Using Neural Network for Recognition of Handwritten Mathematical Documents

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Abstract - **Advancements in modern technologies cannot still override the importance of preparation of handwritten documentations. In particular, handwritten documentations are inevitable in mathematical calculations, mathematical tutorials, preparation of marking schemes and financial reports. This paper presents our approach to the design and implementation of Artificial Neural Network solutions for recognition of handwritten mathematical documents and producing text files. The system consists of three modules for image processing, character recognition and text formation. The Image processing module of the system has been designed to perform thresholding, normalization, segmentation and feature extraction of the handwritten numeric characters. The Image processing module captures the features of handwritten characters and to produce quality inputs for the ANN module. The Artificial Neural Network module for character recognition has been designed with a three layer architecture to use back propagation training algorithm. Image processing has been done through MATLAB while NeuroSolution toolkit has been used for the development of ANN and formation of textual output.**

Keywords- **Image processing, Artificial Neural Networks, Handwritten character recognition**

1. INTRODUCTION

Multifaceted advancements in modern technology, still cannot underestimate the value of handwritten documents. Some handwritten materials can be used as a means of identification of individuals. In addition, hand written documents can be produced at any time without requiring sophisticated technology. The use of handwriting has become even more significant with respect to numeric characters and arithmetic operations. In this sense, policemen, accountants, teachers and examiners are the best examples of people who still use handwritten numeric characters before accessing any device such as a calculator or a computer. As such, computer-based solutions for recognition and transformation of handwritten mathematical documentation have been a research challenge. This area of research goes beyond mere scanning of documents with mathematics and producing editable text documents. This is because, a typical mathematical documents includes more symbols than letters and numbers.

The newer technologies such as personal digital assistants (PDAs) have their impact on handwriting [1]. These inventions have led to the reinterpretation of the role of handwriting, but a pen together with paper is more convenient than a keyboard or a mouse. Obviously, handwritten documents are a preferred way to solve mathematical problems, making schemes, etc. In fact, such documents can be produced without requiring sophisticated technologies, but with a pen and a paper.

Among others, Miguel [2] has developed a numeric character recognition system for mail sorting in the postal department of US. This system has enabled to automate the recognition of postal codes with almost 90% accuracy. Literature mentions that the field of handwritten character recognition is almost thirty years old. There are a number of companies that have been involved in research on handwriting recognition for the past few years [3]. Some handwriting recognition systems go beyond the mere recognition of characters, but work as input preprocessors for some complex computer systems. However, since handwritten characters are specific to individuals, it is rather impractical to develop a handwritten character recognition system for global use.

This paper reports on the design and implementation of recognition of mathematical documents in the Sri Lankan context. The core system has been implemented as an Artificial Neural Networks that has been developed using the Back Propagation training algorithm.

The rest of the paper is organized as follows. Section 2 describes related work in handwritten recognition systems. Section 3 discusses Artificial Neural Network approach to recognition of mathematical documents. Section 4 reports on our design and implementation of Handwritten

Mathematical document Recognition system while section 5 writes on further work.

2. RELATED WORKS IN HANDWRITTERN CHARACTER RECOGNITION

At the outset it is worth mentioning that most character recognitions systems have used techniques in image processing followed by a technology for image recognition. Among other technologies, Artificial Neural Network (ANN) has shown promising results as a technology for image recognition. In fact, ANN has been used not only for image recognition but also for implementing some stages in image processing. For example, Z. Shi and coworkers have used ANN for segmentation and recognition of numeric characters [7]. Further, ANN has been used for segmentation in License Plate Recognition System [18]. However, it should be noted that the scripts which are cursive in nature are difficult to segment. In such events, special algorithms must be used. For example, an area based algorithm has been proposed for the skew detection of characters in Bangla specimen [8]. In this project, before segmentation, the features of images have been extracted by the analysis of specimen through the above algorithm. Finally segmenting points have been recognized through Multilayer Perceptron (MLP) Neural Networks [8].

There are so many applications, where ANN has been used as an approach to recognize characters. For instance, Alexander [17] has used back propagation neural network with one hidden layer to create an adaptive character recognition system. The system was trained and evaluated with printed text, as well as several different forms of handwriting provided by both male and female participants [17]. The handwritten pages were scanned and converting the scanned characters to code readable by MATLAB was achieved with a java application. After that extracted features were fed into neural network.

