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Neural network Based approach for Image skeletonization on Gurumukhi Characters

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***Abstract* - Skeletonization is one of the most important pre-processing steps used in many digital image processing applications. It is the process of creating unit pixel width skeletons. It plays a very crucial role in many image processing applications such as character recognition, medical imaging, biometric authentication etc. Present paper discusses different neural networks used for performing skeletonization. Feed forward pattern recognition neural networks are used for producing the skeletonized images. Several experiments have been done by taking different parameters for neural networks to produce the skeletonized images.**

***Keywords* - Skeletonization, Neural Networks, Feed Forward networks**

I. INTRODUCTION

One of the fundamental requirements is to represent the structural shape of digital images. This can be done by reducing it to a graph. This reduction may be accomplished by obtaining the skeleton of the region using skeletonization also known as thinning. Skeletonization is the process of deleting unwanted pixels from the image in order to obtain unit pixel width skeletons. It is one of the morphological operations that delete the pixels iteratively layer by layer [1]. It is a procedure of reducing an object to its minimum size so that it can be used in various image processing applications. Skeletonization is usually applied on binary images which consist of black (foreground) and white (background) pixels. It takes input to be a binary image, and produces another binary image as output as shown in fig1.

A. Characteristics of good Skeletonization algorithms

For an effective skeletonization, it must reduce the objects into thin lines, and must possess topological and geometric properties. Following are the characteristics of the good skeletonization algorithms:

Fig 1: Simple Concept of Skeletonization

1. It must reduce the skeletons to unit pixel width.
2. It must possess the geometric and topological properties.
3. It should maintain the connectivity of the skeletons.
4. No excessive erosion of the pixels takes place.
5. The algorithm should be efficient in terms of the execution time.

B. Need of Skeletonization

Skeletonization is the most important pre-processing step used in many image analysis techniques such as pattern recognition [1], fingerprint classification [2], etc. Therefore there is always a need for skeletonization due to the following reasons:

1. It takes less processing time as number of pixels in the images is reduced.
2. By reducing an object to a skeleton, useless features such as image noise can be reduced.
3. Skeletonization is helpful in extracting important features such as endpoints and junction points.

C. Applications of Skeletonization

Skeletonization has been used for many image processing applications such as:

1. Pattern Recognition [1]
2. Character Recognition [2, 4]
3. Biometric authentication [4]

4. Fingerprint classification [3]
5. Signature verification [4]
6. Medical imaging [3]

II. SURVEY OF RELATED WORK

Skeletonization is the process of creating unit pixel width skeletons. Many skeletonization algorithms have been proposed over the years. Some algorithms have obtained good results but there are still many deficiencies. Present section reviews some of the papers on skeletonization:

Padole G.V. et al. [1] proposed a new iterative skeletonization algorithm. The algorithm is divided into three stages. First two stages are used for extracting the skeletonized object and the end stage is used for obtaining unit pixel width of the thinned object. Experimental results show that the performance is better for the shape binary images and is rotation invariant. Some problems like superior tails and preserving topology is highly faced.

Abu-Ain W. et al. [2] proposed two new iterative skeletonization algorithms for producing the skeletons of binary images. In the first algorithm skeletonization is done by using two operations that is edge detection and their subtraction. Second algorithm is based on deleting the unwanted pixels conditionally until we obtain a one pixel width skeleton. Comparisons have been done with Zhang Suen algorithm and medial axis transform with the proposed methods. Experimental results proves that the new proposed algorithm produces better results in terms of preserving the topological properties of connectivity and preserves the shape of the binary patterns.

Lam L. et al. [3] discusses wide range of skeletonization algorithms on binary images including pixel based deletion and non pixel based deletion methods. Algorithms are discussed in details in this paper and relationships between the different skeletonization algorithms have also been explored. Various comparisons have been made between skeletons obtained from various skeletonization algorithms on the basis of subjective as well as some objective criteria.

Chatbri H. et al. [4] proposed a framework for thinning algorithms that is robust against noise. Framework uses scale space filtering to generate multiple representations of an input image. The framework is used on different kinds of patterns and compared with some of the existing techniques. Experimental results show that the proposed algorithm is robust against any kind of noise mainly contour noise, dithers etc.

Zhang T.Y. et al. [5] proposed a very fast parallel thinning algorithm. The algorithm consists of two stages. First and second stage consists of four iterations each. Each and every pixel is tested with these particular conditions whether to delete or retain that particular pixel. Experimental results show that it results in a unit pixel width skeleton. The proposed algorithm is very efficient in terms of execution time and thinning of the digital patterns.

Jagna A. et al. [6] proposed a new parallel thinning algorithm. The author has used 3*3 masks under consideration to delete unwanted pixels. The algorithm makes the image one unit pixel width and also helps to preserve the 8 connectivity. Comparison has also been discussed with the previous algorithms and the experimental results shows that the new algorithm shows the increase in performance and high quality images, end point preservation etc.

