

OBJECT SEGMENTATION USING MULTISCALE MORPHOLOGICAL OPERATIONS

Dr. A. Srikrishna¹, P. Pallavi², V. Geetha Madhuri³, N. Neelima⁴

^{1,2,3,4}Department of Information Technology,
RVR & JC College of Engineering,
Chowdavaram, Guntur, Andhra Pradesh, India
atlurisrikrishna@yahoo.com
paladugupallavi3@gmail.com
madhurigeetha33@gmail.com
neelima_nalla@yahoo.co.in

ABSTRACT

Object segmentation plays an important role in human visual perception, medical image processing and content based image retrieval. It provides information for recognition and interpretation. This paper uses mathematical morphology for image segmentation. Object segmentation is difficult because one usually does not know a priori what type of object exists in an image, how many different shapes are there and what regions the image has. To carryout discrimination and segmentation several innovative segmentation methods, based on morphology are proposed. The present study proposes segmentation method based on multiscale morphological reconstructions. Various sizes of structuring elements have been used to segment simple and complex shapes. It enhances local boundaries that may lead to improve segmentation accuracy. The method is tested on various datasets and results shows that it can be used for both interactive and automatic segmentation.

KEYWORDS

Morphology, Structuring Element, Segmentation, Edge Detection, Skeletanization

1. INTRODUCTION

Humans recognize various objects in an image though the objects may vary somewhat in different viewpoints and on various transformations. Object segmentation is useful task in object recognition. The object recognition determines an object in a given set of objects in an image or image sequence. In order to perform object recognition the objects from a give image or image sequence are to be identified. For this object segmentation that is to distinguish objects from background is performed.

Object segmentation [3] is the process of partitioning a digital image into multiple segments (sets of pixels, also known as super pixels). The goal of segmentation is to simplify and/or change the representation of an image into something that is more meaningful and easier to analyze. Object segmentation is typically used to locate objects and boundaries (lines, curves, etc.) in images. More precisely, object segmentation is the process of assigning a label to every pixel in an image such that pixels with the same label share certain visual characteristics.

Some of the applications of object segmentation are content based image retrieval, machine vision, medical imaging, object detection, recognition tasks, traffic control systems, video

surveillance. Object segmentation is the partition of an image into a set of non overlapping regions whose union is the entire image. The purpose of segmentation is to decompose the image into part that is meaningful with respect to a particular application. Concerning visual signal processing, image segmentation is essential for various applications. It describes the process whereby each pixel in an image is labeled, such that pixels with the same label present coherent visual characteristics. This allow for a semantic approach to image analysis. One way to perform image segmentation is to simply utilize the clustering algorithm in the color space domain [1], i.e., HSV or RGB; segmentation can also be based on the statistics of the color space description of the image, e.g., color histogram. These methods are carried out in the color space domain instead of the image pixel domain, whose results depend on the initial cluster setting. Edge-based segmentation is simple but it requires a further linking procedure to segment an image [2], [3], [4]. Among color region-based approaches, the region-growing approach [5] provides an initial set of seeds; regions are then grown by comparing neighboring pixels, which are merged [6] with the region with the closest mean color. JSEG [7], [8], [9], [10] seeks to divide an image into spatially continuous disjoint and homogenous regions based on the image. It uses a region merging approach, but the color information between entire neighboring regions, rather than individual pixels, is utilized. Experiments show that JSEG provides satisfactory results on most color images. The watershed technique splits one image into regions based on its gray-level topology and is performed on the gradient image. Regions are split by watersheds, which are constructed from adjacent catchment basins. Although it has the advantage of being able to segment regions with closed contours, it suffers from over segmentation and requires region merging processing afterward. Multiscale morphological reconstruction [11] is used to eliminate the over segmentation in the watershed algorithm. Graph based segmentation [12], [13] takes the global image information and local spatial relationships into consideration to perform image segmentation. It defines a predicate to measure the boundary evidence between two neighboring regions to yield a graph-based representation of one image.

