the different written digits using Artificial Intelligence and use it as an application to identify the digit.	8. CHANNELS of BEHAVIOUR CH 8.1 ONLINE The obtaining of dataset that has every possible digits type. 8.2 OFFLINE Setting up of the model system application in a manner the criminals don't find it.	

	<p>4. EMOTIONS: BEFORE / AFTER</p> <p>EM</p> <p>Before : Time consuming and stressful work</p> <p>After : Easy to handle and feeling secured and satisfied.</p>		
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Chapter 4

Requirement Analysis

Functional Requirements

FR No.	Sub Requirement (Story / Sub-Task)
FR-1	Image Data: Handwritten digit recognition refers to a computer's capacity to identify human handwritten digits from a variety of sources, such as photographs, documents, touch screens, etc., and categorise them into ten established classifications (0-9). In the realm of deep learning, this has been the subject of countless studies.
FR-2	Website: Web hosting makes the code, graphics, and other items that make up a website accessible online. A server hosts every website you've ever visited. The type of hosting determines how much space is allotted to a website on a server. Shared, dedicated, VPS, and reseller hosting are the four basic varieties.
FR-3	Digit Classifier Model: To train a convolutional network to predict the digit from an image, use the MNIST database of handwritten digits. get the training and validation data first.

FR-4	Cloud: The cloud offers a range of IT services, including virtual storage, networking, servers, databases, and applications. In plain English, cloud computing is described as a virtual platform that enables unlimited storage and access to your data over the internet.
FR-5	Modified National Institute of Standards and Technology dataset: The abbreviation MNIST stands for the MNIST dataset. It is a collection of 60,000 tiny square grayscale photographs, each measuring 28 by 28, comprising handwritten single digits between 0 and 9.

Non Functional Requirements

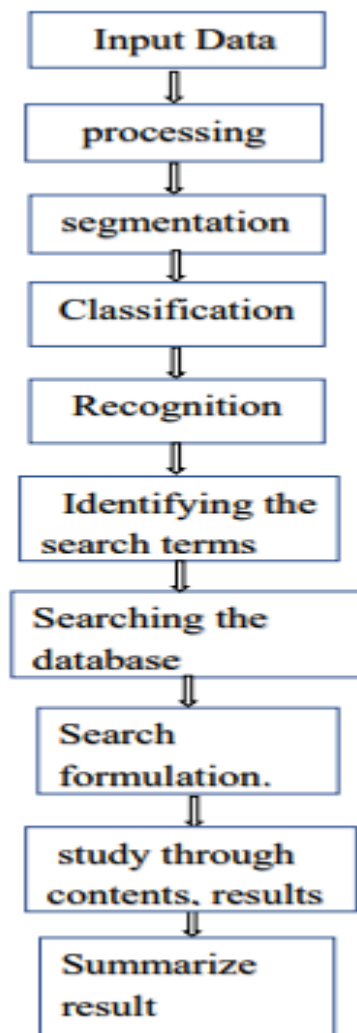
Following are the non-functional requirements of the proposed solution.

FR No.	Non-Functional Requirement	Description
NFR-1	Usability	This application should be used in both mobile and computers.
NFR-2	Security	User security must be priority In the application
NFR-3	Reliability	This application will give an accurate result
NFR-4	Performance	Application will give an high performance(fast and speed)
NFR-5	Availability	This application must be available in all situations.
NFR-6	Scalability	This application must be scalable.

