RECOGNITION OF HANDWRITTEN MATHEMATICAL EQUATIONS: A REVIEW

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Abstract : Every day, the expressions and symbols used in mathematical calculations are prominent and used in a routine manner. To effectively access these documents, they should be digitized and produced in electronic formats. The goal of this review is to bridge the gap between the knowledge that people have about math and the input that they are receiving from the organizers. In addition to the printed documents, handwritten notes and symbols could also be digitized and used to introduce math notation to electronic devices. In addition to the printed documents, handwritten notes and symbols could also be digitized and used to introduce math notation to electronic devices. This review proposes a method that combines the capabilities of a static and complex feature extraction system with a nearest neighbor classifier, support vector machine, back propagation neural network etc. The survey is focused on developing a method to recognize mathematical equations and symbols too.

***IndexTerms* – Math equations & symbols, Recognition, Support vector machine, Neural network, Nearest neighbor .**

I. INTRODUCTION

In addition to being an essential part of human communication, writing in various forms, such as handwritten and printed, has also been used in the preservation of knowledge. This discipline is mainly used for repetitive applications that involve large databases, such as the processing of administrative files and bank checks. It also includes tasks such as reading of legacy documents and analyzing written gestures. One of the most challenging aspects of implementing an automation technique is the variability of the writing styles and habits of people. This is because, for instance, it is not feasible to automatically copy and paste a simple reading activity into a computer. To successfully implement an automation technique, the machine must first acquire a deep knowledge base of domain and a powerful mathematical formalism. The development of automatic reading of writing has greatly improved in the last decade. This is because of the various contributions that were made to the field. On the one hand, there were the many studies that were conducted on the subject, and on the other hand, there were the modern statistical methods that were used to improve the performance of computers. The availability of international databases for printing and handwriting enabled researchers to conduct studies on the performance of their techniques. This also allowed them to compare their methods with those of other researchers. The goal of this review is to develop a method that can recognize the symbols and equations in printed and handwritten documents. In addition, it can be used to perform segmentation and recognition of text data. This method can be complemented with other similar approaches by extracting complex and static features. The development of civilizations has led to the need for new ways to preserve the laws and ideas of the past. Archaeological evidence has shown that writing conservation was carried out in various regions of the ancient world, such as Egypt, Mesopotamia, Persia, and the Levant. Before the invention of paper by the Chinese in the second century, tablets of stone and clay were used to transmit information. Handwriting was the only method of communication until the printing press invention. In addition to writing texts, handwritten communication can also include drawings, diagrams, engineering plans, chemical equations, electrical schematics, and other similar materials. Since writing is a skill that people have developed since birth, it can be said that the writing of each individual has a unique and distinct personality. Some people believe that technological advances could cause handwriting to become extinct. There are numerous digital documents that allow people to exchange information across vast distances in seconds. Despite the popularity of handwriting, it is still a preferred method for expressing ideas and exchanging information. To help facilitate writing in the digital age, various tools have been created, such as interactive whiteboards, digital pens, and mobile devices with touch screens. The evolution of hardware technologies has led to the development of new software that can help users use their handwriting more effectively. These new systems allow users to enter information using their own handwriting and convert their scripts into digital form. Due to the popularity of handwriting, we decided to address the issue of recognizing mathematical expressions online. Although mathematical notation is a very rich 2D format, it is also very important for scientific documentation. Mathematical expressions are a universal tool for communicating with scientists. Although some mathematical expressions may seem complex for non-specialists, they can provide a comprehensive view of the most common problems encountered in various fields. To measure the importance of these expressions, we extracted all the entries from the "Wikipedia" web pages. In this manuscript, we will be reviewed a system that can easily be used to recognize mathematical expressions in 2D languages. We will also talk about the various steps that are required to recognize these expressions.

1.1 **Characteristics of Handwriting**

An optical character recognition system is a type of software that can transform handwritten or t-type documents into a computer-readable format. Initially, this technology was only focused on character recognition. Due to the technological advancements that have occurred in this area, it has now been expanded to other areas. The various types of documents, such as documents, text, and diagrams, are studied by vision and pattern recognition communities. Although we commonly refer to written signals such as a letter or a diagram, we also use the term handwritten to refer to any written expression. As shown in below fig.1, the recognition of handwritten signals is divided into two categories: offline and on-line. On-line signals are analyzed using a combination of on-the-fly and retrospective approaches.

