THE ROLE OF STRUCTURING ELEMENT IN MORPHOLOGICAL IMAGE SEGMENTATION

Pinaki Pratim Acharjya, Dibyendu Ghoshal

Abstract— Image segmentation is one of the most commonly used techniques in digital image processing. In image segmentation edge detection of an image reduces significantly the amount of data and filters out information that may be regarded as less relevant, preserving the important Structuring properties of an image. In recent days new edge detection algorithms are published each year and among these, watershed algorithm which is inherently based on mathematical morphology is an accepted one. In watershed algorithm, structuring elements plays a very unique role. The basic philosophy of using the structuring element in mathematical morphological operation lies in the fact that it serve as a seed or needle to collect the image information. In this paper a new approach of image segmentation and edge detection is presented with watershed algorithm using twelve new and proposed arbitrary structuring elements and morphological smoothing operation to reduce the over segmentation problem has been proposed and accordingly their performances are compared and discussed.

Index Terms—edge detection, structuring elements, watershed algorithm, morphological smoothing.

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1 INTRODUCTION

IMAGE segmentation [1], [2], [3], [4] is a very important image analysis task in digital image processing. Image Segmentation is the process of partitioning a digital image into multiple regions [5], [6]. Actually, partitions are different objects in image which have the same features. The result of image segmentation is a set of regions that collectively cover the entire image, or a set of edges extracted from the image. In morphological image processing the watershed algorithm (which is inherently based on mathematical morphology) [7], [8], [9], [10], [11] is a much admired technique.

Structuring elements [12], [13] plays a very unique role in watershed algorithm. The basic philosophy of using the structuring element in mathematical morphological operation lies in the fact that it serve as a seed or needle to collect the image information. The information may be used to accomplish various image processing operations starting from preprocessing including restoration of damaged or degraded images to feature extraction through image segmentation. From mathematical point of view, a structuring element is a set of Euclidean space or its subspace with certain specific geometric shapes [12]. The concept of structuring element has occupied an important place in mathematical morphology owing to its versatilities in application, variability of the choice of the element depending on the current need, having capability to be applied in an adaptive way i.e., on the position and intensity of the gray level of the image or a part of it.

The choice of different structuring elements would lead to myriad applications [13] and analysis and processing of geometric information of the image lied there in and thus would ultimately decide data distribution and data volume and their nature in the morphological transform. All the above mentioned procedure will determine the complexity of the calculation.

In morphological transformation of digital images, e.g. for thickening or thinning of any image, the specific manner and extent of these changes are controlled by a space referred to as structuring element. From graphical pint of view, structuring elements can be represented either by a matrix having 0's and 1's or as a set of foreground pixels all having values 1. In both the representations, the origin of the structuring elements must be clearly identified.

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In conventional procedure watershed algorithm is need to apply on gradient images. The morphological gradient m of a function f is defined by:

$$m(p) = [(p \oplus S) - (p \ominus S)] \quad (1)$$

Where, $(p \oplus S)(i) = Sup(p(j))$ is the dilation of f at the point x and $(p \ominus S)(i) = Inf(p(j))$ is the erosion of f and S would be the detection of obstacles with the appropriate selection structuring element applied on image. It has been also observed that applying watershed algorithm directly on gradient [14], [15] images using different structuring elements produce over segmentation. Over segmentation is the process by which the image being segmented into small segments [16], [17]. These small segments are usually uniform in size and commonly referred to as super pixels. Over segmentation through extracts important boundaries, may lead to creating insignificant boundaries. To reduce this over segmentation problem morphological smoothing operation has been applied after watershed transform and accordingly better accuracy in detection of edges and lesser over segmented image is obtained.

In the present study, a new approach of image segmentation and edge detection is presented with watershed algorithm using twelve new and proposed arbitrary structuring elements and morphological smoothing [18], [19], [20], [21] operation to reduce the over segmentation problem has been proposed and accordingly the approach and their performances are compared and discussed in section 5 and section 6..

This paper is divided into a choice of sections. In section 2 twelve new and proposed structuring elements are publicized. Section 3 introduces a brief description on watershed algorithm. Section 4 introduces the morphological smoothing operation. Section 5 presents the proposed scheme. The experimental results are discussed in section 6 and we finish this paper with some concluding remarks with section 7.

2 STRUCTURING ELEMENT

A structuring element is a shape, used to probe or interact with a given image, with the purpose of drawing conclusions on how this shape fits or misses the shapes in the image. It is typically used in morphological operations, such as dilation, erosion, opening, and closing, as well as the hit-or-miss transform. From graphical pint of view, structuring elements can be represented either by a matrix having 0's and 1's or as a set of foreground pixels all having values 1. Some conventional structuring elements like arbitrary, ball, diamond, disk, line, octagon, pair, riodicline, rectangle, square are already can be found in many books and litterateurs. In this paper 12 new arbitrary structuring elements namely Plus, Zed, Cross, Star, L, Inverted L, Square boundary, Rectangle boundary, Plus within square boundary, Cross within square boundary, Star within Square Boundary and Z within Square Boundary has been proposed and shown in below.

