Morphological Image Segmentation Analysis

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Abstract:
Fritz Zwicky pioneered the development of General Morphological Analysis (GMA) as a method for investigating the totality of relationships contained in multi-dimensional, non- quantifiable problem complexes. During the past two decades, GMA has been extended, computerized and employed for structuring complex policy and planning issues, developing scenario and strategy laboratories, and analyzing organizational and stakeholder structures.
A morphological image segmentation technique based on the watershed algorithm is proposed. New morphological based pre-processing and post-processing techniques are proposed to reduce over-segmentation, by means of merging and removing spurious segments. The preprocessing aims at removing trivial regions as well as background noise. The post-processing produces a more concise region representation of the watershed-segmented image, where a region adjacency list (RAL) is built for the region merging process. The proposed technique produces effective and significant results in successfully segmenting various objects when tested on a series of well known test images, as shown in this paper.

Keywords: Morphological Analysis, Morphological operations, Threshold techniques, watershed segmentation, region similarity function, region merging, Danielsson function.

1. Introduction

Image segmentation is the division of an image into different regions, each possessing specific properties. In a segmented image, the elementary picture elements are no longer the individual pixels but connected sets of pixels belonging to the same region. Once the image has been segmented, measurements can be performed on each region and neighboring relationships between adjacent regions can be investigated. Image segmentation is therefore a key step towards the quantitative interpretation of image data.

Segmentation of intensity images usually involves five main approaches, namely threshold, boundary detection, region-based processing, pixel intensity and morphological methods.
The threshold techniques [1] are based on the postulate that all pixels whose values lie within a certain range belong to one class. Such methods neglect all of the spatial information of the image and do not cope well with noise or blurring at boundaries.
Boundary-based methods are sometimes called edge detection [2], because they assume that pixel values change rapidly at the boundary between two regions. The basic method is to apply a gradient filter to the image. High values of this filter provide candidates for region boundaries, which must then be modified to produce closed curves representing the boundaries between regions. Region-based segmentation algorithms postulate that neighboring pixels within the same region have similar intensity values, of which the split-and-merge [3] technique is probably the most well known. The general procedure is to compare a pixel with its immediate surrounding neighbors. If a criterion of homogeneity is satisfied, the pixel can be classified into the same class as one or more of its neighbors. The choice of homogeneity criterion is therefore critical to the success of the segmentation.

In pixel intensity based methods, the intensity values of pixels are used to segment the image. The space continuity is not frequently considered in this type of methods. Within this group, there stands out a method of classification of pixels that uses statistical algorithms to assign pixel labels to the image [4].

A well known morphological approach to segmentation, the watershed algorithm, is generally applied to the gradients of the image. The gradient image can be considered as a topography with boundaries between regions, known as ridges. Over time, the watershed transformation has been established to be a very useful and powerful tool for image segmentation.

2. General Morphology

General Morphological Analysis (GMA) was developed by Fritz Zwicky – the Swiss astro- physicist and aerospace scientist based at the California Institute of Technology (Caltech) – as a method for structuring and investigating the total set of relationships contained in multi- dimensional, non-quantifiable, problem complexes (Zwicky 1966, 1969).

Zwicky applied this method to such diverse fields as the classification of astrophysical objects, the development of jet and rocket propulsion systems, and the legal aspects of space travel and colonization. He founded the Society for Morphological Research and advanced the "morphological approach" for some 40 years, between the early 1930's until his death in 1974.

More recently, GMA has been applied by a number of researchers in the USA and Europe in the fields of policy analysis and futures studies (e.g. Godet, 1994; Rhyne 1995; Coyle & McGlone, 1995; Ritchey 1997). In 1995, advanced computer support for GMA was developed at the Swedish Defense Research Agency (for a description, see Ritchey, 2003b). This has made it possible to create interactive, non-quantified inference models, which significantly extends GMA's functionality and areas of application (Ritchey 1998-2011). Since then, more than 100 projects have been carried out using computer aided morphological analysis, for structuring complex policy and planning issues, developing scenario and strategy laboratories, and analyzing organizational and stakeholder structures.

The term *morphology* comes from antique Greek (*morphe*) and means *shape* or *form*. The general definition of morphology is "the study of form or pattern", i.e. the shape and arrangement of parts of an object, and how these "conform" to create a *whole* or Gestalt. The "objects" in question can be physical objects (e.g. an organism, a geography or an ecology), social objects (an organization or other social system) or mental objects (e.g. linguistic forms, concepts or systems of ideas).

The first to use the term *morphology* as an explicitly defined scientific method would seem to be J. W. von Goethe (1749-1832), especially in his "comparative morphology" in botany. Today, morphology is associated with a number of scientific disciplines in which *formal structure*, and not primarily quantity, is a central issue. In linguistics, it is the study of word formation; in biology, it deals with the form and structure of organisms; in geology it concerns the characteristics, configuration and evolution of rocks and land forms.

