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BINARY MORPHOLOGICAL IMAGE PROCESSING ALGORITHM IN COMPUTER VISION APPLICATION

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Abstract

Binary morphological image processing algorithm in computer vision application is reported. The algorithm is simple in implementation and efficient in computation. It is divided into two main parts, firstly method of enhancing occurring defects on the surface of manufactured product is introduced and secondly binary morphological filtering technique is developed to remove noise and other artifacts completely from the product binary images before feature extraction. It has been shown that the algorithm produces good results when tested on a number of manufactured products. The results presented in real images of a ceramic wall tile and biscuit shows the effectiveness of the algorithm.

Introduction

Segmentation of objects is the backbone task in computer vision. The effectiveness of the segmentation task determines the quality and accuracy of computer vision's result. Segmentation is effected by edge detection algorithms. However, the popularly used edge detection algorithms are based on the principle of intensity gradient of an image or object. These gradient-based edge detection algorithms have a major drawback. This drawback is the output image resulting from performing gradient operation is noisy as a result of differentiation operations. The resulting noise is manifested in the form of breaks in the object's outline creating superfluous segments in the otherwise continuous single outline. Also, it can manifest as thick outline, that is, the width of an edge is more than one pixel thick. These two side effects affect the accuracy of object segmentation. A solution to reducing or eliminating unnecessary breaks and thick edges is the application of morphological operations such as dilation and erosion. The dilation operation closes the gaps created by noise and hence connects together segments that are erroneously broken up. Erosion, on the other hand, thins a thick edge until the thickness of the edge is one pixel wide.

Fig. 1 shows the block diagram of automated industrial inspection system (Aborisade, 2005). The preprocessing block involves noise reduction by applying Gaussian filter to blur the image. The segmentation block involves partitioning of the image into objects that form the image. Feature extraction block is concerned with extracting the salient features that characterize the objects in the image. Classification block involves either accepting the product under inspection as needing specified quality, that is, the product passes the quality control or rejecting the product as failing the specified quality control.

This paper presents morphological operations applied to automatic industrial inspection of ceramic surfaces. The effectiveness of our morphological algorithms in industrial inspection is presented and results are discussed. The paper commences in Section 2 by considering the basic concepts of a binary morphological image processing. Sections 3 and 4 present the standard operations performed on ceramic tiles and biscuits moving on a conveyor belt. Simulation Results of the algorithm is discussed in Section 5. The paper ends in Sections 6 with some conclusion.

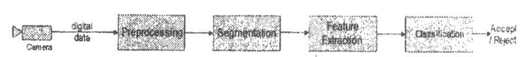


Figure 1: Block diagram of image processing for object recognition

Binary Mathematical Morphology

The field of mathematical morphology originated from the work of the French mathematicians J. Serra and G. Matheron and has now become an important framework that provides an approach to the processing of digital images based on set-theoretic concepts of shape (Matheron, 1974; Serra, 1982, 1988). Morphological operations are derived from the branch of mathematical analysis called Minkowski algebra (Jain, 1989). Following image preprocessing and image segmentation, the operations work to simplify image data preserving their essential shape characteristics and eliminating irrelevancies.

Mathematical morphological algorithms discussed in this paper operate on binary images. The processing differs from convolution approach. It uses tools of nonlinear algebra and operates with point sets, their connectivity and shape. Basically, binary image morphological processing is the analysis of the geometrical relationship between the image and a smaller image called a structuring element (Nick, 2000). The structuring element is moved systematically across the input image, pixel by pixel, placing resulting pixels in the output image (Gregory, 1994). At each input pixel location, the pixel and its neighbours are logically compared against the structuring element, to determine the output pixel's logical value.

The structuring element applied to binary image is represented as a small matrix of pixels of square dimensions of size 3 x 3, 5 x 5, and sometimes greater depending on the application, each with a value of 1 or 0. It is said to fit the image if, for each of its pixels that is set to 1, the corresponding image pixels is also 1. Similarly, it is said to hit an image if, for any of its pixels that is set to 1, the corresponding image pixel is also 1. In both cases, image pixel for which the corresponding structuring element pixel is 0 is to be ignored.

Binary Erosion and Dilation Operations

The sets of black and white pixels constitute a description of a binary image. In the algorithms black pixels are considered as objects, while white pixels are treated as background. The primary morphological operations performed on binary images of the manufactured item in this paper are erosion and dilation. If $f(x, y)$ is a digitized binary image and $\prod_{xy}$ a binary structuring element then erosion and dilation of f by $\prod_{xy}$ are defined by

$$erosion: E(f, \Pi_{xy}) = f \ominus \Pi_{xy} = \bigcap_{(P_x, P_y) \in Domain(\Pi_{xy})} Trans(f : P_x, P_y) \quad (1)$$

$$dilation: D(f, \Pi_{xy}) = f \oplus \Pi_{xy} = \bigcup_{(P_x, P_y) \in Domain(\Pi_{xy})} Trans(f : P_x, P_y) \quad (2)$$

where (p_x, p_y) are elements of the domain of $\prod_{xy}$ and Trans operation denotes the translation of image f by vector (p_x, p_y).