Chen W. et al [7] discusses Zhang and Suen algorithm which has the features of producing connected skeletons with very rapid speed. But the resultant skeletons are not unit pixel width. So, the author proposes a new method to produce unit pixel width skeletons. It first uses the median filter for processing images. Experimental results prove that the proposed method is better in terms of producing unit pixel width skeletons in comparison to the existing algorithm.

Artificial neural networks have been used for many years. Neural networks have remarkable abilities to learn and simplify problems. Present section reviews some papers on skeletonization using neural networks:

Ahmed P. et al. [8] proposed a new technique for thinning using Self Organizing Graph (SOG) which is a modification of SOM (Self Organizing feature map). The algorithm has been used to thin handwritten numeric digits. The proposed algorithm has been tested on six thousand samples. Experimental results prove that the skeletons produced preserve the topology by generating topological maps and do not remove pixels unnecessarily and performs readjustments.

Shang L. et al. [9] proposed a new thinning algorithm by using two pulses coupled neural networks. The two pulses of the two PCNNs are required to meet in order to produce the thinning result. The author has given the criteria of pulse meeting and parameters have also been specified. The proposed algorithm has been used to thin various binary images which divide the image into two separate regions. Experimental results prove that the proposed algorithm is very efficient in skeleton extraction.

Ji L. et al. [10] proposed a new technique for thinning of binary images by using template based PCNNs (Pulse Coupled Neural networks). The template based PCNNs is used for deleting four pixel patterns from the edge of the image. The algorithm is divided into two steps: Coarse removal and fine removal of pixels. Experimental results prove that the shape of the patterns and maintain the connectivity. The proposed algorithm has fast execution time and achieves high thinning rate.

Xu D. et al. [11] proposed a pulse coupled neural networks (PCNNs) method for thinning of the binary fingerprint images. The algorithm combines both sequential and parallel approaches that mean it is iterative in nature. The author uses some square and template method. When a neuron in PCNN satisfies square template, the corresponding pixel to this neuron will be noted down and will be selected for deletion and on the other hand, if a neuron satisfies a triangle template, that corresponding pixel will be removed directly. Experimental results proves that the proposed algorithm is faster as it is iterative in nature and combined sequential and parallel approaches to delete border pixels.

Choudhary A. et al. [12] proposed a new technique to extract the features for the recognition of English handwritten characters. The recognition of handwritten English characters is done by using multilayered feed-forward neural network. Various pre-processing techniques have been applied such as thinning, noise removal, cropping etc. Experimental results prove that very promising results are achieved when binarization techniques along with feed forward neural networks are used as a classifier.

III. NEURAL NETWORKS

Neural networks [13] functions in a same way as our human brain does. It contains a very large number of highly interconnected elements known as neurons. These all neurons work together and process to solve some special problems. Neural networks always learn by examples. The neural networks examples must be selected with much care otherwise useful and effective time is wasted in training the neural network or even worse the network might not be functioning properly. A simple neuron is shown below in Fig. 2.

There are different uses of neural networks [13]:

(a) Classification [13]: Classification problem in neural networks is defined as when we have to classify data or objects according to some given criteria. Example: Pattern recognition [1] problems. Type of networks that can be used in doing classification is feed-forward neural networks.

(b) Prediction: if a neural network is given some inputs, it can be trained to produce outputs from the

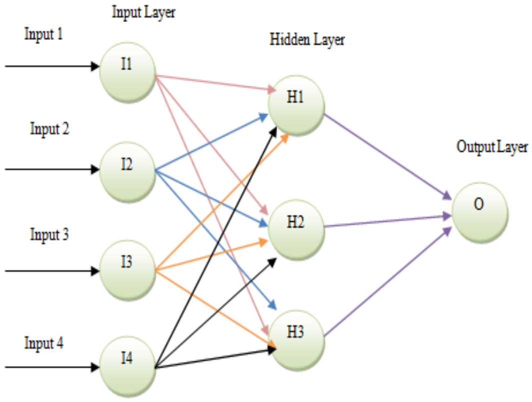


Fig 2: A simple neuron

same. One can use the neural network to predict future values if one have some sort of network that fits properly in a known sequence of values. Type of networks that can be used to predict values are feed-forward neural networks.

(c) Clustering: In some situations, we have some data that is so complex that there is no way to classify them into different categories. Neural networks have extraordinary capabilities to identify some important features from these particular types of data and help them to classify the data into different categories. This technique is helpful in data mining. Types of networks used for clustering can be Adaptive Resonance Theory (ART) [14], Self-organizing maps (SOM) [14].

(d) Association: A neural network can be trained to learn a large number of patterns or objects , when a misshape object is given to the neural network as an input , then it associates it with the nearest one stored in its memory and returns the desired output of that particular object. Type of neural networks that can be used in association can be Hopfield network.