The general-purpose segmentation algorithms [1], [7], [8], [9], [10], [12], [13] represent one image with disjoint regions of homogeneous color/texture features for higher level applications, and the object segmentation ones [11], [14] extract image objects with different gray level variations and noise attacks. The former does not address object segmentation from its design target. The latter focuses on segmenting the object of different scale but do not perform parameter adaptation when dealing with images with different background (BG) variation and object contents. To utilize both region and object-based segmentation capabilities to handle the object segmentation for large-scale database images in a robust and principled manner an algorithm is proposed. The proposed algorithm is known as object segmentation using multiscale morphology (OSMM). Morphological open (close) by reconstruction [14], [15], i.e., OR (CR), with a proper structure element (SE) on the gray levels, to automatically segment images' object region is used. Section 2 discusses the basic terminology of mathematical morphology. Section 3 discusses segmentation using multiscale morphology. Section 4 deals with results and discussions.

2. BASIC TERMINOLOGY OF MATHEMATICAL MORPHOLOGY

2.1. Mathematical Morphological Operations

2.1.1. Dilation

Dilation is one of the elementary operators of mathematical morphology, that is, it is a building block for a large class of operators. The key process in the dilation operator is the local comparison of a shape, called structural element, with the object to be transformed. When the structural element is positioned at a given point and it touches the object, then this point will appear in the result of the transformation, otherwise it will not. In dilation the value of the output

pixel is the maximum value of all the pixels in the input pixel's neighbourhood. In a binary image, if any of the pixels is set to the value 1, the output pixel is set to 1. The dilation of a gray level image $I(x, y)$ by two-dimensional structuring element B is defined as follows

$$(I \oplus B)(x, y) = \max \{I(x - k, y - l) | (k, l) \in B\} \quad (1)$$

2.1.2. Erosion

Erosion is one of two fundamental operations (the other being dilation) in morphological image processing from which all other morphological operations are defined. It was originally defined for binary images, later being extended to gray scale images, and subsequently to complete lattices.

The erosion is one of the elementary operators of mathematical morphology, that is, it is one of the building blocks of a large class of operators. The key mechanism under the erosion operator is the local comparison of a shape, called structural element, with the object that will be transformed. If, when positioned at a given point, the structural element is included in the object then this point will appear in the result of the transformation, otherwise not. The value of the output pixel is the minimum value of all the pixels in the input pixel's neighbourhood. The erosion of a gray level image $I(x, y)$ by two dimensional structuring element B is defined as follows

$$(I \ominus B)(x, y) = \min \{I(x + k, y + l) | (k, l) \in B\} \quad (2)$$

2.1.3. Opening

Opening smoothes the contour of an object, breaks narrow isthmuses, and eliminates thin protrusions. The opening of I by structuring element B is obtained by the erosion of I by B , followed by dilation of the resulting image by B is denoted by $I \circ B$ which is given in the form of equation as follows

$$I \circ B = (I \ominus B) \oplus B \quad (3)$$

2.1.4. Closing

Closing tends to smooth sections of contours but, as opposed to opening, it generally fuses narrow breaks and long thin gulfs, eliminates small holes, and fills gaps in the contour. The closing of I by B is obtained by the dilation of I by B , followed by erosion of the resulting structure by B is denoted by $I \bullet B$ which is given in the form of equation as follows

$$I \bullet B = (I \oplus B) \ominus B \quad (4)$$

2.2. Multiscale Morphological Operations

Let the structuring element B defined in Equations 1, 2, 3, 4 be $n.b$ where b denotes the smallest structuring element size in the discrete domain. The n^{th} homothetic of a convex structuring element b can be obtained by dilating b recursively $n - 1$ times with itself given by Equation 5.

$$n.b = b \oplus b \oplus b \oplus \dots \oplus b \quad (n - 1) \text{ times} \quad (5)$$

By controlling n , the multiscale morphological operations decompose one image into a set of filtered images. These operations are self-calibrated in which the filtered image produced by a structuring element of a particular scale should strictly contain only the features of that scale.

Multiscale morphological reconstruction operations on gray-level images can be applied in a dual approach to segment objects. Let $g = I \circ B$, and the morphological open by reconstruction (OR) can be defined by Equation 6.

$$I \circ B = I_B^{OR(n)} = \delta_b^{n+1}(g, I) \quad (6)$$

Where

$\delta_b^1(g, I) = \min(g \oplus b, I)$, $\delta_b^{j+1}(h, I) = \min(\delta_b^j(g, I) \oplus b, I)$ and n is an integer such that $\delta_b^{n+1}(g, I) = \delta_b^n(g, I)$.

