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Morphological Gradient Based Transformation Controlled Multilevel Edge Detector for Digital Images

Dr.P.Shanmugavadivu [a,*], A.Shanthasheela [b,1]

Abstract - ***This paper presents a generic edge detection technique, using the principle of morphological gradient based transformation. This algorithm brilliantly detects the outer edges and inner edges of the distinct objects in an input image, which gives the freedom to dynamically segment a large object or its subimages based on the requirement. This technique has the ability to bring to light the features / information, which are hidden due to unwanted distortions. This technique finds application in image segmentation.***

Index Terms - *image segmentation, edge detection, morphological processing, morphological gradient, dilation, erosion.*

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I. INTRODUCTION

Image segmentation is an inevitable operation of image processing that subdivides an image into multiple disjoint, non-overlapping and rational regions based on spatial proximity, strong correlation between pixels representing an object, closed boundary, texture etc., [1]. This technique is defined as:

$R = \bigcup_{i=1}^{n} R_i$, where R is the regions of the image

a) for all i and j, i≠j, there exists $R_i \cap R_j = \emptyset$
b) for i = 1,2,3, … , n, $p(R_i)$=TRUE
c) for all i ≠ j, there exists $p(R_i \cup R_j)$ = FALSE where, $p(R_i)$ is a uniformity predicate for all elements in set R_i and Ø is an empty set
d) for all i=1,2,…, n, R_i is a connected component [2] .

Any segmentation methods are based on the identification of sharp local changes in intensity. The main image features of segmentation are isolated points, lines and edges [3]. There are many algorithms to segment the objects of interest, in an image. The traditional segmentation techniques use the intensity / contrast of the neighbourhood pixels of the object boundaries. Thresholding techniques make decisions based on local pixel information and it is effective when the intensity level of the objects and background are significantly different, however the blurred boundaries tend to create undesirable results [4]. Edge detectors are local image processing methods designed to detect edge pixels. As the edge detection finds application in image segmentation, there are many techniques in the literature for edge detection and segmentation. Edge detection methods are insensitive to absolute intensity and are relatively insensitive to low spatial frequency image intensities. Besides, contour based edge detection techniques fail an images with disconnected contour lines, which are to be linked for better segmentation. In the region-based method, the image is partitioned into connected regions by grouping the neighboring pixels of similar intensity levels and then the adjacent regions are merged under some criterion such as homogeneity or sharpness of the region boundaries [5]. The recently proposed active contour model starts with some initial boundary shape represented in the form of curves and iteratively modifies it by applying various operations with respect to energy function [6]. This proposed work focuses on morphological processing for the detection of edges in an image.
Mathematical morphology examines the geometrical structure of an image with small patterns, called structuring elements of discretionary size and shape [7]. This method results in nonlinear image operators and they are outfitted to explore the geometrical and topological structures. This morphological technique is applied to make certain features apparent and to distinguish meaningful information from irrelevant distortions [8].

The morphological operations for image segmentation is explained in section II. The proposed technique is given in section III. The results and discussions are detailed in section IV and the conclusion in section V.

II. MORPHOLOGICAL OPERATIONS FOR IMAGE SEGMENTATION

Morphological processing is described as operations on sets of pixels. The morphological methods find applications such as noise suppression, texture analysis, shape analysis, edge detection, segmentation and skeletonization [9]. Any image can be represented as set of pixels of size M × N. This image set is either represented in two dimensional (2D) space or three dimensional space (3D) [10] as depicted in Fig. 1(a) and 1(b) respectively.

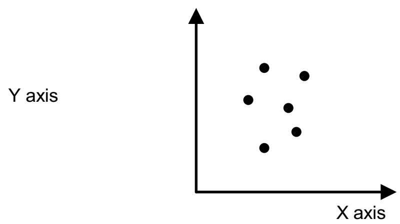

Figure 1a. 2D space representation of an image set

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Dr. P.Shanmugavadivu [a,*],
Department of Computer Science and Applications
Gandhigram Rural Institute –Deemed University, Dindigul - 624302, Tamil Nadu, India
Email: psvadivu@yahoo.com
A.Shanthasheela [b,1],
Department of Computer Science and Applications
Gandhigram Rural Institute –Deemed University, Dindigul - 624302, Tamil Nadu, India
Email: shanthasheela.a@gmail.com

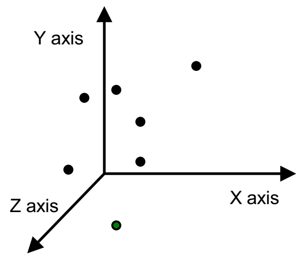


Figure1b. 3D space representation of an image set

If an image is considered as a set, then the set operations such as subset, union, intersection, disjoint, complement, difference, reflection and translation can be performed on it.

a. For the discrete image sets A and B
   1. if a is the index of a pixel in A, then $a \in A$
   2. if a is not in A then $a \notin A$
   3. if every element that is in A is also in B then A is a subset of B, then $A \subset B$
b. The union of A and B is the collection of all elements that are in one or both set. The union is the set represented by.

