University of Manchester

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Final Year Project Report

Offline Handwriting Recognition using Neural Networks

Abbas Mustafaoglu
BSc Computer Science
Supervised by Dr Javier Navaridas
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Abstract

In the field of Artificial Intelligence, scientists have made many enhancements that helped a lot in the development of millions of smart devices. On the other hand, scientists brought a revolutionary change in the field of image processing and one of the biggest challenges in it is to identify documents in both printed as well as hand-written formats. One of the most widely used techniques for the validity of these types of documents is 'Character Recognition'. Optical Character Recognition (OCR) is an extensively employed method to transform the data of any form (handwritten or typed) into electronic format. This data can be used anywhere, in any field, like database, data analysis, etc. There are millions of techniques introduced now that can be used to recognize handwriting of any form and language. In the suggested system, we will be handling the issue of machine reading alphabetical figures. I tried developing such a system that corresponds to the ability of human beings to identify such characters or symbols. The objective is to make a system that can classify a given input correctly.

Acknowledgements

I wish to acknowledge my supervisor, who entirely guided me to start this project. Because of his kind and helpful supervision, my tasks became easier. Finally, I would like to give special thanks to my friends for their kind support and for never letting me to give up during work stress. Without their support, I could not have accomplished my task.

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1 Introduction

1.1 Introduction

Optical character recognition (OCR) is basically a software established for the translation of images that are captured with the help of a scanner and converted into text that is machine-editable, or to transform pictures of characters or symbols into a ASCII or Unicode standard format. [7] We will be building a character recognition system by employing JAVA in this particular project. In these times, there is a great requirement of this kind of a recognition system. In today's world, where our main focus or emphasis is on employing efficient and cost-effective methods, many people are now using technology to perform tasks that have previously been laborious as well as time consuming. The essence of our modern gadgets is their efficiency as well as their role in reducing labour intensity. Computers are now used as a more well ordered and well regulated alternative for taking and managing notes and for eradicating potential issues regarding clarity of handwriting or misplacing sheets of papers. Additional advantages of preferring technology involve the comfort of making such notes better at a later time, as well as reducing the wastage of physical space. As such, these electronic documents would be saved on drives. One more example regarding the benefits of the present technology is utilization of tablets for both professionals and students, conserving the need for several books and various important documents, once more preventing wastage of extra physical space and letting all necessary data be kept inside a small piece of equipment. Data management has gained considerable prominence in engineering executions. Given that the industry sector is consistently increasing throughout the past several decades, a significantly greater demand over automated machinery can be observed. These automated machinery depend heavily towards data management in the form of character identification utilities. A simple example for such can be comparing data management akin to organization of mails at a relevant distribution complex, under which all data is processed by OCR platforms. Then, decisions are undertaken through automated machinery arms to sort the correct mail towards the correct lane so that all mails are sorted in relevance to the areas they need be delivered.

Character identification is a procedure that allows potency of diverse functions featuring mitigated manual input, thus limiting bias and mitigating mistakes. Below are a couple of samples of various functions of its platform under numerous life necessities.

- Exploring data under diverse databanks.
- Searching images via search engines.
- Exploring patient history and medical record for academic purposes, including statistics
- Performing personal history searches to find individuals wanted by the legal authorities

- For assessment of documents for the purpose of proof reading.
- Self-navigation platforms.
- For turning text databases into an electronic format.
- Employing in postal or communicating services for sorting.

Therefore, it becomes obvious that OCR platforms are incredibly useful for such functions and could be manipulated more to be employed in various other tasks of daily life that can be personal as well as commercial in nature. This project will be concentrating on making a character recognition system by employing neural networks in JAVA.

1.2 Objective

The aims of this study are:

- To review literature offered of various sorts of alphabetical detection systems that can be deployed so that they can carry out hand-written CRS. The objective behind the review of literature is to figure out strategies that are most appropriate and are efficient in regards to consumed resources and time, therefore justifying their execution.
- To develop an algorithm for JAVA as well as a method in JAVA that acknowledges hand-written alphabetical symbols and works well in any given circumstance as well as laboratory environments and ideally in a comparatively low time-frame.
- To conduct assessments in effect for ascertaining the accuracy alongside performance of suggested designs and state additional studies that can be conducted so as to boost the accuracy and performance.
- To develop hand-written character recognition system in JAVA by utilizing an image processing tool box.
- To carry out tests on devised algorithms in JAVA Intellij IDEA on varied test pictures and consequently determine problems within the created algorithm. Assessment is to be based on success rate as well as time consumed and the algorithm's capability to functions in various circumstances.