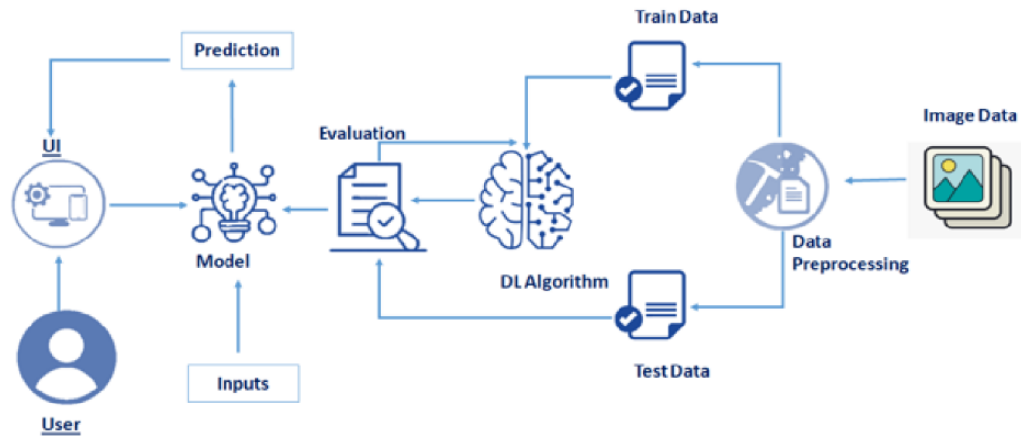
Chapter 5

Project Design

Data Flow Diagram



Solution and Technical Architecture



S.N o	Characteristics	Description	Technology
1.	Open-Source Frameworks	an open-source Python library developed by the Google Brain labs for deep learning research, you will take hand-drawn images of the numbers 0-9 and build and train a neural network to recognize and predict the correct label for the digit displayed	Keras, Tensor flow, Numpy, Pillow, Tkinter technology

2.	Security Implementations	The developed application should be accessible in the way it can only respond to the	Encryptions, IAM Control

		comments of the relevant users	
3.	Scalable Architecture	The app format makes it easier to handle and operate.	Not yet determined
4.	Availability	The developed solution tends to be available in the market at any time	Not yet determined
5.	Performance	Highly proper and betterment functionalities are to be ensured in the designed solution	Not yet determined

User Stories

User Type	Functional Requirement (Epic)	User Story Number	User Story / Task	Acceptance criteria	Priority	Release
Customer (Mobile user)	Install application	USN-1	As a user, I should be able to install the application easily.	User can access my application through mobile /computers	High	Sprint-1
	User input image	USN-2	As a user, I am able to upload images in the	User can give input image	High	Sprint-1

			app to predict the result or digit.			
	User requirement	USN-3	As a user, I should decide the font size so that my requirements must be sorted out.	Users can give requirements.	Low	Sprint-2
	View result	USN-4	As a user, I see result obtained	User can get result	High	Sprint-1
	Login	USN-5	As a user, I can log into the application by entering email & password	Login by password	High	Sprint-1
Customer Care Executive	Safe and secure		For users all the information given by them must be safe and secure.		High	Sprint-1
Administrator	Accurate result		The administrator must try to give accurate results.		High	Sprint-1

Chapter 6

Project Planning and Scheduling

Sprint Planning and Estimation

Sprint	Functional Requirement (Epic)	User Story Number	User Story / Task	Story Points	Priority	Team Members
Sprint-1	Registration	USN-1	As a user, I can register for the application by entering my email, password, and confirming my password.	2	High	Shreya B T
Sprint-1	Login	USN-2	As a user, I can log into the application by entering email & password	1	High	Chetana S
Sprint-2	Upload Image of digital document	USN-3	As a user, I can able to input the images of digital documents to the application	2	Medium	Priyadharshini M

Sprint-2	Prediction	USN-4	As a user, I can predict the word	1	Medium	Deva Dharshini S
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Sprint-3	Upload Image of Handwritten document	USN-5	As a user, I can able to input the images of the handwritten documents or images to the application		High	Chetana S
Sprint-3	Recognize text	USN-6	As a user, I can able to choose the font of the text to be displayed	1	Medium	Shreya B T
Sprint-4	Recognize digit	USN-7	As a user I can able to get the recognised digit as output from the images of digital documents or images		Medium	Priyadharshini M

Sprint-4	Recognize digit	USN-8	As a user I can able to get the recognised digit as output from the images of handwritten documents or images		High	Deva Dharshini S
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Sprint Delivery Schedule