$$A \cup B = \{p \mid p \in A \quad or \quad p \in B \quad or \quad p \in A, B\}$$

c. If a pixel in column x and row y has index as p = x + Ny. The p can find the column and row coordinates by
   x = p mod N and
   y = p/N
   where N is the maximum number of rows in the set.
d. The intersection of two sets A and B is

$$A \cap B = \{p \mid p \in A \quad and \quad p \in B\}$$

e. If A and B are the two disjoint sets then,

$$A \cap B = \phi$$

f. The complement of a set A is the set of elements in the image grid G that are not in A:

$$A^c = \{w \mid w \in G \quad and \quad w \notin A\}$$

g. The difference of two sets A and B, is denoted by A − B is

$$A - B = \{w \in A \quad and \quad w \notin B\}$$

h. For an image set A, reflection of all the points about the origin of the set is given as
   $\hat{A} = \{ w \mid w = -a \text{ for } a \in A\}$
i. Translation about the point z is,
   $(A)z = \{ c \mid c = a + z, \text{ for } a \in A\}$

The morphological image processing operations process any images based on shapes. Morphological operations apply a structuring element to an input image and create an output image of the same size. The structuring element is used to probe the input image and it is a matrix consisting of only 0's and 1's that has any arbitrary shape and size. The pixels with values of 1 define the neighborhood. The basic morphological operations commonly used are dilation, erosion. Dilation and erosion are combined to implement image processing operations as opening and closing [10]. The other dilation and erosion based morphological operations like top-hat and bottom-hat are used for filtering.

Dilation adds pixels to the boundaries of objects in an image. While performing dilation, the value of the output pixel is the maximum value of all the pixels in the input pixel's neighborhood [11]. In a binary image, if any of the pixels is set to the value 1, the output pixel is set to 1. In dilation, pixels beyond the image border are assigned the minimum value afforded by the data type.

Erosion removes pixels on object boundaries. Erosion is performed when the value of the output pixel is the value of all the pixels in the input pixel's neighborhood. In a binary image, if any of the pixels is set to 0, the output pixel is set to 0. The number of pixels added or removed from the objects in an image depends on minimum the size and shape of the structuring element used to process the image[12]. In erosion, pixels beyond the image border are assigned the maximum value afforded by the data type.

Opening and closing of an image is performed using the basic morphological operations, erosion and dilation. Opening of an image erodes an image and then dilates the eroded image using the same structuring element for both operations. Closing of an image dilates an image and then erodes the dilated image using the same structuring element for both operations [13].

The morphological bottom-hat operation subtracts the original image from a morphologically closed version of the image. It is used to find intensity troughs in an image [14].

The morphological top-hat operation subtracts a morphologically opened image from the original image. It is used to enhance the contrast in an image [15].

The mathematical morphology is a tool for image extraction and region / shape description as boundary and skeletons. Morphological techniques are widely used for either pre- or post-processing like filtering, thinning and pruning [11].

III. PROPOSED WORK

The proposed technique of Morphological Gradient based Transformation Controlled Multilevel Edge Detector for Digital images (MGT-ED) is intended to find edges in an image using morphological approach. Morphological gradient (MG_I) is calculated using morphological erosion and dilation. The difference between morphological dilation and erosion computes the image gradient. Then, the inner details are revealed by finding the negative of the gradient image (NG_I). To differentiate the objects from its background in an image, morphological bottom-hat transformation is performed by subtracting the images with its morphological closed image. The average intensity is computed as AVG. Using AVG, the edges are smoothened and a binary image is formed. To remove the background in the image, the largest connected object is found and is subtracted from its edge. The largest connected region finding algorithm starts by labeling all the components in binary image. Then, the number of pixels in each connected region is calculated and the label of the largest connected region is found. Finally the detected edges are displayed as resultant image.

A. *Algorithm* of MGT –ED

Step 1. Read an input image (I).
Step 2. Find the gradient of the image using morphological processing (MG_I)
Step 3. Find the negative image of the gradient image (NG_I)
Step 4. Subtract original image from the closed image using bottom-hat transformations.
Step 5. Find the average pixel of image I (AVG)
Step 6. Find the binary image based on AVG to smoothen the image.
Step 7. Find the largest image using the largest connectivity to remove background.
Step 8. Remove smaller regions from the image

Step 9. Display the resultant image with the detected edges (OE).