1.3 Significance

This project holds great significance since it aims to assist in easing the conversion from physical to electronic type. Such capacity holds significant credibility and its advantages are limitless. This converts hand-written symbols from simple pictures to helpful information that may be utilized in computers. These hand-written or printed documents do not stay in a large pile of pages in the

workplace; instead they are now turned into digital information that can be easily interpreted by the computers. This also makes the process of searching these documents easy. Information is turned into digital format without any individual having to do the tedious work himself [7]. Physically written characters are the place of initiation. Numerical evaluations of enormous large data volumes hold considerable appeal for an organization, as correct comprehension as well as proper predictive analysis on data can scale down costs and expand revenues. OCR can aid the functions of daily life in multiple ways, while its benefit towards industrial executions has no limitations. A few prominent sectors of its implementation have been elaborated below. Invoice scanning, under which a considerable volume of invoices need to be processed, in effect to keep the databanks updated. This facilitates for a fast and safe payment data assessment and many others [2]. In the banking industry, it could be used for clearing cheques without requiring human input. In this case, ATM machines can accept cheques and process them with no use for human input. This method allows for the saving of previous time, which can be spent towards tasks and functions that can improve the business even further [4]. Libraries, under which enormous quantities of information can also be acquired in a matter of moments through inputting only select words. Data pertaining to reading interest can be acquired easily, instead of needing to waste considerable time finding the correct book with interesting contents to read [3]. Legal authorities, under which a suspected individual could be found with a few clicks, a policeman can go through the data bank of different law authorities, regardless of the data being old or new. In court procedures, significant volumes of paper are transferred into to electronic format, therefore safely preserving them for the future alongside for academic purposes, to be stored in an easily accessible databank [1]. Automobile license plate identification, under which speeding automobiles can be identified and automatically granted penalties and fines with no need to introduce human input, different examples include number plate recognition at parking locations, etc. Spam identification over internet based rostrums where look alike information is recognized and responsible individuals are removed. Captcha software is used in order to recognize human usage on internet platforms; it is utilized to save machines from security vulnerabilities and hacking, mitigating the possibility of human-induced faults. Proper identification of the code confirms human usage and subsequently allows accessibility to the web context. Various other necessary human interactions, including booking of hotels, emailing, banking, academic data, file hosting and flight itineraries, are all conducted over the website and generally are secured through passwords. Captcha software protects this important data from being hacked by viruses, through ensuring that they are available solely to humans [6]. In credit to OCR, the healthcare industry has utilized the technology to a successful extent, under which large amounts of patient histories are organized into digital type daily over a fast speed. Medical and administrative employees maintain hundreds of patients daily, with every patient having distinctive forms to be managed. OCR utilities aid the management of insurance and medical documents through making them easily available in the databank [9].

2 Background

Following the introduction of computerization, individuals have been inserting information into computers through the medium of a keyboard. However, this is not very efficient; inclination regarding automated data insertion functions has incremented. It is currently recognized as 'automatic identification', which is an all-encompassing term regarding a wide variety of present procedures. This includes radio frequency, magnetic ink, vision platforms, reading of bar codes, optical mark reading, magnetic stripe, etc. [5] Optical character recognition is also included in these. This is especially useful as well as convenient when data that is comprehendible by people as well as machines is needed and any other inputs cannot be presumed. This project concentrates mainly on the most basic form of the OCR process, that is, one that utilizes a very few processing initiatives or that can be easily replicated [9]. This is all to ensure best usage of time, as well as resources, hence establishing it as the most efficient procedure. The next diagram is provided to allow exhibition of the comprehension gained through the literature [10]. These could be split into two procedures available for identification of characters.