Similarly, let $h = I \bullet B$ the morphological close by reconstruction (CR) can be defined by Equation 7.

$$I \bullet B = I_B^{CR(m)} = \epsilon_b^{m+1}(h, I) \quad (7)$$

where

$\epsilon_b^1(h, I) = \max(h \ominus b, I)$, $\epsilon_b^{j+1}(h, I) = \max(\epsilon_b^j(h, I) \ominus b, I)$ and m is an integer such that $\epsilon_b^{m+1}(h, I) = \epsilon_b^m(h, I)$.

3. SEGMENTATION USING MULTISCALE MORPHOLOGY

The general-purpose segmentation algorithms such as mean shift segmentation, edge based segmentation represent one image with disjoint regions of homogeneous color or texture features for higher level applications, and the object segmentation ones such as watershed segmentation, graph based segmentation extract image objects with different gray level variations and noise attacks. The former does not address object segmentation from its design target. The latter focuses on segmenting the object of different scale but do not perform parameter adaptation when dealing with images with different background (BG) variation and object contents. In order to overcome the drawbacks, segmentation using multiscale morphology has been proposed. This method utilizes both region- and object-based segmentation capabilities to handle the object segmentation in a robust and principled manner. Figure 1 shows the block diagram of the object segmentation using multiscale morphological reconstructions.

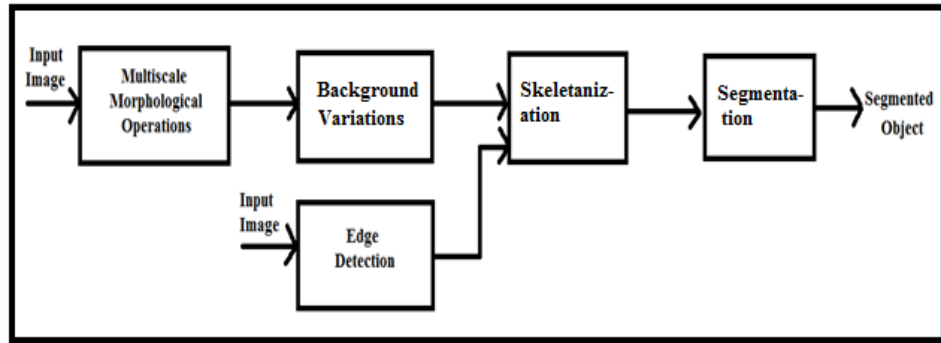


Figure 1. Object Segmentation using Multiscale Morphology.

3.1. Background Variations

Open by reconstruction (OR), close by reconstruction (CR) and top- (bottom-) hat operations are used to segment object regions I_O^α and their gray levels $I_O = I \wedge I_O^\alpha$, where \wedge is a binary AND operation. The reconstruction operations of OR (CR) would not be fully iterated for stable outcome so that convex (concave) gray-level variation regions can be located. The image processed by this *partial* OR (CR) operation is denoted as $I_B^{OR(n-)}$ with $n^- < n$ to be distinguished from the fully reconstructed one in that requires n iterations. The basic idea is images with identifiable back ground regions (BGs) usually present homogeneously evolving gray-level BGs, i.e. $(\partial f / \partial x)$, $(\partial f / \partial y)$ is continuous. When performing gray-level open by reconstruction (OR) operations on image with suitable structuring element sizes most background (BG) regions would coincide with the processed image $I_B^{OR(n-)}$. To precisely locate back ground regions (BGs) the structuring element size in $I_B^{OR(n-)}$ should be properly selected such that object boundaries are identifiable. For precisely locating the structuring element, structuring element size is gradually enlarged and the frame difference of gray levels between I and $I_B^{OR(n-)}$ i.e. $\Delta I_B^{OR(n-)}$ which is given by Equation 8 is calculated (difference of gray levels for consecutive structuring elements is calculated).

$$\Delta I_B^{OR(n-)} = |I - I_B^{OR(n-)}| = \sum_{x,y} |I(x,y) - I_B^{OR(n-)}(x,y)| \quad (8)$$

The threshold value is calculated by using the Equation 9

$$threshold_B^{n-} = \Delta I_B^{OR(n-)} - \Delta I_B^{OR(n-1)} / a \times b \quad (9)$$

where $a \times b$ is the size of the image.

