INNOVATIVE THINNING AND GRADIENT ALGORITHM FOR EDGE FIELD AND CATEGORIZATION SKELETON ANALYSIS OF BINARY AND GREY TONE IMAGES

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ABSTRACT

A commonly used method for thinning regions on binary images consists of examining windows of 3 x 3 pixels throughout an image, and erasing the enter pixel if thinning criteria are met. Critical study will be made in present research to develop a new thinning algorithm based on kXk windows for the categorization and skeleton analysis of images. The advantage of this algorithm is they peel thick layers from the boundaries of image regions and also reduces overall iterations of thinning algorithm and reduces overall complexity of these proposed methods.

Keywords: *Thinning Criteria, Categorization, Skeleton Analysis, Window*

1. INTRODUCTION

Thinning is an image processing operation in which binary valued image regions are reduced to lines that approximate the center skeletons of the regions. It is usually required that the lines of the thinned result are connected for each single image region, then these can be used to infer shape and topology in the original image. A common use of thinning is in the preprocessing stage to facilitate higher level analysis and recognition for such applications as Optical Character Recognition, diagram understanding, fingerprint analysis, and feature detection for computer vision. A common thinning approach is to peel the region boundaries until the regions have been reduced to thin lines. This process is performed iteratively – on each iteration every image pixel is inspected, and single – pixel wide boundaries that are not required to maintain connectivity or end lines are erased set to 0 . Other recent methods have been proposed to thin with a fixed number of steps not dependent on the maximum line thickness. For these non –iterative methods, skeletal points are estimated from distance measurements with respect to opposite boundary points of the regions. These non-iterative methods are less regularly repetitive, not limited to local operations

For the iterative approach the decision whether to erase a pixel set its value from 1 to 0 is made based on the values of its neighbors within a 3X 3 pixel region containing it. In this paper we extend and generalize the 3X3 method to a kX k method, where k≥ 3. Based on the thinning criteria, a central (k – 2) X (k - 2) core of pixel may be erased. In section2 the thinning criteria, in section3 the thinning requirements, in section4 multi-value and binary-value algorithms, in section5 implementation details, in section 6 results of the algorithms are shown and discussed.

2. THINNING CRITERIA

In this section, the criteria for pixel erasure and some definitions are stated and illustrated in Fig.1:

Window – A window, W(x,y,k) at pixel location(x,y) consists of kXk region, where the range of x and y are
{(⎮(x . y)+r)⎮- ⎮(k-1)/2) ⎮≤ r≤ ⎮k/2⎮) }
where [.] rep integer function.

Core- For a kXk window, the core is the (k-2)X(k-2) pixel region enclosed within the one pixel wide perimeter. The core is represented, R(x,y,k) where the range of x and y are {(⎮(x . y)+r)⎮- ⎮(k-3)/2) ⎮≤ r≤ ⎮(k-2)/2⎮) }

Neighborhood – For a kXk window, the 4(k-1) perimeter pixels constitute the neighborhood of the contained core.

Corner – The corners of a kXk windows are four neighborhood pixels located in the upper left, upper right, lower right, and lower left of the square these are numbered in neighborhood as 0, k-1, 2(k-1), and 3(k-1) respectively.

Side – There are four sides of contiguous pixels, each separated corners and represented as N, S, E, and W, for top, bottom, right, and left, respectively.

1 and 0 – These are used to designate the binary pixel values.

Erased – A pixel is to be erased because of thinning can be set to intermediate value.

The thinning Criteria stated as:

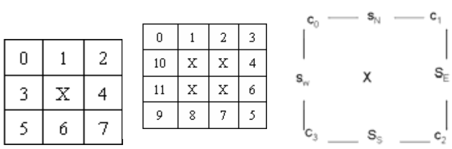
For a kXk window, if its core R(x,y,k) is 1, then it may be erased

Criterion 1 : $\chi(\eta) = 1$ is necessary so that the connectivity of a structure is not altered.

Criterion 2: $\varphi_1(\eta) > k-2$ maintains end lines and

Criterion3:$\varphi_0(\eta) > k-2$ is the inverse condition of criterion2.

Fig.1



3X3 Window 4X4 Window kXk Window

3. THINNING REQUIRMENTS

The thinning requirements are the following

1.Connected image region thin connected line structures,
2.The thinned results be minimally 8-connected,
3.Approximate end line locations be maintained,
4.The thinning results approximate the medial lines , and
5. Extraneous spurs caused by thinning be minimized.

The results of k x k thinning must maintain connectivity as specifies by requirements 1 is essential. By requirements 2, the resulting lines will always contain the minimal number of pixel that maintain 8-connectedness.For kXk thinning the degree of approximation for requirements 3 and 4 is a function of k. As k is increased, the coarseness of approximation is also increased.