- Online Methods
- Offline Methods

Both procedures host their own advantages alongside disadvantages. This figure exhibits the different identification platforms that these procedures can be further split towards. Hand-written recognition or identification system is

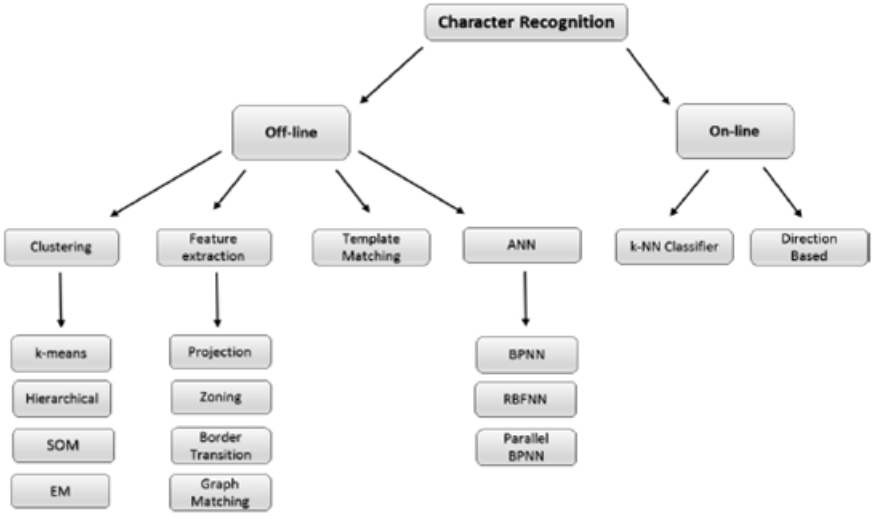

Figure 1: Classification Method

distinguished into four different stages; preprocessing, feature extraction, clas-

sification and post processing. The data is acquired from a tablet and it constitutes of strokes functions x.y organized over occurrence, time, force, and velocity. Further timing data alongside the structure of strokes elements leads to significant ease with online character identification compared to recognition of offline physical writing identification. Velocity and force data are convenient for personality analysis as well as identification of separate individuals, etc., but they do not come in handy towards character identification given the unique force alongside the speed of writing. Strokes are evaluated through following the course of the movement of the pencil amidst the up and down events. Such raw input strokes comprise of plenty of breaks and inconsistencies and enormous amount of data, which cannot be processed solely by human input. Therefore, preprocessing and pattern extraction are carried out against raw strokes.

2.1 Preprocessing

Preprocessing is called a primary step of character identification or recognition and it is normally known as crucial phase for a great recognition rate [11]. The chief aim of preprocessing in any system design is to normalize input and remove variations like noise, etc., because in the presence of these variations, recognition rate will lessen. For character recognition, system input of the preprocessing phase is raw characters and output is normalized noise free data. Several basic techniques used for preprocessing are normalization, filtering, skew detection, noise removal, slant correction, etc. If noise reduction is not performed at the time of preprocessing, that would lead to poor segmentation and finally recognition rate will be too low. Additionally, various preprocessing steps are carried out in the first stage in order to normalize the handwritten strokes/characters. These include noise removal as well as base estimation and diacritical marks [1]. In the Character Fetching phase, the handwriting is stored in the form of an array of pixels in a bitmap image format. The drawn character is of high resolution; it has to be first cropped, wherein the white space is removed and the input is fitted to the boundaries. Some authors executed segmenting through segmentation of the character over an extreme vertical node, appropriate with the character direction. However, histogram based segmentation is very easy to implement and it produces very good results. Characters have different heights and shapes. These can be segmented out by setting local maxima and local minima. These can be clustered out on the basis of similar local minima and maxima values.

