1. Introduction

Thinning is the operation that seeks a connected region of pixels of a given property set to a small size [Life07]. Other terms commonly used are **"Shrinking"**, **"Skeletonization"** and **"medial axis transformation"**. Skeletons are compact and powerful way of representing the overall structure of a planer region. The skeleton of a binary object as shape descriptor has been proven to be effective for many applications such as character recognition and object recognition [Alex09].

In image processing elements in a binary pattern may have either value 1 or value 0.

Intuitively, most skeletonization algorithms consist of iteratively executing many passes over the pattern, where in each pass a few dark points are deleted. In any pass, a dark point to be deleted from the pattern must satisfy the following intuitive criteria:

(a) It is an edge-point.

(b) It is not an end-point (not a point which lies on the extremities of a stroke).

(c) It is not a break-point (it is not a point where it's deletion would break the connectedness of the pattern).

(d) It's deletion must not cause excessive erosion (an open-ended stroke should not be iteratively deleted).

To delete a break point $\mathbf{P_1}$ the 8-neighborhood as shown in figure(1), are examined and it's marked for deletion if satisfies all the rules applied to it [Melh01].

P9	**P2**	**P3**
P8	**P1**	**P4**
P7	**P6**	**P5**

Figure 1: the eight neighbors of a pixel

2. Survey of Related Work

The popular and well-proved thinning algorithms in the literature are Zhang suen algorithm and Hilditch algorithm. The Zhang suen algorithm does not support for the two pixel thick image and also has the problem of discontinuity in the image. The Hilditch algorithm has the problems not extracting straight lines with a complex implementation. However the proposed algorithm can settle the problem of discontinuity in images and with a simple implementation. The proposed followed in Zhang Suen and Hilditch algorithms for image thinning is as follows.

a- Zhang Suen algorithm

The Zhang suen algorithm consists of successive of two basic steps applied to the contour points of the given region, where a contour is any pixel with value 1 and having at least one 8-neighbor valued 0. With reference to the 8-neighbor definition shown in figure (1)

The first step flags a contour point P for deletion if the following conditions are satisfied:

(a) $2<=N(P_1)<=6$.

(b) $S(P_1)=1$.

(c) $P_2*P_4*P_6=0$.

(d) $P_4*P_6*P_8=0$.

Where $N(P_1)$ is the number of nonzero neighbors of p1,that is

$$N(P_1)=P_2+P_3+........P_8+P_9$$

and $S(P_1)$ is the number of 0,1 transitions in the ordered sequence of $P_2,P_3,.......,P_8,P_9$.

In the second step, conditions (a) and (b) remain the same, but conditions (c) and (d) are changed to

(c) $P_2*P_4*P_8=0$.

(d) $P_2*P_6*P_8=0$.

Step 1 is applied to every pixel in the binary region under consideration. If one or more of the conditions (a) through (d) are violated, the value of the point in question is not changed. If all conditions are satisfied the point is flagged for deletion. It is important to note, however, that the point is not deleted until all points have been processed. This prevents changing the structure of the data during execution of the algorithm. After step 1 has been applied to all pixels, those that were flagged are deleted (changed to 0). Then step 2 is applied to the resulting data in exactly the same manner as step 1.

One iteration of thinning algorithm consists of:

1- Applying step1 to flag pixels for deletion.

2- Deleting the flagged pixels.

3- Applying step2 to flag the remaining pixels for deletion.

4- Deleting the flagged points.

This basic procedure is applied iteratively until no further points are deleted [Gonz04]. Figure (2-b) shows the implementation of the Zhang Suen to the figure (2-a).

(a) **(b)**

Figure (2)(a) image before thinning

(b) Result of Zhang Suen algorithm.

b- Hilditch's algorithm

Naccache and Shinghal presented an algorithm of Hilditch's for thinning edges. This algorithm is applied by moving a 3 by 3 window over the image and a set of rules applied to the content of window. A pixel marked for deletion if it satisfies all rules applied to it. This basic procedure is applied iteratively until no further points are deleted. The main steps of Hilditch's algorithm are as follows:

Step 0 first defines the following:

1- $B(P_1)$ to be the number of dark 8-neighbors of P_1.

