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I. BADANYUK, I. NEVLIUDOV, D. NIKITIN

TOPOLOGICAL IMAGE PROCESSING FOR COMPREHENSIVE DEFECT AND DEVIATION ANALYSIS USING ADAPTIVE BINARISATION

The subject of this article is the preparation for recognition and comparison of real topological images of printed circuit boards (PCBs) using adaptive image binarisation with an "automatic window" (the area for scanning the image "Block size"). **The aim of the** work is to improve the method of adaptive binarisation for images obtained by technical vision systems by developing an automatic algorithm for detecting the required value of the image binarisation window. **Objectives**: to analyse the subject area for the analysis of technical images of the topology of the SOE; to describe the finding of the global binarisation threshold (t) using the "Otsu" method; to perform global image binarisation; to calculate the standard deviation of binarisation; to process the results obtained to find the required value of the Block size; to test the developed algorithm in software. **Results**: an image processing algorithm with automatic adjustment of the "Block size" binarisation window was implemented and tested; software was developed using the proposed algorithm and the performance of global binarisation with an improved method of finding the "Block size" values for scanning an image in processing small elements of the SE topology was compared. This will allow solving the following issues: noise removal – removing noise from the image (noise can occur due to poor scan or photo quality, as well as due to the presence of small spots on the surface of the PCB); image segmentation – dividing the image into separate elements such as contours, zones and text (this process can be automated using image processing software); element detection – finding and separating individual elements such as resistors, capacitors and other components depicted on the topology. **Conclusions**: according to the results of the work, an algorithm for automatically adjusting the size of the scanning area "Block size" for binarisation of technological images of the SE topology has been developed. The following advantages of this algorithm can be distinguished: automatic finding of the optimal scanning area Block Size; resistance to image noise without the use of smoothing filters; finding details in areas of contrast difference.

Keywords: process image processing; adaptive binarization; Otsu method; GP topology; finding "Block size".

Introduction

Industry 4.0 is based on advanced research in the fields of artificial intelligence, robotics, cloud computing, additive technologies, etc., the synthesis of which has allowed to improve production processes. The most important area of concept development within Industry 4.0 is the development of new approaches and tools for cyber-physical production systems (CPPS) [1–3]. The peculiarity of the CPPS application is the synthesis of the physical and cybernetic worlds into a single information eco-space, which allows creating very flexible reconfigurable production lines [4]. One of the promising areas of application of CPPS is their implementation in the production of high-tech electronic products and improvement of technical vision systems.

PCB topology image processing is an important component of Industry 4.0, as images can be used for automated quality control and visual inspection of manufacturing processes related to PCB production. The main applications of PCB topology image processing in Industry 4.0 are as follows [5]:

1. Quality control. Image processing can be used to control the quality of printed circuit boards, for example, to detect defects that may be invisible to the human eye. Image processing software can automatically recognize defects, such as damaged traces, short circuits, missing parts, and others, and notify operators of their presence.

2. Visual inspection. Image processing can be used for real-time visual inspection of printed circuit boards. It can help ensure product accuracy and quality during production.

3. Process monitoring. Image processing can be used to monitor PCB manufacturing processes. It can help track equipment movement, monitor temperature and other parameters of the production process.

4. Automatic topology recognition. Image processing can be used to automatically recognize the topology of printed circuit boards. This can help in the automated process of mounting electronic components on printed circuit boards;

5. Virtual reality: Image processing can be used to create a virtual model.

Various methods are used for image processing, such as [6]:

1. Image filtering – used to reduce noise in the image, improve contrast and other image properties.

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Filtering methods include median filtering, Gaussian filtering, and others.

2. Image segmentation – used to highlight individual objects in an image. This can be useful for automated object recognition, image classification, and more.

3. Feature detection – used to extract specific features of an image, such as colour, shape, and texture. This can be useful for image classification and more.

4. Pattern recognition – used to automatically recognize objects in an image and classify images using machine learning algorithms.

These image processing methods can be used individually or in combination to achieve a specific image analysis goal.

Image binarization is the process of converting an image with graded hues into an image where each pixel can only be white or black. Different methods can be used to binarize an image. One of the simplest methods is global processing, when a threshold value is set, and all pixels with a hue above the threshold are considered white, and those with a hue below the threshold are considered black. This method is applicable to images with high contrast. Optimization methods use statistical approaches to determine the threshold, such as the "Otsu" method, which automatically determines the threshold to maximize the inter-class dispersion between pixels with different hues.

There are also methods that use machine learning algorithms to solve the image binarization problem, such as neural networks. These methods can be useful for binarizing complex images with a high degree of detail.

Unresolved components of the overall problem

The process of binarization is inherently simple and straightforward when it comes to noise-free and highly detailed images. However, this process can become complicated, especially if the source image contains small elements, noise, complex backgrounds, shadows, or heterogeneity in the image.