2.2 Feature Extraction

The primary goal of the feature extraction phase is to extricate the pattern that is more appropriate for categorization. These features can be of different types, like horizontal features, vertical features, texture based features, etc. Identification of every segment depends on selection arc type, feature angle, relative position, length ratio and connection angle. Another way to find the feature is (according to biological visual perception) to extract the simple cells

and grow these cells on the basis of connected component concept. Some other useful features can be directional features, like size, shape, writing direction, slope, and chart and ending coordinates. The technique of feature extraction algorithm is evident from its designation. It includes an identification of characters or symbols on the basis of their features or aspects that are alike. This concept resembles humans in how they identify characters on the basis of their features or aspects [8]. The developer needs to inform the code regarding the specific significant features which are needed to be recognized through manual procedures. Some of such features could constitute characteristics, i.e. aspect ratio, number of strokes, ratio of pixels to right of vertical half or horizontal half point, distance from image centre, etc. All such various algorithms are utilized in character identification algorithm, inclusive of recognition of physical writing. The review of literature reading presents a study on character identification, it was obvious that little effort had been directed towards improvement of the features. The recognition process could be significantly improved by feature enhancement because it removes the misperception regarding characters that are near-identically shaped. This approach might provide the programmer additional control over the features utilized for recognition or identification. This technique takes longer to be conducted but gives accurate results.

2.3 Classification

In simple words, classification is defined as the process of assigning labels (categories, classes) to unseen observations (instances of data). In machine learning, this is done on the basis of training an algorithm on a set of available data. Classification is a supervised learning method, where a "teacher" assigns a label to every student in the class for a particular task. The label is a simple number that identifies the class of particular instance. It is usually represented as a nonnegative integer. There are many machine learning models that implement classification, these are known as classifiers. The aim of classifiers is to decide under the umbrella of feature-space in order to assign the accurate label to an incoming instance. In general, the decision boundary is a hypersurface that separates an N dimensional space into two partitions, itself being N−1-dimensional.

In unsupervised learning, network is self-learner because no conclusions are yielded towards input data vectors. The Self-Organizing Map, developed by Professor Kohonen, is a very useful model for many applications, especially character recognition.[7] It is related towards a viable class of networks for learning. No human involvement is needed during the entire process, i.e. learning as well as classification and it requires little information about the characteristics of the input vector. The main goal of an SOM is converting an inbound input pattern of random dimensions of 1-d or 2-d dimensional distinct maps, and performing this transformation in a topological order. In order to set up an SOM, we place neurons towards the nodes of both dimensional platform. In this project, we used a self-organizing map for classification purpose [7]. The detailed design approach is explained in next section.

3 Design and Implementation

Proposed Approach

Amidst the various recognition platforms accessible presently, it remains critical to choose the correct procedure on merits of the provided rate of success, consumed time, accuracy and effectiveness for a diverse span of executions. This should yield a more effective execution towards differentiation of the issues with which these frameworks are challenged. The suggested procedure or technique for handwritten alphabetical character identification is a self-organizing map (SOM) using artificial neural network [7]. This procedure is considered the fundamental issue for the duration of this research. OCR using SOM is the simplest as well as the most widely utilized. Because of the sort of data that is being evaluated, the SOM method is appropriate for this project. As discussed previously in this study, unsupervised learning is what this technique is based on, which means that no human intervention is involved during the learning process and forms their own classification of training data. Rudimentary procedures involved in the procedure are acquirement of data through appropriate optical scan equipment, filtration of noise or other unnecessary signals inside the data, teaching data towards image recognition, send that data as an input to the network then finally write the recognized letter in a text file as an output. Following the introduction of computerization, individuals have been inserting information into computers through the medium of a keyboard. However, this is not very efficient; inclination regarding automated data insertion functions has incremented. It is currently recognized as 'automatic identification', which is an all-encompassing term regarding a wide variety of present procedures. This includes radio frequency, magnetic ink, vision platforms, reading of bar codes, optical mark reading, magnetic stripe, etc. [5] Optical character recognition is also included in these. This is especially useful as well as convenient when data that is comprehensible by people as well as machines is needed and any other inputs cannot be presumed.

Self Organizing Map (Neural Network)

SOM, also known as self-organizing feature map,is an unsupervised learning style of AAN, which is used to produce a typically two dimensional input space towards training samples, titled 'map' [7]. This special type of neural network does not require a target output. Under SOM, the one or two-dimensional neurons are situated towards the lattice nodes. In the learning process, neurons are selectively adjusted in input pattern types. The locations of neurons are adjusted through such an effective method that an efficient coordinate framework for various input features is established through the lattice. A SOM is categorized through the development of an elaborated map on input patterns [7]. The fundamental objective of self-organization map is to change an inbound input pattern of random dimensions of 1-d or 2-d dimensional distinct map, and perform this transformation in a topological order. In order to set up SOM, we place neurons over the nodes of 1d or 2d platform. In this project we used a self-organizing map for classification purpose. [7]

Components of Self Organization Map

The some algorithm comprises of four essential steps:

Initialization
In this stage all weights (**wi's**) are stated using small arbitrary values.