To find a proper structuring element B such that it yields a nearly stable gray-level variation, i.e., threshold given by Equation 9 should nearly approach zero. The proper B has threshold given by Equation 9 values between 0 and 1, and different images would require different $B_c(B_c)$ to achieve the aforementioned stability due to differing object contents.

3.2. Edge Detection

The edge pixels of the input image I are detected by using morphological operations. The edge pixels denoted by $Edge(I)$ for an image I is given by the Equation 10

$$Edge(I) = Dilation(I) - Erosion(I) \quad (10)$$

where $Dilation(I)$, $Erosion(I)$ are dilation, erosion operations on input image I as defined in Equations 1, 2 respectively.

3.3. Skeletanization

The skeleton of an object $L(I)$ can be obtained by edge image and background variations. The skeleton obtained using skeletanization process is given by Equation 11.

$$L(I) = Edge(I) \&\& \Delta I_B^{OR(n-)} \quad (11)$$

3.4. Segmentation

The skeleton obtained using skeletanization process is given as the input for reconstruction of object. In the reconstruction the input image is dilated by varying sizes of structuring element B which satisfies the condition using *threshold* value given by Equation 9 which is in the range of 0 and 1. Let $C_1, C_2, C_3, \dots, C_{n-}$ be the outputs of dilation for varying sizes of structuring elements. Then the segmented object is given by Equation 12.

$$\text{Segmented object} = C_1 \parallel C_2 \parallel C_3 \parallel \dots \parallel C_{n-} \quad (12)$$

The overall process of segmentation is given in the Algorithm

3.5. Algorithm Object Segmentation using Multiscale Morphology (OSMM)

Step 1: Read the input image.

Step 2: Convert the image into gray scale image.

Step 3: Perform “opening(erosion followed by dilation) or closing (dilation followed by erosion)” of the input image using varying sizes of structuring elements.

Step 4: The structuring element size is gradually enlarged and the frame difference of gray levels between I and $I_B^{OR(n-)}$ i.e. $\Delta I_B^{GR(n-)}$ which is given by Equation 8 is recorded.

Step 5: Calculate the threshold by using the formula in Equation 9.

Step 6: The structuring elements whose threshold values are between 0 and 1 are stored.

Step 7: Calculate the edge pixels of the input image by using the formula in Equation 10.

Step 8: Perform detaching process given by Equation 11.

Step 9: Perform reconstruction of segmented by using Equation 12.

4. RESULTS AND DISCUSSIONS

We evaluate shape prototypes in the context of object segmentation. These object segmentation techniques are used as a pre processing step for object recognition. We begin with a set of 200 objects, representing distinct views of collection of 101 objects from Caltech101 database. We are using this step as a pre processing step for object recognition so the input image consists of only one object.

To evaluate the performance of the algorithm correctness and completeness criteria are considered which are defined by Equations 13 and 14 respectively.

Correctness can be defined as the percentage of correctly extracted region (ground truth) by the segmentation algorithm and can be calculated using Equation 13.

$$\text{correctness} = \frac{TP}{TP + FP} * 100\% \quad (13)$$

Completeness can be defined as the percentage of the ground truth region extracted by the segmentation algorithm and can be calculated using Equation 14.

$$\text{completeness} = \frac{TP}{TP + FN} * 100\% \quad (14)$$

where to obtain the true positive (TP) image a logical AND operation was performed between the ground truth and the resultant image. The difference between the ground truth image and the true positive image was taken as the false negative (FN) image of the respective segmented image. The difference between the segmented image and the true positive image was taken as the false positive (FP) image of the respective segmented image. The TP, FP, FN are illustrated in Figure 2. Here we consider the ground truth which is a manually segmented image. The ground truth images are compared with the image segmented with the proposed algorithm. The Figure 3 to Figure 8 shows that the segmented images using proposed algorithm are very similar to ground truth. The objective analysis of the segment is evaluated using correctness and completeness which is shown from Table 1 to Table 6. The correctness is above 80% in most of the cases and completeness is above 90% in all cases.

