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# Knowledge Extraction in Digit Recognition Using MNIST Dataset:
## Evolution in Handwriting Analysis

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## ABSTRACT

In handwriting recognition, traditional systems have relied heavily on handcrafted features and a massive amount of prior data and knowledge. Deep learning techniques have been the focus of research in the field of handwriting digit recognition and have achieved breakthrough performance in the last few years for knowledge extraction and management. KM and knowledge pyramid helps the project with its relationship with big data and IoT. The layers were selected randomly by which the performance of all the cases was found different. Data layers of the knowledge pyramid are formed by the sensors and input devices, whereas knowledge layers are the result of knowledge extraction applied on data layers. The knowledge pyramid and KM helps in making the use of IoT and big data easily. In this manuscript, the knowledge management principles capture the handwritten gestures numerically and get it recognized correctly by the software. The application of AI and DNN has increased the acceptability significantly. The accuracy is better than other available software on the market.

## KEYWORDS

Convolutional Neural Network (CNN), Handwritten Digits Recognition, Hidden Layers, Machine Learning, MNIST Dataset

## INTRODUCTION

Handwriting recognition is a process, which has been a centre of attraction for analysts since 1998, with nearly all the calculations structured at a point. In this process, the error rate obtained by direct classifier was 12% in 1998, which gradually decreased to 0.23% in 2012 when applied by convolution nets. Nowadays, as there is a drastic increase in the amount of information, Researchers and AI specialists are trying their level best to create and approve solo learning strategies, for example, auto-encoders, profound learning models, etc.

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In this research work, a handwriting recognition framework is actualized with the celebrated MNIST informational index. This index is a well known dataset. It consists of a large database, which is required for training and assessment of various image processing systems. Machine learning is one of the fields where this data is regularly used in order to test and train various systems. By using KM and converting all the data achieved to knowledge it can help in solving many other problems.

Digit recognition system (DRS) is a subfield of image processing that is used to scan the image or documents with the help of the MNIST database or dataset. The main goal of this research work is to implement a project and discuss its accuracy which scans the image digits using basic image correlation, also known as matrix matching. The six cases performed different outputs as shown in subsequent sections, all the cases are different from each other which show different accuracy and different performances. Still, the rapid and high growth of the handwritten numerical data generated recently and rising availability of massive processing power urge for improvements in recognition accuracy and deserves much needed further investigation (Hamad, K. et al., 2016).

Convolutional neural networks (CNNs) are found to be very effective in recognizing the structure of handwritten digits/characters in many ways, which also helps in automatically finding distinct features. This scenario makes CNN the best available solution for solving handwritten digit recognition problems. We have introduced a suitable combination of learning parameters in designing a CNN that helps us achieve a new absolute record in classifying MNIST handwritten digits. Knowledge obtained can help in further training machines and making predictions and reducing computation required in understanding the whole image.

## Research Objective

Digit recognition systems are being used on a very large scale in today's world because the handwritten digits are not always in the correct size, shape or style. That's why, a lot of problems may occur to find the correct digit in the real world with the help of a machine (Dorosh, N. et al., 2020).

When we include ensemble architecture, it helps in increasing the network's recognition accuracy. So here, the objective is to accomplish comparable accuracy by using a pure CNN architecture without using ensemble architecture. As, ensemble architecture introduces computational cost and high testing complexity. Therefore, in order to acquire accuracy even better than ensemble architecture, we are trying CNN architecture, with additional bonus profit of reduced operational complexity and cost.

## Identification and Motivation of Issue

This research work gives us the motivation to create a model using CNN (Convolution Neural Network) that would be able to receive and identify digits in the form of images. Also, the goal of the program is to learn about CNN, and apply it to handwriting recognition systems (Dorosh, N. et al., 2020). The aim of this research paper is to find the accuracy of CNN to classify handwritten digits using multiple hidden layers.

Our motive in this research work is to explore the various design possibilities like kernel size, receptive field, and stride size, number of layers, padding and dilution for CNN-based handwritten digit recognition.

## Application of Handwriting Analysis

Handwritten digit recognition is one of the practically important issues in pattern recognition applications. Digits are used in different types of data like vehicle number plate, written data, meter reading etc. In the modern world digit recognition plays an important role in many user authentication applications. It can be used in vehicle number plate recognition which uses a number plate in order to identify the vehicle. This vehicle number plate recognition system is used in the area around top government offices like Parliament, Supreme Court etc.

Digit recognition can also be used in postal mail sorting, handwriting recognition, form data entry, historical document preservation in archaeology departments, old document automation in libraries

and banks. All these areas deal with large databases therefore demand high recognition accuracy, lesser computational complexity and consistent performance of the recognition system. In future, this study has major implications in hand written answers checking in examinations and human hand writing notifications. It can also be used to perform the predictive analysis of any terrorist messages after screening their content partially (Ahlawat, S. et al, 2020).

## Use of Machine Learning and AI In Hand Gesture Recognition

Gesture recognition is a means of human-machine interaction via body actions. The interaction of human and computer takes place through traditional input devices like mouse, keyboard etc. Hand gestures can act as a useful medium for the human-computer interaction and can make the interaction easier. Gestures vary from person to person in orientation as well as shape. Hence non-linearity exists here.

It has been proved in recent researches that Convolutional Neural Network (CNN) can be used for image representation and classification as CNN can learn complex and non-linear relationships among images. And also recently gesture recognition based on machine learning has been developed rapidly in human-computer interaction as a graphics processor unit (GPU) and artificial intelligence(AI) image processing has been introduced. Machine learning algorithms such as support vector machine (SVM), neural networks are widely used in gesture recognition(Islam, M. et al, 2019).

## Cyber Physical Systems For Hand-Writing Recognition and Their Accuracy

Digit recognition systems can also prove helpful for the visually impaired persons. The input to such a system is the pressure sensor data. This data is obtained from a sensor pad which has 256 capacitive pressure sensors. This system recognizes correctly the 2-D shape of a digit which is placed on the sensor pad. In the first step of the recognition process the Euler number is used to achieve a preliminary classification while in the second step fourth order central moment is applied to correctly recognize the input. Also, it can be seen that deep learning using Convolutional Neural Networks is becoming a popular technique for challenging computer vision applications. But deep learning's power consumption and bandwidth requirements limit its application in embedded and mobile systems with tight energy budgets. Bio-inspired Angle Sensitive Pixels(ASP), custom CMOS diffractive image sensors **(Paul, A. et al, 2012).**

## Knowledge Pyramid

The latest Knowledge Pyramid tries to set the knowledge hierarchy within the ambience of the true world. This Knowledge pyramid is inverted (if compared with the old knowledge pyramid). Here, there is more information than the data. Similarly more knowledge than information and more wisdom than knowledge.

The data layers of this pyramid are the results of sensors and input devices, whereas the knowledge layers are the result of knowledge extraction applied on data layers**.**

As per revised knowledge pyramid, the reality i.e. real world object, person or situation is in centre, accordingly the suitable data is collected through sensors or social media on which analysis has to be performed. After refining and preprocessing operations, information is obtained and through mining exercises, knowledge and through visualizations and graphical analysis, AI and ML applications, predictive models, wisdom is achieved. This wisdom is cream and can be used for individual to organizational learning for different purposes.

## Knowledge Management

Knowledge management is the technique or procedure that is used to capture, distribute and use knowledge in an efficient manner. It is an approach used in various disciplines making best use of KM to achieve organizational goals. Knowledge Management circumscribes psychology, epistemology, along

with cognitive science. Better understanding of Knowledge Management can increase throughput, innovation and can amplify what is known for both, an individual and organizational perspective**.**

In recent times, the ability to refine a significantly large volume of data, information and knowledge to gain computational and competitive advantage and the significance of raw data and text analytics to this effort is gaining strength.

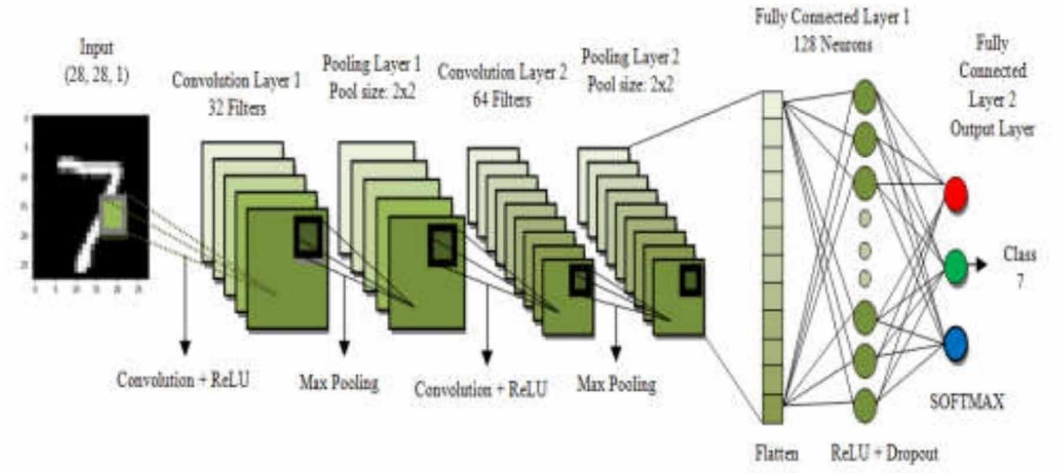
The basic components of a knowledge management strategy can be made useful for the management of pyramid activities with seven steps. The Knowledge Pyramid and KM helps in making the use of IOT and Big data easily, opening new opportunities for future work too **(Jennex, M.E., 2017).**

## LITERATURE SURVEY

CNN is playing a major role in image processing and it is being used in natural small localized areas. CNN is also used in Nano-technologies like classification (Dorosh, N. et al., 2020). There are many different other methods of image processing but CNN is best because of using Keras with the one or multiple layers, which provide multiple layers at a same time to detect fault and classification, that's why high accuracy takes place (Gulli, Antonio et a., 2020).

