Detection and localization of differences on the images of printed circuit boards

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Abstract

The systems of non-destructive control have been widely practiced in science and industry. This paper focuses on the development of the technique of detection and localization of differences on the images of printed circuit boards, which is achieved by comparing of the images with the reference ones.

Keywords: *Defect detection, Image Processing, Interest points detectors, local descriptors.*

1. INTRODUCTION

The aim of the developed technique was detection of differences on the images printed circuit boards, localization of these differences and pick out so as an operator can analyze them after that. Thus, it was necessary to work out appropriate algorithms and programs. The acquired images of printed circuit boards can have different orientation and location relative to each other. Generally printed circuit board images can be rotated in relation to each other at arbitrary angle. An example of the original image of printed circuit board is presented on Figure 1. The straightforward approach is searching among all possible variants of orientation and location. Because of extreme computational burden this approach is rarely used. Another way is to derive an invariant description of the image, for example, by means of Fourier or Fourier-Mellin transformations [1] .This approach can be used mainly for template matching. It is necessary to stress that our main aim was to develop procedure not for template matching but for defect detection. That’s why we couldn’t use invariant description.

Thus image geometry aligning on the base of matched local descriptors at interest points was used to achieve rotation and scale invariance.

After geometry aligning tested and reference images we search for difference. This technique is described in section 3 of this paper.

Thus the whole procedure consists of the following steps:

1. Image aligning.

2. Subpixel aligning.

3. Removing of background and inscription.

4. Calculating of cross-correlation measure for searching differences.

5. Localization and picking out of differences.

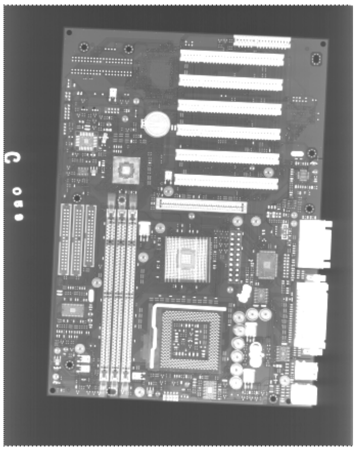

Figure 1: An original image of printed circuit board**.**

2. IMAGE GEOMETRY ALIGNING

As mentioned above to achieve image transformations invariance it was decided to use approach on the base of interest points. The extracted interest points are matched and then affine transformations are calculated for image geometry aligning Different approaches on the basis of interest point detectors can be found in literature. Each of such approaches consists of three main stages.

1) Extraction of points or regions of interest. A region of interest is a region that is invariant to image transformation. Accordingly a point of interest is a point that is invariant to image transformation

2) The calculation of invariant local descriptors on the base of extracted interest point or region. A descriptor is a vector of some calculated values. A descriptor can contain from tens to hundreds elements.

3) Local descriptors matching and checking whether descriptors are in accordance with the same affine transformation.

The paper [2] presents different examples of detector of interest points and regions invariant to a rotation (Harris points), rotation and scaling (Harris-Laplace regions, Hessian-Laplace regions), affine rotation (Harris-Affine regions, Hessian-Affine regions). After the extraction of the corresponding region an invariant descriptor is built on its base. On the one hand the descriptor has to be invariant to image transformation and inaccuracy in extracting of a point of interest or region of interest. On the other hand it has to be distinctive enough to avoid false matching. The distance between the descriptors can be calculated with the help of Euclid distance or Mahalanobis distance. The simplest way of descriptor matching can be made if the distance between the descriptors is less than the predetermined threshold value. Another way is the nearest neighbor based matching. In this case two regions Da and Db are matched if the descriptor Da is the nearest neighbor to Db and if the distance between them is below a threshold. With this approach a descriptor has only one match. The third matching strategy is similar to nearest neighbor matching except that the threshold is applied to the distance ratio between the first and the second nearest neighbors. Thus, the regions are matched if

$$\| Da-Db \| / \| Da-Dc \| < t,$$

Where Db is the first and Dc is the second nearest neighbor to Da. The main advantages of using interest point detectors for template matching and pattern recognition are their robustness to partially occlusions and the possibility to calculate affine transformation parameters for transformation of one matched image to another.

In the paper [2] performance evaluation of different local descriptors was made. SIFT (Scale Invariant Feature Transform) [3] showed the best results. The University of British Columbia has applied for a patent on the SIFT algorithm in the United States. Commercial applications of this software may require a license from the University of British Columbia. Regions of interest are extracted by means of DoG algorithm, which localizes points at local scale-space maxima of the difference-of-Gaussian. This approach is similar to with Hessian-Laplace regions detector. On the base of extracted region invariant descriptors are calculated with the help of gradient location and orientation histograms. Descriptors dimensionality is 128 elements. Descriptors matching are made by means of RANSAC algorithm. Among low-level dimensionality descriptors steerable filters showed the best results.