Global binarization cannot detect details in parts of the image where there are contrast differences. To solve this problem and detect more details in the image, adaptive binarization is used, but to use adaptive binarization, it is necessary to find the "Block size" parameter that affects the search area for details in the image [6–7]. Currently, there is no general method for finding the optimal Block size.

Statement of the problem and purpose of the study

The main objective of the study is to improve the method of adaptive binarization for images obtained by technical vision systems by developing an automatic algorithm for detecting the required value of the image binarization window. To achieve this goal, it was decided to develop an algorithm for automatically finding the size of the scanning area in adaptive binarization for processing technological images of the SOE topology. To solve this problem, the following is necessary:

– to analyze the subject area and consider the features of binarization of technical images of the SE topology;

– find the threshold of binarization by "Otsu";

– to find the standard deviation of binarization;

– process the obtained results to find the required value of the "Block size" of adaptive binarization;

The final result is the implementation of the obtained algorithm for finding the values of "Block size" of adaptive binarization in a software product for image processing.

Materials and methods

The process of image binarization is the conversion of a colour image into a two-colour black-and-white image. The main parameter for binarization is the threshold value (t) – the value with which the brightness of each pixel is compared. Based on the comparison results, the pixel is assigned a value of 0 or 1. The threshold value will be the criterion for checking the intensity of the image point [7].

There are various binarization methods that can be divided into two groups: global and local.

In the first case, the threshold value remains unchanged throughout the binarization process. This can be mathematically described by formula 1. In the case of adaptive binarization, the image is divided into regions, in each of which a local threshold is calculated [8].

$$f(i,j)=\begin{cases}0, & (i,j)<t\\ 1, & (i,j)\geq t.\end{cases} \tag{1}$$

The global binarization function is shown in Fig. 1.

The main task of binarization is to reduce the amount of information and leave the main data with which further processing will be performed. Global and local binarization is a basic processing, and this method is poorly suited for images with high contrast and a lot

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of noise [8–9]. This is due to the definition of processing thresholds for pixels in the image (Fig. 2).

Successful binarization simplifies further work with the image. On the other hand, failures in the binarization process can lead to distortions, such as line breaks, loss of significant details, and violation of object integrity, noise, and unpredictable distortion of characters due to background heterogeneity [10].

To determine the thresholds in binarization, the "Otsu" method is used. The main task of this method is to find the required threshold value for binarization. The process of separating foreground pixels from the background is called thresholding. This is a dispersion-based method for finding the threshold value at which the weighted dispersion between foreground and background pixels is the smallest. The key idea is to go through all the possible threshold values and measure the spread of foreground and background pixels. Then find the threshold at which the scatter is the smallest.

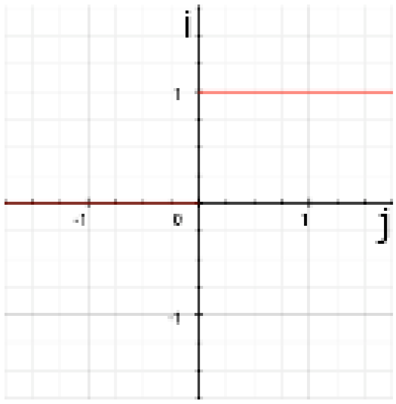
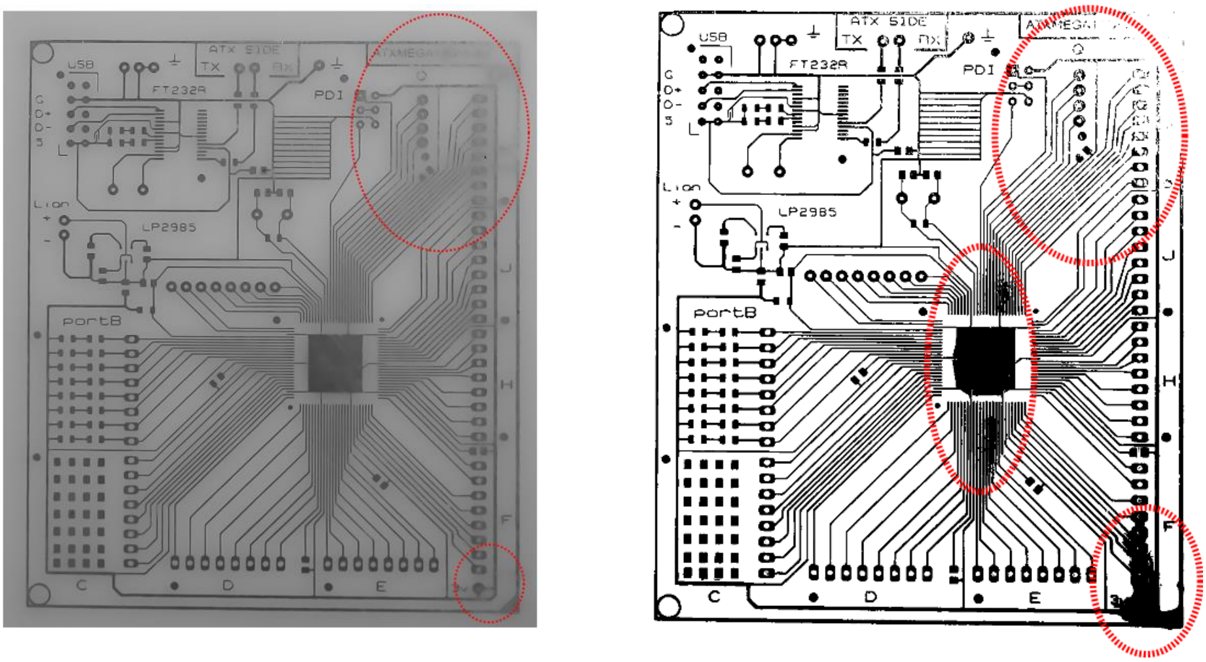