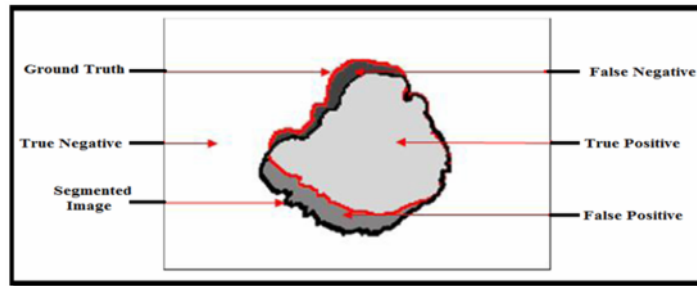


Figure 2. Ground truth region of object and segmented region

Lilly.png

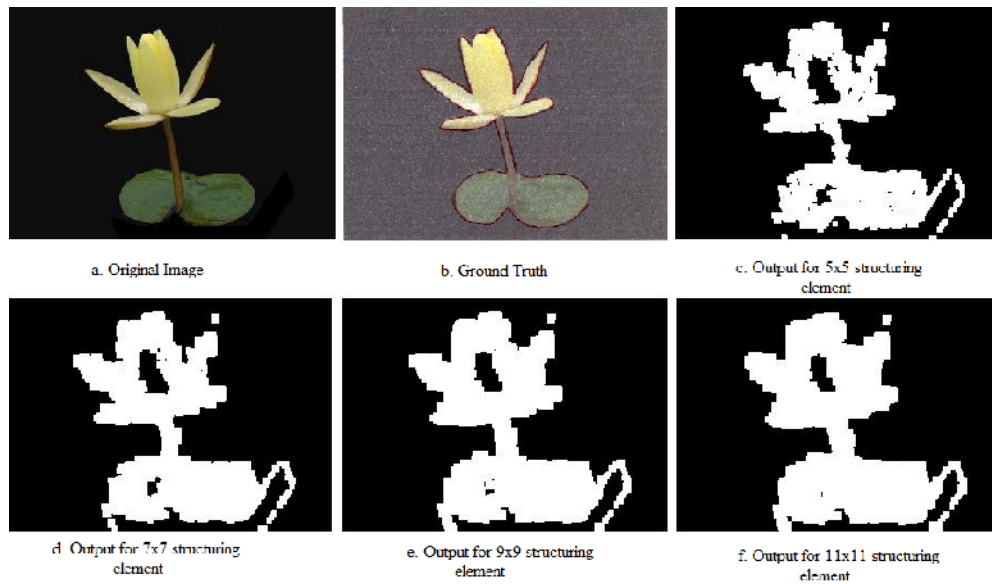


Figure 3. a. Shows the Lilly image. b. Shows the ground truth which is taken manually. c-f represent the output of the image with varying structuring elements.

Table 1. Correctness and Completeness values for various sizes of structuring elements for Lilly.png.

Structuring Element Size	Correctness	Completeness
5x5	86.8629	90.5704
7x7	81.7156	93.7795
9x9	77.2008	95.2278
11x11	75.0547	96.3634
13x13	72.6632	97.4097
17x17	67.6016	98.7240

Scissors.jpg

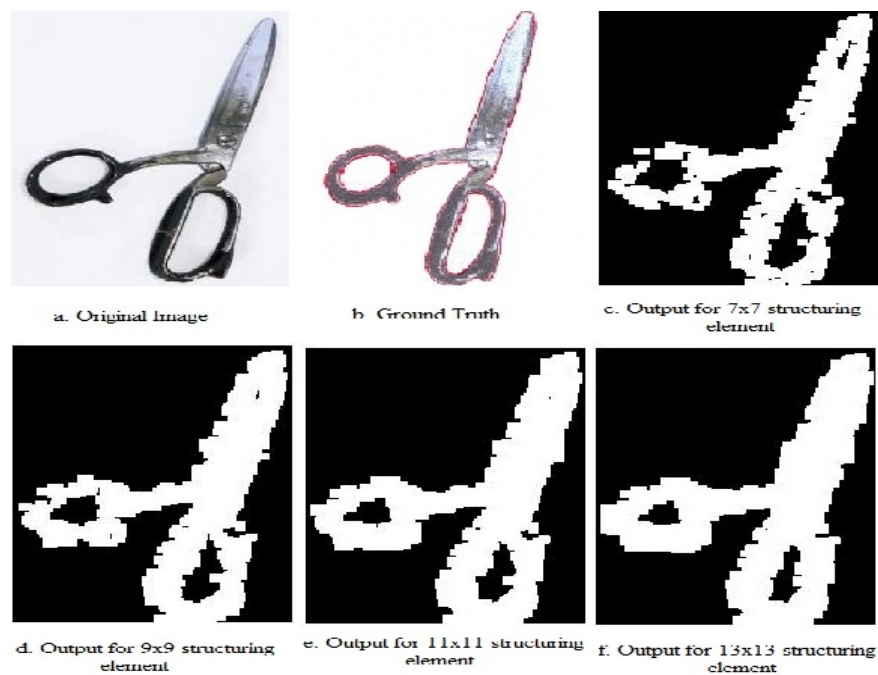


Figure 4. a. Shows the Scissors image. b. Shows the ground truth which is taken manually. c-f represent the output of the image with varying structuring elements