IV. USE OF NEURAL NETWORKS IN SKELETONIZATION

a) Neural networks has extraordinary abilities to extract the meaning from any sort of complicated data that can be used to derive some objects/patterns that humans and other computer based techniques are not able to detect.
b) A trained neural network can be called as an "expert" for analyzing and processing any kind of information. [15]
c) Thinning problem requires two major tasks to be implemented: (a) removing the unwanted thick pixels (b) stopping the thinning process when the skeletons are very close to unit pixel width [15].
d) The first task can be done easily. The main problem arises in the second part, because the stopping decision has to be done automatically. This can be achieved using a real time cellular neural network by training the neural network.
e) Most of the conventional thinning approaches suffer from noise sensitivity and rotation dependency. With the use of neural networks we can perform thinning invariant under arbitrary rotations. [15]

Neural network takes a different approach as compare to conventional thinning. Conventional thinning is based on algorithmic approach i.e. computer follows a specific set of conditions so as to delete the unwanted pixels. The proper steps have to be given if we want that the computer deletes the necessary pixels. That thing bound the problem solving capabilities in conventional thinning approach. But a neural network function in the same way as human brain does. Neural networks always learn by examples. They reduce the number of instructions to be executed. Hence they take less execution time and faster than the conventional thinning approaches.

V. FEED-FORWARD NEURAL NETWORKS

Artificial neural networks are widely used over the past years due to their remarkable abilities to learn and help to simplifies problems. These neural networks have well distributed nature. There are hundreds of neural networks available. But feed forward neural networks are such types of neural networks which can be considered as universal approximators [16].

Feed forward neural network consists of three layers: input layer, hidden layers and an output layer. It is one of the best examples of supervised learning where inputs and targets are given in advance. Feed forward neural network consists of high number of processing units commonly known as neurons. The operation of this network can be divided into two parts:

a. Learning Phase: It is a supervised learning algorithm where inputs and targets are given in advance to learn the exact patterns.

b. Classification Phase: After learning the patterns from the learning phase, neural network is able to classify the images.

VI. IMPLEMENTATION

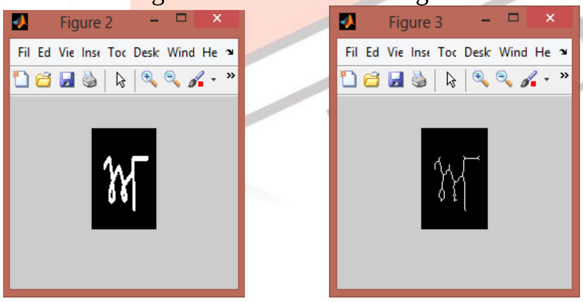
a. Dataset Used: Dataset consists of 41 Gurumukhi characters of 95*65 size each.

Table 1: Experimental results using neural network for performing skeletonization

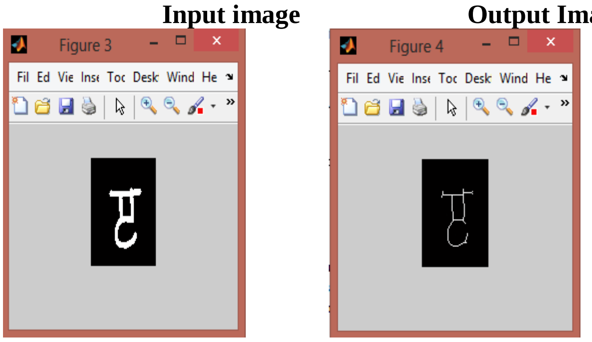
Experiment	First Experiment	Second Experiment
Learning rate	0.75	0.9
Training method used	traingdx	Traingdx
No of epochs taken to converge	200	500
Time Taken to execute	1.06	4.04
Gradient	6.18	6.61
Performance Function	SSE (Sum Squared Error)	SSE(Sum Squared Error)
No. Of training data	41 images of 95*65 each	41 images of 95*65 each
Performance Goal	0.01	0.10
Number of neurons in hidden layer	20	40
Momentum Constant	0.95	0.95
Accuracy	96.83%	92.65%

VII. RESULT ANALYSIS

Neural network is trained by using 41 different images of size 65*95 each. Neural network is trained by using network training parameters mentioned above. After training the neural network we get the desired outputs as shown below in fig 3 :



Input image **Output Image**



Input image **Output Image**

Fig 3 : Input and skeletonized images

VIII. CONCLUSION AND FUTURE SCOPE

From the above result analysis discussed in section VII it can be concluded that with the help of neural networks we can produce better skeletonized images. Neural networks are able to learn patterns very fast. Neural networks are able to simplify problems quickly. Parameters are selected on the basis of random experimentation. Present paper covers two best experiments which are able to achieve high accuracy and produces better skeletonized images.

In future, other neural networks can also be applied for producing skeletonization. Moreover, it can be tested on other datasets and more parameters can be added in order to perform better skeletonization.

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