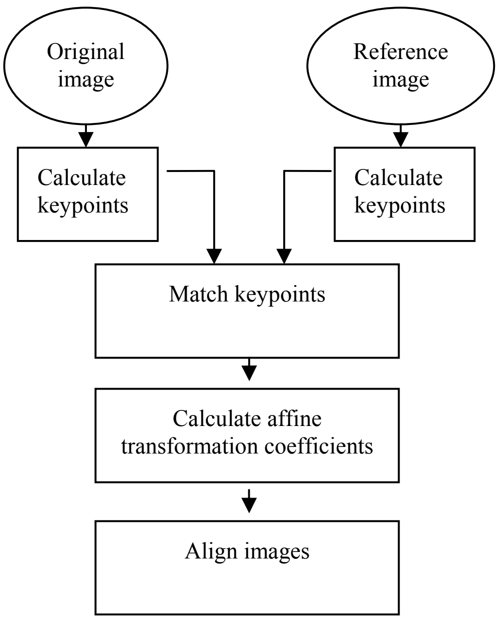

Figure 2: The algorithmic diagram of image alignment**.**

Figure 2 presents general algorithmic diagram of image alignment on the base of local descriptors. After descriptors matching we calculate average affine transformations and equalize image location and orientation as respects to origin of coordinates. An example of the aligned image of Figure 1 is presented on Figure 3.

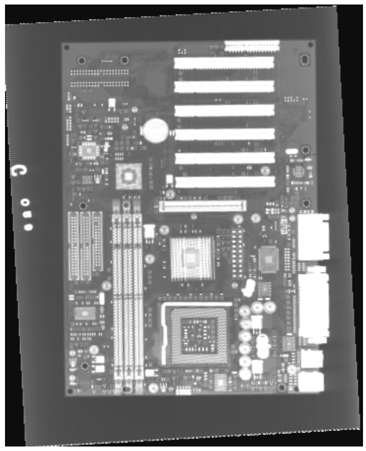

Figure 3: An aligned image**.**

The equalized image may contain inaccuracy in aligning. It may have a negative influence on correctness of matching results, especially, if we use for matching the cross-correlation measure. For example, the error of localization of extracted region in SIFT approach can achieve the value of three pixels. That's why subpixel aligning is necessary. To align the image with more accuracy the cross correlation coefficients for reference image and shifted images of equalized image are calculated within the area of 3x3 pixels.

3. SEARCH FOR DIFFERENCE (DEFECT DETECTION)

The acquired printed circuit board images often have non uniform background, especially if we deal with roentgenogram. The printed circuit board images may contain additional foreign objects, for example inscription for the purpose of image identification. Before defect detection it is necessary to remove the background and foreign objects. The following can be of use here:

1) The maximum level of background pixels (Imax) and the maximum number of background pixel in the section (Nmax) are specified.
2) String-by-string and column-by-column scanning are performed. If the pixel value is less than Imax, it is considered to be a background one. If the number of background pixel in the section is more than Nmax, the whole section is considered to be a background and is zeroed.

Thus, background and small foreign objects beyond the printed circuit board area are removed. Value selection of Imax и Nmax depends on the condition of image acquiring. An example of the original image with a removed background is presented on Figure 4.

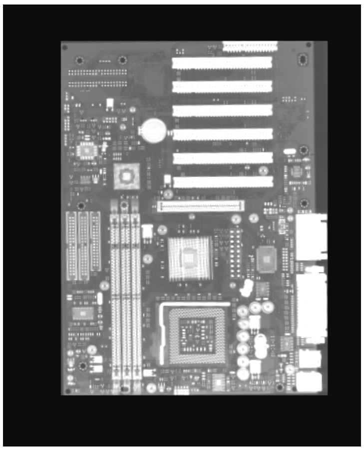

Figure 4: An image with a removed background.

Other possible sources of false alarms are inaccuracy in image aligning and the presence of noise. To minimize the influence of noise and aliasing effects, which occurred while aligning, smoothing should be performed. In our case we used Gaussian Blur filtering (sigma is equal 1.5).

After getting rid of possible sources of false alarms, defect detection with the use of cross correlation can be performed. In the correlation-based defect detection applications, a reference image and a scene image are compared in a pixel-by-pixel basis. Two small windowed subimages of coincident pixel locations from the two respective compared images are used to compute the normalized cross correlation. Due to technique offered by Tsai [4] this procedure becomes independent from the size of windowed subimages, it is possible because we use so called sum tables. An example of crosscorrelation surface of the original image is presented on Figure 5.

Figure 5: Crosscorrelation surface of the original image (size of searching window is 10 x 10).