Table 2. Correctness and Completeness values for various sizes of structuring elements for Scissors.jpg

Structuring Element Size	Correctness	Completeness
7x7	86.3627	79.4165
9x9	82.1526	85.8422
11x11	79.8946	88.6663
13x13	78.5122	91.3224
15x15	78.129	95.0174
17x17	74.5465	97.4122

Mandolin.jpg

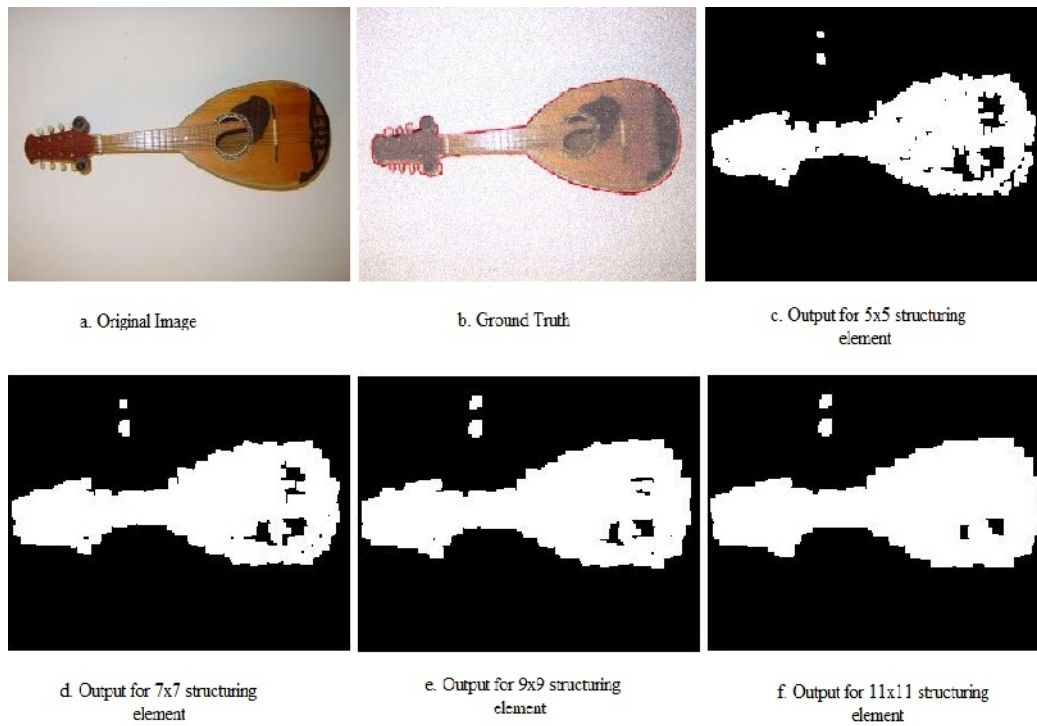


Figure 5. a. Shows the Mandolin image. b. Shows the ground truth which is taken manually. c-f represent the output of the image with varying structuring elements.

Table 3. Correctness and Completeness values for various sizes of structuring elements for Mandolin.jpg

Structuring Element Size	Correctness	Completeness
5x5	91.1111	90.4906
7x7	86.8741	94.5327
9x9	83.3252	96.9289
11x11	81.4175	98.4424
13x13	78.5678	99.1486
15x15	75.0938	99.6657