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) Plus

1	1	1	1	1
0	0	0	1	0
0	0	1	0	0
0	1	0	0	0
1	1	1	1	1

(b) Zed

1	0	0	0	1
0	1	0	1	0
0	0	1	0	0
0	1	0	1	0
1	0	0	0	1

(c) Cross

1	0	1	0	1
0	1	1	1	0
1	1	1	1	1
0	1	1	1	0
1	0	1	0	1

(d) Star

1	0	0	0	0
1	0	0	0	0
1	0	0	0	0
1	0	0	0	0
1	1	1	1	1

(e) L

1	1	1	1	1
0	0	0	0	1
0	0	0	0	1
0	0	0	0	1
0	0	0	0	1

(f) Inverted L

1	1	1	1	1
1	0	0	0	1
1	0	0	0	1
1	0	0	0	1
1	1	1	1	1

(g) Square Boundary

1	1	1	1	1	1	1
1	0	0	0	0	0	1
1	0	0	0	0	0	1
1	0	0	0	0	0	1
1	1	1	1	1	1	1

(h) Rectangle Boundary

1	1	1	1	1	1	1
1	0	0	1	0	0	1
1	0	0	1	0	0	1
1	1	1	1	1	1	1
1	0	0	1	0	0	1
1	0	0	1	0	0	1
1	1	1	1	1	1	1

(i) Plus within Square Boundary

1	1	1	1	1	1	1
1	1	0	0	0	1	1
1	0	1	0	1	0	1
1	0	0	1	0	0	1
1	0	1	0	1	0	1
1	1	0	0	0	1	1
1	1	1	1	1	1	1

(j) Cross within Square Boundary

1	1	1	1	1	1	1
1	1	0	1	0	1	1
1	0	1	1	1	0	1
1	1	1	1	1	1	1
1	0	1	1	1	0	1
1	1	0	1	0	1	1
1	1	1	1	1	1	1

(k) Star within Square Boundary

1	1	1	1	1	1	1
1	1	1	1	1	1	1
1	0	0	0	1	0	1
1	0	0	1	0	0	1
1	0	1	0	0	0	1
1	1	1	1	1	1	1
1	1	1	1	1	1	1

(l) Z within Square Boundary

Fig 1. Proposed structuring elements. (a) Plus, (b) Zed, (c) Cross, (d) Star, L, (f) Inverted L, (g) Square Boundary, (h) Rectangle Boundary, (i) Plus within Square Boundary, (j) Cross within Square Boundary, (k) Star within Square Boundary, (l) Z within Square Boundary.

3 WATERSHED TRANSFORM

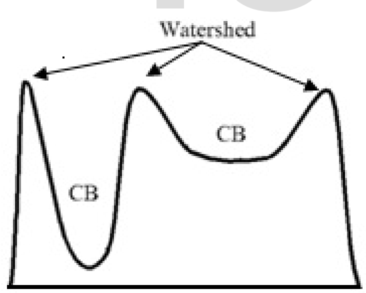

Fig 2. Watershed segmentation-local minima yield catchment basins, local maxima define the watershed lines.

Watershed transform is the technique which is commonly used in image segmentation. It is now being recognized as a powerful method used in image segmentation due to its many advantages such as simplicity, speed and complete division of the image. Watershed transform or Watershed Algorithm is based on grey-scale morphology. It is classified as a region-based segmentation approach. Even when the target regions having low contrast and week boundaries, watershed transformation can provide closed contours. When a landscape or topographic relief is flooded with water, the divide lines of the domains of rain falling over the regions forms the watersheds. Intuitively, a drop of water falling on a topographic relief flows towards the "nearest" minimum. The "nearest" minimum is that minimum which lies at the end of the path of steepest descent. In terms of topography, this occurs if the point lies in the catchment basin of that minimum. An alternative approach is to imagine the landscape being immersed in a lake in which holes are pierced in the local minima is called the catchment basin. Water will be filled up at these starting local minima and at points where water coming from different basins would meet and dams will be built. When the water level reaches the highest peak in the landscape the process is stopped. As a result, the landscape is partitioned into regions or basins separated by dams, called watershed lines or simply watersheds. The mathematical formulations are shown in below.