As shown in Figure-1 of CNN layers, there are seven layers that take place in CNN method in which five layers are followed by one layer as input and other one remaining layer works as an output layer which is used to recognize handwritten digits (as per Fig. 1).

**Figure 1. A Seven Layered Convolution Neural Network for Digit Recognition**




Being a problem for well-differentiated, multi-machine learning techniques such as regression, KNN, SVMs and Neural Networks have been investigated to obtain digits with high accuracy (as per Fig. 2) (Umapada Pal et al., 2012).

As with each existing research, KNN and SVM in the thinking class may cause scalability difficulties, and may be comparing the default of the second classifier.

**Figure 2. Error Rate of Different Classification Algorithms**

| Sr. No | Algorithms | Error Rate |
|---|---|---|
| 1 | Random Forest Classifier | 3.11% |
| 2 | K Nearest Neighbors | 3.33% |
| 3 | Supervised Vector Machine | 2.09% |
| 4 | CNN | 1.28% |

## Literature Survey

To build a strong Neural Network for this project, we should make use of Knowledge Management(KM). Knowledge Management (KM) involves several disciplines such as psychology, cognitive science etc. The objective of KM is to get insights of the data that we are using and also enable people and firms to cooperate, share, create, use and reuse knowledge. We have a very large amount of data present around us and all over the internet but to acquire knowledge from that data we require understanding of KM. Neural networks can be trained in a better way with the help of this knowledge (Jennex, M.E., 2017).

## Available Software and System For Hand Writing Recognition

### *OmniPage Ultimate*

This software is combined with artificial intelligence and neural networks. It provides the best results.It includes more than 120 language recognition which makes sure that the converted text is as accurate as possible. It has the latest OCR technology which picks up handwritten text very well. It easily allows to edit, share and search the PDF document. Free trial is also available from their official website. It reduces the amount of time spent in conversion of files, lower operational costs, and managing and sharing documents (Hamad, K. et al, 2016).

### *TopOCR*

It is one of the best handwriting recognition software. It is an optical character recognition application. It uses a sourced image captured by a scanner or digital camera and offers a dual pane format which displays the original image on the left and the conversion on the right. When the text is loaded on the right-side panel, one can read it and also correct any mistakes. After the completion the text can be saved to an array of different formats. It also has a text-to-speech engine. It is available in windows only. It supports 11 languages and also has a PDF export feature. It's free trial version is also available (Sahu, N. et al, 2017).

### *Simple OCR*

It is a freeware tool which recognizes approximately 120,000 words. It allows to add more words to it's dictionary. It has more than 97% accuracy. It even identifies formatted text and it is also possible to set it to ignore formatting. It is a speedy tool. It is available on desktop only. It is the popular freeware OCR software with hundreds of thousands of users worldwide. It is 100% free and not limited in any way. It uses the despeckle or noisy document feature if the handwriting which is being converted is messy. It can be set to decipher whole documents, portions, or multiple documents in batches (Hamad, K. et al, 2016).

### *Software For Handwriting Recognition & Transformation For Dark Data*

Since, everywhere in the globe, the govt. of many countries are facing pressure to be more active and transparent in their functioning so all the processes and happenings has to be brought before

all to make the system transparent. Specially the secret operations, foreign policies, heavy defense and healthcare purchases etc. are areas where the challenges are hidden transactions are in cursive handwriting, signatures and constrained and unconstrained handprints has to be understood.

These software are able to detect and curb the high instruction on image and noise levels to improve the accuracy and optimize the performances. Hand written data and fields available in free formats are challenges and contain structure in big data which plays a crucial role in big organizations.

(Ref. https://www.parascript.com/blog/best-icr-software-for-handwriting/)

Besides this, the professionals are also trying to design the software which can read and understand the complex and crypto coded human hand writing and so the terrorist messages can be understood and can be dealt with in advance.

## TOOLS AND TECHNIQUES USED

During the project we have used various tools and techniques to get best results. We used python as our base tool for implementation of the text recognition through CNN algorithm with 5 layers along with the MNIST dataset of numerals.

CNN algorithm is one of those algorithms which are being used prominently in the field of computer vision. It is widely used in the field of object detection and recognition in an image with a great efficiency as compared to other neural network algorithms.

This can be easily observed through "Figure 2" of this document.

### MNIST Dataset

MNIST stands for "Modified national institute of standards and technology". It is a large sized dataset widely used in the field of computer vision and convolutional neural networks(CNN). MNIST dataset is used for training and testing the systems which includes numerals as data. it holds binary images of handwritten digits.

This Dataset contains 60,000 images which is used for training and cross validation.

Additional 10,000 images are also present for testing purposes. All the images of dataset are into 28*28 sizes which makes the total dimension vector as 28*28=784(Sharma, I., et al., 2020).

As shown figure 3, all the digits are in 28*28 size which makes a unique and stable combination to recognize the handwritten digits.

### Applying Knowledge Pyramid

As per the current structure of knowledge pyramid, since it is inverted now so, the knowledge obtained from the data set will be raw and it will be refined from semi and fully structured data. To convert into wisdom, complex mathematical operation will be performed so that the knowledge obtained will be useful for individual and for organization and can be applied in designing much runtime software to check fraud and crime. The knowledge management will play a crucial role here.

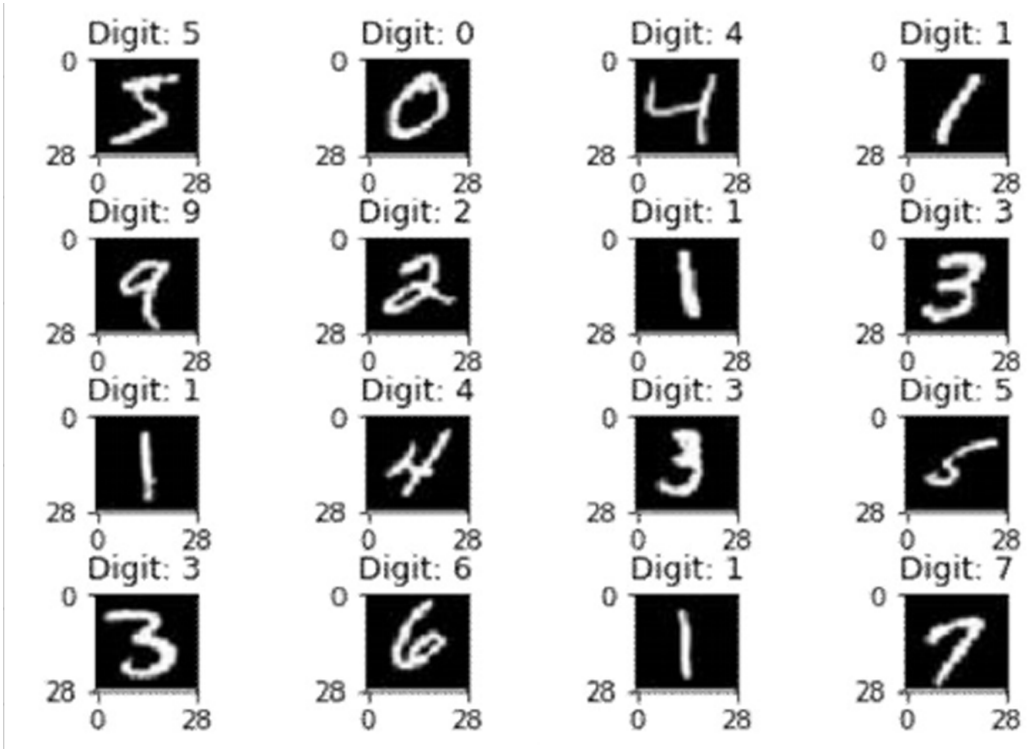
## METHODOLOGY IN OUR RESEARCH WORK

### Procedure

*Step 1:*

In this step, the handwritten document is scanned and digits are extracted from that document by the system. Then, the digits are arranged in a sequence of characters as a string. This input can serve as a prominent base for gathering various vital information derived from text extraction. The Devices used in this process can be a digital camera or a scanner.

**Figure 3. Samples of MNIST Dataset**




*Step 2:*

In this step, extracted image's digits gets resized to 28*28 dimension. This step is important because the dimensions of a handwritten document's data is specific to the writing sense and stroke style of the writer. So this step brings the input data to a fixed standard size. Also, the size of images in MNIST data set is with the dimensions of 28*28 which makes the comparison more convenient. This modified data further can be used as a base data for other comparisons. This data can pile up and contribute to a very large dataset i.e. Big Data. This big data can be used to give us vital information which can give useful outcomes on processing.

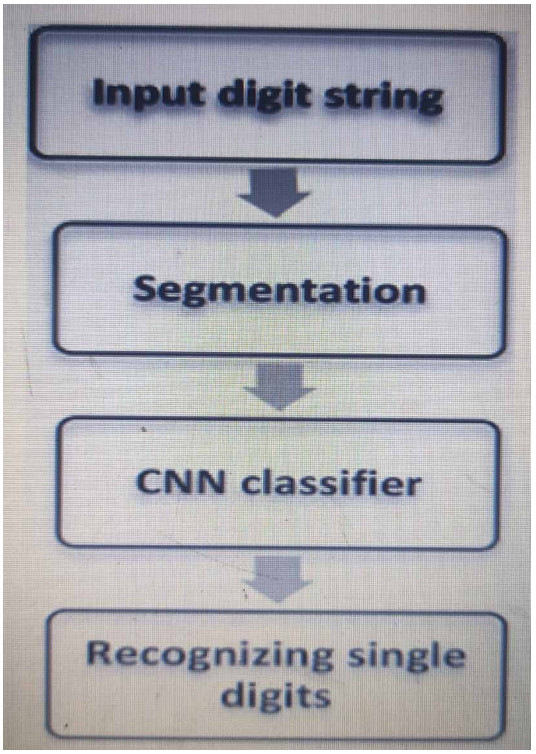
*Step 3:*

In this step, multiple layers of CNN are employed on the dataset which makes the digits more clear. Along with this, image processing techniques are employed to classify the input. This step brings the handwritten document closer to the digital document. After the processing the handwritten document becomes a more convenient source through which one can get some insight of the real data present in the handwritten document file and can provide knowledge which can be used for decision making and further uses.