Sprint	Total Story Points	Duration	Sprint Start Date	Sprint End Date (Planned)	Story Points Completed (as on Planned End Date)	Sprint Release Date (Actual)
Sprint-1	20	6 Days	24 Oct 2022	29 Oct 2022	20	02 Nov 2022
Sprint-2	20	6 Days	31 Oct 2022	05 Nov 2022	20	05 Nov 2022
Sprint-3	20	6 Days	07 Nov 2022	12 Nov 2022	20	12 Nov 2022

Sprint-4	20	6 Days	14 Nov 2022	19 Nov 2022	20	19 Nov 2022
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Chapter 7

Coding and Solutioning

Feature 1:

This is one feature since we are using the cross-categorical entropy as loss function. We have to specify the network that the given labels are categorical in nature. The raw data can contain various different types of data which can be both structured and unstructured and needs to be processed in order to bring to form that is usable in the Machine Learning models. Since machine learning is based on mathematical equations, it would cause a problem when we keep categorical variables as is. Many algorithms support categorical values without further manipulation, but in those cases, it's still a topic of discussion on whether to encode the variables or not. After the identification of the data types of the features present in the data set, the next step is to process the data in a way that is suitable to put to Machine Learning models. The three popular techniques of converting Categorical values to Numeric values are done in two different methods.

1. Label Encoding.
2. One Hot Encoding.
3. Binary Encoding.

Encoding variability describes the variation of encoding individually inside a category. When we talk about the variability in one hot encoding, the variability depends on the time of implementation in which it decides the number of categories to take that do have sufficient impact on the target. Other encoding methodologies do show a significant variability which is identified at the time of validation.

In our solution, we used One Hot Encoding.

```
y_train = np_utils.to_categorical(y_train, number_of_classes)
```

```
y_test = np_utils.to_categorical(y_test, number_of_classes)
```

Another feature is that we have used only a minimum number of CNN layers in our code and thus making it more efficient.

```
model.add(Conv2D(64, (3, 3), input_shape=(28, 28, 1), activation='relu'))
```

```
model.add(Conv2D(32, (3, 3), activation = 'relu'))
```