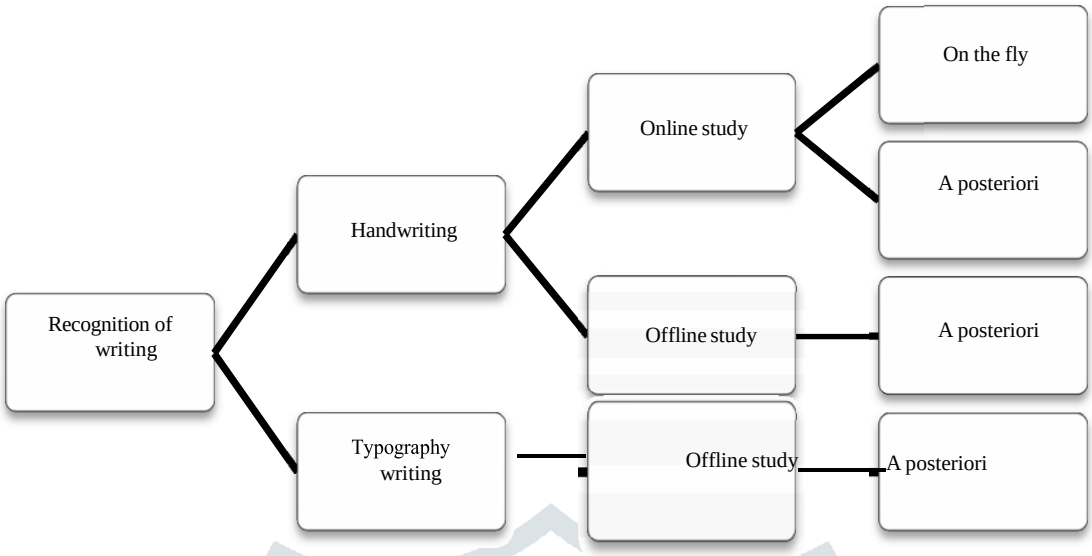

Figure 1: Domains of recognition systems according to the nature of writing and theirrecognition strategies

Over the years, various technological advancements have been made in the recognition of handwriting. However, there are still many problems that remain. To solve these problems, we try to involve both the knowledge of the domain and the entry constraints in question. An off-line signal is a type of recognition that occurs when handwriting is scanned using a camera, scanner, or other equipment. It can be done digitally or by extracting data from an online entry. Before performing the actual recognition, it's important to clean the image. In order to perform effective off-line signal recognition, various image processing steps are required. These include morphological operations, binarization, and skeletonization. These steps are usually performed in a heavy manner for industrial applications. Off-line writing recognition systems are mainly used for performing specific tasks such as reading postal addresses and performing automatic check reading. An off-line write signal consists of a matrix of elements that are either white or black, and these have varying levels of gray or color. Since it is a static signal, it cannot be analyzed without first taking into account the writing's dynamics. It is widely accepted that writing on-line is easier than doing so off-line. However, in order to take advantage of its advantages, work has been conducted on transforming an off-line signal into an on-line one. This process is very challenging, as online writing is commonly used in various fields such as education and medicine. The numbers of researchers have introduced the concept of two-dimensional (2D) extensions of handwriting. These extensions can be used in various applications. The input tool can have a significant impact on the recognition methodology and system structure. For instance, tools such as tablets and smart phones allow users to receive visual feedback without having to go through the laborious process of setting up and implementing a recognition system. One of the most important advantages of interactive input tools is that they allow users to interact with the symbols without having to go through the laborious process of setting up and implementing a recognition system. This allows them to perform validation and correct errors immediately. Another important factor that is considered when it comes to implementing a recognition system is that it should be compatible

with the user's interaction. In off-line write recognition systems, the posterior recognition is automatically imposed when the entire ink is present. This is also true in the case of digital pens, which are designed to recover the ink after the user writes. The total amount of information that was written is available to the system. Although the implementation of the posterior recognition method can be more challenging without the validation of the user, it can still provide a significant advantage by keeping the overall context of the writing. In this study, we will discuss the various aspects of this method and how it can be used to improve the performance of off-line write recognition systems.