Seahorse.jpg

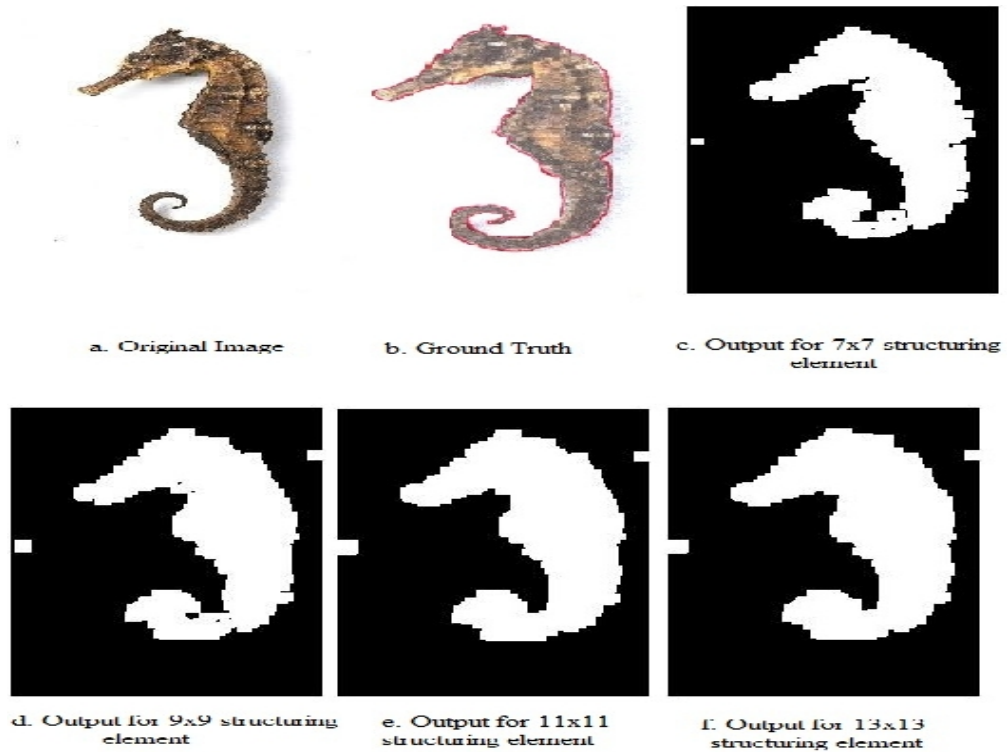


Figure 6. a. Shows the Seahorse image. b. Shows the ground truth which is taken manually. c-f represent the output of the image with varying structuring elements.

Table 4. Correctness and Completeness values for various sizes of structuring elements for Seahorse.jpg

Structuring Element Size	Correctness	Completeness
7x7	90.0999	93.7143
9x9	85.1340	96.0395
11x11	83.0496	96.8145
13x13	81.0013	97.2830
15x15	78.7993	97.5981
17x17	76.5526	98.1602