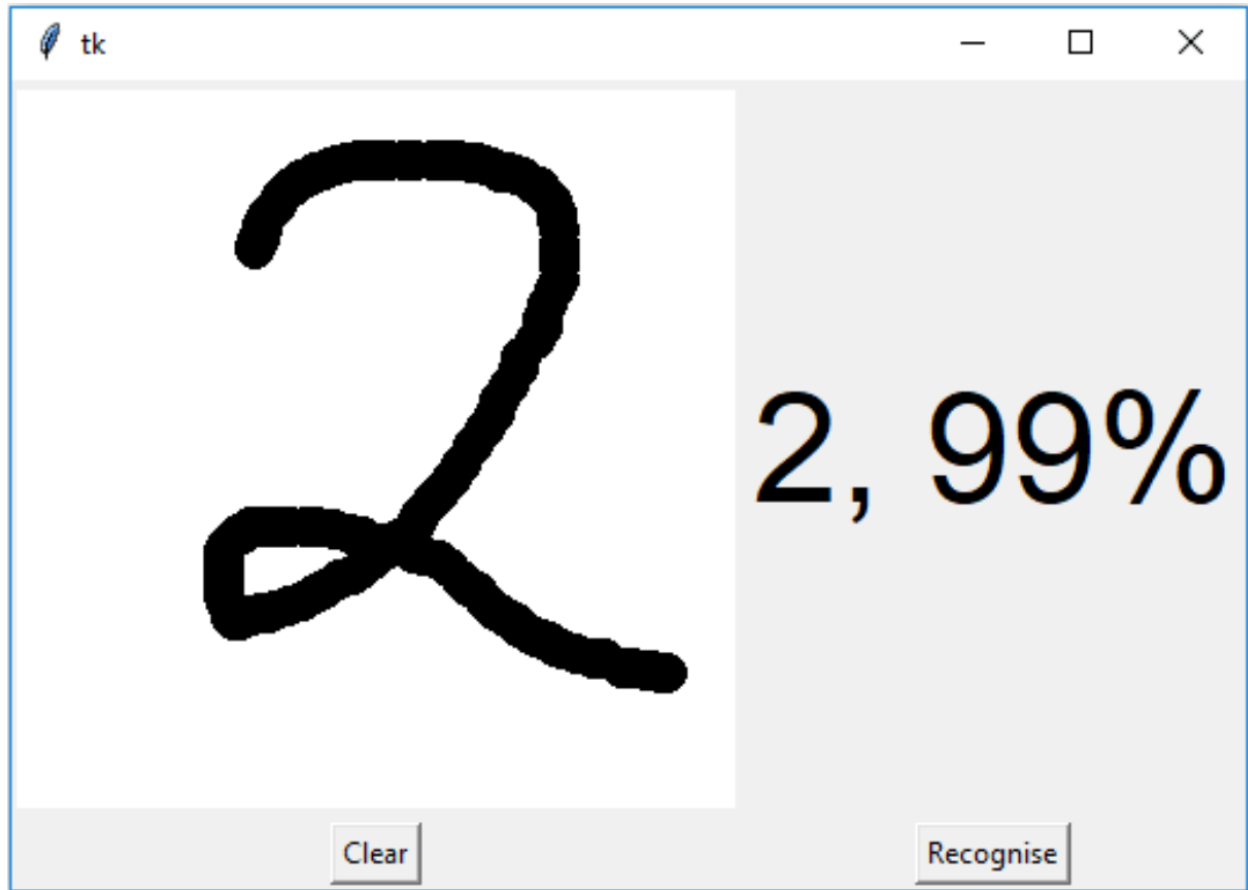
```
model.add(Flatten())
```

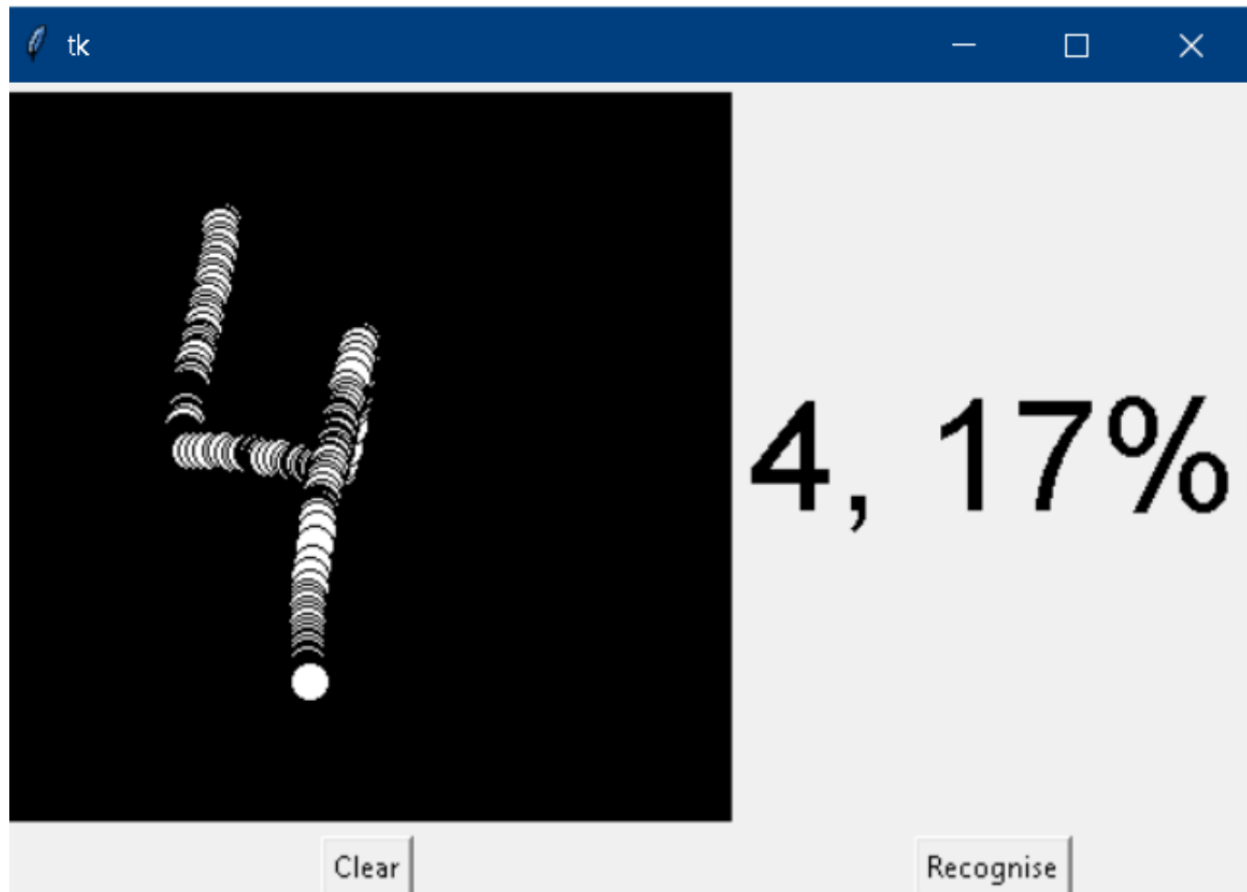
```
model.add(Dense(number_of_classes,activation = 'softmax'))
```