2- An edge-points as a dark points with at least one white 4-neighbor.

3- An end-point as a dark point with at the at most one dark 8-neighbor.

4- The crossing-number as

$$X(P_i) = \sum_{i=2}^{5} b_i$$

Where Bi=1 if (point P(2i-2) is white and either P(2i-1)or P(2i) is dark

Bi=0 otherwise

One can notice that if the crossing-number of P_1 is not equal to 1, then P_1 is a break point.

In any given pass, the input pattern is scanned row wise from left to right and from top to bottom. A dark point P_1 is flagged if all of the following six tests H1-H6 return the value True.

H1:$P_2+P_4+P_6+P_8<=3$ /* P_1 is an edge-point*/

H2:$B(P_1)>=2$ /* P_1 is not an end-point */

H3:$N(P_1)>=1$ /* $N(P_1)$ is number of unflagged dark 8-neighbors of P_1*/

The test prevents dark points at "tip a tin line" or in "approximate circular subsets" from being iteratively deleted.

H4:X(P_1)=1 /*P_1 is not a break-point*/

H5:either P_4 is unflagged X_4(P_1)=1 /*X4(P_1) is the crossing-number of P_1 **Or** if temporarily assume that P_4 is white. This test prevents excessive erosion*/

H6:either P_6 is unflagged Or X_6(P_1)=1 /*prevent excessive erosion*/

By implementing Hilditch's algorithm, figure (3-a) thinned to figure (3-b)[life07].

(a) (b)

Figure (3)(a) image before thinning

(b) Result of Hilditch's algorithm.

3. ***The proposed algorithm Thinning by Back –propagation, TBP***

After the implementation of the two previous methods to perform thinning operation, the results show that the Hilditch's algorithm gives somewhat better results than Zhang Suen algorithm, therefore the proposed BP net has been implemented depending on the Hilditch's algorithm. The accuracy of the BP net is equivalent to Hilditch's algorithm but it is little bit faster than Hilditch's algorithm. The network consists of three-layers, in the network configuration; there are nine input units, one corresponding to each neighbor in the input pattern, six hidden units, and one output unit as shown in figure (4). Since, there are 8-neighbors so that the total number of examples are 256. The net is learned so that it can classify the input patterns into the classes if deletable pixels or undeletable pixels. The following section presents the way in which the TBP depends on the Hilditch's algorithm.

To train the TBP, both the input and the desired output are required. The inputs to the net are the 256 examples. The desired output is prepared by the Hilditch's algorithm to produce the needed output. This output will be used as a desired output to the TBP net. By implementing the thinning algorithm image of figure (5-a) was thinned to that of figure (5-b).

Table (1) shows a comparison of the three thinning algorithms depending on the distortion, connectivity, implementation complexity, and execution time. The execution times are measured for the images shown in figures (2, 3, 5).

Table (1) comparison of Zhang Suen, Hilditch and TBP:

Algorithms	Distortion produced	Connectivity	Implementation complexity	Execution Time
Zhang Suen	Medium	Connected	Complex	10 Sec.
Hilditch	Highest	Disconnected	Medium complex	6 Sec.
TBP	Medium	Disconnected	Simple	4 Sec.