Flamingo.jpg

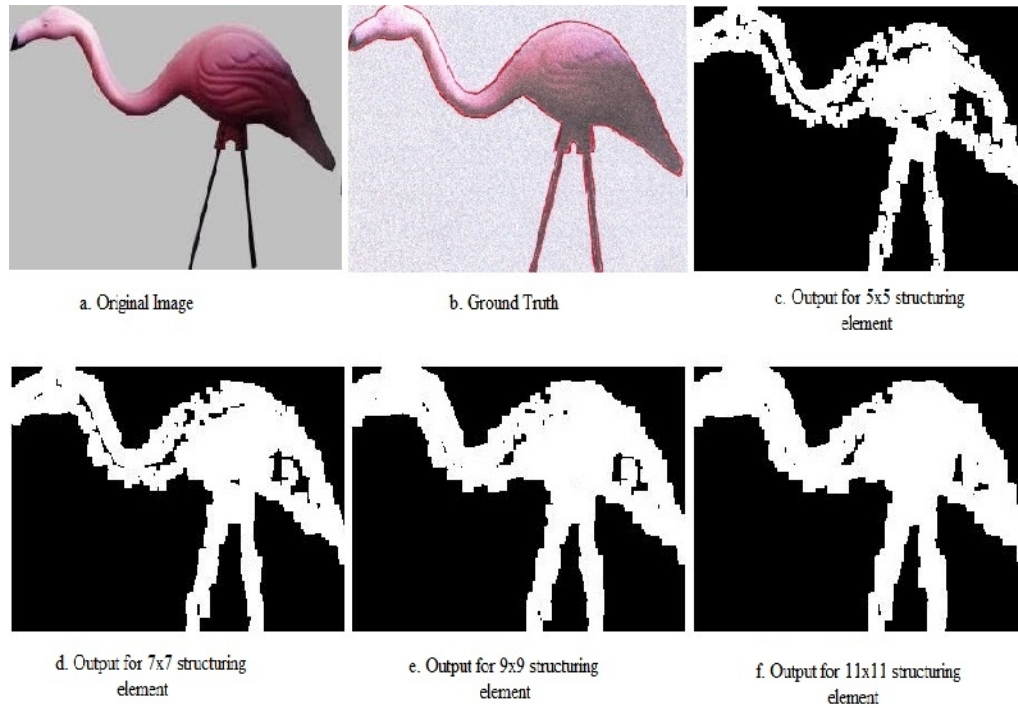


Figure 7. a. Shows the Flamingo image. b. Shows the ground truth which is taken manually. c-f represent the output of the image with varying structuring elements

Table 5. Correctness and Completeness values for various sizes of structuring elements for Flamingo.jpg

Structuring Element Size	Correctness	Completeness
5x5	85.456	85.3091
7x7	81.234	92.5348
9x9	77.6136	96.1200
11x11	74.9444	97.2496
13x13	73.3578	97.90656
15x15	71.6859	98.6985

Dragonfly.jpg

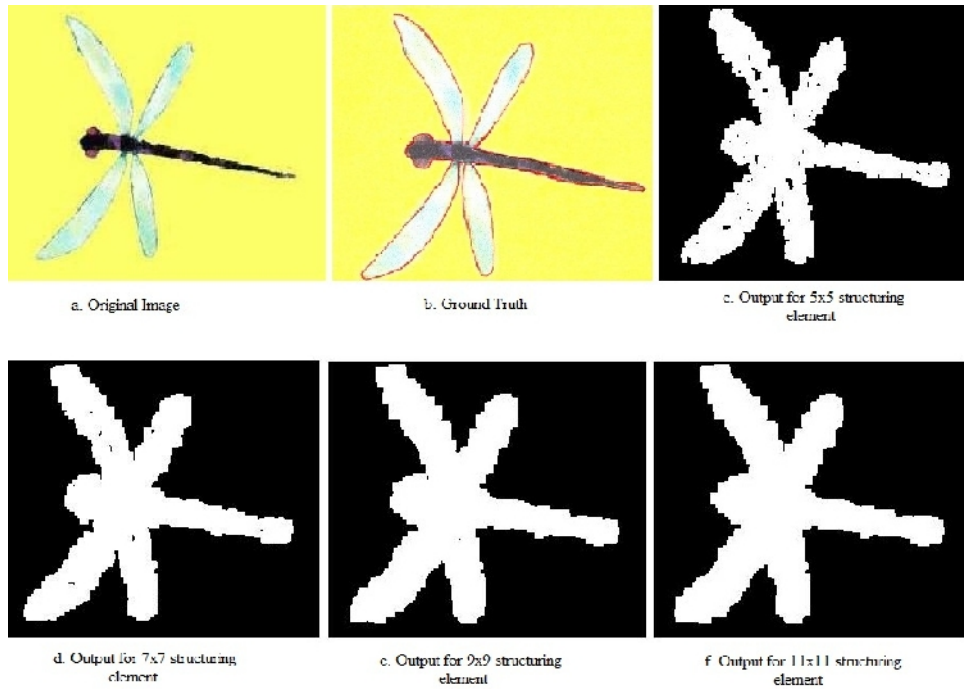


Figure 8. a. Shows the Dragonfly image. b. Shows the ground truth which is taken manually. c-f represent the output of the image with varying structuring elements.

Table 6. Correctness and Completeness values for various sizes of structuring elements for Dragonfly.jpg

Structuring Element Size	Correctness	Completeness
5x5	84.6530	97.1433
7x7	80.0787	99.3071
9x9	76.1462	99.6933
11x11	74.6419	99.7501
13x13	71.6884	99.8012
15x15	69.0193	99.8523

5. CONCLUSIONS

A simple and regular image object segmentation method has been proposed to deal with large-scale image databases. It performs dual multiscale morphological reconstruction operations on the gray levels of entire images to identify the objects. Experiments have demonstrated that OSMM yields better image object segmentation accuracy, both on shape region and boundary. The results show that the correctness and completeness of the image increases as the structuring element increases. The segmentation process can be used for identification of object in any database.

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