Chapter 8

Testing

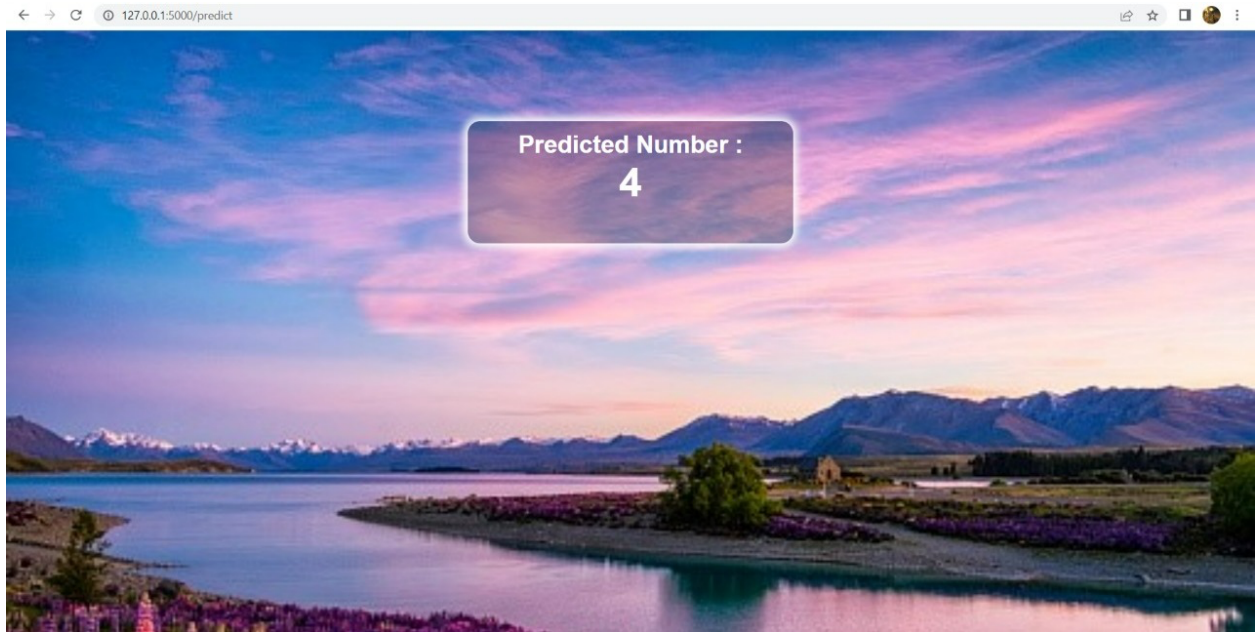
Test Cases :





Test Case Analysis





Chapter 9

Results

Performance Metrics

Application performance monitoring (APM) no longer means just measuring the performance, availability, and user experience metrics of application software. To truly understand just how well an application is performing, monitoring tools must capture performance metrics that align with and support business objectives.