Assume, M_i where $i= 1$ to n be the set of coordinates points in the regional minima (catchment basins), of the image $P(x,y)$ and $C(M_i)$ be the coordinates points of catchment basins associated with the regional minima M_i

$$Tn = \{(s,t) \mid P(s,t) < n\} \quad (2)$$

Where,

$T[n]$ = set of points in $P(x,y)$ which are lying below the plane $p(x,y) = n$

min, max = minimum or maximum gray level value.

n = stage of flooding varies from min + 1 to max + 1

Let $C_n(M_1)$ be the set of points in the catchment basin associated with M_1 that are flooded at stage n.

$$Cn(M1) = \cap \{C(M1), T[n]\} \quad (3)$$

Where,

$$Cn(M_i) = \begin{cases} 1, & if\ (x,y) \in C(M_i) and (x,y) \in T[n] \\ 0, & otherwise \end{cases} \quad (4)$$

$C[n]$ is the union of flooded catchment basin portions at the stage n.

Where,

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$$C[n] = Cn(m1) \cup Cn(m2) \ldots\ldots Cn(mR) \quad (5)$$

$$C[max + 1] = C(m1) \cup C(m2) \ldots\ldots C(mR) \quad (6)$$

If the algorithm keeps on increasing flooding level then $C_n(M_i)$ and $T[n]$ will either remain constant or increase. Algorithm initializes$C[min + 1] = T[min + 1]$, and then precedes recursively by assuming that at step n $C\ [n - 1]$ has been constructed.

Let, G is a set of connected components in $T[n]$ and for each connected component $g \in G[n]$, there possibilities will arise.

1. $g \cap C[n - 1]$ is empty.

2. $g \cap C[n - 1]$ contains one connected component of $C[n - 1]$.

3. $g \cap C[n - 1]$ contains more than one connected component of $C[n - 1]$.

4 MORPHOLOGICAL SMOOTHING

One way to achieve smoothing is to perform a morphological opening followed by a closing. Opening smoothes the contour by removing thin bridges and eliminating thin protrusions.

$$A \circ B = (A \ominus B) \oplus B \quad (7)$$

Closing also smoothes the contour, but by enforcing bridges and closing small holes.

$$A \bullet B = (A \oplus B) \ominus B \quad (8)$$

The boundary of opening with a circular structuring element corresponds to rolling a ball on the inside of the set. The boundary of closing corresponds to rolling a ball on the outside of the set.

5 PROPOSED APPROACH

In signal processing and in digital image processing the term Morphology refers to a special type of filtering and structuring elements. Besides extracting boundaries, morphology can shape smoothing and removal of small holes. Selecting an appropriate structuring element is a key factor in morphological image processing. The basic theory of edge detecting morphological structuring elements is to construct different structure elements in the same square window. From graphical pint of view, structuring elements can be represented either by a matrix having 0's and 1's or as a set of foreground pixels all having values 1. In both the representations, the origin of the structuring elements must be clearly identified. The flowchart of the proposed approach is stated below. This approach is mainly based on generating gradient images using various structuring elements, smoothing of gradient images using morphological approach and obtaining edges or ridge lines with watershed algorithm which is a tool for morphological image processing.

In first step of proposed approach two real life color images are chosen and accordingly converted into a gray scale image in second step. The gray scale image also called as black and white image only contains the intensity information of an image varying from black at the weakest intensity to white at the strongest. In third step the gradient image is computed using different structuring elements which are proposed in this paper and accordingly shown in section 2. The gradient magnitude image has high pixel values along object edges and low pixel values everywhere else. In next step morphological smoothing operation in done on gradient images and accordingly watershed transform is computed in the final step. The final segmented images are shown in Figure: 5 to 28.

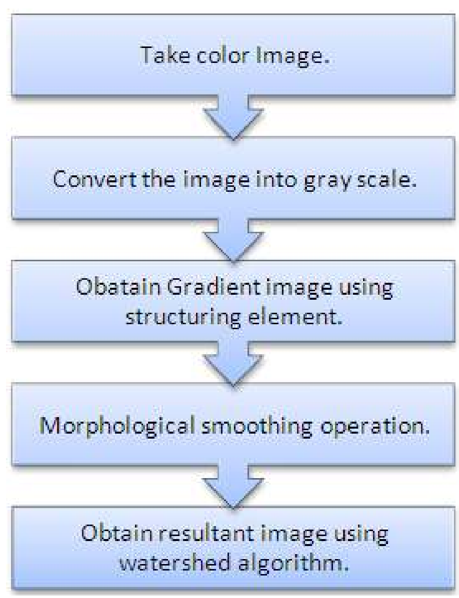


Fig 3. Flowchart of proposed approach.