B. Flowchart

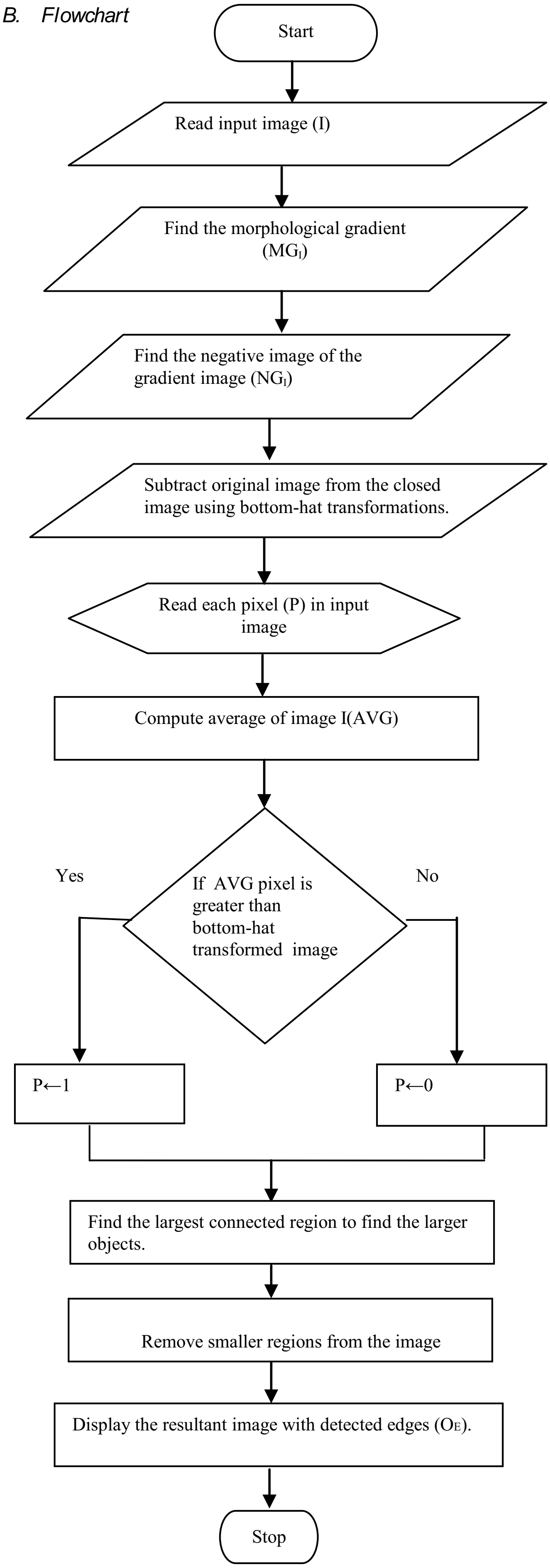


Figure 2. Flowchart of MGT-ED

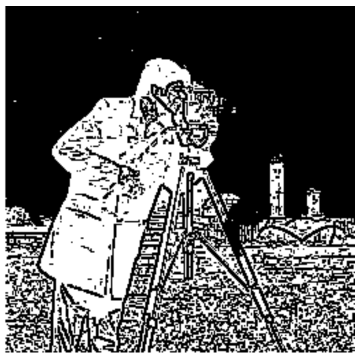
III. RESULTS AND DISCUSSION

The proposed technique is implemented using MATLAB 6.5 and it is tested with standard and real time images. The proposed algorithm is found to detect most of the edges in a given image, which facilitates the identification of objects in largely connect regions. It is clear from the output images that the proposed algorithm, detects the edges of distinct objects of the input image as well as the inner edges of contoured objects, which aid us to segregate the subimages of the larger images.

The performance of MGT-ED is depicted with reference to cameraman, coins and monkey, as given in fig. 3(a), (c) and (e) respectively and their corresponding resultant images are given in Fig. 3 (b), (d) and (f). The processed image initially, the gradient image is found and is inversed to reveal the inner details. Then, the inversed image is filtered using bottom-hat transformation and then smoothened using average pixel value of the input image. After that the largest connected region is found, which for most of the images, the background. Finally the largest region is subtracted from the smoothened image.

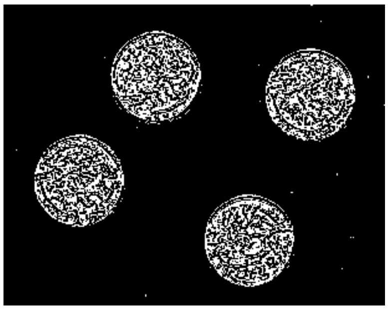
The obtained results of the proposed algorithm highlight the fact that all the distinct objects in the images are detected and meanwhile bring out the hidden details which were not visible prior to the application of MGT-ED algorithm. This algorithm can be extended to separate the distinct objects because of every edge of the objects in the input image is well detected by MGT-ED.

(a)



(b)

(c)



(d)

(e)

(f)

Figure 3. (a) Cameraman image , (c) Coins image , (e). Monkey image, Figure (b).,(d), (f). edge detected image of (a),(c) and (e) respectively

V. CONCLUSION

This paper proposes, a morphological operation based edge detection mechanism, which effectively detects all the continuous and discontinuous edges and then differentiates the detected edges from the background. This technique provides the scope and freedom to identify the edge details in an image. Further modification will result better for fine edges. This principle of edge detection can be extended on medical images too.

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BIOGRAPHY

Dr. P. Shanmugavadivu received Ph.D., in Image Restoration from Department of Computer Science and Applications, Gandhigram Rural Institute - Deemed University,, Gandhigram, India, 2008 and is working as Associate Professor in the same department. Her research interests are image restoration, image enhancement and image segmentation.

A.Shanthasheela is currently pursuing Ph.D. at Department of Computer Science and Applications, Gandhigram Rural Institute – Deemed University, India. She has two years of teaching experience and one year of research experience to her credits. Her areas of interest include Image Segmentation, Object Oriented programming.