The off line cursive handwriting recognition system has also used image processing and neural network as technologies [4]. Here image processing is used to capture data from a handwritten document and conventional flat bed scanner has been used. The scanned image must be segmented into separate words and then a series of image processing operations is carried out to normalize the image. After that it has used neural network to estimate data for each frame of data in the representation [4].

Segmentation and Recognition of the hand written numerical chains were mainly based on the evaluation of neural network performances, trained with the gradient backpropagation algorithm [5]. Vertical projection was used to segment the numeric chains at isolated digits and every digit was presented separately. Used parameters to form the input vector of the neural network are extracted on the binary images of the digits by several methods: Distribution sequence, Barr features and centered moments of different projections and profiles [5].

Most of the character recognition systems work as a part of an integrated system. They are also specific to some countries and applications. Therefore, such systems cannot be used globally. ANN based systems cannot be also adapted for a purpose other than for which it has been trained. Although we deal with just 10 numerals, there is a need for developing a different numeric character recognition system that depends on the application and the context. Since our project deals with recognition of mathematical documentation, there is a need for recognition of extra symbols other than ten digits. Theses symbols include brackets, sings of mathematical operations (e.g. +, -, /, x, =, >, <). Next section describes our approach to design and development of an ANN-based system for handling mathematical symbols.

3. PROPOSED APPROACH

Our approach to the identification of handwritten mathematical documents comprises three steps, namely; image processing, image recognition and producing the output as a text document written to a file. We have used the standard techniques of image processing; while the image recognition is handled by an ANN trained in the supervised mode with the aid of backpropagation training algorithm. It is evident that ANN is the best technology for applications such as recognition of handwritten characters, which are rather incomplete and cannot be represented in an algorithmic manner.

Next we briefly describe our approach in terms of input, output, process, users and overall benefits of the system.

Input – The input for the system would be the scanned documents with handwritten numeric characters and mathematical symbols. For example, a typical 8.5 X 11 inch page is scanned at a resolution of 300 dots per inch to create a gray

scale image of 8.4 megabytes. The resolution is dependent on the smallest font size that needs reliable recognition.

Output – The output of the system will be a text file that shows numeric characters and mathematical symbols as shown in the original handwritten document. This document is legible and editable if necessary.

User- The users of the system would be persons such as teachers, examiners, students and accountants who produce mathematical documents and wish to transfer the documents as text files that can be edited.

Process – In our approach, firstly the handwritten mathematical document will be scanned and saved as an image. After that the scanned image is normalized because an image can have different sizes and appear at different positions. Then noise will be removed in normalizing the image before thresholding. The pixels of the scanned image will be read as the input for the ANN. The ANN uses backpropagation algorithm for training the input data. Finally the output will be saved as a text file.

Benefits – There are various benefits of the system for handling mathematical documents. Firstly, it can be used for a customized usage by a given person. Since it is convenient to solve mathematical problems manually, our solution will be immensely beneficial to persons like teachers, students, accountants, etc. Secondly, with the use of ANN, even the cursive handwritten documents can be recognized by the system. As such one does not need to worry about his/her handwriting seriously. Thirdly, the system goes beyond the recognition of numeric characters, but processes an editable document that can be used for a secondary purpose. For instance, using this system one can produce handouts and presentation materials upon the preparation of handwritten lecture notes, etc.

4. DESIGN AND IMPLEMENTATION

The top level architecture of the design of our system is shown in Fig. 1. It comprises three modules, namely, Image Processing Module, Artificial Neural Network Module and Output Generator Module. In our design, Artificial Neural network Module is fundamental to the entire system. Next we briefly describe the design and implementation of each module.