Competition
Towards individual pattern of input, neurons process values for relevant function that provides the initial step for competition. The specific neuron which has smallest value is considered the victor.

Cooperation
The victor neuron discovers the spatial situation of excited neurons that lies in neighborhood so that it can create the cooperation among neighboring neurons.

Adaptation
In order to enhance the response of winning neuron, the stimulated neurons reduce their particular values so that weights are adjusted according to the arrangement of input lattice. The layered structure of SOM is shown in the diagram below:-

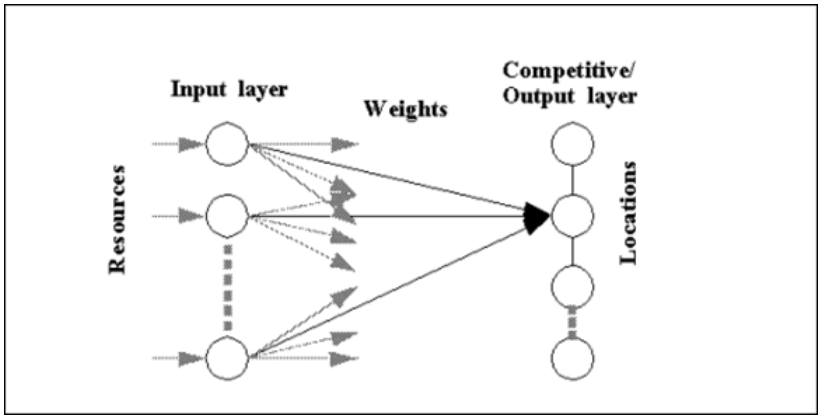

Figure 2: SOM Algorithm

Steps of the process
The proposed design was implemented in JAVA using image processing utility. The image was taken using the appropriate image acquirement tool present with the utility. The acquired image was transformed into a computer understandable format. Pre-processing is performed on the acquired image. After this step, the image becomes smooth and ready for processing. The image is converted into binary format for perfect segmentation. [9] Finally, the segmented image is sent at the input of the neural network for classification purpose. The elabo-

rated execution procedure has been elaborated further in the upcoming section. However, these phases have been elaborated in a more detailed style in the next diagram.

Algorithm of character identification includes the specific procedures:

- Initially, characters under research are chosen for the purpose of identification.
- Image is filtered for the purpose of refining.
- Binarization is performed using otsu method.
- Binary image is sending for segmentation purpose.
- SOM algorithm is applied and recognized letter from the output of KNN is written into the text file for display.

The administration of the effort towards the procedures elaborated prior in the OCR platform constituents was implemented in effect to establish effective identification of physical writing recognition. The execution has been elaborated further in the upcoming section. For all individual stages, alongside their integration with JAVA, had hosted multiple functions elaborated below.

- Pre-processing and Segmentation phase
- Feature Extraction phase
- Classification phase
- Post processing phase

1. **Pre-processing phase**
   This stage emphasizes transfer of the data from the actual text image towards either a bitmap or binary matrix type following its acquisition through a scanner. The acquired image was collected through a phone camera under the JPG image type. The background comprised of simple white paper, whereas the writer had been instructed to make writing identical to the conventional Times New Roman font. The image is provided below.