*Step 4:*

In this step, handwritten digits are tested against the MNIST dataset. In this process, each numeral is checked against every numeral present in the dataset giving out accuracy percentage.This phase can be used to get and create wisdom for a particular individual.

**Figure 4. Simple Steps for Digits Recognition with MNIST**




## Discussion and Diagram

All the Necessary Diagrams to explain the functionality of our Research work are mentioned below ( Fig. 5 to Fig. 8)

Here, the activity diagram depicts how the procedure is undertaken by the digit recognition system. Firstly, after starting the process, we will upload the digit image. If the format of the image is not supported, then the system will show an error message and will take us back to the initial stage. But if the format of the image is supported, then the system will pass the subject image through the image acquisition stage, and then through the image preprocessing stage where the image is converted to the grayscale image, which is then converted to the binary format and after that, it is then normalized.

But, if the preprocessed image is not clear, then the system will again show an error message and will again take us back to the initial stage. But, if the preprocessed image is clear, then it will pass through various stages which include image segmentation, feature extraction and then the classification or recognition. Then after completing all the steps, the system will generate a process at the end.

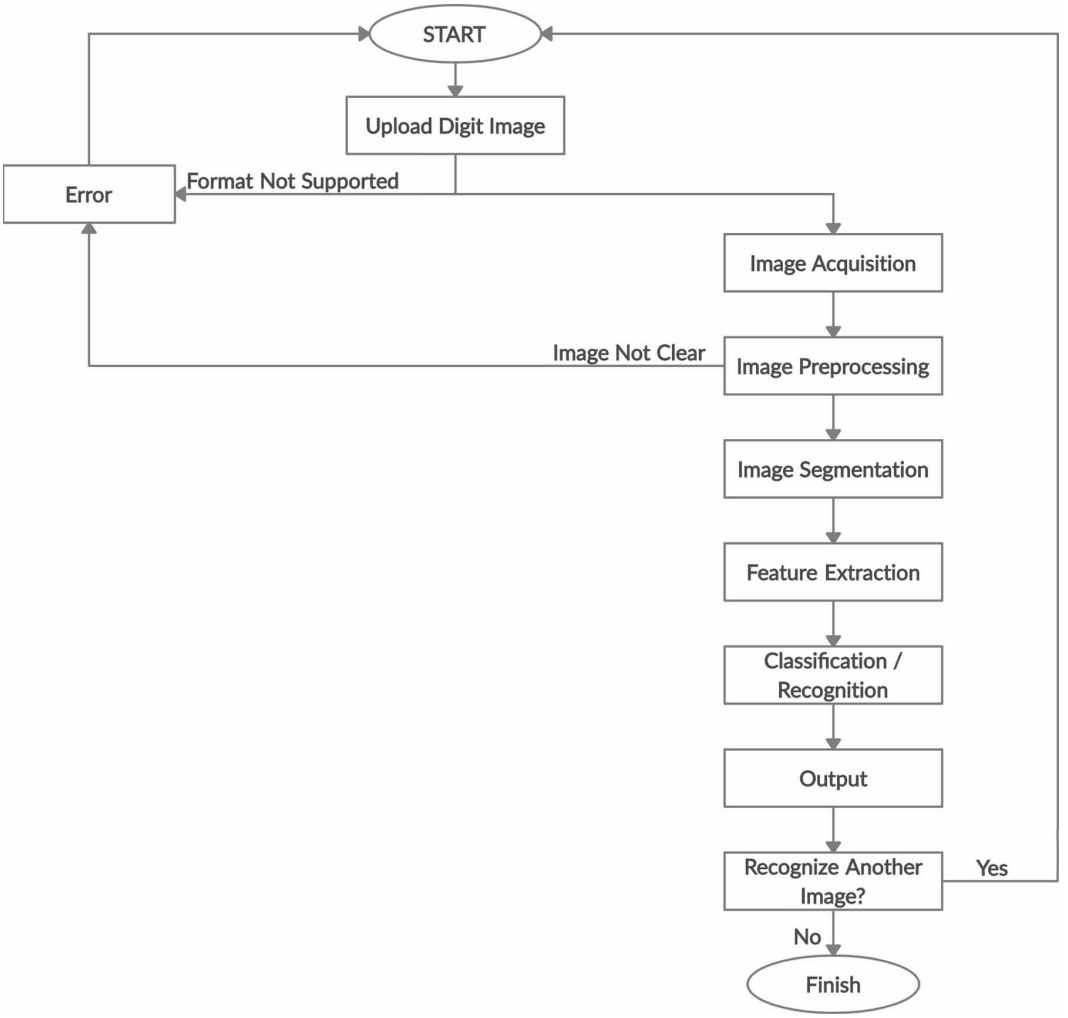
The network contains 784 neurons as input data which means the input layers consists of 28*28 pixels. on the grayscale the white pixel with the value of 0 and the black pixel with the value of 1. Hence, CNN models have 5 hidden layers ( as per Equations 1,2 and 3) (as per Fig. 9 and 10).

For the performance of cost function the equation is expressed as -

The 1st hidden layer is the decision layer responsible for extraction in input data. Addition to this, it contains many feature maps with readable headers and repair units.

The kernel size determines the filter area. The repair unit is used as a trigger function at the last of each case layer and layer that is fully connected to enlarge model performance. Next hidden layer pool layer 1. Reduces flow information to the display layer then decreases the no. of parameters again the complexity of the model. Various large pool lakes, central swimming, and L2 swimming.

**Figure 5. Activity Diagram for Digit Recognition Systems**




Here, maximum swimming used to decrease in size maps for each feature. Conversion layer 1 and 2 have the same function as output layer 1 and also no ponding layer 2.

To decrease the excess weight, stop the standard method is applied to a fully connected layer 1.It occasionally quenches specific neurons during training in order to improve network performance by providing more efficient mightily. The output of the layer network has 10 neurons and finds the digits from 0 - 9 output layers.

This is done by an algorithm known as gradient descent (as per Fig. 10).

As shown in figure the graphical representation of cost vs. weight .Where the gradient descent algorithm is unstable when training the very large data (as per Fig. 12).

## CNN Algorithm and It's 5 Layer Functioning

Convolutional Neural Network (CNN) is one of the main algorithms which is used to perform image recognition, object detection and object recognition from a given image. This algorithm is widely used in object detection and recognition as it has very good accuracy as compared to other neural networks.

**Figure 6. Flow Chart for Digit/Character Recognition System.**

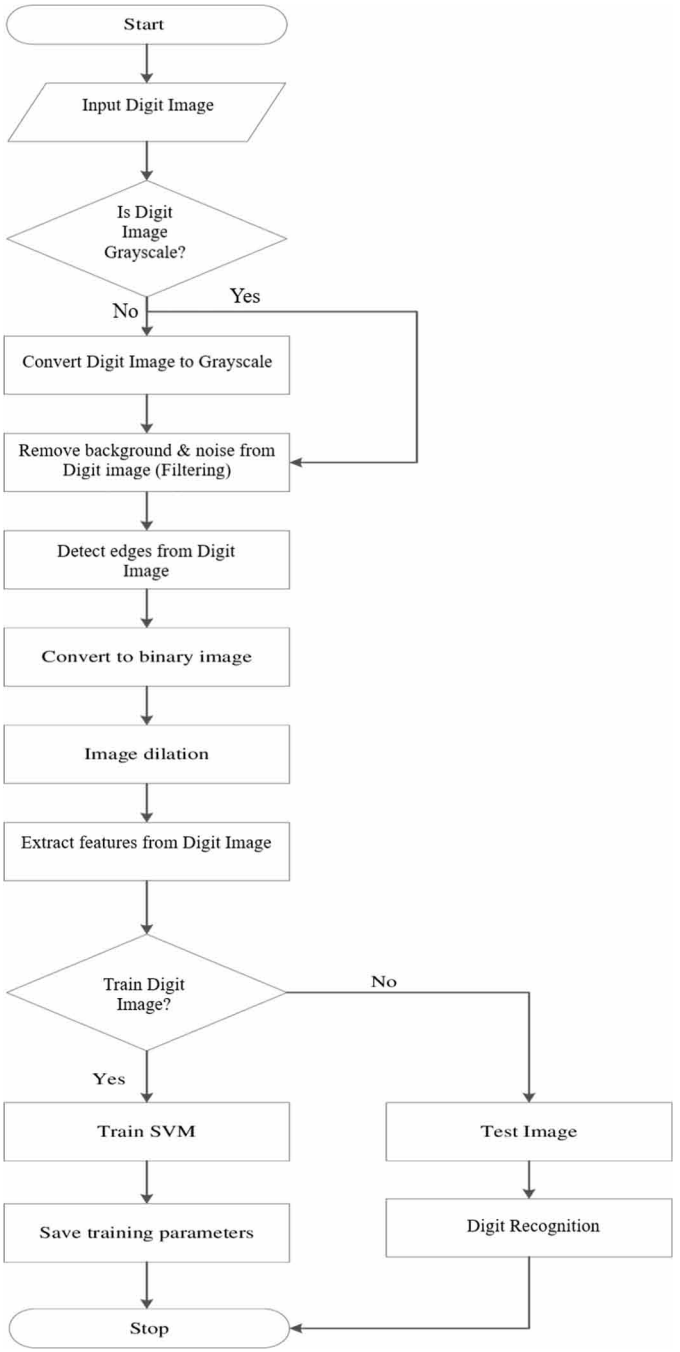


Figure 7. Sequence Diagram for Digit Recognition System.