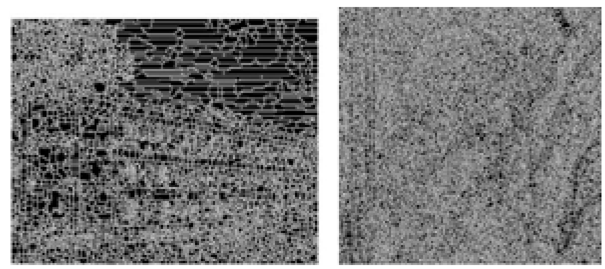
6 EXPERIMENTAL RESULTS AND DISCUSSION

Twelve new arbitrary structuring elements have been proposed to carry out image segmentation using watershed algorithm. They are namely Plus, Zed, Cross, Star, L, Inverted L, Square boundary, Rectangle boundary, Plus within square boundary, Cross within square boundary, Star within Square Boundary and Z within Square Boundary. Two real life images has been chosen to do the experimental work, "Lena" image of 512x512 dimensions and "BITM" image of 417x334 dimensions and accordingly shown in figure 4(a) and figure 4(b). It has been observed from the final segmented images (figure 5 to figure 16) using propped Structuring elements with watershed algorithm that the images are extremely over segmented and accordingly shown in section 6.1. To reduce the over segmentation problem morphological smoothing operation is applied after watershed transform and better accuracy is achieved in detection of edges with lesser over segmentation, the final resultant images (figure 17 to figure 28)are shown accordingly in section 6.2. The statistical measurements with entropy, PSNR and MSE are also shown in table 1 and in table 2. In table 1 the statistical measurements of segmented images using proposed Structuring elements followed by watershed transform is shown. In table 2 the statistical measurements of segmented images using proposed Structuring elements with watershed transform followed by morphological smoothing operation, that is with proposed approach is shown below. It is found from the statistical measurement using the proposed approach(Table 2), that for BITM and Lena image, Rectangle Boundary structuring element and Plus within Square Boundary structuring element produces lower entropy and for both the images L Structuring element produces higher entropy. In respective of PSNR the BITM image with Star structuring element produces higher PSNR and Plus within Square Boundary structuring element produces lower PSNR, for Lena image, Square Boundary structuring element produces higher PSNR and Cross structuring element produces lower PSNR. In respective of MSE, for BITM image, Plus structuring element produces higher MSE and Plus within Square Boundary structuring element produces lower MSE, for Lena image, Cross structuring element produces higher MSE and Square Boundary structuring element produces lower MSE.

(a) (b)

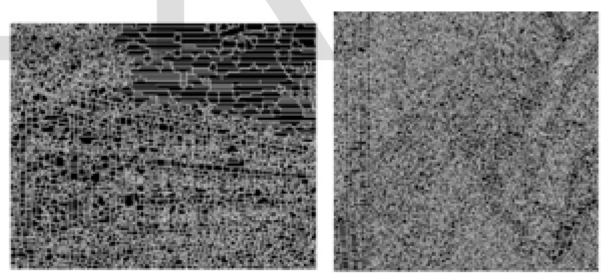
Fig 4. Original images of (a) BITM, (b) Lena.

1.1 Segmented Images Using Proposed Structuring Elements With Watershed Transform



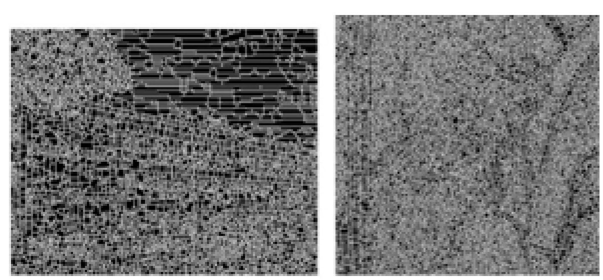
(a) (b)

Fig 5. (a) BITM with plus Structuring Element, (b) Lena with plus Structuring Element.



(a) (b)

Fig 6. (a) BITM with Zed Structuring Element, (b) Lena with Zed Structuring Element.



(a) (b)

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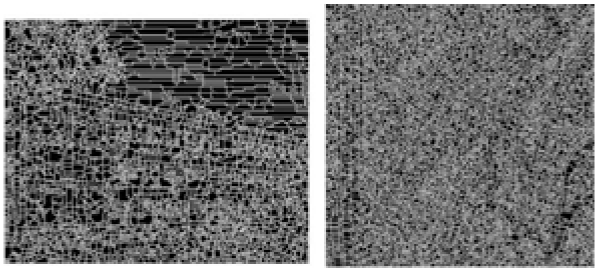
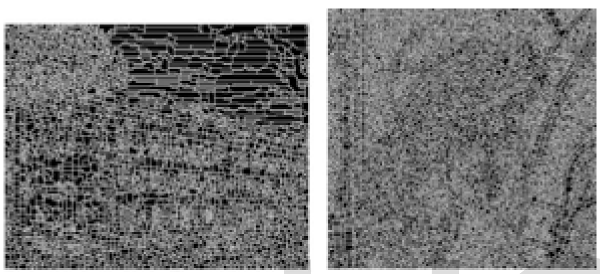
Fig 7. (a) BITM with Cross Structuring Element, (b) Lena with Cross Structuring Element.