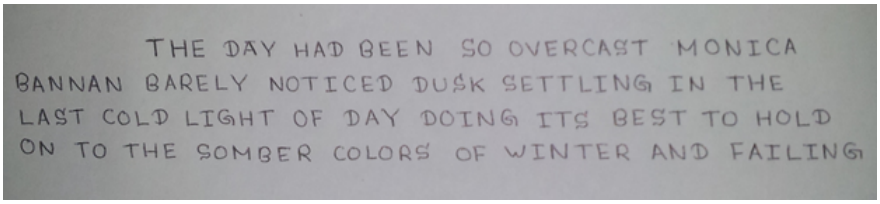

Figure 3: An example of an Acquired Image

In this phase, Gaussian kernel is applied to the image for smoothing. Then image resizing is performed. After resizing, median filter is applied to the image and the resultant image is as follows:

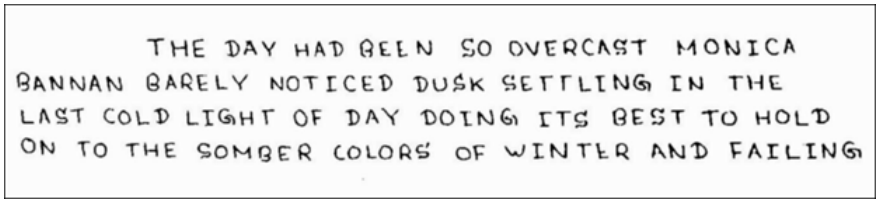

Figure 4: Filtered image

In effect to binarize the image, the Otsu's procedure was utilized, perhaps the most effective procedure. The algorithm considers that the image, which for the function of threshold is constituted with two pixel classes (e.g. back and foreground), subsequently processes the optimal threshold value so that these two classes can separate easily and their variance is minimal. It has two major advantages; speed (given that length array of 256 and histograms were utilized) and simplicity under the execution. To obtain a binary image, it initially has to be transferred onto grayscale format. By using the following method in JAVA **BufferedImagetoGrayScale (BufferedImage origin)**,the image is converted into grayscale. To binarize an image, we can set the threshold manually (for example, 120, etc.), but manual selection does not always give most effective conclusion (and it is not the speediest procedure). Otsu's procedure elaborates the binary value of threshold for the image. The method **private static int partialOtsuTreshold(BufferedImage original, int start_x, int end_x, int start_y, int end_y)** iterates by using all the possible threshold values and calculates a spread of pixels so that we get to know if either pixel falls in the back or foreground. The objective is figuring out the suitable threshold value, under which the agglomeration of fore and background pixel dissemination are minimal.

2. **Segmentation phase**

   The segmentation procedure divides the image into more comprehensive sections and acquires more relevant data. This procedure constitutes the fundamentals of the identification procedure given that effective segmentation influences the identification rate for all OCR designs. Under JAVA, the unique class is specifically created for the objective of segmentation. The objective for segmenting is to divide the image into smaller sections, which hold distinct elements (i.e. nodes, curves, shapes, sizes, etc.). This aids the utility to preserve its features that identify characters from each other, therefore making this procedure fundamental to the entire identifying objective. The binary image we get in the preprocessing stage is sent

into the segmentation phase in order to get the character separately. Each character is segmented with a bounding box as an outcome.

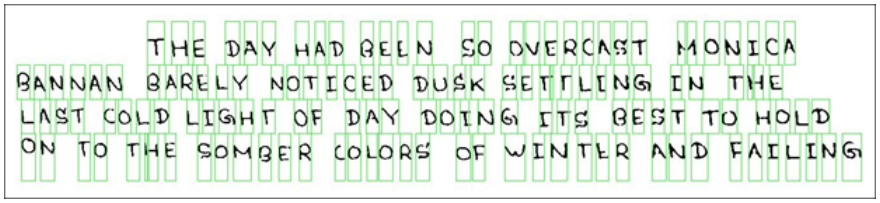

Figure 5: Segmented Image

3. **Feature Extraction Phase and Classification Stage**

   Following the segmentation phase, features need to be acquired. The acquirement procedure, aka feature extraction phase, is the procedure under which data is taken out of the images for categorization. Under this procedure, sub features of segmented texts are recognized on the basis of their starting points, end points, lines, curves, sizes, shapes and widths, etc. Under this procedure, the feature input of the characters is executed and subsequently the solitude. Following such, they are contrasted with the data acquired from the databank, therefore facilitating evaluation for any identical structures. For example, an image consisting of text is divided into various lower levels of symbols and characters. Subsequently, these characters constitute the binary format, which can be easily facilitated by the computer. The categorization procedure recognizes the information sourced from the extracted features. SOM is utilized for the purpose of categorization. The phases of SOM are succinctly provided below:

   - Initialization
     → Initial weight vectors **wj** with random values.
   - Sampling
     → Create a sample training input vector **A** from input.
   - Matching
     → Set weight vector as the winning neuron P(**A**) whose value is closest to input vector.
   - Updating
     → Update weight by using equation
   - Continuation
     → Recurrence of steps from step 2, lasting until feature map halts varying

4 Results and Discussions

The Algorithm is implemented in JAVA using intellij IDEA environment. The following Graphical user interface is made to represent the software.