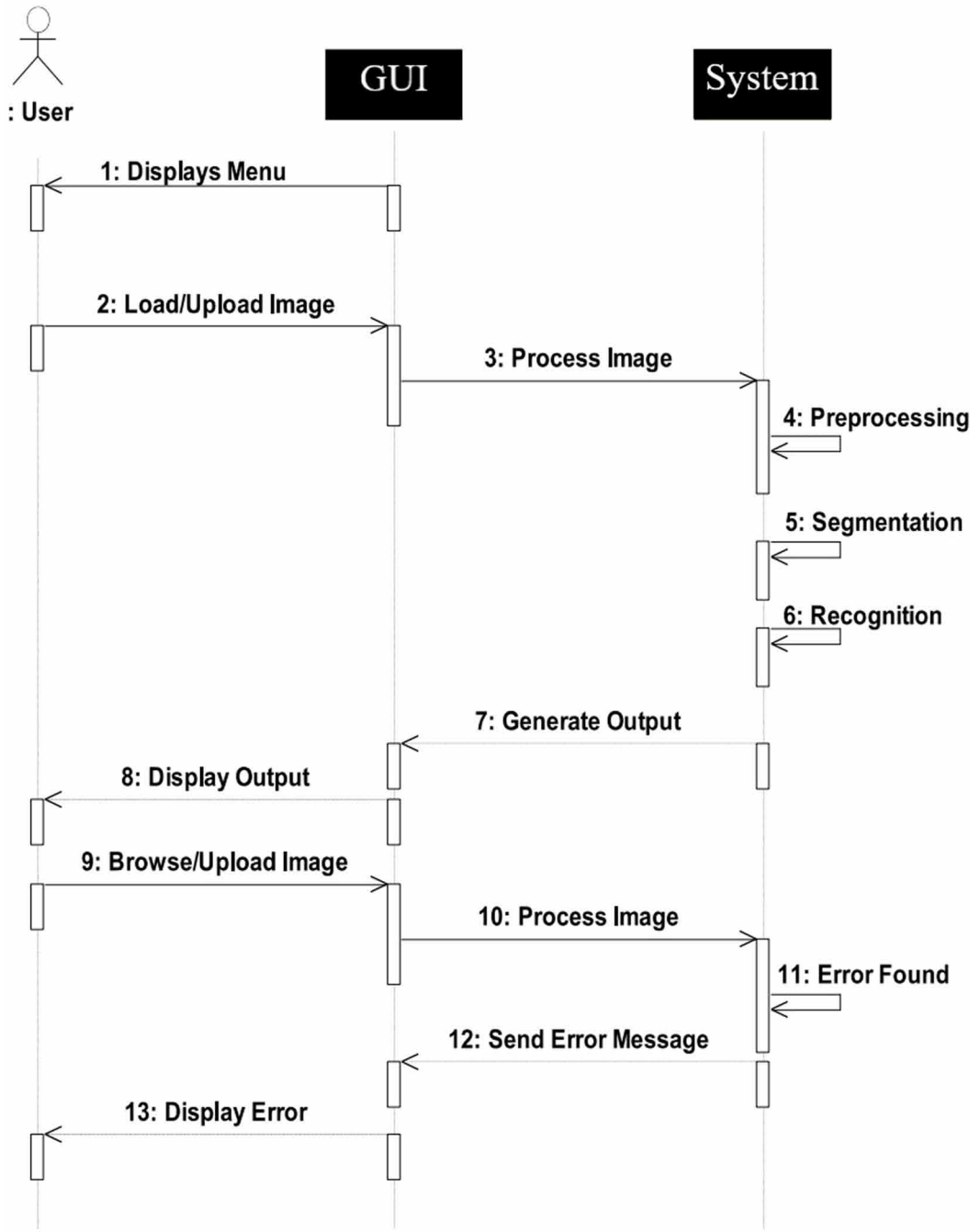
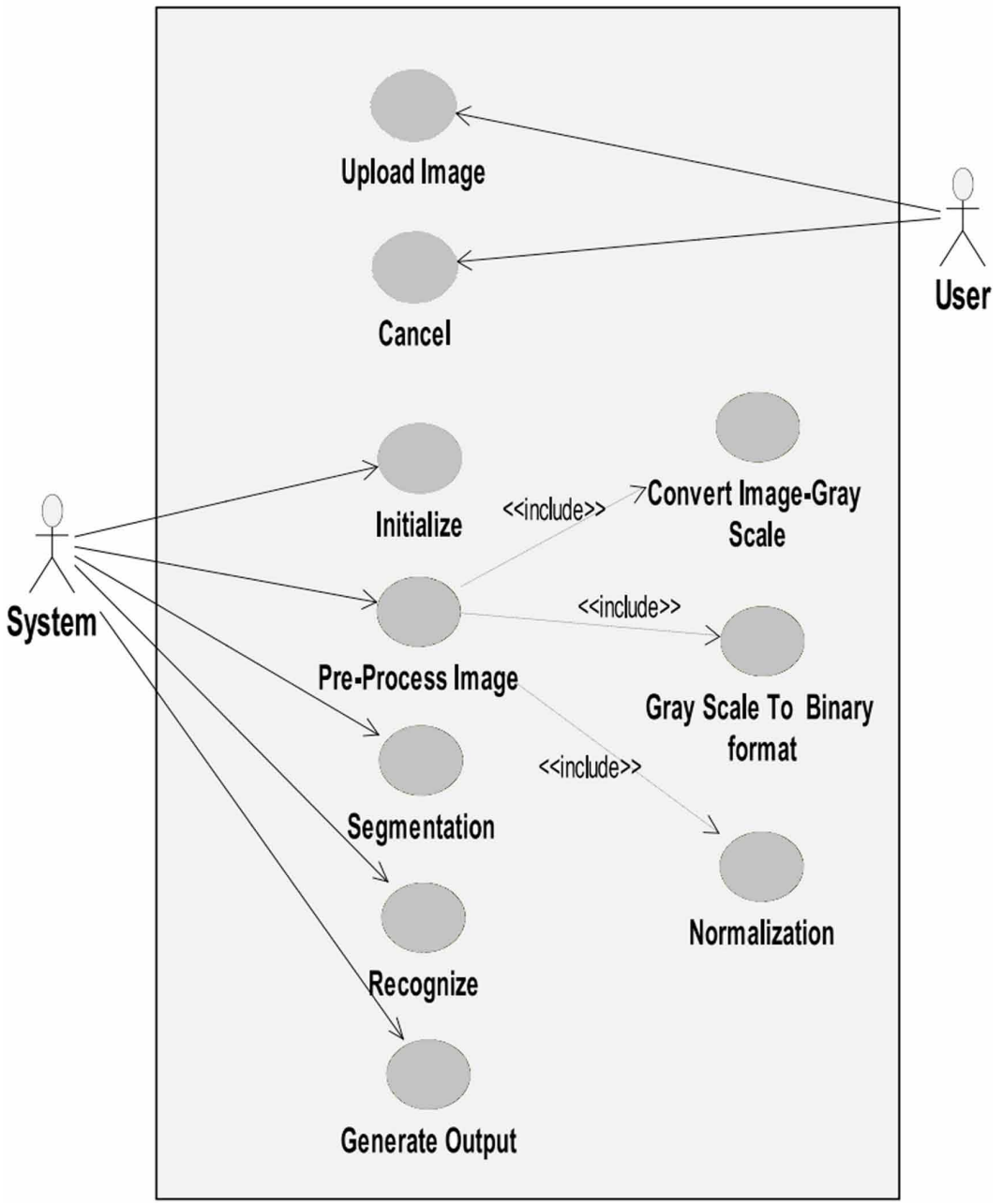


**Figure 8. Use Case Diagram for Digit Recognition System.**




*Types of Layers*

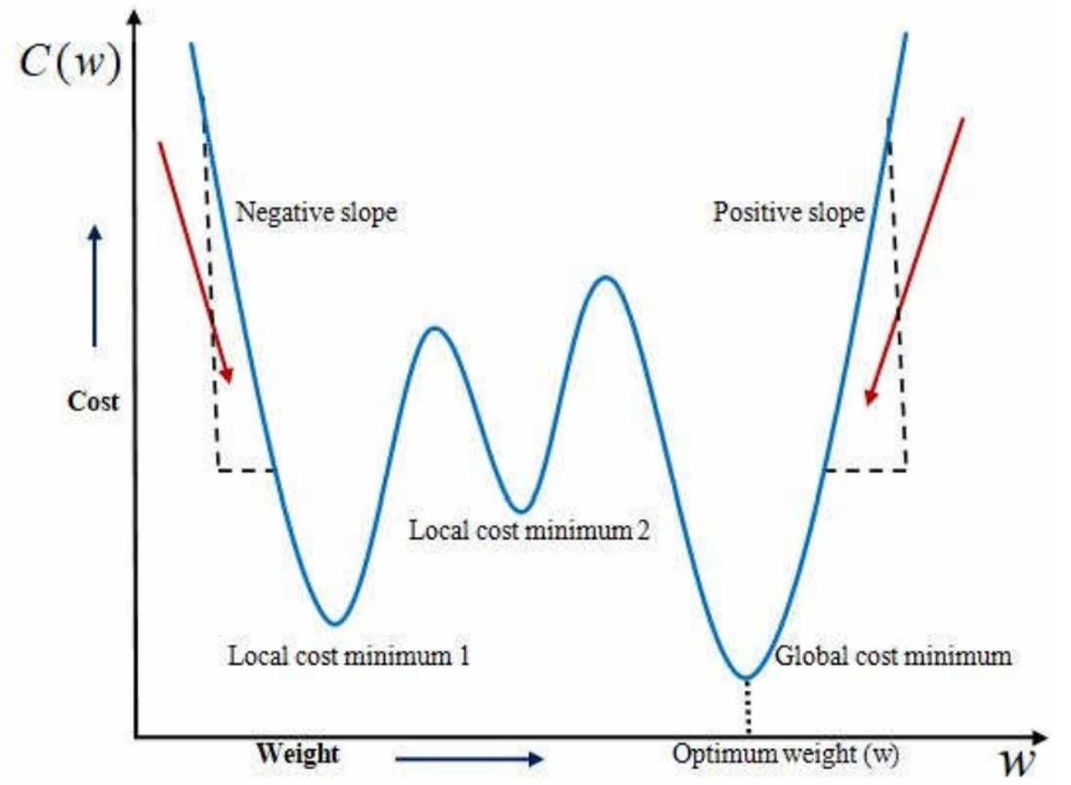
Let's understand the working of layers by taking an example of an image of dimension 32 x 32 x 3.

