DEFECT DETECTION IN MATERIAL IMAGES BASED ON ENERGY MOMENTS

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The task of defect detection in material images is analyzed. An algorithm for defect detection based on energy moments is proposed. Results of practical experiments are shown.

Introduction

Analysis of quality of materials (steel sheets, pipes, etc) is very important task for many industrial applications. To provide the desired quality, monitoring of material and defects should be performed time to time. Monitoring is a periodic checking of material structure by using non-destructive testing methods. During monitoring, new defects can be detected and control of earlier detected defects is performed.

This task is decomposed into scanning of material to obtain digital images, detecting of zones containing possible defects, image preprocessing, defect detection based on comparison of processed image with the previous one, and measurement of defect parameters. The volume of image data is usually enormous and this requires powerful computers and is usually time consuming.

At first, interactive image processing procedures have been developed and used for this task. However, automatic solutions are more desirable. One of the main problems related to detection methods based on the "difference image" lies in the lack of efficient automatic techniques for discriminating between changed and unchanged pixels in the difference image. Such discrimination is usually performed by using empirical strategies or manual trial-and-error procedures, which affect both the accuracy and the reliability of the change-detection process [1].

There are several approaches to detecting changes in remote sensing images. In the paper [1], the authors propose two automatic techniques (based on the Bayes theory) for the analysis of the difference image. A new feature-based approach to automated multitemporal and multisensor image registration was developed in the paper [2]. Feature matching was done both in feature space and image space based on moment invariant distance and chain code correlation. The characteristic of this technique is that it combines moment invariant shape descriptors with chain code correlation so as to establish the correspondences between regions in two images. A popular satellite-based land cover change detection technique is to use the spectral information to set up a binary "change/no-change"mask [3]. For each pixel, if there is a big enough difference between the reflectance values for two images acquired at different times, the area represented by that pixel is considered to have changed. The difference between these change detection methods is in the way they determine a "big enough difference".

The idea of energy moments using to detect image changes has been proposed in paper [7] that showed good results. There are other approaches based on application of Trace transform [4], mathematical morphology [5], and principal component transform [6].

In this paper, we extend the approach proposed in paper [7] for task of defect detection in material images. This approach allows to detect image object defects based on an analysis of image lines that allows real-time image processing. The approach is based on the idea of energy moments and computing energy moments for image rows and/or columns.

1. Energy moments

Let B = {bij} is an image with size MxN. Idea of our approach is to transform the image in distribution of centres of energy moments of image strokes and columns. To do this, energy moments are computed for every stroke and column.

It is always possible to find a point L in i-th stroke that will make energy moments of its elements as equal. Let us call this point as a center of stroke energy moments (CEM) and denote it as Li.

CEM can be expressed through stroke geometric moments of first and zero order:

$$L_i = m_{i1}/m_{i0}, \qquad (1)$$

where $m_{i1} = \sum_{j=0}^{n} (j * bij)$, a $m_{10} = \sum_{j=0}^{n} bij$.

For CEM of higher order, L_i satisfies the following condition:

$$\sum_{j=0}^{Li} (bij\text{-}bmin)^n (L_i - j) = \sum_{j=L}^{n} (bij\text{-}bmin)^n (j - L_i). \qquad (2)$$

Solving the equation (2) for L_i, we obtain

$$L_i = \sum_{j=0}^{n} j*(bij\text{-}bmin)^n) / \sum_{j=0}^{n} (bij\text{-}bmin)^n \qquad (3)$$

To take into account changing of brightness, it is necessary to add coefficient b_0 in (3) with required sign. Formula (3) is used under stationary coordinate system for detection of changes for dynamic images. For processing of stationary (single) image, detection of changes is performed for neighbouring strokes or in current stroke upon reference one.

Model of i-th stroke can be represented by the following function:

$$M_i(J) = F_i(b_{ij}, L_i \mid j=1,2, \ldots, N) \qquad (4)$$

Taking into account that distribution of energy in stroke is defined as brightness values $\{b_{ij} \mid j=1,2, \ldots, N\}$, CEM is a function of vector of brightness of image pixels, i.e.

$$L_i=G_i(b_{ij} , | j=1,2, \ldots,N) \quad (5)$$

Let as denote distribution of stroke CEM as f(Li), i=1,2,..., M. In the same way, CEM of columns can be computed (denote as g(Lj), j=1,2,...,N). Joint distribution of CEM of strokes and columns is called an image CEM distribution (H(Li,Lj)).

2. Defect detection by CEM

Defect detection is performed in two steps:

- detection of zones containing posiible dfects;
- contouring and detection of defects.

The detection of situation change in an image by analyzing CEM distribution is performed in the following way.