To compute either erosion or dilation, we position $\prod_{xy}$ such that its origin is at image pixel coordinates (x, y) and apply the rule

$$erosion: g(x, y) = \begin{cases} 1 & if\ \Pi_{xy}\ fits\ f \\ 0 & otherwise \end{cases} \quad (3)$$

$$dilation: g(x, y) = \begin{cases} 1 & if\ \Pi_{xy}\ hits\ f \\ 0 & otherwise \end{cases} \quad (4)$$

to create a new binary image in which a pixel has a non-zero value at that location in the input image. The input pixel cases of erosion and dilation operations are illustrated in Figure 2.

Morphological Filtering

The main idea for morphological operation is to enhance the important image features of interest. However, noise of the imaging system usually added to the acquired images results in difficulty of extracting features for object classification process. In removing noise or other artefacts surrounding the input image completely in our case opening morphological operation is used. Opening of a binary image $f(x, y)$ by structuring element, is defined by

$$open(x, y): open(f, \Pi_{xy}) = dilate(erode(f, \Pi_{xy}), \Pi_{xy}) \quad (5)$$

When opening the image with 3 x 3 rectangular structuring elements, the defects smaller than this rectangular window is eliminated. Similarly, when opening with 5 x 5 rectangular structuring elements, the defects smaller than this rectangular window is removed. By repeating this process with structuring elements of different sizes, 3 x 3, 5 x 5, 7 x 7, 11 x 11, the proper information about the amount and size of defects on an image is obtained. As the input features extraction/measurement for object recognition system, the filtering result F_k, which is given by the following expression, is used (Chang et al., 1997):

$$F_K = \sum_{i=0}^{M} \sum_{j=0}^{N} O_K(i, j), \quad k = 3,5,7,9,11 \quad (6)$$

where F_k is the summation of every pixel point in each opening image O_k with different structuring elements k x k on the image M x N image. The filtering images and corresponding F_k values are shown in Fig. 4.

Experimental Results

The algorithm presented has been implemented and programmed in C^{++} on an IBM-PC compatible Pentium IV MMX 2.4GHz Computer. A number of specimens were used in testing the performance of the erosion and dilation algorithms. Figure 3 shows the binary erosion and dilation operation results of a detected defect on a ceramic tile specimen. The erosion uniformly reduces the size of black objects (defects) on a white background in the ceramic tile image. Dilation has the opposite effect to erosion, it adds a layer of pixels to the detected defect, thereby enlarging it. The figure demonstrates that the erosion and dilation operations depend on structuring element size. The larger the structuring elements the more pronounced the effect will be. Multiple application of the erosion operation shrinks the touching defects until they finally separate while multiple application of the dilation operation expands broken defects until they finally merge into one.

Figure 4 shows the result of morphological filtering operation performed on the binary image of a biscuit. By opening the image with a 9 x 9 structuring element, we get the image shown in Figure 4(c). The noise and other artefacts surrounding the biscuit were eliminated completely. One very important thing that was noticed in Figure 4 is the effect of the structuring element size on the output image. Opening of the image with too large structuring element as shown in Figure 4(d) though removed the noise blobs, but damaged the output image.

Conclusion

The effectiveness of binary morphological algorithm in industrial inspection was presented. The algorithm was developed to improve the quality of an image produced by segmentation processes before feature extraction in the inspected manufactured item in computer vision application. The evaluation results on a limited number of specimen products seemed very promising and demonstrate the effectiveness of the algorithm as a basis for feature extraction/measurement in a complete image analysis system for manufactured products in real time-processing.