The premise behind kXk thinning stated as : “ By generalizing thinning to kXk from 3X3, a trade-off may be made between the number of iterations and coarseness of the thinned result.”

4.MULTI-VALUE AND BINARY-VALUE ALGORITHMS

The kXk thinning criteria discussed in section 2 is the necessary condition to erase a single core. When thinning is applied to the entire image the presence of previous neighboring erasures will affect the thinning decision. In this section two algorithms are described for kXk thinning of an image.

The First Multi-Value algorithm where the pixels are processed in raster-scan order, that is row-column order from top left to lower right.

The Second Binary-Value algorithm where all pixels can be operated upon each clock cycle independently of the resultant values of other pixels on the same clock cycle.

4.1 Multi-Value Algorithm

In Multi-Value algorithm, data are processed in raster-scan order; row-column order, however, other orders including boundary following can be followed with similar approach

.Steps of the Multi-Value Algorithm:

Step 1: For each location(x,y) in ascending order;
Initialize k’=k
For window W(x,y,k’)
Initialize Erased value = 1 then test thinning criteria
If thinning criteria met in 1.2
Initialize Erased value = 0 and other to 1 then test thinning criteria
Test connectivity w.r.t. thinning criteria
If Core = anchor core then Initialize core=0
Else
Begin
Initialize k-k’=1
If (k’≥3) go to step 1.2
End
Step 2: If no pixels erased then STOP
Else Set all Erased to 0 then go to Step1

4.2 Binary-Value Algorithm

In Binary-Value algorithm all the pixels can be operated upon simultaneously; the thinning results on a pass do not affect the thinning operations on that pass. To accomplish this independence, each iteration is separated into four separate sub cycles and thinning is applied only to windows that are on N, S, E, and W borders on four sub cycles.

Steps of the Binary-Value Algorithm:

(Note : No need to retain Erased values; Erased value is 0)

Step 1 : Repeat in a circular square in order (N, S, E, W) do for all border windows

1.1 Initialize k'=k

1.2 For window W(x,y,k') test thinning criteria

Begin

If thinning criteria met Initialize core=0

Else

Begin

Initialize k'=k'-1

If (k'≥3) go to 1.2

End

End

If no pixels erased in circular square order the STOP

Else go to Step 1 for next border detection in sequence.

5. IMPLEMENTATION

The kXk method is the result of extending and generalizing the classical 3X3 approach to a larger window sizes. In our implantation, testing at each location for all window sizes, k'=k,….,3 done in parallel. For diagram thinning, where long straight lines are predominant, larger k is especially effective for quick thinning. For a sampling of a variety of images comprising diagrams, fingerprints, contour maps, and edge images can be used. The underlying requirement in the conception of the kXk method the algorithms whose operations were highly repetitive and local, and that operated in raster-scan order to enable pipelining.

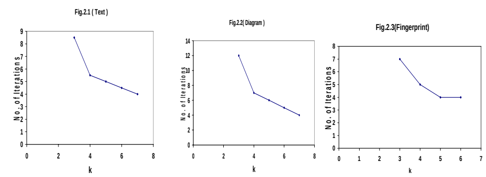


Fig. 2.1, 2.2 & 2.3 Shows number of iterations versus 'k' for Multi-Value algorithm applied to samples of text, diagrams, and fingerprints respectively

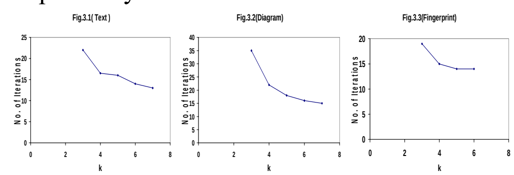


Fig. 3.1, 3.2 & 3.3 Shows number of iterations versus 'k' for Binary-Value algorithm applied to samples of text, diagrams, and fingerprints respectively

6. RESULTS

The advantage of using k>3 is that fewer iterations are often needed to reach the thinned result. A disadvantage is that the result is often coarser for k>3 than for k=3. The number of iterations will be given as a measure of computation for the Multi-Value algorithm and number of sub cycles (four per iteration) for Binary-value algorithm.