1. **Input Layer:**This layer stores the raw input of an image with dimension 32 x 32 x1.
2. **Convolution Layer:** This layer performs the computations to obtain the output volume. Output volume can be obtained by performing dot product between all filters and image patches.

Figure 9. The Mathematical Operations Occurring at the First and Second Hidden Layer

$$C(w,b) = \frac{1}{2n}\sum_{x}\left[ y(x) - a^2 \right]^2$$

Figure 10. The Mathematical Operations Occurring at the First and Second Hidden Layer




3. **Activation Function Layer:** This layer applies activation function to each and every element of the output of the second layer. Some most frequently used activation functions are Sigmoid, Tanh, RELU, Leaky RELU, etc. The volume does not change in this layer.
4. **Pool Layer:** Main function of this layer is to decrease the size of volume. Decreasing the volume makes the computation fast and reduces the memory. Pool layer also prevents over fitting. Two common types of pooling layers are max pooling and average pooling.
5. **Fully-Connected Layer:** This layer is a regular neural network layer. It takes input from the previous layer and outputs the class using an activation function and classifies the input image.

## IMPLEMENTATION AND RESULTS

In this, CNN is applied on MNIST dataset to handwritten digits recognition to observe the accuracies. The accuracy is validation using python training and accuracy (As per Table 1).

Figure 11. The Gradient Descent Method for Specific Neurons

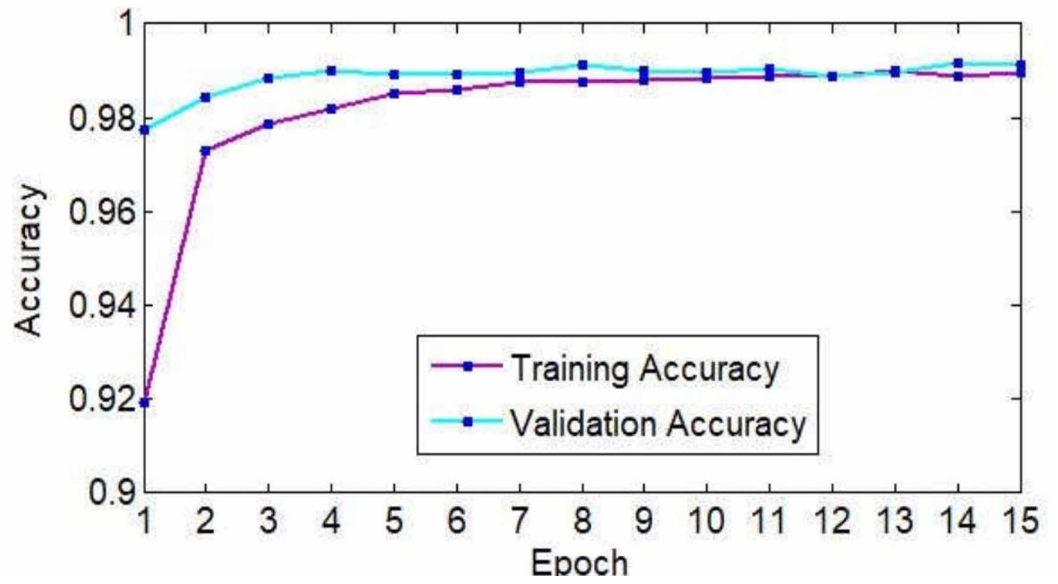
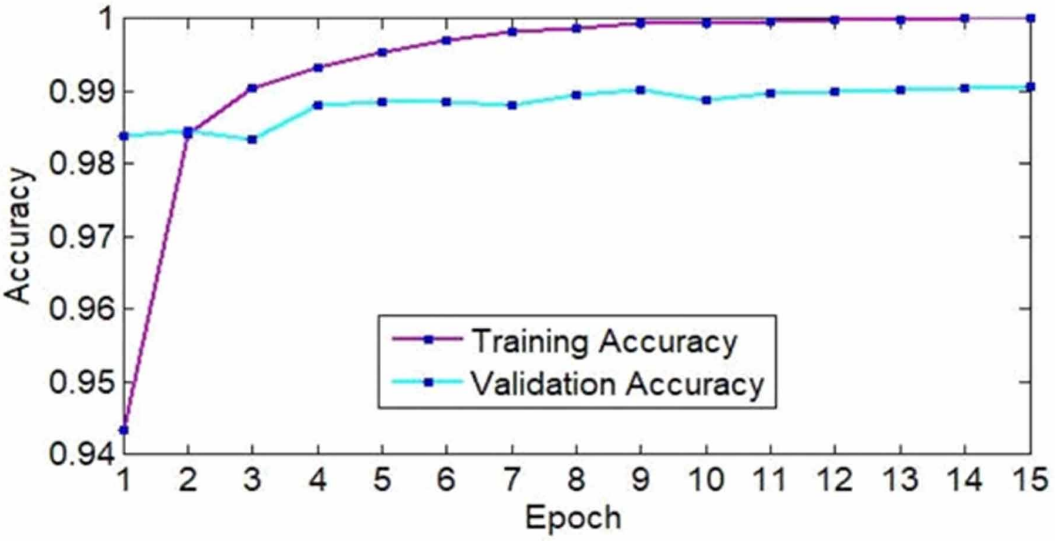



Figure 12. The Mathematical Operations Occurring at the Intermediate Hidden Layer




This Table shows the maximum and minimum training after using six different cases and this table also provides the validation accuracies of CNN.

Addition to this, in this table all six cases take place which provide the actual results to the handwritten digits with the help of MNIST dataset (as per Fig. 12 to Fig. 17).

After applying the MNIST recognition the output comes which contains 2 layers and 10 neurons and recognition the digits from 0 to 9.

- In this case where pooling 1 and convolution 2 are used .which is connected to each other during the recognition of digits or the testing .

**Figure 13. This figure show the observed accuracy for case one in which the first hidden layer is convolution layer one which use 32 filters at the time of recognition which are in the size of 3*3 pixels.**

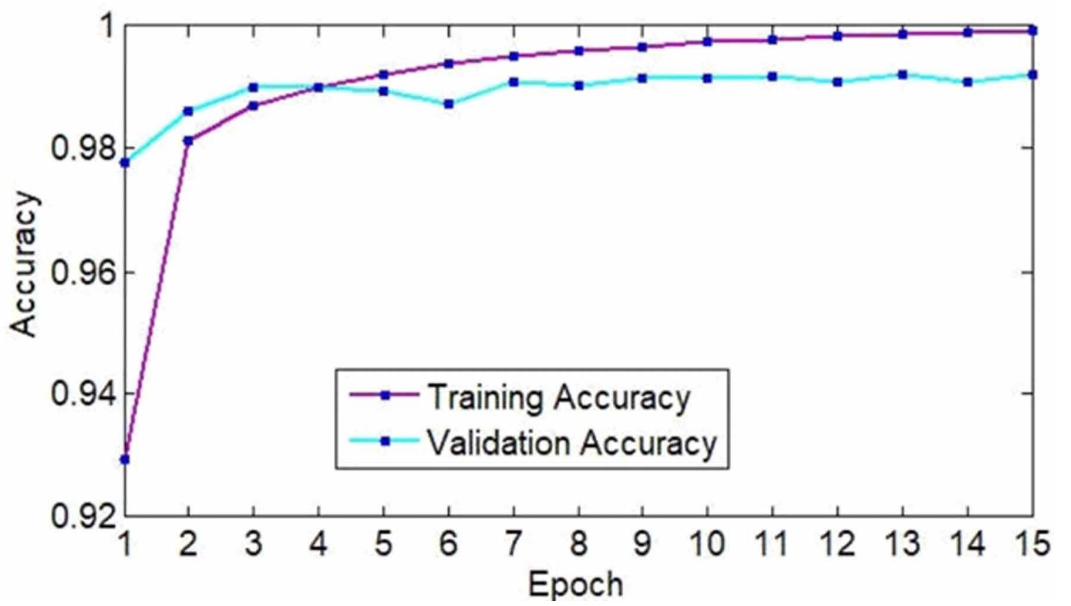
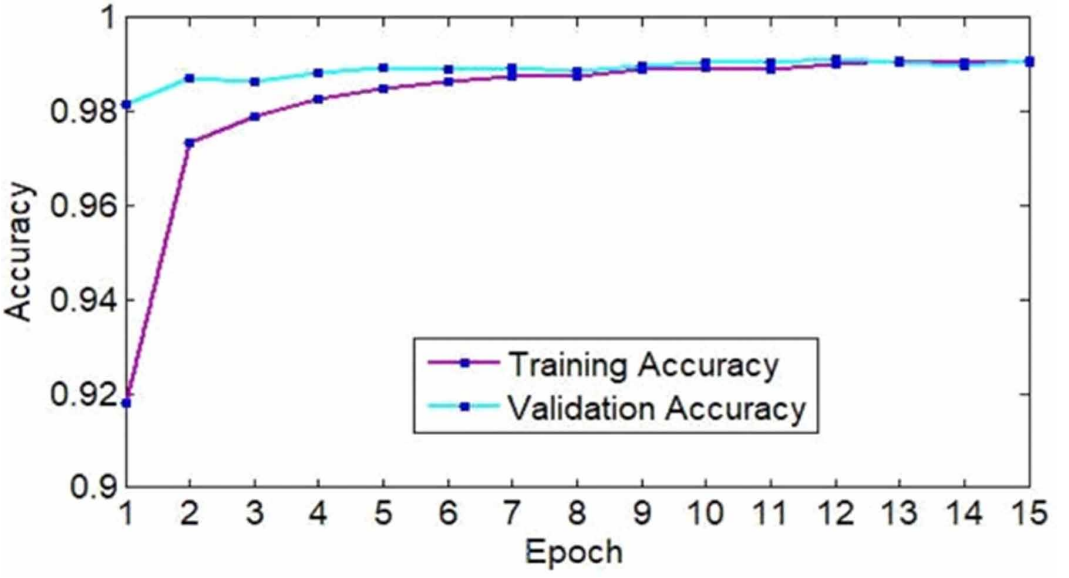



**Figure 14. This shows the accuracy of training and validation of the layers as shown.**




- In this case two convolutions are used by pooling layers, flatten layers and connected layers. In this case a dropout will be used and the validation of the accuracy of digits will take place.
- the minimum training accuracy is found approx. 98.11% at the epoch 12 and the maximum training accuracy is found approx. 97.18% at the epoch 14.