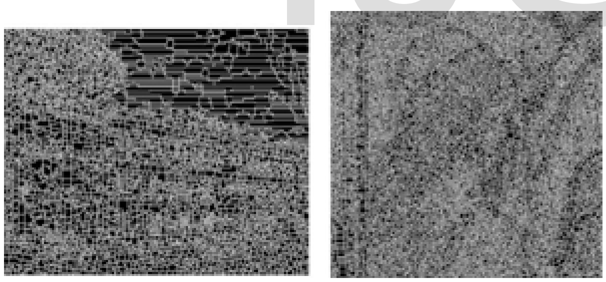
(a) (b)

Fig 8. (a) BITM with Star Structuring Element, (b) Lena with Star Structuring Element.



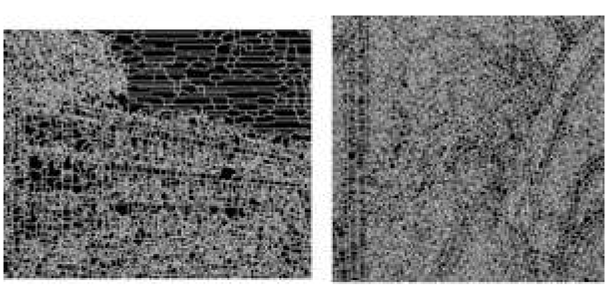
(a) (b)

Fig 9. (a) BITM with L Structuring Element, (b) Lena with L Structuring Element.



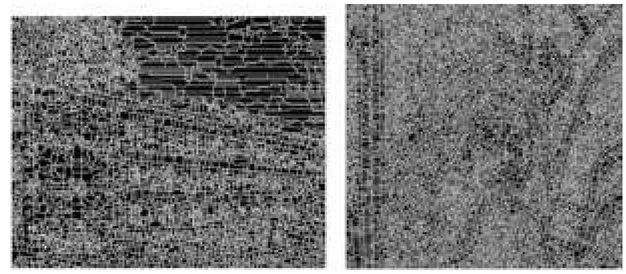
(a) (b)

Fig 10. (a) BITM with Inverted L Structuring Element, (b) Lena with Inverted L Structuring Element.



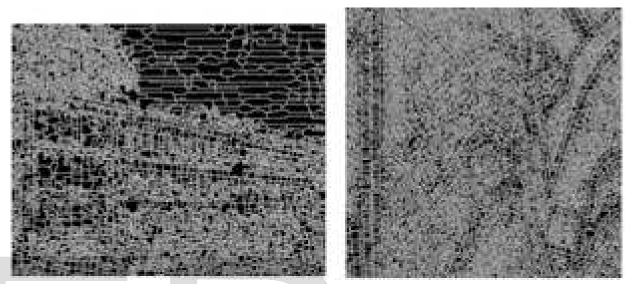
(a) (b)

Fig 11. (a) BITM with Square Boundary Structuring Element, (b) Lena with Square Boundary Structuring Element.



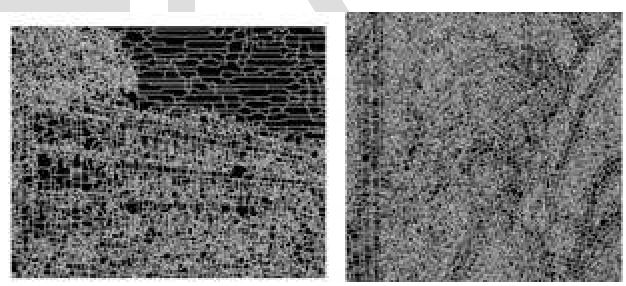
(a) (b)

Fig 12. (a) BITM with Rectangle Boundary Structuring Element, (b) Lena with Rectangle Boundary Structuring Element.



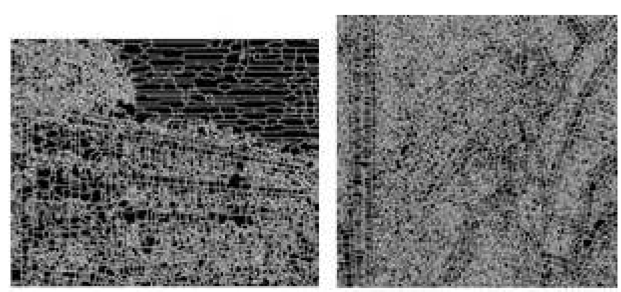
(a) (b)

Fig 13. (a) BITM with Plus within Square Boundary Structuring Element, (b) Lena with Plus within Square Boundary Structuring Element.