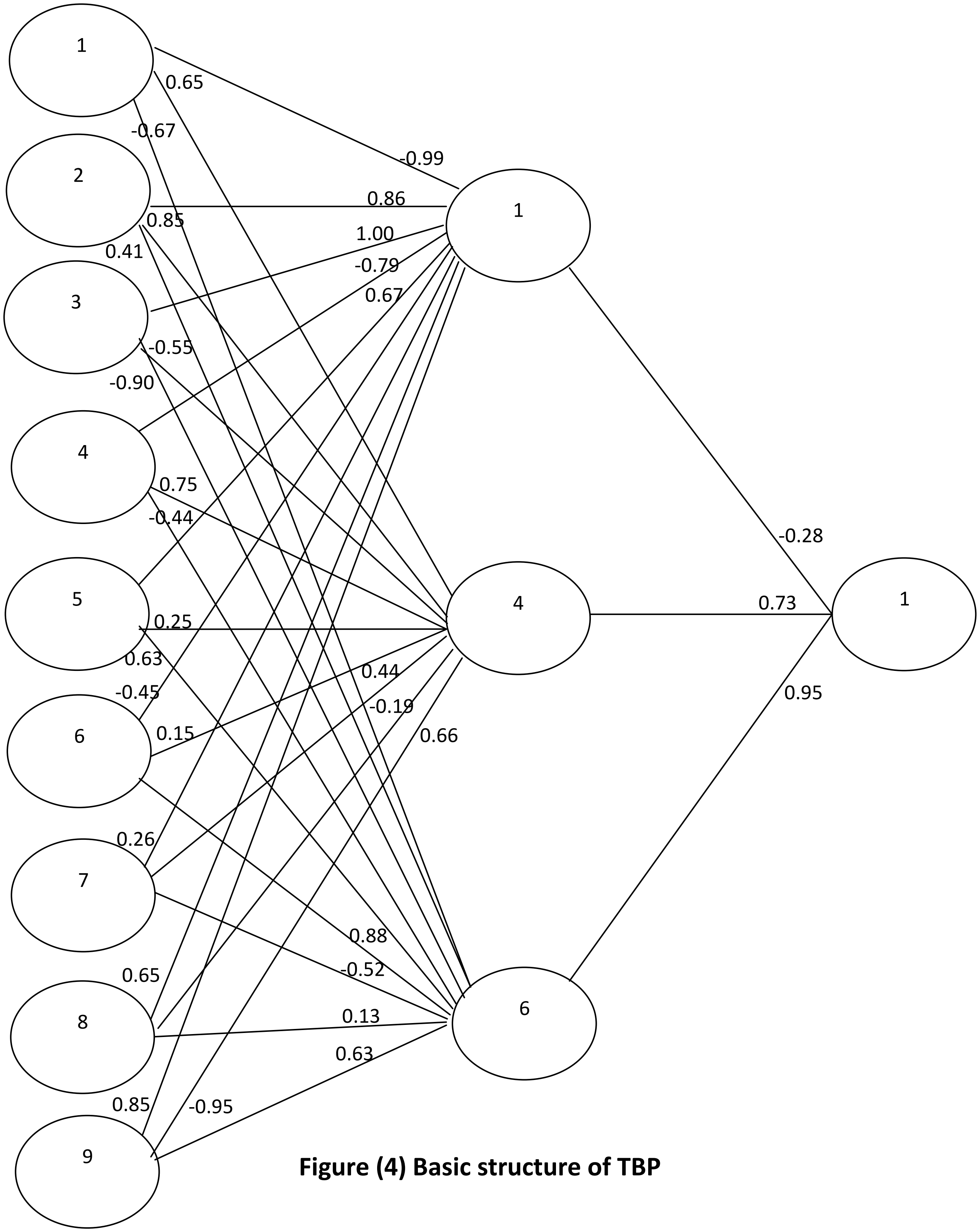

Figure (4) Basic structure of TBP

One hundred test images are processed by using these algorithms and the execution times varying from 8-20 sec., 7-19 sec., and 4-12 sec. for Zhang Suen, Hilditch, and TBP respectively.

Note that the training session is not complex because the input vectors and the desired outputs are generated automatically as the variations of 8-bits from 0 to 255. The desired weights are obtained after 537 repetitions.

(a) (b)

Figure (5) (a) image before thinning

(b) Result of TBP algorithm.

Conclusion

The results show that the Hilditch's algorithm gives somewhat better results than Zhang Suen algorithm, therefore the proposed Thinning Back-propagation (TBP) algorithm net has been implemented depending on the Hilditch's algorithm.

The accuracy of the TBP net is equivalent to Hilditch's algorithm but it is little bit faster than Hilditch's algorithm.

The distortion of the algorithm (TBP) is medium and the implementation complexity is simple comparing with Hilditch's algorithm and the disconnectivity of the line is appear in the proposed algorithm.

Another note that should be mentioned is that TBP requires a training session depending on 256 examples.

References

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