**Figure 15. Observed Accuracy for case 3**

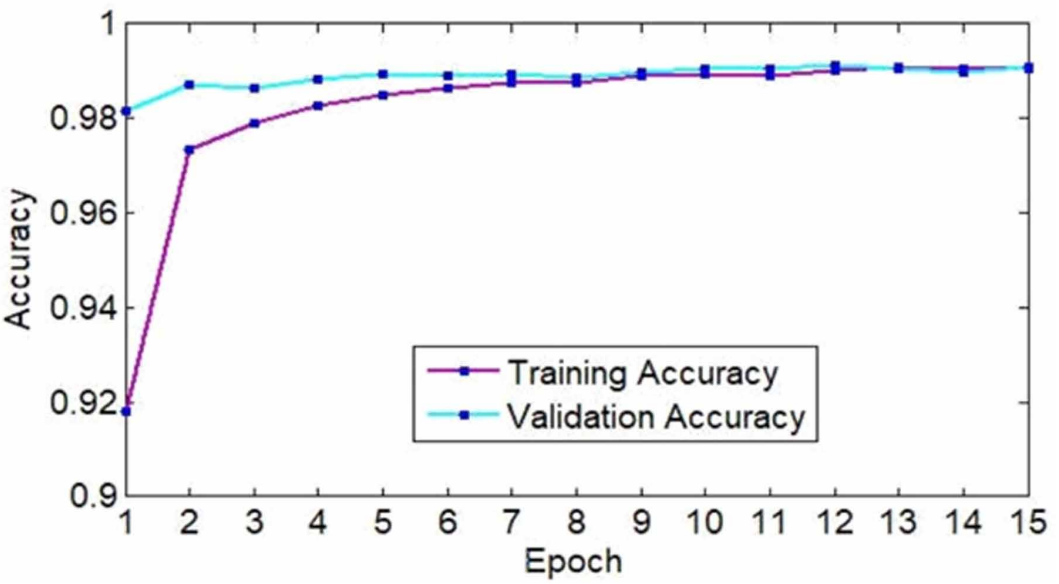



**Figure 16. Observed Accuracy for case 4**

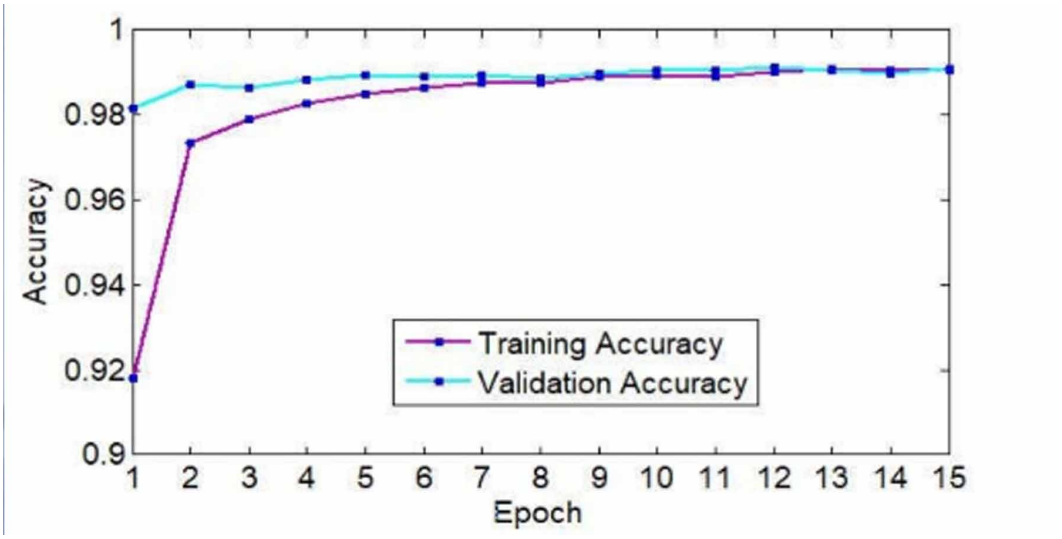
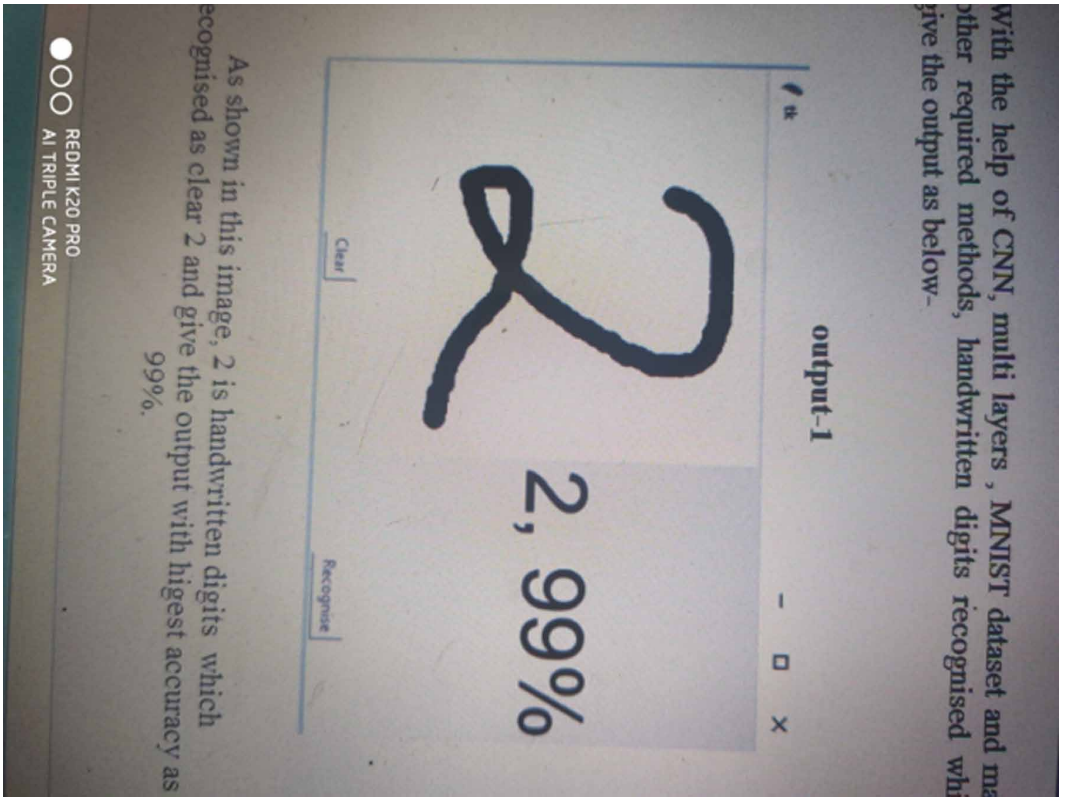



Figure 18. In this case, the total number of hidden layers which make the combination using pooling and convolutions layers also show the different output which affect the accuracy of the digit recognition.

- These six cases show the different output with different layers by which during the recognition of digits every layer affects the output of the recognition.
- From the above cases the maximum accuracy was found nearly 99.13% in the case 5 and the minimum accuracy was found approx. 96.55% in the case 8 during the digits recognition.

**Figure 17. Observed Accuracy for case 5**




Currently, the authors planned to build a multi-layer neural feed forward network using both Keras and - an interface for displaying machine learning algorithms in Python.

This network contains perceptions inside layers that absorb the input and transfer the information to the next part. The team planned on building a multifaceted CNN deposition and layers of maxpool and final exit layer by activmax activation 3,4.

## OUTPUT

With the help of CNN, multi layers, MNIST dataset and many other required methods, handwritten digits recognized which give the output as below(as per Fig. 18, 19 and 20)

Our model will pretend that the input image is unseen and new for the system and then our model will predict the integer that the image represents.

The ***load_image ()*** function will return the loaded image which will be ready for classification.

After loading the input image our system will force the image to be in grayscale format and then force the size to be of 28×28 pixels.

Next, we call the **predict classes ()** function to predict the digit that the image represents.

### *Output-1*

As shown in the above image, 2 is written on the input image. So our model has predicted the integer that the image represents with an accuracy of 99%.