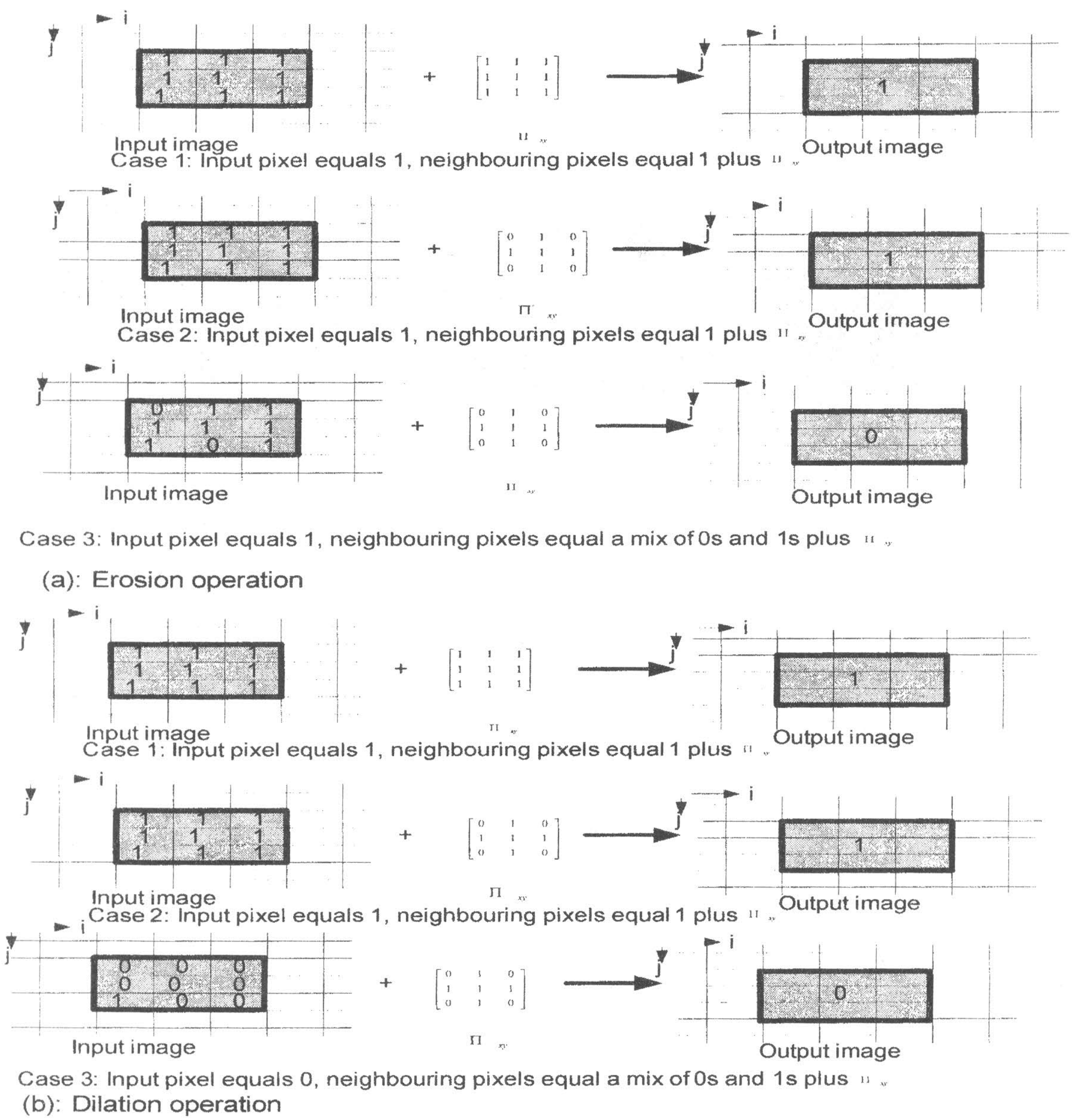
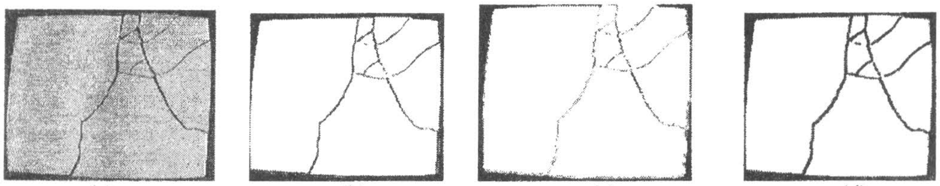
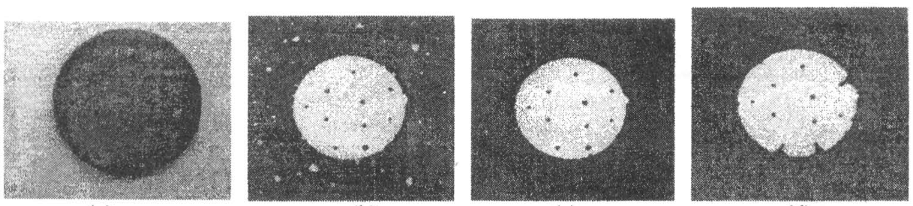


Figure 2: Input pixel cases of binary erosion and dilation operations



(a) (b) (c) (d)

Figure 3: Results of binary morphological image processing on a defective ceramic tile. (a) Original grey scale image. (b) Thresholded image. (c) Eroded image. (d) Dilated image.



(a) (b) (c) (d)

Figure 4: Results of binary morphological filtering on a biscuit and F_k values. (a) Original grey scale image. (b) Thresholded image surrounded by crumbs. (c) Result of opening by 9 x 9 structuring element F_9= 5468. (d) Result of opening by 17 x 17 structuring element F_{17}= 1264.

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