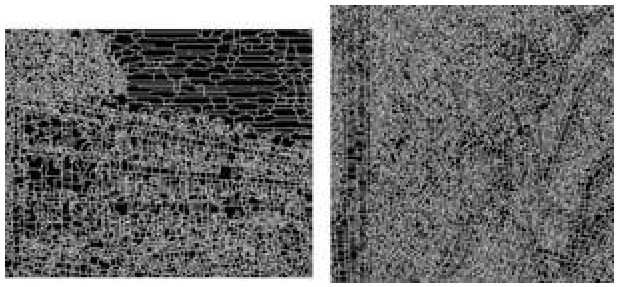
(a) (b)

Fig 14. (a) BITM with Cross within Square Boundary Structuring Element, (b) Lena with Cross within Square Boundary Structuring Element.



(a) (b)

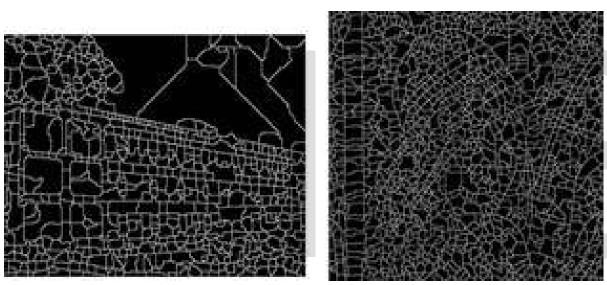
Figu 15. (a) BITM with Star within Square Boundary Structuring Element, (b) Lena with Star within Square Boundary Structuring Element.



(a) (b)

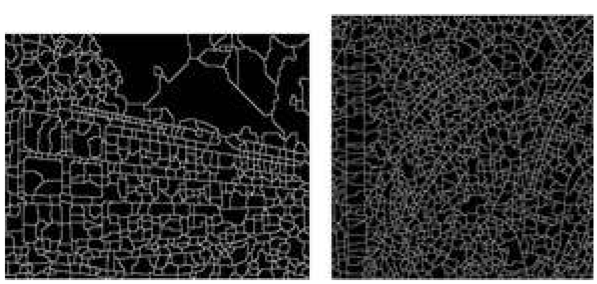
Fig 16. (a) BITM with Z within Square Boundary Structuring Element, (b) Lena with Z within Square Boundary Structuring Element.

1.2 Segmented Images Using Proposed Structuring Elements With Watershed Transform Followed By Morphological Smoothing Operation



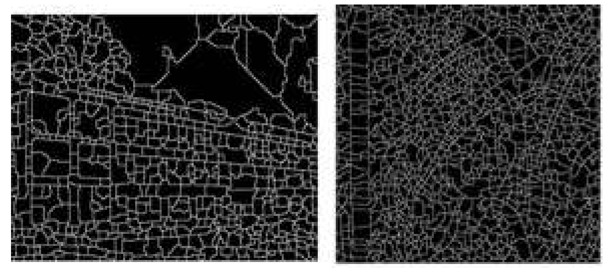
(a) (b)

Fig 17. (a) BITM with plus Structuring Element, (b) Lena with plus Structuring Element.



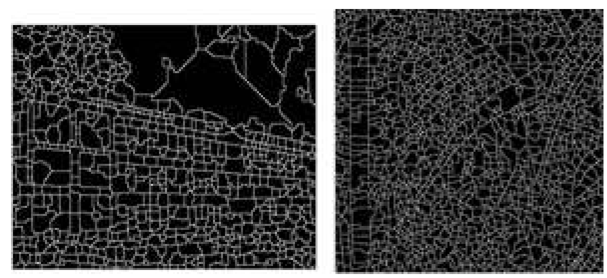
(a) (b)

Fig 18. (a) BITM with Zed Structuring Element, (b) Lena with Zed Structuring Element.



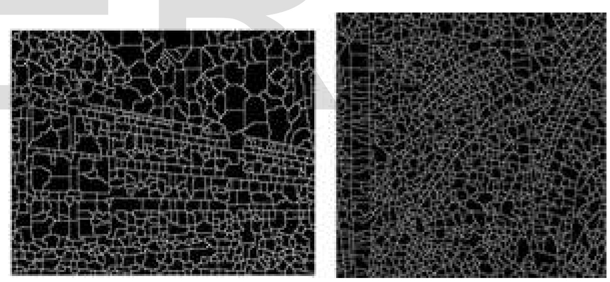
(a) (b)

Fig 19. (a) BITM with Cross Structuring Element, (b) Lena with Cross Structuring Element.