1.2 Segmentation & Classification

One of the most important factors that you need to consider when it comes to constructing a graph is the ability to segment it into its basic elements. In on-line signals, you can lift the symbols between them. One of the most important factors that you need to consider when it comes to constructing a graph is the ability to segment it into its basic elements. Although it is possible to find the groupings of symbols that are related to the same symbol, it is not always easy to do so. For instance, in some languages, it is possible to construct a whole graph with only a single plot. An example of a chemical equation in below fig. 2 shows that, the features of a hypothesis with the same color can be grouped together in a manner that is syntactically correct. However, even if the symbols are quite different in the equation, it is not always feasible to group them into a single classification. For instance, if the second interpretation of the same concept is not correct, then the language model might not be able to solve the problem.

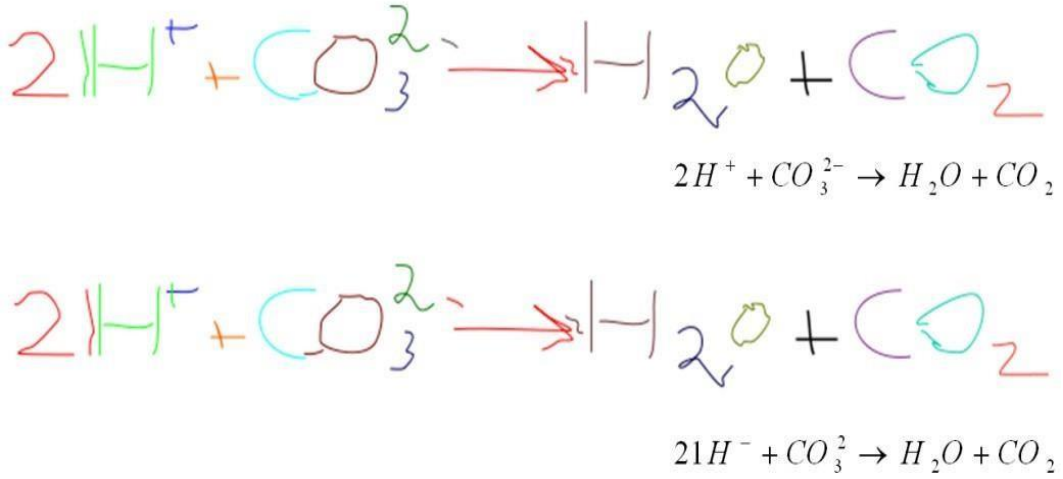

Figure 2: Two possible segments of a chemical equation and their interpretations [1]

In fig. 3, we can see that it is not easy to segment a handwritten circuit diagram into its various sections. The dashed lines indicate the points where a break might be possible, and this makes it difficult to choose the appropriate segmentation points.

