Identification of the letter A from a white page using graph theory

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***Abstract*—The objective of this work is to identify whether a character written on a white sheet of paper is the first letter of the english alphabet in captial.**

I. Introduction

Language is a very integral part of the society. we need language to express our thoughts, feelings and ideas. Every language needs a medium of communication. Script is one such medium and almost every language has a script in which it can be written. Humans learn to read from experience and therefore understand the words and letters by looking at the text but computers are not intelligent beings like humans. They have to be programmed to recognize the different letters in the language. So, Character recognition is a challenging and a very important aspect of pattern recognition.

II. Motivation

In an era of big data where the amount of data being produced keeps growing exponentially, we now have newer techniques which utilize insanely large sized datasets to provide state of the art results. The root of the problem is however much simpler. Instead of utilizing large datasets, a more direct approach would to would be to analyze the structure of the letters and use that knowledge to identify them. So, the motivation was to examine the structure of a letter and identify it. A common feature among many letters is that they are usually graphs. hence, we can exploit of the properties of the respective graphs in order to identify them.

III. Implementation

We came up with two different methods for the recognition of letter ”A”. In the first approach, we attempt to find the properties of the letter ’A’ in the figure. In the second approach, we try to the model the figure as a graph and validate its properties. Some of the essential terms used here are connectivity, endpoints and branch points.

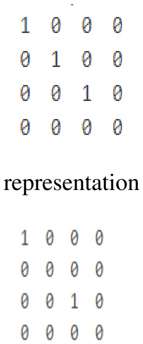
a) Connectivity: The number of neighbours of a point which are equal to one in the binary image gives its connectivity. Thus, Maximum connectivity of a point can be 8.

b) Endpoints [1]: These are the positions in the binary image where the structure ends ie. where the structure made by ones ends as binary image is made by zeros and ones.

c) Branch points [1]: These are the positions in the binary image which are connected to two or more ones and hence form a branch.

d) Skeleton: A Skeleton of the image gives a one pixel length figure which approximates the shape of the original figure, This is an important pre-processing step necessary to extract the branch points and end points of the image.

e) Edge: An edge is said to be present between two points if there is a skeleton without any major curves connecting the two points.



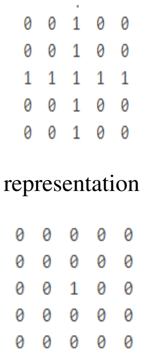
```
1 0 0 0
0 1 0 0
0 0 1 0
0 0 0 0
```

(a) Matrix representation of a image

```
1 0 0 0
0 0 0 0
0 0 1 0
0 0 0 0
```

(b) Endpoints matrix representation

Fig. 1: Description of end points



```
0 0 1 0 0
0 0 1 0 0
1 1 1 1 1
0 0 1 0 0
0 0 1 0 0
```

(a) Matrix representation of a image

```
0 0 0 0 0
0 0 0 0 0
0 0 1 0 0
0 0 0 0 0
0 0 0 0 0
```

(b) image contains the branch point of (a), this point has connectivity of 4

Fig. 2: Description of branch points and connectivity

A. Approach 1

We make some assumptions regarding the inout image for this approach as character recognition is a very vast topic. We assume that the image is clear ie. no noise in the image, image is thinned already as our motivation is only recognition of the letter ”A” and the final assumption is that only captial letters are considered.

a) Method : First we resize the image for even distribution then we try to find the skeleton of the image, by which we can easily find endpoints of the image using morphological operators in Matlab. Then we find the branch points of the image which we match with the characteristics of ”A”. Characteristics of ”A” which we are taking are 1. The start point of ”A” is having connectivity 2, and connected to its two diagonal neighbors ie. if start point is (i,j) the connected points are (i+1,j-1) and (i+1,j+1). 2. Image should contain more than three branch points and endpoints because conversion of a image in pixels may cause some distortions . 3. The middle part of ”A” contains the branching part. Now we check for these three characteristics in the image and if present, then the image is recognized as ”A” otherwise the image is of some other letter.

b) Time Complexity: Extraction of features ie. endpoints , branch points , skeletonization of a given image cause O(n*m) complexity where n are number of rows and m are number of columns in the matrix representation of the given image.

B. Approach 2

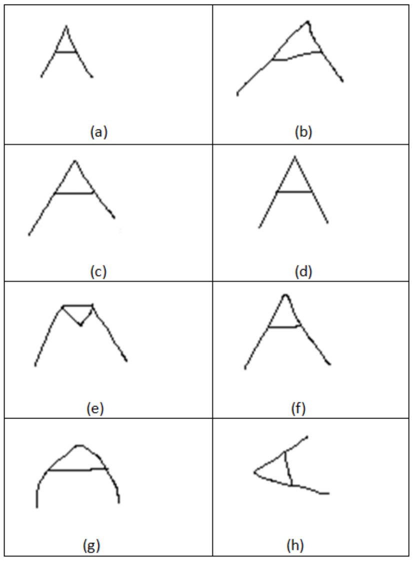
a) Method: Many letters in the English alphabet can be viewed as graph data structure. The letter ’A’ can be viewed as a graph as well. It is a graph which has two pendent edges and the non-pendent vertices of these edges are connected. These vertices are also connected to another common vertex. Therefore we treat the figure as a graph and examine its properties to decide whether the obtained figure is the letter ’A’ or not.

First, we clean the image and remove any outlier points that may corrupt the image. Then, we skeletonize the image to obtain the skeleton of the figure in the image. The skeleton obtained is a binary image where ones represent the skeleton and zeroes the background. The skeleton is one pixel thick and hence now suitable for applying the algorithm. This is done by performing morphological image processing on the image.

We find the the branch points and end points in the skeleton by traversing the image and checking the neighbourhood of each point. Any pixel with more than 3 neighbours can be considered as a branch point and those pixels with only one neighbour are considered to be end points. For every pair of these points we check if there is a skeleton connecting them by applying breadth first traversal. If they are connected, it means that there is an edge between those two points. Applying this process to every pair of points, the graph is constructed. Then, the graph is checked for the properties which are necessary for the figure to be the character ’A’ as mentioned in the previous paragraph. We also have to factor in the orientation of the graph such that the two pendent vertices are the left most and the right most points in the skeleton as well as the common point being the top most element in the skeleton.

b) Time Complexity: The first part of this technique is to apply some image processing techniques like cleaning, thinning and skeletonizing the image which requires time of the order O(n*m) where n and m are the dimensions of the image. Then we extract the endpoints and branch points from the image which once again requires a fixed time of O(n*m). If the number of branch and end points obtained is k, then the amount of time required to check for connections between them will be of the order O(k*k*n*m) in the worst case. Finally validating the obtained graph requires a time of the order O(k). So overall, The worst case time complexity of the algorithm is of the order O(k*k*n*m) where n,m are the dimensions of the image and k is the number of branch and end points.

Fig. 3: Different types of A



IV. Conclusion

We can use both the approaches for the alphabets but there are some constraints added to it.The image should be clean and the letter should be thin.If the image has no noise except the letter,then the image is called clean image.Clean image improves recognition accuracy.If these constraints are satisfied,the both the methods can be applied for all the alphabets.If the constraints are not satisfied,then the extraction of the letters would be difficult and may not even be possible.

References

[1] https://in.mathworks.com/help/images/ref/bwmorph.html

[2] http://scikit-image.org/docs/stable/api/api.html