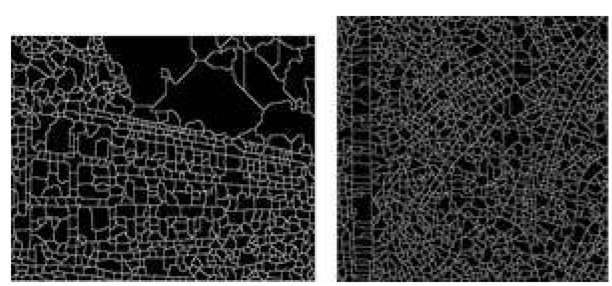
(a) (b)

Fig 20. (a) BITM with Star Structuring Element, (b) Lena with Star Structuring Element.



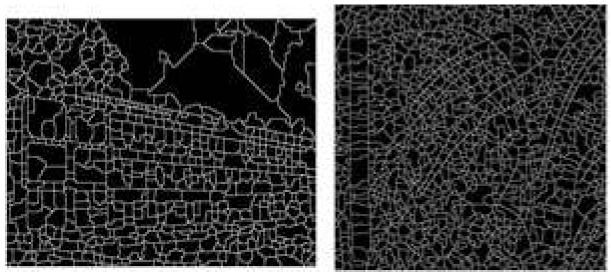
(a) (b)

Fig 21. (a) BITM with L Structuring Element, (b) Lena with L Structuring Element.



(a) (b)

Fig 22. (a) BITM with Inverted L Structuring Element, (b) Lena with Inverted L Structuring Element.

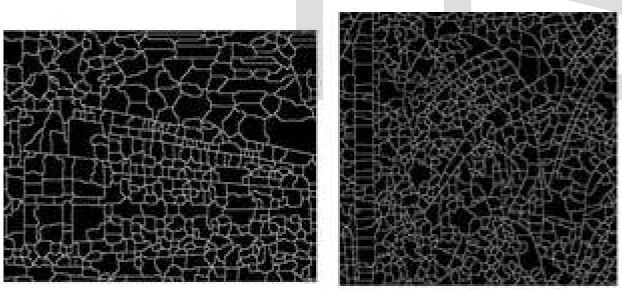


(a) (b)

Fig 23. (a) BITM with Square Boundary Structuring Element, (b) Lena with Square Boundary Structuring Element.

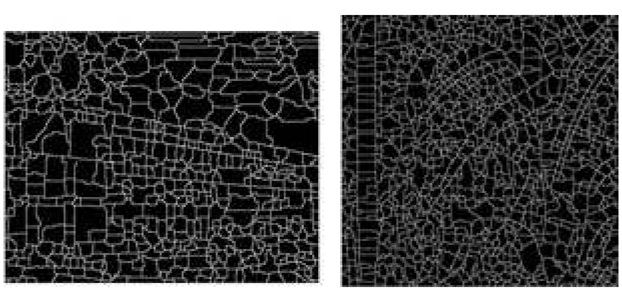
(a) (b)

Fig 24. (a) BITM with Rectangle Boundary Structuring Element, (b) Lena with Rectangle Boundary Structuring Element.



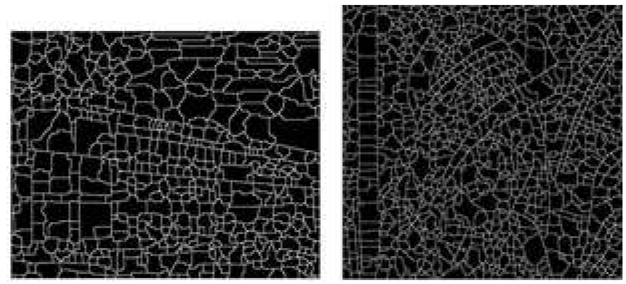
(a) (b)

Fig 25. (a) BITM with Plus within Square Boundary Structuring Element, (b) Lena with Plus within Square Boundary Structuring Element.



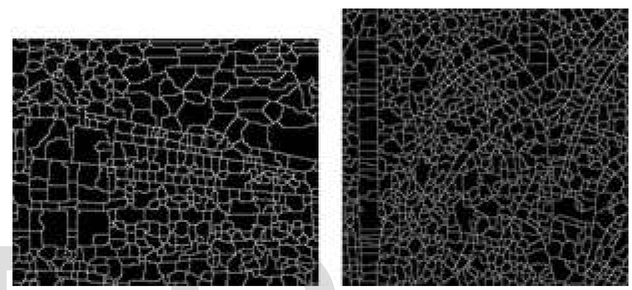
(a) (b)

Fig 26. (a) BITM with Cross within Square Boundary Structuring Element, (b) Lena with Cross within Square Boundary Structuring Element.



(a) (b)

Fig 27. (a) BITM with Star within Square Boundary Structuring Element, (b) Lena with Star within Square Boundary Structuring Element.



(a) (b)

Fig 28. (a) BITM with Z within Square Boundary Structuring Element, (b) Lena with Z within Square Boundary Structuring Element.