Enterprises have a mix of commercial and custom applications servicing internal users and external customers, often on a global scale. The best way to ensure a great user experience across the board is by writing error-free code, pushing better applications into production faster, and providing actionable insights into all pre-production and production applications. This all starts in development and includes the following metrics every APM tool should capture.

Maintaining application performance is critical for ensuring that your applications are working at the required levels. Our Application Performance Monitoring Buyer's Guide contains profiles on the top application performance monitoring vendors, as well as questions you should ask providers and yourself before buying. We also offer a Network Monitoring Buyer's Guide if you're in the process of evaluating or buying network performance management solutions.

User Satisfaction / Apdex Scores

The application performance index, or Apdex score, has become an industry standard for tracking the relative performance of an application. It works by specifying a goal for how long a certain web request or application transaction should take. Those transactions are then bucketed into satisfied (fast), tolerating (sluggish), too slow, and failed requests. A simple math formula is then applied to provide a score from 0 to 1.

Your chosen APM solution should automatically track satisfaction scores for every one of your applications and web requests. Presenting scores in a larger range, like 0—100 instead of 0—1, is also desirable, as it makes insights easier to understand and act upon.

Average Response Time

Averages are still a useful application performance metric, but those metrics should be aligned with business goals. The average response time for a digital storefront, for example, could mean the difference between staying in business and closing shop. Everyone from your Ops team to executive leadership wants to know average response times, and the value of your chosen APM tool comes from capturing averages that tell you how performance impacts business goals.

Error Rates

As noted above, critical application performance incidents can result in significant costs in revenue, time, and brand reputation for your organization. While the last things you want your users to see are errors, a late or faulty response to incidents is even worse.

APM tools monitor errors using three common ways to track this important metric:

1. HTTP Error Percent – Number of web requests that ended in an error
2. Logged Exceptions – Number of unhandled and logged errors from your application
3. Thrown Exceptions – Number of all exceptions that have been thrown

Each method captures error rates, but you want your APM tool equipped to integrate error tracking and logging with full transaction tracing to quickly resolve issues and keep users happy. It is common to see thousands of exceptions within an application, and without preset thresholds and anomaly identification, your team can spend costly time addressing the wrong issue or being late to solving a mission-critical problem.

Count of Application Instances

Cloud computing means your hosted applications scale up and down to accommodate user demand, making it vital to know how many server/application instances are running at any given time. Auto-scaling most certainly saves you money during off-peak times, but your APM tool also needs to recognize and resolve unique monitoring challenges before impacting your bottom line.

For example, automatically scaling applications based on CPU usage may prevent CPU usage from ever getting high by increasing the number of server instances where your application resides. This will make your hosting bill go way up, so you'll

want a programmable APM tool that understands how best to automate resource allocation.

Request Rate

Pretty much every essential performance metric is impacted by increases and decreases in the traffic your application receives. Request rates also provide insights into spikes and inactivity and are useful for correlating to other application performance metrics, making this essential metric key to application success.

A busy API that suddenly gets no traffic at all, for example, could be really bad or simply help you understand the dynamics of how your application scales. The number of concurrent users is a slightly different but relative metric for your APM tool to track, as it provides context and correlates to other essential application metrics.

Application & Server CPU

A basic and critical performance metric, application and server CPU monitoring is an essential part of all monitoring tools. For maximum benefit, your APM tool needs to track per server usage, as well as an aggregate across all individually deployed instances of your application. Essential monitoring metrics work in concert to help your applications deliver a great user experience.

Application Availability

SLAs and monitoring application uptime are fundamental to business success, so measuring if your application is online and available is a key performance metric. For web and online applications, simply scheduling regular HTTP checks is the easiest way to monitor application availability with checks that look at response times, status codes, and even specific content on your web pages.