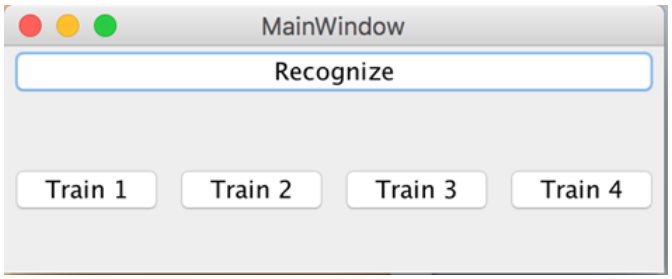

Figure 6: Graphical User Interface

When program will execute using intellij IDEA environment then the GUI will appear that is shown above. GUI consists of following five buttons.

Train 1: The purpose of this button is to train the images that are used as a reference for matching and classification. The following window will appear when user clicks on this button. Then the user will select the image for training.

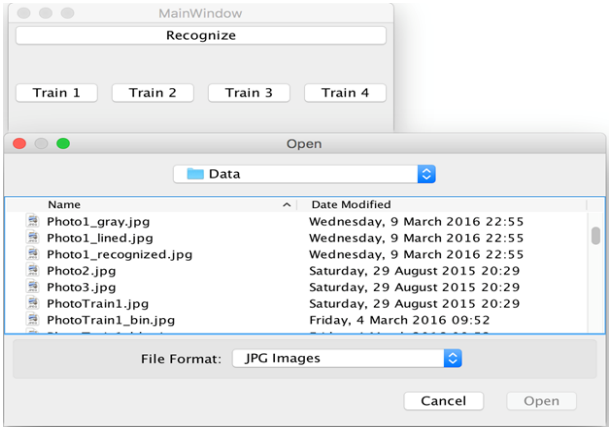

Figure 7: Selection to train image

Recognize: This button is made to select the test image and it will be processed for recognition. The research has been executed appropriate within the deadline, whilst effectively executing recognition of characters. By executing this sort of computation heavy processing, accuracy with the processed is achieved. The issues belong to either technical or glitch nature, owning to the structure itself, warranting later elaboration. Each stage of the structure utilize individual operational axiom, which influences the efficacy [9]. Given that

each following phase is based greatly over the effective functionality of the prior stage, any early mistakes, regardless of how trivial and unnecessary, can maintain a significant influence on the effective execution over the entire procedure of identification, particularly towards the accuracy. Any glitch in the initial, pre-processing stage to efficiently remove noise problems and host effective normalization could cause the following stages to fail in execution. Given that the identification procedure can go through only single characters, the sample data constituted solely of characters that were not connected. Furthermore, it becomes important to reduce the amount of non-essential information from the file, leaving solely the text characters [10]. A failure to carry out correct segmentation disconcerts the program so the accuracy of recognition is badly affected. Classification needs exact feature extraction, problems that happen amidst the feature extraction procedure decrease the rate of recognition alongside the aggregate operational tendencies of the structure.

5 Test and Evaluation

In this section, we will be examining the accuracy rate of each letter trained by Neural Networks by comparing with the recognized sentences. Test cases will be analyzed by Latin Alphabet Letters written by me and my friend, in order to increase the accuracy rate of the given sentence.

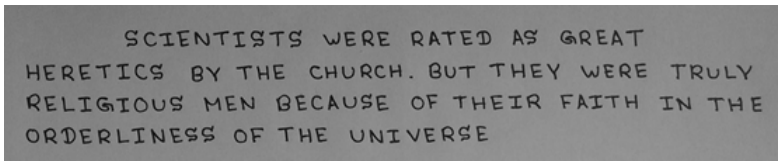

Figure 8: Sample Sentence

Accuracy rate of each letter after training the letters and recognizing the image is shown in Figure 9. Accuracy rate is calculated by first calculating the total sum of the given letter and then finding the percentage of given letter where it's false. As you see, letters such as I and G have a very low accuracy where the accuracy of letters N and T is satisfactory.