For all rows of an original image, CEMs Lo are computed and the function of CEM distribution is formed which is unique for a given image. When the full image is scanned, the function is built and stored. When a new image is analyzed, for every row (or column) CEM Li is computed by using formula (3) and compared with the CEM of the same row (column) for the previous image. The difference between two CEMs in every pixel is computed by using the formula:

$$D_i(L)= \sqrt{(L_i - L^0{}_i)^2} \quad (6)$$

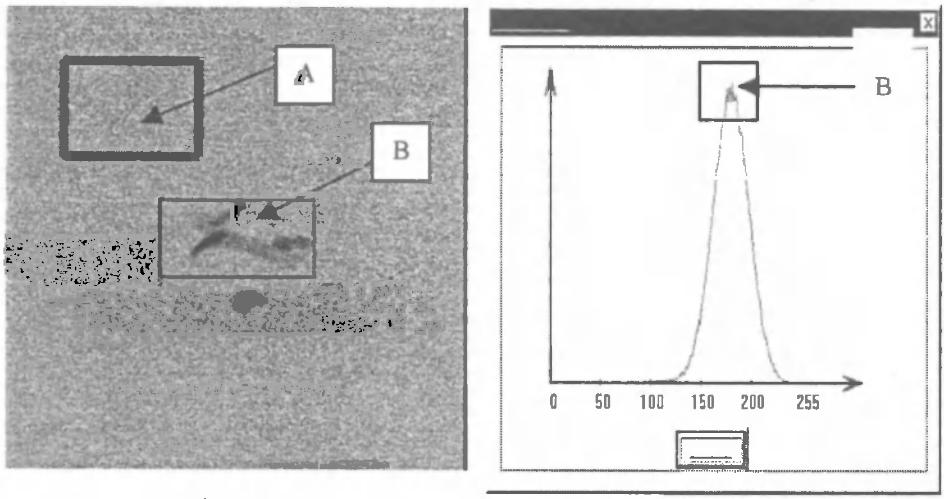
Image CEM is denoted as $D(L) = \{D_i(L) \mid i=1,\ldots,N\}$.

Fig. 1,a shows image of material containing defect. "White" noise has been added to the image. Histogram shown in Figure 1b is typical for whole image except fragment B containing defect.

During one image inspection, stroke CEM are computed. Comparison of CEMs of neighbouring strokes are performed. Number of elements N_D in D(L) exceeding apriori given value $D(L)_{доп.}$ is counted. If N_D is less then given value N_D^0, the decision is taken that two images have no changes. Otherwise, there are changes.

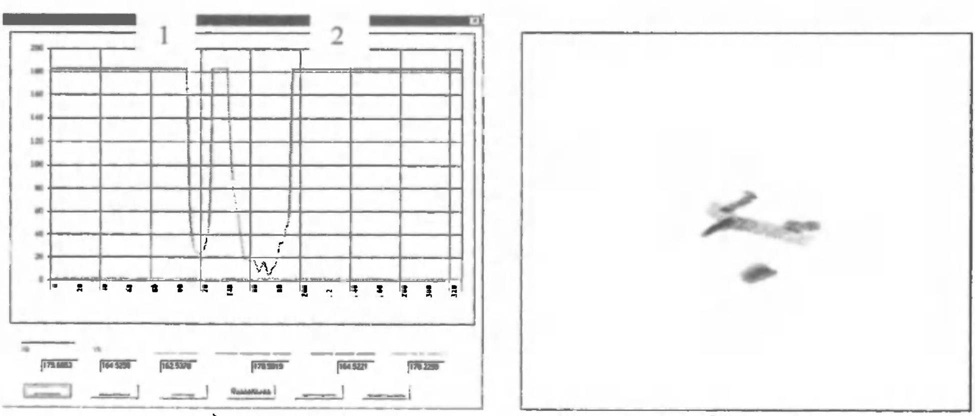
So, the distribution of CEMs, can show where changes occurred. On the basis of this, we can easily detect the changed region on the original image. If there are changes in several places in one row, an analysis of image columns can be applied.

Fig. 2,a shows graphics of CEM for the whole image. In Interval [1,2] stroke changes have been detected. Defect pattern corresponds to these changes (Fig. 2,b). Then, contouring of defect is performed (Fig. 3).



a) b)

Fig. 1. Initial image (a) and its histogram (b)



a) b)

Fig. 2. Centres of energy moments (a) and detected defect (b) from image shown in Fig. 1,a

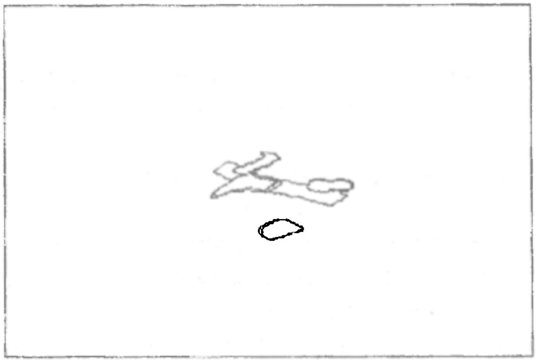


Fig. 3. Contours of the detected defect

3. Discussions

The approach was been tested on processing of material images. Experiments were performed with an IBM PC, and showed that the proposed approach allows:

- to detect changes in one pixel in an image;
- to detect changes in a line-by-line processing scheme that can be used in real-time image processing;
- to detect coordinates of places where changes occur. To calculate the coordinates of a rectangle where change occurred it is necessary to get CEM representation of image columns;
- it can be implemented on a standard PC and does not require a large memory volume.

The proposed image representation can be considered as an integral feature of the whole image. The detected object (its bounding rectangle) can be cut from the image and given more detailed analysis. CEM image representation allows one to compress images dozens of times but it is not a compressed image representation because an original image can not be reconstructed from its CEM representation. The time required for change detection does not depend on the number of objects and changes in the image.

Conclusion

We propose an approach that allows detection of all changes based on the analysis of image lines. The approach is based on the idea of energy moments and computing energy moments for image rows and/or columns. The approach developed allows one to detect any changes (up to one pixel) and detection time does not depend on the number of changes. The approach has been tested on material images and showed high quality and speed.

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