**Figure 18. Figure shows the output that our model has accurately predicted the correct digit i.e 2 with accuracy of 99%**

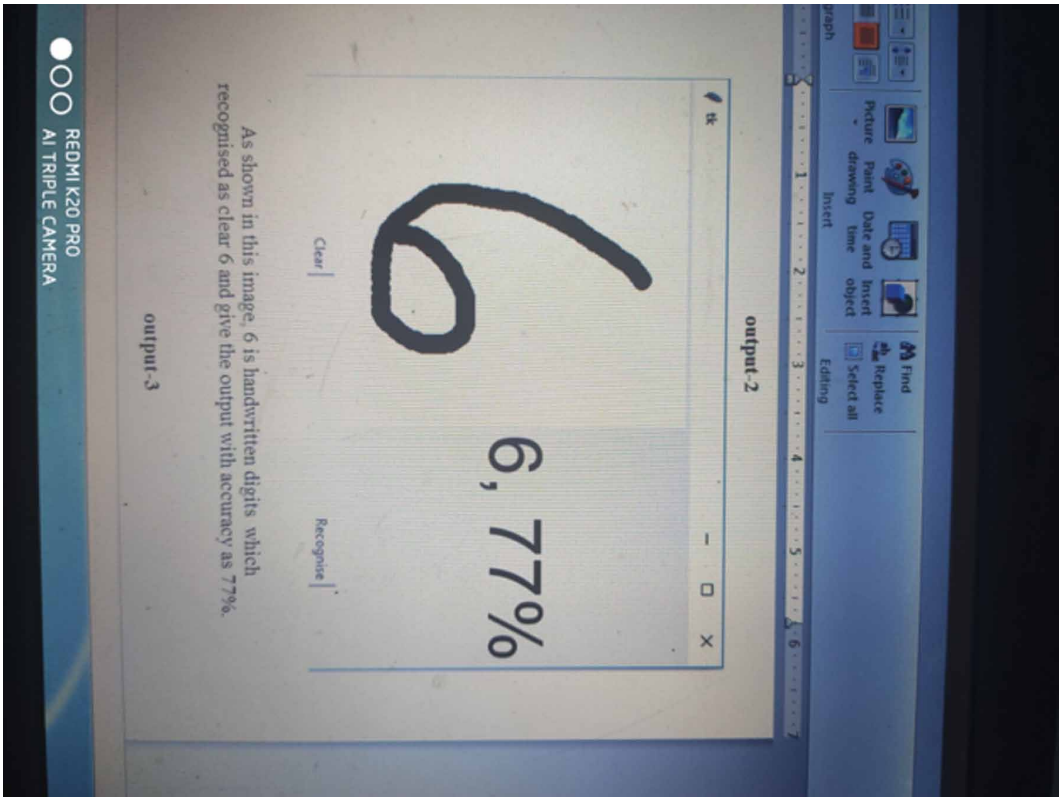



**Figure 19. Figure shows the output that our model has accurately predicted the correct digit i.e 6 with accuracy of 77%.**

### *Output-2*

As shown in the above image, 6 is written on the input image. So our model has predicted the integer that the image represents with an accuracy of 77%.

### *Output-3*

As shown in the above image, 5 is written on the input image. So our model has predicted the integer that the image represents with an accuracy of 70%.

## Accuracy

System's accuracy depends on its training and how good the handwriting of the sample is and how easy it is to differentiate each word from each other. Some digits are quite similar to each other like 1 and 7, 6 and 8, 3 and 8, 9 and 0, which is quite confusing for computers and proves to be a high hurdle sometimes and may even reduce the accuracy of the system.

It may also be possible that the exactness among all perceptions in the exhibition was discovered to be 97.07% when the number was tested to be 6. In addition, the miss ratio in all our tests was roughly approx 0.049449. Also, the least testing miss ratio was around 0.21313 when the number was tested to be 1. The lowest miss ratio will provide CNN with better execution to accomplish good picture goals & commotion handling. Later on, we will try to watch the variety in the general grouping precision by fluctuating the quantity of cluster size and concealed layers. We can also improve the accuracy of our model by trying various methods like by Tuning Pixel Scaling, Tuning the Learning rate and tuning the Model depth.

## LIMITATIONS

The six cases performed different outputs as shown above; all the cases are different to each other which show different accuracy and different performance. The layers were selected randomly by which performance of all the cases are different.

**Figure 20. Figure shows the output that our model has accurately predicted the correct digit i.e 5 with accuracy of 70%.**

| HR | HS | HT | HU | HV | HW | HX | HY | HZ | IA | IB | IC | ID | IE | IF | IG | IH | II | IJ | IK | IL | IM | IN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pixel225 | pixel226 | pixel227 | pixel228 | pixel229 | pixel230 | pixel231 | pixel232 | pixel233 | pixel234 | pixel235 | pixel236 | pixel237 | pixel238 | pixel239 | pixel240 | pixel241 | pixel242 | pixel243 | pixel244 | pixel245 | pixel246 | pixel247 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 66 | 231 | 253 | 253 | 253 | 108 | 40 | 40 | 115 | 244 | 253 | 253 | 134 | 3 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 85 | 168 | 237 | 252 | 250 | 250 | 250 | 250 | 252 | 250 | 250 | 250 | 250 | 252 | 250 | 209 | 56 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 57 | 236 | 181 | 35 | 0 | 0 | 0 | 0 | 12 | 207 | 13 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 149 | 207 | 58 | 116 | 227 | 254 | 253 | 253 | 209 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 47 | 226 | 253 | 193 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 118 | 253 | 250 | 241 | 254 | 253 | 253 | 253 | 223 | 215 | 169 | 50 | 2 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 95 | 251 | 251 | 251 | 120 | 0 | 175 | 251 | 251 | 251 | 231 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 78 | 253 | 253 | 48 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 124 | 244 | 251 | 235 | 188 | 253 | 251 | 251 | 235 | 188 | 213 | 251 | 251 | 244 | 83 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 33 | 170 | 253 | 120 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 44 | 241 | 253 | 242 | 233 | 233 | 192 | 133 | 50 | 12 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 6 | 110 | 148 | 186 | 116 | 126 | 82 | 21 | 5 | 11 | 74 | 249 | 232 | 32 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 93 | 253 | 253 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 72 | 247 | 209 | 14 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 255 | 255 | 255 | 255 | 255 | 191 | 128 | 255 | 255 | 255 | 255 | 255 | 255 | 128 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 255 | 255 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 191 | 255 | 128 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 127 | 252 | 252 | 253 | 252 | 252 | 252 | 208 | 253 | 252 | 252 | 252 | 252 | 253 | 63 | 0 | 0 |
| 0 | 0 | 0 | 18 | 253 | 114 | 12 | 0 | 0 | 0 | 0 | 0 | 101 | 253 | 158 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 78 | 253 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 57 | 141 | 253 | 254 | 253 | 254 | 253 | 254 | 253 | 254 | 139 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 21 | 254 | 253 | 142 | 0 | 0 | 0 | 0 | 41 | 234 | 253 | 193 | 51 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 60 | 161 | 246 | 254 | 254 | 254 | 254 | 254 | 247 | 252 | 61 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 60 | 254 | 254 | 23 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 162 | 253 | 253 | 253 | 95 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 55 | 252 | 254 | 254 | 254 | 254 | 254 | 187 | 151 | 44 | 19 |
| 0 | 0 | 0 | 0 | 0 | 191 | 255 | 255 | 255 | 255 | 255 | 255 | 255 | 255 | 255 | 255 | 255 | 255 | 128 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15 | 231 | 113 | 0 | 0 | 0 | 31 | 245 | 159 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 85 | 243 | 118 | 2 | 0 | 0 | 0 | 3 | 202 | 253 | 253 | 37 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 114 | 169 | 168 | 197 | 251 | 253 | 251 | 253 | 251 | 253 | 251 | 225 | 56 | 0 |

The maximum and minimum accuracy was observed with different cases with the help of different algorithms and different methods with MNIST dataset. Data to knowledge conversion requires much more computational power than just working on data, increasing system requirements of the project. KM is different from working on data only, hence, much more complex and requires higher skill.

Although the system achieves almost perfect accuracy, it can't reach the 100% accuracy mark. It's computational cost and testing complexity may be low compared to ensemble architecture, it is still not trivial. Some digits are quite similar to each other like 1 and 7, 6 and 8, 3 and 8, 9 and 0, which is quite confusing for computers and proves to be a high hurdle sometimes and may even reduce the accuracy of the system. KM helps in understanding data and making predictions which helps a lot but it isn't still 100% accurate or totally safe for public use like traffic fines. For KM large amounts of data are required to train the machine and improve accuracy by reducing errors, so although the machine starts with low accuracy, it starts to chase 100% accuracy as data received increases.

Humans have different handwritings and some are not quite understandable or distinguishable even for humans, these types of cases prove to be a challenge for the system. System's accuracy depends on its training and how good the handwriting of the sample is and how easy it is to differentiate each word from each other. The system doesn't have capability to identify its errors and notify users or correct them.

## RECOMMENDATION AND NOVELTY

### Recommendation

There are multiple methods that can help us in recognizing digits, for example DNN (Deep Neural Network), DBF (Deep Belief Network), CNN (Convolution Neural Network), etc.. In this research paper, we combined CNN with MNIST dataset which provided higher accuracy and a clear image with high performance. In order to enhance the performance of Digit Recognition System, we tested various versions of this network in order to avoid costly feature extraction and complex digit image processing. We can also use data and knowledge for future research. IoT and Big data are big customers for the knowledge attained by our project. This knowledge can also help in training neural networks and AIs. Also, with the help of this research work, we left behind the traditional recognition system which was quite a complex ensemble approach. Still the poor hand writing, cursive letters and intentionally done bad hand writing is a great challenge in this domain. Sufficient knowledge extraction to convert into wisdom is difficult for current workers of this area.

### Novelty

The capability of this system in thoroughly investigating different parameters and objectives of CNN architecture that helps us in providing best accuracy in recognition for the combined dataset. The different cases were tested with the help of different algorithms and maximum & minimum accuracy were noted. The maximum accuracy was observed as 99.13% and the minimum accuracy was observed as 92.42%. This digit recognition system provided higher accuracy and it will definitely help expediting all large-scale exhibition systems.

## FUTURE RESEARCH DIRECTIONS

Research can be performed in various architectures of Convolutional Neural Network (CNN). Also, investigation of domain specific recognition can be performed. With the help of different algorithms, we can optimize the training parameters like number of layers, kernel sizes of filters, learning, etc. The algorithm proposed in this research paper can be modified further to improve the minimum or maximum accuracy of recognition.

The algorithm we applied in the recognition of handwritten digits, can also be applied further for the recognition of handwritten characters. Also, the proposed algorithm should be applied on large databases in order to determine the efficiency of the system developed.

The Knowledge Pyramid and KM helps in making the use of IOT and Big data easily, opening new opportunities for future work too. Advancements in related technologies opens many ways to modify and improve the workings of this project. The data and Knowledge extracted by this project is extremely precious and flexible for future researchers. With the IOT machines can be trained to not require human interaction at all like automatic traffic fining through traffic cameras. Accuracy of the project is yet to achieve flat out accuracy which can be a great topic of research (Jennex, M.E., 2017).