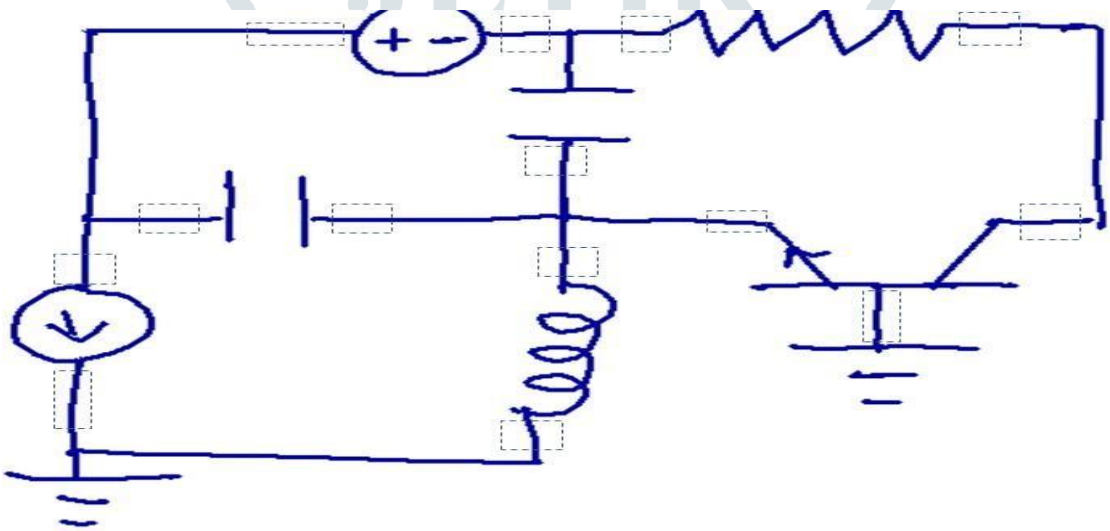

Figure 3: The permissible zones for cutting a circuit diagram [1]

With an off-line signal, it is not possible to set a condition that would allow one to separate the symbols. This makes it difficult to split the symbols into multiple components. This also adds to the complexity of the segmentation process since it requires both the recognition of the symbols that touch and the separation of the components. When there is an explanatory text in the graph, the segmentation process becomes more complex. This is because the powerful tool used to recognize graphic symbols cannot automatically recognize text. To solve this issue, first, you have to separate the various components from the rest of the graph. Another solution is to ask the user to indicate the input mode by switching between the recognition modules. This is not very comfortable since it limits the user's freedom since there are many existing texts in the graph. The classification of symbols is a crucial step in a 2D language recognition system. Due to the abundance of literature on the subject, it is not as challenging as it sounds. Due to the varying features of 2D languages, the classification of symbols is not as simple as it sounds. In addition to the variability of handwriting, the system should also take into account the multiple lines that can be written in a symbol. In 2D languages, there are many symbols that can be used in different ways. For instance, some of these may play a role in the context of a message or in the position of the symbol. In order to make the classification process more robust, it is usually necessary to apply a standardization step.

1.3 Interpretation

The goal of an interpretation is to find the meaning of a given graph. It usually consists of a syntactical and structural analysis, and it aims to correct any errors that might occur in recognition or segmentation. Analyzing the structure of the graph is also important to convert it into a digital format. Through structural analysis, it can be possible to extract information from a given symbol, such as its spatial relationships and topology. This information can then be used to justify the arrangement of the symbols in a given structure. For instance, in structures such as flowcharts, electrical diagrams, and diagrams, it might be useful to use

constraints on the connectivity between connectors and symbols. A set of connectivity constraints has been identified for electrical diagrams that are based on a priori knowledge. For instance, if one wants to connect two wires to a horizontal resistance, he would need to find two connectors on the left side and one on the right. This approach is not ideal, as it doesn't provide the necessary syntactic description of the graph. Having the schema's syntax helps in identifying the unknown values in a given structure. For instance, when there are global and local contextual dependencies in musical scores, an attribute grammar can be used to interpret them. An attribute grammar can also help in identifying the various attributes of a given structure. For instance when composing musical scores, the simplest rule of this type of grammar is that the symbols are composed of primitives. More complex rules are then used for partition representation. Due to the existing rules governing the composition of musical scores, a set of contextual constraints has been proposed.

II. LITERATURE REVIEW

The character recognition procedure begins by viewing a scanned image of an equation's progression. It then decides its meaning and interprets the picture to a computer-written equation. a Feed Forward Neural Network and an Izhikevich neuron model is applied for pattern recognition of Digits and Special characters [2]. Through analyzing and concluding characteristics of the document images in PDF files as well as itseffects on mathematical formula identification, this paper designs a related parameteradjustment algorithm for avoiding influences on the performance of mathematical formulaidentification caused by the resolution variation [3]. Recently various deep learning architectures such as Convolution neural network (CNN), Deep neural network (DNN) and Long short term memory (LSTM) RNN have been applied to fields such as computer vision, speech recognition and natural language processing where they have been shown to produce state- of-the-art results on various tasks.

