ELECTRONICS AND ELECTRICAL ENGINEERING
ISSN 1392 – 1215 2010. No. 8(104)
ELEKTRONIKA IR ELEKTROTECHNIKA

T 170 ELECTRONICS
ELEKTRONIKA

Morphology-Based Approach to Detection of Free Form Line Objects in Grayscale Images

I. Mednieks
Institute of Electronics and Computer Science,
Dzerbenes iela 14, LV-1006 Riga, Latvia; phone: +371 7554500, e-mail: mednieks@edi.lv

Introduction

Industrial inspection systems using X-ray scanners become increasingly popular for detection of different (glass, stone, metal) small contaminants in food products which may appear there due to the technological process. Alternatively, packages may contain objects which are considered undesirable with respect to the quality of the product, e.g. fishbones in fish fillets, bones in chicken fillets etc. To detect the presence of such objects, conveyor- based production lines are equipped with X-ray systems and processing of X-ray images in real time is performed for separation of faulty packages. There is a general demand to increase the speed of the conveyor that leads to lower signal to noise ratio (SNR) in obtained images and reduced time available for image processing. To meet the requirements, both image processing hardware and exploited methods should be enhanced. In particular, methods that can be implemented by fast procedures are preferred as real time operation of the equipment is needed.

Mathematical morphology (MM) defines a set of image processing operations over grayscale and binary images that are useful to process images based on their shapes. Introduction to basic MM operations can be found in [1]. It has attracted considerable attention for solving different application tasks [2, 3, 4]. Usually sequential combination of necessary morphological operations is applied to solve the problem. Each operation is defined using the binary image of structuring element related to the shape and size of interest, chosen from the a priori knowledge about the objects to be detected.

The paper focus on solving particular application task of processing grayscale image representing "normal" objects and, optionally, foreign bodies, which appear in images as lines of different thickness and curvature. Examples of such application are detection of fishbones or small metal wires in food fillets. Image processing method for solving this task is presented. However, the approach can be used for different other applications where processing of similar grayscale images is required. Then it might be necessary to adjust the proposed processing steps to the particularities of the application task, e.g. parameters of foreign bodies to be detected as well as noise level related to specific image acquisition conditions.

General definition of the task follows the one described in [5], i.e. we have to identify foreign bodies in grayscale digital images represented by matrices $\boldsymbol{A} = (a_{ij})$ of integer numbers where each number corresponds to one image pixel and represents the detected brightness level of that pixel. Brightness levels in X-ray images are in general perturbed by noise related with characteristics of the hardware as well as surrounding environment. The same first pre-processing step as in [6] is applied, i.e. linearization of the X-ray system's response. As a result, a matrix of rational numbers is obtained. Sample image after such pre-processing is illustrated in Fig. 1. Here we may notice several objects appearing as darker lines of different forms over the background related to "normal" objects that are scanned by the X-ray system. Both background objects and lines related to foreign bodies are influenced by noise so that background objects are not homogenous but lines may appear disrupted.

The proposed method contains the following sequential processing steps of that matrix:

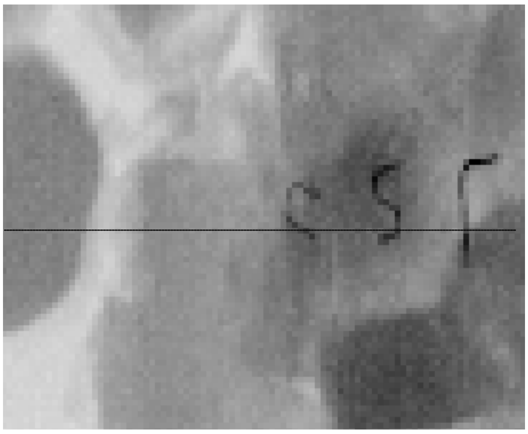

Fig. 1. Sample image with foreign bodies appearing as dark lines of different forms

1. Elimination of the background trend;
2. Thresholding for extraction of binary image possibly related to foreign bodies;
3. "Gluing" parts of the foreign bodies possibly disrupted due to noise;
4. Skeletonisation of free form line objects;
5. Calculation of the object length for making decision about the presence of the foreign body.