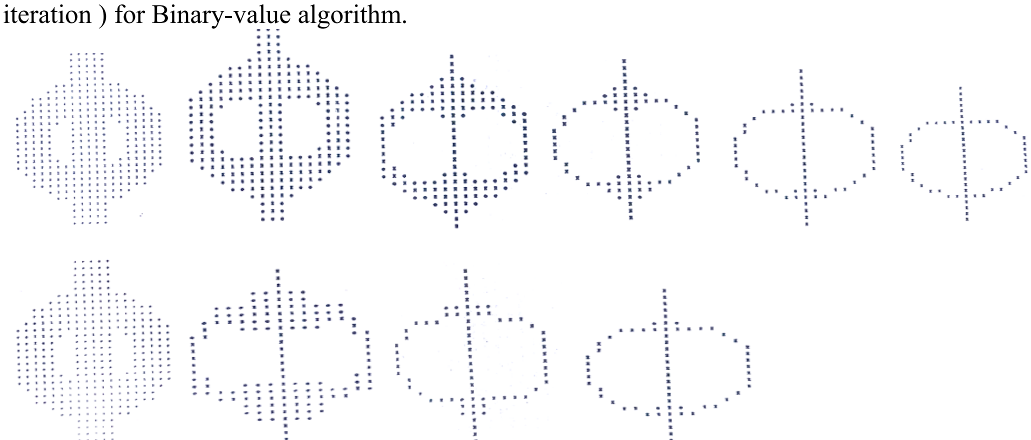


Fig.4 shows results after each iteration for thinning the image of the letter φ using the Multi-Value algorithm for k=3 and k=4. The number of iterations required for thinning by using 3X3 widow are six, and for 4X4 window are four. The reason for this is evident especially for the results after the first iteration; 2X2 bites are erased for k=4 where as one pixel bites for k=3.

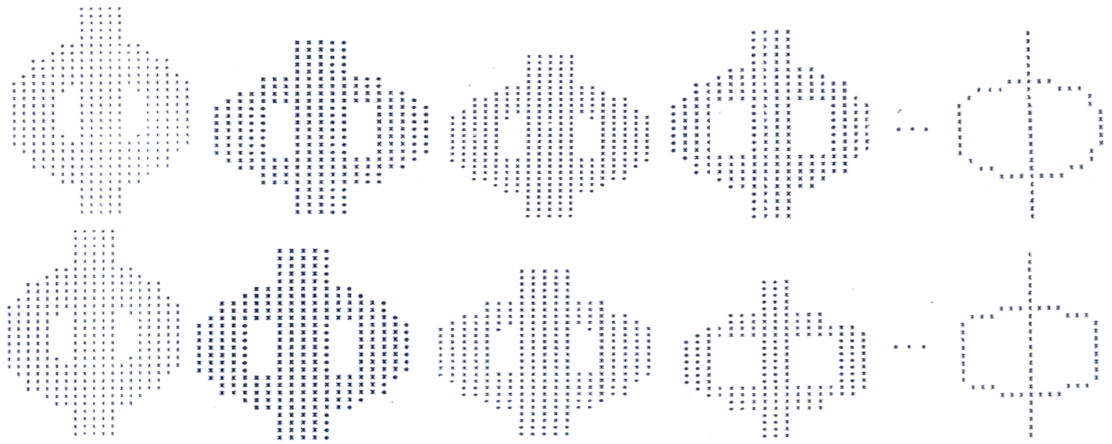


Fig.5 shows results for thinning the image of the letter φ using the Binary -Value algorithm for k=3 and k=4. The number of sub cycles required for thinning for k=3 are fourteen, and for k=4 are ten sub cycles.

Fig 6.2 Fig 6.3 Fig 6.4 Fig 6.5 Fig 6.6

Fig 6.1

Fig. 6 Shows results by Multi-Value algorithm on original image in Fig 6.1 for k=3 to 7 in Fig. 6.2 to Fig.6.6

Fig 7.1 Fig 7.2 Fig 7.3 Fig 7.4 Fig 7.5 Fig 7.6

Fig. 7 Shows results by Binary -Value algorithm on original image in Fig 7.1 for k=3 to 7 in Fig. 7.2 to Fig.7.6

7. CONCLUSION

The purpose of this paper is to extend the widely used iterative method of thinning on 3X3 windows to the more general one of kXk windows. This enables flexibility in the choice of the pixel thickness peeled from the region boundaries for each iteration, the advantage is that as k is increased, fewer iterations are often required. The kXk thinning criteria is an extension of 3X3 method. This kXk method guarantees connectivity and perfect thinning that is to minimally 8 connected lines. Two algorithms for implementing thinning criteria are described. Computation for Multi-Value algorithm is O(M2ni), where M2 is the number of pixels, and ni is the number of iterations. For Binary-Value algorithm because of the necessity of four sub cycles per iteration, computation is O(4ni). The use of larger k reduces the number of iterations required by about ½(k-2). The computational savings have been illustrated that may be achieved using k≥3.

8. ASSUMPTIONS AND LIMITATIONS

kXk thinning is not guaranteed to give a unique result for different values of k and for real images containing noise, any unique result would rarely be achieved any how. The kXk thinning proposed in this paper is more most practical on images where the shapes are lines or elongated regions, and for these the main objective his to thin quickly to one - pixel width while retaining connectivity and end point location.

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