Essentially, general morphological analysis is a method for identifying and investigating the total set of possible relationships or "configurations" contained in a given problem complex. In this sense, it is closely related to *typology analysis*, although GMA is more generalized in form and has far broader applications[8].

3. Morphological Segmentation

In the analysis of the objects in images it is essential that we can distinguish between the objects of interest and the rest. This latter group is also referred to as the background. The techniques that are used to find the objects of interest are usually referred to as *segmentation techniques* – segmenting the foreground from background.

In some image analysis and machine vision applications such as industrial defect inspection or biomedical imaging segmentation based on thresholding or edge detection is not sufficient because the image quality is insufficient or the objects under inspection touch or overlap. In such applications, morphological segmentation is an effective method of image segmentation.

Morphological segmentation partitions an image based on the topographic surface of the image. The image is separated into non-overlapping regions with each region containing a unique particle[8].

Thresholding can segment objects from the background only if the objects are well separated from each other and have intensity values that differ significantly from the background. Binary morphology operators, such as close or open, often return inaccurate results when segmenting overlapping particles.

Use morphological segmentation to segment touching or overlapping objects from each other and from the background. Also, use morphological segmentation when the objects have intensity values similar to the background.

Morphological segmentation is a multiple-step process involving several NI Vision functions. The following list describes each morphological segmentation step and where to find more information about each step[9],[10].

1. Use a global or local threshold to create a binary image.
2. If necessary, use binary morphology operations to improve the quality of the image by filling holes in particles or remove extraneous noise from the image.
3. Use the Danielsson function to transform the binary image into a grayscale distance map in which each particle pixel is assigned a gray-level value equal to its shortest Euclidean distance from the particle border.
4. Perform a watershed transform on the distance map to find the watershed separation lines.
5. Superimpose the watershed lines on the original image using an image mask.

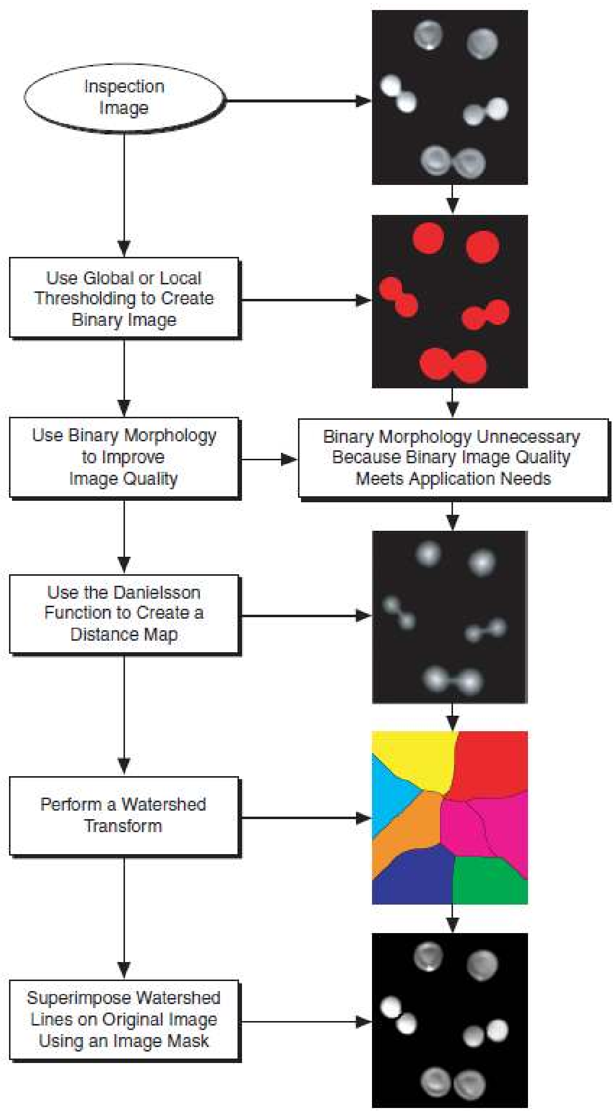

Fig1. Morphological Segmentation Process

The following steps illustrate the implemented method of segmentation process objects.

1.Threshold—**(Grayscale»Threshold)**

Threshold the image to isolate the objects we want to segment from the rest of the image.

2.Remove Noise— **(Binary»Advanced Morphology or Binary»Particle Filter)**

Remove extraneous information from the binary image using various morphology operations. For example, we can fill in holes with the Advanced Morphology option *Fill holes* or remove noise with the *Particle Filter* function.