The following sections will discuss these steps in more detail. Steps 1, 3 and 4 exploit operations related to mathematical morphology, the others are quite straightforward.

Extraction of foreign bodies based on "bottom-hat" filtering

Two fundamental operations defined in mathematic morphology are dilation and erosion [1]. They are applied for processing of grayscale and binary images in different combinations to derive other suitable procedures. MM is exploiting the concept of the "structuring element" (SE) which is a fragment of a binary image defining the shape of interest around the "origin", i.e. the reference pixel. Operations of MM are performed in the following way: each pixel of the image to be processed (pixel of interest) is related to the "origin" of the structuring element and its neighbouring pixels are involved in operation if the SE contains a "1" in a corresponding position. In the resulting image, original value of the pixel of interest is replaced by the result of the defined operation. If the operation is dilation, the value of the output pixel is calculated as the maximum value of all neighbourhood pixels involved. If the operation is erosion, the value of the output pixel is calculated as the minimum value of all neighbourhood pixels involved. For processing of pixels at image borders, special padding of images is applied. Here we will assume that padding is performed by repeating the values of the edge pixels outside the borders of the images.

Morphologic "closing" is defined as sequentially performed dilation and erosion of the image, using the same structural element for both operations. Closing allows to eliminate small objects in the image so it can be used to extract the background image. When it is performed, original image can be subtracted from the background image to reveal small foreign objects. Such operation is named "bottom hat" filtering in MM.

Let us illustrate the result of the bottom hat operation applied to a sample row of a grayscale image, marked with a dashed line in the sample image of Fig. 1.

Fig. 2. compares the original line with the result of morphological closing using the structural element defined as a vector of 5 neighbouring pixels. Here we can notice that closing has followed the background, leaving the brightness drops related to foreign objects untouched. By subtracting initial line form the closed version, we obtain the result of bottom hat filtering presented in Fig. 3.

Here we notice that the background trend is eliminated and line pixels related to foreign objects are indicated by positive peaks in the signal. Nearly the same result could have been achieved by more traditionally used median filtering [6] using the filter length 7 (Fig. 4). However, bottom hat filter is easier to implement as it uses

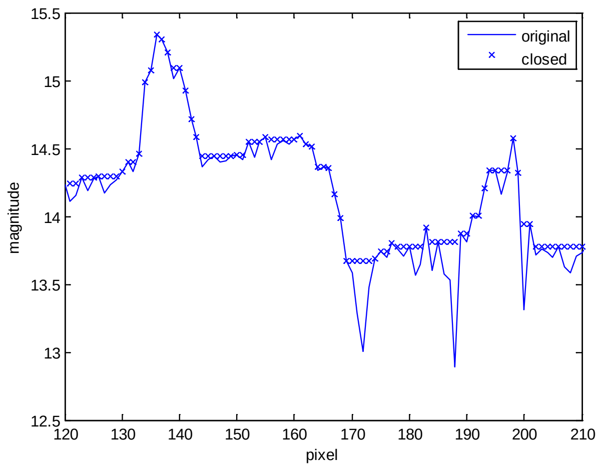

Fig. 2. Results of morphological closing of selected row of the image

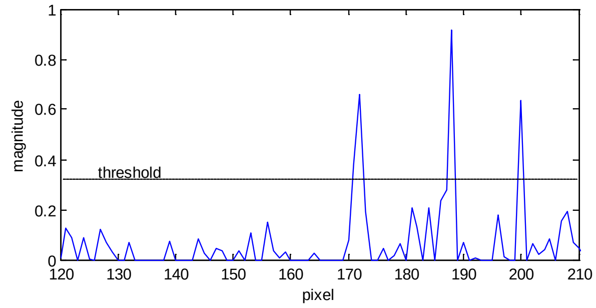

Fig. 3. Sample line of the image after the compensation of the background trend using morphological closing