Table 1

Statistical measurement of segmented images using proposed Structuring elements with watershed transform.

SEGMENTED IMAGE	ENTROPY	PSNR	MSE
BITM with Plus	2.9379	7.1060	1.2661e+004
Lena with Plus	3.1518	7.5080	1.1542e+004
BITM with Zed	2.9441	7.2526	1.2241e+004
Lena with Zed	3.1724	7.5263	1.1493e+004
BITM with Cross	2.9384	7.1805	1.2446e+004
Lena with Cross	3.1616	7.5207	1.1508e+004
BITM with Star	2.9435	7.2649	1.2207e+004
Lena with Star	3.1776	7.5118	1.1532e+004
BITM with L	2.9475	7.2372	1.2285e+004
Lena with L	3.1700	7.5217	1.1506e+004
BITM with Inverted L	2.9444	7.2560	1.2232e+004
Lena with Inverted L	3.1671	7.5385	1.1461e+004
BITM with Square Boundary	2.9441	7.2266	1.2315e+004
Lena with Square	3.1693	7.5134	1.1528e+004

Boundary			
BITM with Rectangle Boundary	2.9438	7.2187	1.2337e+004
Lena with Rectangle Boundary	3.1722	7.5182	1.1515e+004
BITM with Plus within Square Boundary	2.8783	7.0380	1.2861e+004
Lena with Plus within Square Boundary	3.1623	7.5051	1.1550e+004
BITM with Cross within Square Boundary	2.8840	7.0708	1.2764e+004
Lena with Cross within Square Boundary	3.1735	7.4961	1.1574e+004
BITM with Star within Square Boundary	2.8774	7.0964	1.2689e+004
Lena with Star within Square Boundary	3.1743	7.5081	1.1542e+004
BITM with Z within Square Boundary	2.8832	7.1456	1.2546e+004
Lena with Z within Square Boundary	3.1810	7.5347	1.1471e+004

Table II- Statistical measurement of segmented images using proposed Structuring elements with watershed transform followed by morphological smoothing operation.

SEGMENTED IMAGE	ENTROPY	PSNR	MSE
BITM with Plus	2.5519	7.3803	1.1886e+004
Lena with Plus	2.9904	7.6321	1.1217e+004
BITM with Zed	2.5749	7.4316	1.1747e+004
Lena with Zed	2.9360	7.6312	1.1219e+004
BITM with Cross	2.5696	7.4367	1.1733e+004
Lena with Cross	2.9130	7.6140	1.1264e+004
BITM with Star	2.5901	7.4065	1.1815e+004
Lena with Star	2.9712	7.6206	1.1247e+004
BITM with L	2.7212	7.5093	1.1538e+004
Lena with L	2.9924	7.6254	1.1234e+004
BITM with Inverted L	2.6012	7.3978	1.1839e+004
Lena with Inverted L	2.9754	7.6169	1.1256e+004
BITM with Square Boundary	2.5725	7.4369	1.1733e+004
Lena with Square Boundary	2.9512	7.6344	1.1211e+004
BITM with Rectangle Boundary	2.5133	7.3842	1.1876e+004
Lena with Rectangle Boundary	2.8820	7.6343	1.1211e+004
BITM with Plus within Square Boundary	2.6096	7.5517	1.1427e+004
Lena with Plus within Square Boundary	2.8012	7.6252	1.1235e+004
BITM with Cross within Square Boundary	2.6247	7.5359	1.1468e+004
Lena with Cross within Square Boundary	2.8567	7.6186	1.1252e+004
BITM with Star within Square Boundary	2.6227	7.5452	1.1444e+004
Lena with Star within Square Boundary	2.8395	7.6214	1.1244e+004
BITM with Z within Square Boundary	2.6166	7.5407	1.1455e+004
Lena with Z within Square Boundary	2.8595	7.6225	1.1242e+004

CONCLUSION

For digital images, structuring elements plays a significant role in image segmentation and edge detection in morphological image processing. The choice of different structuring elements would lead to myriad applications and analysis and processing of geometric information of the image lied there in and thus would ultimately decide data distribution and data volume and their nature in the morphological transform. In this paper a morphological study with twelve new and proposed arbitrary structuring elements to accomplish the image segmentation and edge detection task with watershed algorithm followed by morphological smoothing operation has been carried out. The statistical analysis are also shown and as per visual perception analysis the segmented images with proposed approach yields better accuracy in detection of edges and the over segmentation problem is also reduced.

DEDICATION

One of the others (Dibyendu Ghoshal) dedicates the entire study to the loveliest and loving memory of his only one and younger sister Kumari Sumita Ghoshal who herself was a gem of the scholars, a symbol of wisdom and art, peerless beauty and simplicity, unfathomable knowledge and generosity.

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