Garbage Collection

Applications written in .NET, C#, and other programming languages that use garbage collection often hide the root cause of performance problems. Garbage collection can actually cause processes to suspend, applications to virtually freeze and CPU usage to soar – unless monitored.

It's important that your APM solution has the capability to monitor the most popular languages using garbage collection – the Performance Counter of —% GC Time for .NET applications and JMX metrics for Java – in order to ensure optimal performance.

Tracing

Every organization is different, and the most useful APM solutions will support business transaction profiling, or tracing, to help analyze the flow of every user transaction. Full transaction tracing enables you to quickly isolate and address performance issues by tracking the user's journey through your infrastructure and identifying the exact line of code, database query or third-party integrations that negatively impact application performance – giving you the chance to resolve issues before they create a poor user experience.

Analytics and Reporting

Analytics and reporting are at the core of what makes APM data more useful for organizations, providing actionable insights to IT managers, engineers, and anyone else in the business or IT decision-making process. The growing number of remote workers has magnified the challenges IT organizations face and demonstrated to business leaders the importance of high-functioning IT resources to internal users and external customers.

IT organizations leverage analytics and reporting features to help drive business initiatives beyond the user experience, including cost reduction, resource planning, usage, allocation, and lifecycle management. APM analytics and reporting give business leaders real-time access to data that can significantly impact the profitability and impact of business decisions, making it essential for your APM solution of choice to have deep and wide capabilities.

As organizations embrace the importance of the user experience, APM solutions will need to evolve to include more capabilities that provide deep observability, real user monitoring, and other capabilities that impact the digital user experience. In the meantime, Gartner Research provides valuable user reviews of top APM solutions in the firm.

```
Epoch 1/5
1875/1875 [=====] - 198s 106ms/step - loss: 0.2493 - accuracy: 0.9501 - val_loss: 0.0901 - val_accuracy: 0.9732
Epoch 2/5
1875/1875 [=====] - 199s 106ms/step - loss: 0.0752 - accuracy: 0.9772 - val_loss: 0.0983 - val_accuracy: 0.9690
Epoch 3/5
1875/1875 [=====] - 196s 105ms/step - loss: 0.0541 - accuracy: 0.9834 - val_loss: 0.0880 - val_accuracy: 0.9770
Epoch 4/5
1875/1875 [=====] - 197s 105ms/step - loss: 0.0420 - accuracy: 0.9864 - val_loss: 0.0959 - val_accuracy: 0.9742
Epoch 5/5
1875/1875 [=====] - 194s 104ms/step - loss: 0.0345 - accuracy: 0.9886 - val_loss: 0.1096 - val_accuracy: 0.9725
```

Chapter 10

Advantages and Disadvantages

Advantages:

- More organized files
- Easier data retrieval
- Historical preservation
- Can be easier form of writing
- Verification methods

Disadvantages:

- Not always accurate
- Unique style of writing
- Spacing of letters or words
- Poor images of text
- Different languages
- Modern handwriting compared to historical

Chapter 11

Conclusion

Our project HANDWRITTEN DIGIT RECOGNITION deals with identifying the digits.

The main purpose of this project is to build an automatic handwritten digit recognition method for the recognition of handwritten digit strings.

In this project, different machine learning methods, which are SVM (Support Vector Machine), ANN (Artificial Neural Networks), and CNN (Convolutional Neural Networks) architectures are used to achieve high performance on the digit string recognition problem.

Chapter 12

Future Scope

The task of handwritten digit recognition, using a classifier, has great importance and use such as – online handwriting recognition on computer tablets, recognize zip codes on mail for postal mail sorting, processing bank check amounts, numeric entries in forms filled up by hand (for example - tax forms) and so on. Future scope of this system is we can improve this by implementing this as a hardware using sensors.

APPENDIX

Source Code :

[HDR cloud deployment.ipynb](#)

Github Link :

[IBM-Project-26449-1660026946](#)

Demo Link :

[https://youtu.be/E8cOsSK4Xys](#)