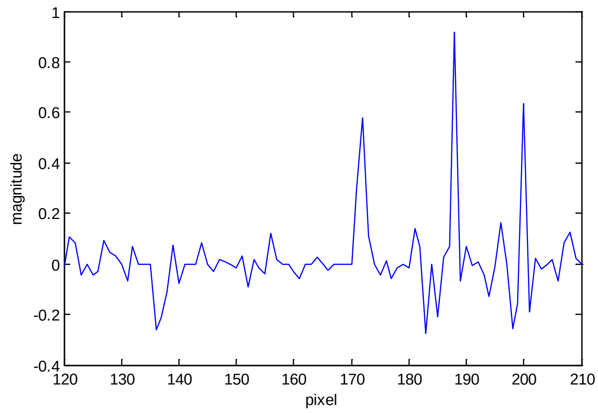

Fig. 4. Sample line of the image after the compensation of the background trend using median filtering

Fig. 5. Results of background compensation using closing

much simpler comparison operations instead of calculations of median values and filter length to be used is smaller for obtaining the same result.

When the bottom hat filtering is applied with two-dimensional structuring element (square of 5x5 pixels), we obtain an image with background objects eliminated and foreign bodies revealed as brighter objects (Fig. 5).

To separate foreign bodies from the background noise, a threshold is applied and binary image obtained where pixels of foreign objects take the value "1" and appear white (Fig. 6).

However, due to the level of inherent noise related to image acquisition, it is usually not possible to choose a single threshold for reliable separation of pixels related to foreign bodies and some further processing is needed to separate true foreign bodies from objects related with noise, as explained below.

Fig. 6. Sample image after background compensation and thresholding

Gluing of detected objects

As it can be noticed from Fig. 6, image of particular foreign body can be disrupted due to the influence of noise. To "glue" such separated parts, it is proposed to exploit a special procedure filling in gaps between white pixels up to the chosen distance. If the distance is equal to 1, centre pixels of the following fragments of binary images are filled in with "1":

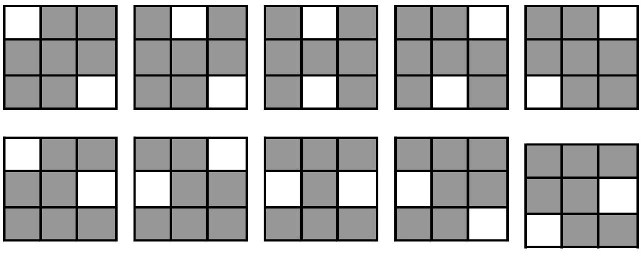

Fig. 7. Structuring elements exploited for gluing of disrupted line objects

This can be efficiently implemented using a table lookup procedure. The result is illustrated in Fig. 7.

Here we may notice that disrupted parts of larger (rightmost objects) were glued but leftmost object was not

Fig. 7. Sample image after gluing of disrupted line objects

due to the larger distance between the separate parts. To overcome this, gluing operation can be adjusted to glue objects over the larger distance.

The final decision about the presence of a foreign body can be made on the basis of their minimum size of interest. This would eliminate objects related to noise and make sure that only real foreign bodies with the size that is not negligible are found.

Estimating the size of objects

To calculate the size of different foreign bodies appearing in images as free form line objects, it should be taken into account that their width may be different. It is particularly true if the task of detecting fishbones is considered. To calculate length of objects, MM offers skeletonisation as a mean to convert thick objects into lines with a width of 1 pixel. Fig. 8 shows the result of this operation when it is applied to our sample image after gluing of objects. After that, objects are thin and number of white pixels in each object can be simply counted for making the decision about the presence of a foreign object on the basis of a length threshold chosen on the basis of application characteristics. It may be noticed that skeletonisation is not always necessary as there might be a prior information about the thickness of possible foreign objects and all of them could be of the same thickness.

Fig. 8. Skeletonisation results of a sample image.

Conclusions

1. Mathematical morphology provides a set of efficient procedures that can be exploited for detection of foreign bodies in grayscale images. In particular, most of these operations are simple and can be implemented in software operating in real time mode.