The proposed algorithm can be modified further for the recognition of broken characters or digits. This kind of recognition system is really important as this can help us in various fields like forensics, reading postal addresses, forms filled by candidates, bank check amounts. Also, with the help of machine learning, the system will be able to produce precise and accurate outcomes.

## CONCLUSION

In this research paper we have implemented a CNN algorithm with 5 layers in order to make digit recognition in handwritten documents. To make it happen we have used MNIST dataset which consist of more than 60,000 images for training and additional 10,000 images for testing purposes.

While researching, we found out that this CNN approach is much better than "Random Forest classifier", "K nearest neighbors" and "supervised vector machine" with utmost 1.28 error rate. Also, it gave better results because of use of multiple layers and keras which helped in the reduction of error in classification.

This system is very helpful for solving real time problems such as the problem of faulty written cheques in banking documents, Forensic etc. Also, by employing the same strategy with alphabets we may use it as a full-fledged similarity index checker of handwritten documents along with their digital conversion.

This technique is also helpful for visually impaired people, as that digital document can be further translated to an audio file.

Knowledge attained through this project not only helps in automating other projects it also helps with Big data and IOT. AI and Neural Network will be specially helped by this. Compatibility of the project with knowledge based technologies is really high due to its nature of data based project. It has really good data for big data operations.

KM is different from working on data only, hence, much more complex and requires higher skill but as we are moving towards more advanced times and researching better and advanced technologies, this will be really impactful on society.

While working on this we found out that our technique still has some weak areas, for example sometimes a fluent stroke of digit '3' may appear similar to digit '8' and same with the '6' and '0', '7' and '1'. This could be a good replacement of traditional OCR technique. Although we received exceptionally good results but still we have approx. 1.28 error rate.

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## APPENDIX

As it is already discussed, each image is of 28X28 dimension which gives 784 entries corresponding to image and pixel intensity.
In the dataset, the first column, called "label", is the digit that was drawn by the user. The rest of the columns contain the pixel-values of the associated image.
Tabular Data set, Sample Data Set is given as per Image 22.

**Figure 21. MNIST dataset for testing**

| HR | HS | HT | HU | HV | HW | HX | HY | HZ | IA | IB | IC | ID | IE | IF | IG | IH | II | IJ | IK | IL | IM | IN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pixel225 | pixel226 | pixel227 | pixel228 | pixel229 | pixel230 | pixel231 | pixel232 | pixel233 | pixel234 | pixel235 | pixel236 | pixel237 | pixel238 | pixel239 | pixel240 | pixel241 | pixel242 | pixel243 | pixel244 | pixel245 | pixel246 | pixel247 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 66 | 231 | 253 | 253 | 253 | 108 | 40 | 40 | 115 | 244 | 253 | 253 | 134 | 3 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 85 | 168 | 237 | 252 | 250 | 250 | 250 | 250 | 252 | 250 | 250 | 250 | 250 | 252 | 250 | 209 | 56 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 57 | 236 | 181 | 35 | 0 | 0 | 0 | 0 | 12 | 207 | 13 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 149 | 207 | 58 | 116 | 227 | 254 | 253 | 253 | 209 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 47 | 226 | 253 | 193 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 118 | 253 | 250 | 241 | 254 | 253 | 253 | 253 | 223 | 215 | 169 | 50 | 2 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 95 | 251 | 251 | 251 | 120 | 0 | 175 | 251 | 251 | 251 | 231 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 78 | 253 | 253 | 48 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 124 | 244 | 251 | 235 | 188 | 253 | 251 | 251 | 235 | 188 | 213 | 251 | 251 | 244 | 83 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 33 | 170 | 253 | 120 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 44 | 241 | 253 | 242 | 233 | 233 | 192 | 133 | 50 | 12 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 6 | 110 | 148 | 186 | 116 | 126 | 82 | 21 | 5 | 11 | 74 | 249 | 232 | 32 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 93 | 253 | 253 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 72 | 247 | 209 | 34 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 255 | 255 | 255 | 255 | 255 | 191 | 128 | 255 | 255 | 255 | 255 | 255 | 255 | 128 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 255 | 255 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 191 | 255 | 128 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 127 | 252 | 252 | 253 | 252 | 252 | 252 | 208 | 253 | 252 | 252 | 252 | 252 | 253 | 63 | 0 | 0 |
| 0 | 0 | 0 | 18 | 253 | 114 | 12 | 0 | 0 | 0 | 0 | 0 | 101 | 253 | 158 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 78 | 253 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 57 | 141 | 253 | 254 | 253 | 254 | 253 | 254 | 253 | 254 | 139 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 21 | 254 | 253 | 142 | 0 | 0 | 0 | 0 | 41 | 234 | 253 | 193 | 51 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 60 | 161 | 246 | 254 | 254 | 254 | 254 | 254 | 247 | 252 | 61 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 60 | 254 | 254 | 23 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 162 | 253 | 253 | 253 | 95 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 55 | 252 | 254 | 254 | 254 | 254 | 254 | 254 | 187 | 151 | 44 | 19 |
| 0 | 0 | 0 | 0 | 0 | 191 | 255 | 255 | 255 | 255 | 255 | 255 | 255 | 255 | 255 | 255 | 255 | 255 | 128 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15 | 231 | 113 | 0 | 0 | 0 | 31 | 245 | 159 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 85 | 243 | 118 | 2 | 0 | 0 | 0 | 3 | 202 | 253 | 253 | 37 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 114 | 169 | 168 | 197 | 251 | 253 | 251 | 253 | 251 | 253 | 251 | 225 | 56 | 0 |

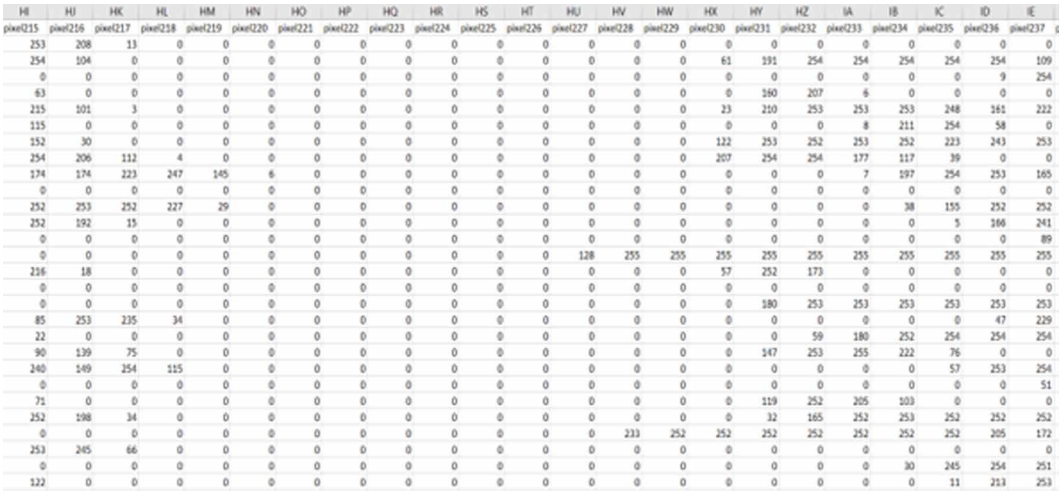
1. **Test Dataset:**

As we have already discussed, each image is of 28X28 dimension which gives 784 entries corresponding to image and pixel intensity. In this partial screenshot, some of the entries are visible in which, Vertical entries depict pixel intensities and Horizontal entries depict different images (As per Figure 21).

2. **Training Dataset:**

Sample of this data set is given as per Fig. 21
As we have already discussed, each image is of 28X28 dimension which gives 784 entries corresponding to image and pixel intensity. In this partial screenshot, some of the entries are visible in which, Vertical entries depict pixel intensities and Horizontal entries depict different images (As per Figure 22).

**Figure 22. MNIST dataset for training**



| HI | HJ | HK | HL | HM | HN | HO | HP | HQ | HR | HS | HT | HU | HV | HW | HX | HY | HZ | IA | IB | IC | ID | IE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pixel215 | pixel216 | pixel217 | pixel218 | pixel219 | pixel220 | pixel221 | pixel222 | pixel223 | pixel224 | pixel225 | pixel226 | pixel227 | pixel228 | pixel229 | pixel230 | pixel231 | pixel232 | pixel233 | pixel234 | pixel235 | pixel236 | pixel237 |
| 253 | 208 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 254 | 104 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 61 | 191 | 254 | 254 | 254 | 254 | 254 | 109 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 254 |
| 63 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 160 | 207 | 6 | 0 | 0 | 0 | 0 |
| 215 | 101 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 23 | 210 | 253 | 253 | 253 | 248 | 161 | 222 |
| 115 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 211 | 254 | 58 | 0 |
| 152 | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 122 | 253 | 252 | 253 | 252 | 223 | 243 | 253 |
| 254 | 206 | 112 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 207 | 254 | 254 | 177 | 117 | 39 | 0 | 0 |
| 174 | 174 | 223 | 247 | 145 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 197 | 254 | 253 | 165 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 252 | 253 | 252 | 227 | 29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 38 | 155 | 252 | 252 |
| 252 | 192 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 166 | 241 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 89 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 128 | 255 | 255 | 255 | 255 | 255 | 255 | 255 | 255 | 255 | 255 |
| 216 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 57 | 252 | 173 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 180 | 253 | 253 | 253 | 253 | 253 | 253 |
| 85 | 253 | 235 | 34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 47 | 229 |
| 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 59 | 180 | 252 | 254 | 254 | 254 |
| 90 | 139 | 75 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 147 | 253 | 255 | 222 | 76 | 0 | 0 |
| 240 | 149 | 254 | 115 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 57 | 253 | 254 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 51 |
| 71 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 119 | 252 | 205 | 103 | 0 | 0 | 0 |
| 252 | 198 | 34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 32 | 165 | 252 | 253 | 252 | 252 | 252 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 233 | 252 | 252 | 252 | 252 | 252 | 252 | 252 | 205 | 172 |
| 253 | 245 | 66 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 30 | 245 | 254 | 251 |
| 122 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 213 | 253 |

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