3.Create Distance Map—(**Binary»Advanced Morphology**) Use the *Danielsson* option to transform the binary image into a grayscale image in which the center of each object represents a local maximum in the image. If you were to look at the topographical surface of the image after applying the distance map, each object would appear as a smooth, gradual peak.

4. Apply Watershed Transform — **(Grayscale»Watershed Segmentation)**
Apply the watershed transform to segment the image into local zones. A zone is determined by the watershed line that separates the influence zone of each peak.

4. Morphological Transformations

4.1. Morphology

Morphology is a technique of image processing based on shape and form of objects.
Morphological methods apply a structuring element to an input image, creating an output image at the same size. The value of each pixel in the input image is based on a comparison of the corresponding pixel in the input image with its neighbors. By choosing the size and shape of the neighbor, you can construct a morphological operation that is sensitive to specific shapes in the input image. The morphological operations can first be defined on grayscale images where the source image is planar (single-channel). The definition can then be expanded to full-colour images.

4.2. Morphological Operations

Morphological operations such as erosion, dilation, opening, and closing. Often combinations of
these operations are used to perform morphological image analysis [3], [17]. There are many
useful operators defined in mathematical morphology. They are dilation, erosion, opening and
closing. Morphological operations apply structuring elements to an input image, creating an
output image of the same size. Irrespective of the size of the structuring element, the origin is
located at its centre.

4.2.1.Dilation and Erosion

Morphology is a broad set of image processing operations that process images based on shapes. Morphological operations apply a structuring element to an input image, creating an output image of the same size. In a morphological operation, the value of each pixel in the output image is based on a comparison of the corresponding pixel in the input image with its neighbors. By choosing the size and shape of the neighborhood, you can construct a morphological operation that is sensitive to specific shapes in the input image.

The most basic morphological operations are dilation and erosion. Dilation adds pixels to the boundaries of objects in an image, while erosion removes pixels on object boundaries. The number of pixels added or removed from the objects in an image depends on the size and shape of the structuring element used to process the image. In the morphological dilation and erosion operations, the state of any given pixel in the output image is determined by applying a rule to the corresponding pixel and its neighbors in the input image. The rule used to process the pixels defines the operation as a dilation or an erosion. This table lists the rules for both dilation and erosion.

Operation	Rule
Dilation	The value of the output pixel is the *maximum* value of all the pixels in the input pixel's neighborhood. In a binary image, if any of the pixels is set to the value 1, the output pixel is set to 1.
Erosion	The value of the output pixel is the *minimum* 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.

Table1. Rules for Dilation and Erosion

The following fig.2 illustrates the dilation of a binary image. Note how the structuring element defines the neighborhood of the pixel of interest, which is circled. The dilation function applies the appropriate rule to the pixels in the neighborhood and assigns a value to the corresponding pixel in the output image. In the figure, the morphological dilation function sets the value of the output pixel to 1 because one of the elements in the neighborhood defined by the structuring element is on.

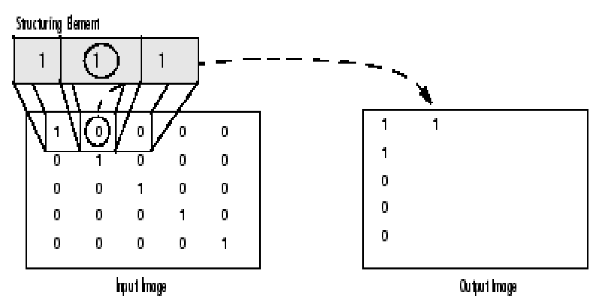

Fig2. Morphological Dilation of a Binary Image

The following figure illustrates this processing for a grayscale image. The figure shows the processing of a particular pixel in the input image. Note how the function applies the rule to the input pixel's neighborhood and uses the highest value of all the pixels in the neighborhood as the value of the corresponding pixel in the output image.

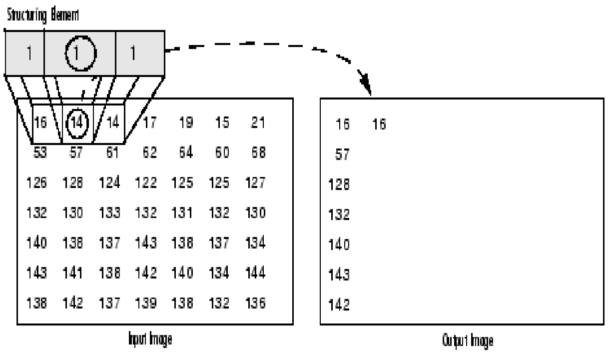

Fig3. Morphological Dilation of a Grayscale Image

4.2.2. Processing Pixels at Image Borders (Padding Behavior)

Morphological functions position the origin of the structuring element, its center element, over the pixel of interest in the input image. For pixels at the edge of an image, parts of the neighborhood defined by the structuring element can extend past the border of the image.