2. Using the bottom hat filtering, small foreground objects can be effectively extracted from the background clutter. Comparing to widely used median filtering approach, this type of filter provides similar results with smaller size of involved neighbourhood pixels and is based on simpler mathematical operations, thus it may appear preferable for implementation of real time systems.

3. Proposed image processing approach can be successfully applied for detection of foreign bodies in objects represented by grayscale images if such bodies appear as free form line shapes there. The approach can be successfully applied for solving industrial application tasks on the basis of X-ray imaging systems operating in real time mode.

References

1. **Gonzalez R. C., Woods R. E.** Digital Image Processing, second ed. – Prentice–Hall, 2002. – 793 p.
2. **Chen T., Wu Q. H., Rahmani–Torkaman R., Hughes J.** A pseudo top–hat mathematical morphological approach to edge detection in dark regions // Pattern Recognition 35, 2000. – P. 199–210.
3. **Mak K. L., Peng P., Yiu K. F. C.**. Fabric defect detection using morphological filters // Image and Vision Computing 27, 2009. – P. 1585–1592.
4. **Lerallut R., Decenciere E., Meyer F.**. Image filtering using morphological amoebas // Image and Vision Computing 25 2007. – P. 395–404.
5. **Mednieks I., Skageri A.** Real Time Image Processing for Object Detection // Electronics and Electrical Engineering. – Kaunas; Technologija, 2009. – No. 4(92).– P. 33–36.
6. **Lorencs A., Mednieks I., Sinica–Sinavskis J.** Fast Object Detection in Digital Grayscale Images // Proceedings of the Latvian Academy of Sciences, 2009. – Vol. 63. – No.3. – P. 116–124.

Received 2010 02 15

I. Mednieks. Morphology-Based Approach to Detection of Free Form Line Objects in Grayscale Images // Electronics and Electrical Engineering. – Kaunas: Technologija, 2010. – No. 8(104). – P. 27–30.

A method for detection of free form line objects in grayscale images is proposed, based on several sequential processing steps, partly using operations of mathematical morphology. The steps include background compensation, thresholding to obtain binary images, gluing breaches in binary images of objects, skeletonisation, calculation of object length, and making decision about the presence of the object on the basis of its length. The method can be used e.g. in X-ray systems for detection of contaminants in food packages if the images of contaminant objects take the form of a line object with any shape, e.g. fishbones, small metal wires etc. The paper describes application task, ideas behind the method, processing steps and results obtained by processing real X-ray images obtained by food control systems. Ill. 8, bibl. 6 (in English; abstracts in English, Russian and Lithuanian).

И. Медниекс. Обнаружение объектов формы свободной кривой в рентгеновских изображениях на основе морфологии // Электроника и электротехника. – Каунас: Технология, 2010. – № 8(104). – С. 27–30.

Рассмотрен метод обработки серых изображений для обнаружения формы объектов свободной кривой. Метод состоит из нескольких один за другим следующих шагов, часть из которых используют операции математической морфологии: компенсация фона, применение порога для получения бинарного изображения, склеивания частей объектов, скелетонизация, вычисление длины объектов с последующим решением о присутствии объекта на основе его длины. Метод может быть использован в рентгеновых системах промышленного контроля для обнаружения посторонних объектов в продовольственных продуктах, если эти объекты в изображениях принимают вид свободной кривой. Рассмотрена решаемая задача, идеи на которых основан метод, шаги обработки и результаты, полученные с использованием метода для обработки реальных рентгеновских изображений. Ил. 8, библ. 6 (на английском языке; рефераты на английском, русском и литовском яз.).

I. Mednieks. Laisvos formos objektų aptikimas, naudojant morfologinius rengenografinius vaizdus // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2010. – Nr. 8(104). – P. 27–30.

Analizuojami nauji būdai laisvos formos vaizdams aptikti. Pagal rengenografinius vaizdus, naudojant matematines morfologines operacijas, apskaičiuojama formų tono kompensacija. Pateikiami įvairių objektų atskirų dalių tyrimo rezultatai. Il. 8, bibl. 6 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).