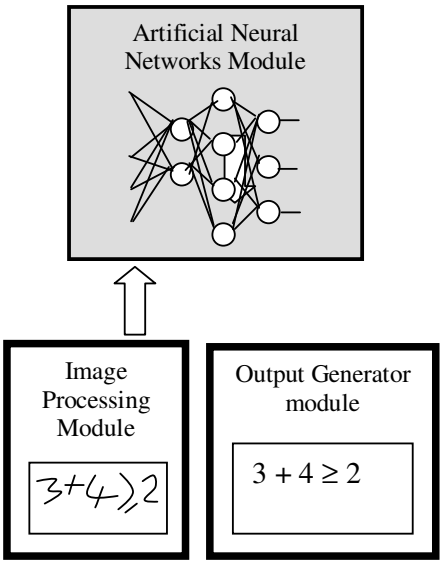

Fig. 1 :Top Level architecture of the system

4.1 Image Processing Module

The image processing module consists of three steps. They are, image normalization, thresholding and feature extraction. This module has been implemented by MATLAB and NeuroSolution. The image processing module works as a preprocessor for the Artificial Neural Networks module. During a training session images of numbers and mathematical symbols can also be used from a drawing tool such as Photoshop. However, in the actual use of the system the image processing module should scan images that are coming to the system.

The image processing module reads a scanned image as the input and normalizes the image in the first place. At this step, this module ensures that features of the image have not been affected due to normalization, which fixes the image into a standard size. The basic steps in image normalization in MATLAB are;

```
r1=imread('image name') // Read image;
r2=imcrop(r1,[width,Height]) // Crop image;
r3=imresize(r2,[32,32]) //change the size of image;
```

During the task of thresholding in the image processing module extracts the foreground (ink) from the background (paper) [9]. This process improves the clarity of the image by increasing intensity of some unclear pixels in the original image. It should be noted that thresholding is necessary to be applied in image processing to

handle the unclear sectors in original images [14]. Basic steps in MATLAB to threshold an image:

level = graythresh(r3)// threshold normalized image;

Having applied the thresholding on the image, the image processing module next performs the operation of feature extraction. This process digitizes the image. The feature extraction function has been implemented with the use of NeuroSolution [19].

4.2. Artificial Neural Network Module

The Artificial Neural Network Module receives digitized input vectors (32x32) created by the image processing module. The ANN has been implemented as a three layer network to be trained using backpropagation training algorithm. This module has been designed and developed with the use of NeuroSolution to identify 10 digits and other mathematical symbols such as +, -, /, x, =, <, >, ≤, ≠, ≥ (and).

Our study on various environments for ANN development shows that NeroSolution is a better choice due to various reasons. Among other reasons, NeuroSolution is capable of accepting image files directly as the input for the neural networks. Further, NeuroSolution also allows facilities for changing parameters pertaining to the quality of the image. As in most ANN training environments, Neursolution also provides facilities for changing network and training parameters during a training session. However, we have noticed that NeuroSolution version that we have used has a limitation of requiring reentering inputs during a retraining session.

We have been training the images of digits and the above symbols for the multi layer neural network architecture. In this regard, various architectures with a different number of layers and neurons have been experimented. The network accepts input with 32x32 pixels and learns them into 18 different digits and symbols. At present we have tried various architectures and also preliminary testing was done. Currently the training is in progress to accommodate more training data and to increase the accuracy of recognition of images.

4.3 Output Generator Module

The output generator module has been designed to write the output recognized by the trained network into a text file. This file will be as same as the original document that has been converted into a sequence of images. We are currently working in this module, and it requires consideration of some important factors. For instance, this module should be developed to highlight the characters which are identified with some ambiguity. Undoubtedly, a form of post-editing is preferable on the output file to ensure the accuracy of the output generated. However, the process of editing would not be that time consuming if the Output generator module can highlight any ambiguity.

5. CONCLUSIONS AND FURTHER WORK

This paper has discussed the need for transforming handwritten mathematical documents into legible and editable forms on the computer. We are inspired by that fact that many people including lecturers, teachers, students, examiners and accountants are still used to produce handwritten documents before processing those documents on computers. It is evident that ordinary scanning cannot be used as a solution for the requirement except for processing the documents with letters and numbers. However, mathematical documents include various symbols that are unique for mathematics. In view of that we have reported the design and development of Artificial Neural Network-based systems for the recognition of mathematical documents and transforming them into an editable format. We discussed the overall system as per three modules, namely; Image processing module, ANN module and the Output Generator module. We have already completed the development and incremental testing of the first two modules. The development of output generator module is in progress. The system has been developed with the use of MATLAB and NeuroSolution. The system will be able to run on an ordinary PC.

Further improvements to the systems will be done as per training of more inputs to the system to give a high level of generalization and accuracy. The development of the output generator module will also be done in parallel.

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