The supervised learning vector quantization neural network categorized under artificial neural network. The images of digits are recognized, trained and tested. Experimental results show that theperformance of SVM is much better than other techniques reported in literature [4]. The utilization of a handwritten mathematical symbols database which is characterized by the diversity of symbols writings in order to have a mathematical symbolsrecognition system robust and be able to know most of these symbols. [5] This system is based on four necessarysteps: The first concerns the preprocessing techniques (Normalization, Filtering, Binarization and Skew detection and correction). The last step is the symbols classification (SVM). This paper also presented the results obtained by using this system (expressions segmentation, symbols recognition and the expressions recognition). It has represented and demonstrated the hand written character recognition using back propagation network. A Neural system is a machine that is intended to show the manner by which the cerebrum plays out a specific task or function of interest [6]. In [7], this framework depends on four important advances: The second and third steps are individually: the articulations division (connectedcomponent algorithm) and the feature extraction (Radon change). The last step is the symbol classification (SVM). In this paper, they introduced likewise the outcomes gotten by utilizing this framework (expression segmentation, symbol identification and the expression identification). They have introduced a review toward perceiving manually written math symbols and expressions. Distinctive stagestowards the identification process are broke down out of which feature extraction and classification stage is given significance because of its incredible affect on generally speaking exactness and identification rate. Among different component extraction systems, projection histogram and pyramids of oriented gradients are observed to be most appropriate feature that yields better accuracy and support vector machine as a appropriate classification method [8]. This paper has utilized KNN with various types of separations or distances to measure closeness between each representation level. These papers infer that the outcomes are empowering. The developed framework outperforms significantly the statistical approach what's more; the execution of Minkowski distance permits a superior detection of categorical similarity [9]. In [10], among various element extraction systems, Character geometry is chosen as the feature extraction techniques. After various executions it has been discovered that k-NN classifier has extraordinary accuracy compared with SVM as classifier. The effectiveness of K-NN decreases with the increase in dataset. This paper has presented an end to - end framework to perceive Online Handwritten Mathematical equations and introduced framework has three sections: a convolution neural network for feature extraction, a bidirectional LSTM for encoding extracted features, and a LSTM and an consideration show for producing target LATEX [11]. In this research, the encoder is enhance by utilizing densely connected convolutional network as they can strengthen feature extraction and encourage gradient propagation particularly on a little training set. Additionally present a novel multi- scale consideration model which is utilized to manage the recognition of math symbols in various scales [12]. This paper has presented structural analysis technique for the identification of on-line manually written math expressions dependent on a minimum spanning tree consideration and symbol dominance [13]. This paper has presented an online framework for identifying manuallywritten math matrices context of an interactive computational tool called MathPaper. Automatic segmentation and identification of multiple expressions are dependent on a spacing algorithm that use identified symbol identities, sizes, and relative location of individual symbols [14].

By doing the quantitative and qualitative analysis on the results getting through various researchers it is concluded that, there is a still scope of research as there is no. of challenges for the recognition of handwritten mathematical equations and symbols due to touching symbols, overwriting, complicated mathematical equations, 2D structure etc. So, it is necessary to do the research on recognition of complicated handwritten mathematical equations with various issues like touching symbols, overwriting etc. Through the literature survey it is cleared that for high recognition rate, multilayer perceptron neural network with back propagation algorithm, support vector machine and nearest neighbor classifiers are mostly used. Some unique and weighted features have to extract to get overall good performance, efficiency, throughput and high recognition rate.

III. CONCLUSIONS

It is observed that the features like width to height ratio, centroid, zoning, boundary box, labeling and counting total number of elements in the equations, statistical features as well as complex features such as entropy, skew, kurtosis, variance, mean, standard deviation, no. of elements in the equation, labeling etc. have been considered by researchers. It is necessary to consider sensitivity,

specificity, accuracy, precision in the recognition of handwritten mathematical equations and symbols to get good experimental results with simulation. The error histogram, ROC and confusion matrix will be useful for measuring the performance of recognition in terms of efficiency and throughput.

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