After training the given letters with more data sets, results are improved, such as the letter I has gained 60 %, and the letter N has gained 10%. However, there has been a small decline in the letters T and H, about 25% and 5% respectively. The main reason for the decline is because of the similarity of T and I and this problem can be solved by writing different types of T and I's. It's still not guaranteed that the accuracy rate will reach 100% but it will slightly increase if the handwriting is well processed by the system.

However, considering the complexity of the project, the total accuracy of the given sentence is more than 80%.

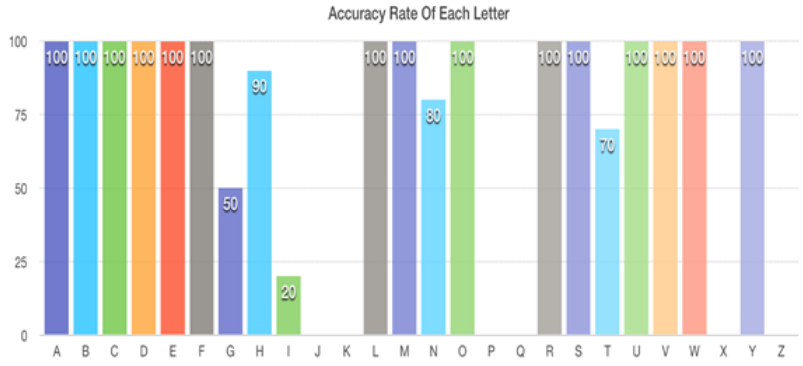

Figure 9: Accuracy rate of each Letter

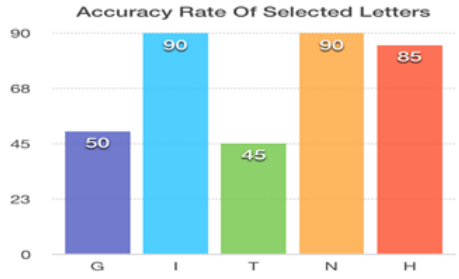

Figure 10: Accuracy rate of selected Letter

6 Concluding Remarks

6.1 Conclusion

The structure behind identification of physical writing characters has been exhibited through this research. The span of this research involved functions, i.e. acquisition of images, selection of characters, categorization, pre-processing process, and creation of outcomes. A study was furthermore conducted with effect to evaluate the structural performance. Various developmental aspects are worth providing citation. The effectiveness of an OCR platform is based on the rate of conversion and accuracy. The accuracy is based on the volume of correct predictions establishing amidst the testing procedure. Nevertheless, the rate of conversion is speed, over which the extraction of data was effectively executed. Under this research, a procedure has been recommended, alongside an algorithm as implemented to effectively take out information and exhibit it over a GUI. Several hindrances made the entire procedure more difficult, pertaining

mostly towards misperception amidst images, i.e. D and B, identical features amidst letters, i.e. l or I, where l is L and I is i. Another major issue was the limited volume of test images. The tested material constituted my personal writing. Any differentiation over the style of physical writing could lead to poor accuracy in the recognition of input. All individuals possess unique handwriting and the software simply facilitates the infinite array of various writing styles. Printing quality, too, has a major influence over the extraction of data, i.e. data under black ink, featuring a black background will be difficult to identify, likewise, information which was exhibited over poor writing, i.e. writing from a young child, or someone lacking basic writing skills, would fail to provide the desired outcomes. The color of the utilized ink also influenced the accuracy of the outcome, given that the rate of conversion was different between various shades and colors of ink.

6.2 Future Work

The study to this point accomplishes the procedure for identification of characters utilizing JAVA and assessments were carried out on quite a lot of data units available. A lot of time has been employed in order to manufacture a most appropriate method that really works. Nonetheless, additional work can also be completed in order to improve the outcomes and solve the problems that were confronted with by the training of a bigger set of images. Furthermore, it is anticipated to function for the facial attention techniques.

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