A large size of windows makes possible to decrease the effect of noise and aliasing, but area of differences is localized with the accuracy comparable with the sizes of searching window. In this connection the results for a larger searching window (35x35) should be calculated and in case the crosscorrelation measure is less then the threshold value the location of the difference should be elaborated by means of a less searching window (10x10).

Thresholding leads to the extracting of a set of points which indicate a low level of crosscorrelation measure of the searching windows having a center at these points. An example of set of thresholded points is presented on Figure 6.

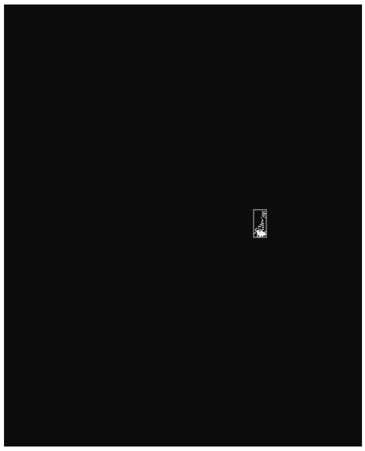

Figure 6: An image with localized differences.

To find a minimal framed rectangle localizing the area of differences the following algorithm:

1) The image is considered to be binary consisting of background and object pixels.
2) Successive search of objects points is carried out. If the point is near the border of one of the existing rectangle regions (that is the distance less than the threshold), it is extended to include this point of the object. If the point of the object is far beyond the border of one of the existing rectangle regions, a new a region is built on its base.
3) When successive search is completed the rectangular regions are examined to joint intersecting and to remove nested regions.

If the differences between the images is large such a method will extracts the only rectangular region framing the image of printed circuit board with the exception of the background pixel.

4. PERFOMANCE MEASUREMENT

A computer Pentium IV 2,66 GHz, 1 GB RAM, GeForce FX 5200 128 MB was used to carry out the measurements. The digital copies of scanned images were used as original and reference images. The aim of the experiments was timing of the work of the algorithm and its constituent parts. The characteristics of an original and reference image(width, height, color depth) are presented in the first column of table 1. The time spent on image alignment in millisecond is presented in the second column of table 1. The time spent on removing of background and inscription in millisecond is presented in the third column of table 1. The time spent on detection and localization of differences in millisecond is presented in the fourth column of table 1. The total time required for completing of the whole algorithm is presented in the fifth column of table 1.

Table 1: Results of performance measurement.

Original Image, W x H x Color Depth	Image aligning, ms	Removing of background and inscription, ms	Detection and localization of difference, ms	Total, ms
1. 3624 x 4477 x 8	12494	2832	8697	24293
2. 3420 x 4317x 8	10918	2771	8587	22276
3. 3482 x 4366 x 8	20723	2627	8653	32003
4. 342 x 431 x 8	6865	4.12	74.7	6943.82
5. 342 x 431 x 8	5676	4.3	74.9	5793.9
6. 342 x 431 x 8	11279	3.60	75.1	11357.7

In the experiments which results are presented in table 1original images with different orientation and location were used.

Differences in orientation and location between an original and reference images are presented in table 2.

Table 2: Differences in orientation and location between an original and reference images.

Number of experiment	Angle of rotation (approx), degrees.	Location (approx), pixels	Comment
1	10	100	
2	80	100	
3	10	100	Mirror reflection
4	10	10	
5	80	10	
6	10	10	Mirror reflection

5. CONCLUSION

As the result a technique of detection and localization of differences on the images of printed circuit boards was developed. The advantages of this technique are the following:

1) It is possible to work with images which are rotated, scaled and shifted in relation to the reference image.
2) It is possible to ignore nonuniform background and inscriptions in the image background.

The experiments were carried out over a set of printed circuit board roentgenogram having one or more of the following features: arbitrary angle of rotation, arbitrary shift nonuniform background, inscriptions.

The experiments have proved the efficacy of the developed technique to achieve our goals. In the software we have developed the time required for processing is less than the time required for scanning.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

[1] G.S Cox, G. de Jager. *Invariance in Template matching, Proceedings of the Fourth South African Workshop on Patter Recognition, pp. 152-156, 1993.*

[2] K. Mikolajczyk, C. Schmid. *A performance evaluation of local descriptors, In Proceedings of Computer Vision and Pattern Recognition, June 2003.*

[3] D. G. Lowe, *Distinctive Image Features from Scale-Invariant Keypoints, International Journal of Computer Vision, 60, 2 (2004), pp. 91-110. 2004.*

[4] D. M. Tsai, C. T. Lin**,** *Fast normalized cross correlation for defect detection, Pattern Recognition Letters, volume 2,Issue 1, November 2003, pp. 2625-2631, 2003*

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