To process border pixels, the morphological functions assign a value to these undefined pixels, as if the functions had padded the image with additional rows and columns. The value of these padding pixels varies for dilation and erosion operations. The following table describes the padding rules for dilation and erosion for both binary and grayscale images.

Operation	Rule
Dilation	Pixels beyond the image border are assigned the minimum value afforded by the data type. For binary images, these pixels are assumed to be set to 0. For grayscale images, the minimum value for uint8 images is 0.
Erosion	Pixels beyond the image border are assigned the *maximum* value afforded by the data type. For binary images, these pixels are assumed to be set to 1. For grayscale images, the maximum value for uint8 images is 255.

Table2. Rules for Padding Images

4.2.3. Structuring Elements

An essential part of the dilation and erosion operations is the structuring element used to probe the input image. A structuring element is a matrix consisting of only 0's and 1's that can have any arbitrary shape and size. The pixels with values of 1 define the neighborhood.

Two-dimensional, or *flat*, structuring elements are typically much smaller than the image being processed. The center pixel of the structuring element, called the *origin*, identifies the pixel of interest the pixel being processed. The pixels in the structuring element containing 1's define the *neighborhood* of the structuring element. These pixels are also considered in dilation or erosion processing.

Three-dimensional, or *nonflat*, structuring elements use 0's and 1's to define the extent of the structuring element in the x- and y-planes and add height values to define the third dimension.

4.2.4. Combining Dilation and Erosion

Dilation and erosion are often used in combination to implement image processing operations. For example, the definition of a morphological *opening* of an image is an erosion followed by a dilation, using the same structuring element for both operations. The related operation, morphological *closing* of an image, is the reverse, it consists of dilation followed by an erosion with the same structuring element. We can use morphological opening to remove small objects from an image while preserving the shape and size of larger objects in the image. Closing of an image is the reverse of opening operation.

5. Methodology

It is proposed to use Java & MATLAB as primary tool with its supporting tool boxes for mathematical modeling and performance evaluation.

In this work, two methodologies to compute the image background are proposed. Also, some operators to enhance and normalize the contrast in grey level images with poor lighting are introduced. Contrast operators are based on the logarithm function in a similar way to Weber's law . The use of the logarithm function avoids abrupt changes in lighting. Also, two approximations to compute the background in the processed images are proposed. The first proposal consists of an analysis by blocks, whereas in the second proposal, the opening by reconstruction is used given its following properties: a) it passes through regional minima, and b) it merges components of the image without considerably modifying other structures.

In mathematical morphology, increasing and idempotent transformations are frequently used. Morphological transformations complying with these properties are known as morphological filters [19]–[20]. The basic morphological filters are the morphological opening and closing using a given structural element. The reconstruction transformation notion is a useful concept introduced by Mathematical Morphology. These transformations allow the elimination of undesirable regions without considerably affecting the remaining structures of the image. This characteristic arises from the way in which these transformations are built by means of geodesic transformations [19].

Regional maxima or minima are defined as follows[22].

A regional maximum of a grayscale image is a connected component of pixels with a given value (plateau of altitude), such that every pixel in the neighborhood has a strictly lower value. Methodology to compute the background parameter was proposed. The methodology consists in calculating the average between the smallest and largest regional minima. However, the main disadvantage of this proposal is that the image background is not detected in a local way. As a result, the contrast is not correctly enhanced in images with poor lighting, since considerable changes occur in the image background due to abrupt changes in luminance [24]. Weber's law has a logarithmic relation. This technique is applied to image processing to enhance the image effectively. Morphological transformations (Opening by reconstruction, Erosion-Dilation method) and Block Analysis is used to detect the background of gray level and colour images [26]. These techniques are first implemented in gray scale and are then extended to colour images by individually enhancing the colour components. For aiding better results, the compressed domain technique is used exclusively for colour image enhancement. The major advantage of the this method is that it can be used for any type of illumination. In all the above methods, the enhancement of the background detected image is done using Weber's law (modified Weber's law for compressed domain) a critical analysis of various advantages and drawbacks in each method are performed and ways for overcoming the drawbacks are also suggested. In image acquisition, background detection is necessary in many applications to get clear and useful information from an image which may have been picturized in different conditions like poor lighting or bright lighting, moving or still etc. This Section deals with background analysis of the image by blocks [31].

6. Conclusion

In this paper, we have been proposed a morphological based preprocessing and post-processing technique for watershed segmentation. The pre-processing technique composes of morphological smoothing and a global thresholding value. It effectively reduces over segmentation.

In addition, a morphological based region merging technique was developed for the merging of spurious segments. Although developed for general images, the proposed algorithm has also shown good performance when extended to other types of images such as medical images & sports images . The proposed algorithm allows for better object recognition, as shown in this paper.

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