Fig. 1. Binarization function



a) b)

Fig. 2. Implementation of global binarization: a) input image; b) binarized image

The interactive binarization algorithm searches for a threshold (t) that minimizes the intra-class dispersion, defined as the weighted sum of the dispersion of the two classes (background and foreground). Grayscale colours are usually in the range of 0–255 (0–1 in the case of a floating hue). So, if we choose a threshold of 100, then all pixels with values less than 100 will become the background, and all pixels with values greater than or equal to 100 will become the foreground of the image [11–13]. The formula for finding the interclass dispersion at any threshold t is given in Equation 2.

$$\sigma_m^2(t) = \omega_{bg}(t)\sigma^2_{bg}(t) + \omega_{fg}(t)\sigma^2_{fg}(t), \quad (2)$$

where $\omega_{bg}(t)$ and $\omega_{fg}(t)$ are the probabilities of occurrence of a certain type of pixels for each class at the threshold value t;

$\sigma_m^2(t)$ – share-weighted amount of dispersions.

To understand what probability means in this case, let:

– P_{all} – the total number of pixels in the image;

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– $P_{BG}(t)$ – the number of background pixels at threshold t;

– $P_{FG}(t)$ – the number of foreground pixels at the moment of time t.

Thus, the probability of occurrence of a certain type of pixel can be set by the formula:

$$\omega_{bg}(t) = \frac{P_{BG}(t)}{P_{all}}, \quad (3)$$

$$\omega_{fg}(t) = \frac{P_{FG}(t)}{P_{all}}. \quad (4)$$

The dispersions can be calculated using the formula 5 given below:

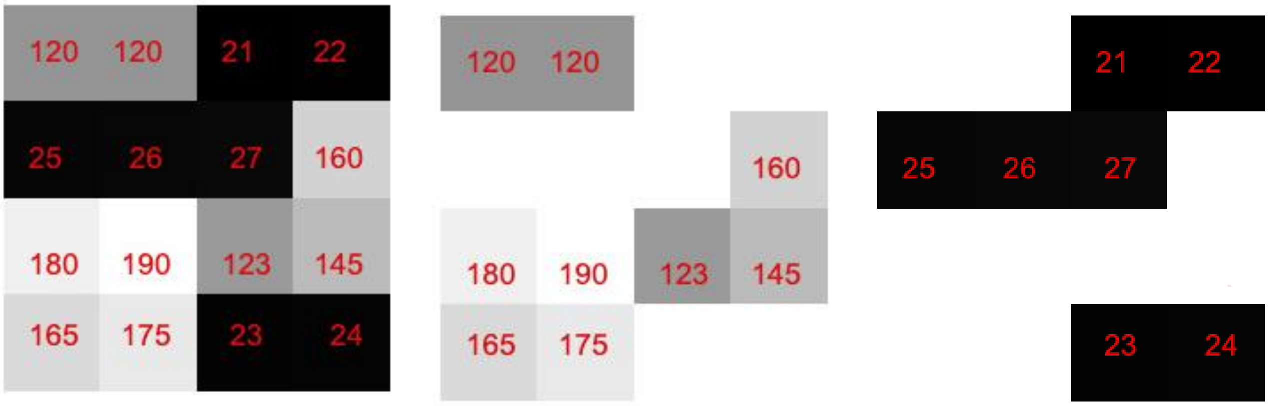
$$\sigma^2 = \frac{\sum (x_i - x_{sr})^2}{N-1}, \quad (5)$$

where x_i is the pixel value at position i in the group (bg or fg);

x_{sr} – average pixel value in the group (bg or fg);

N is the number of pixels.

Let us consider the example of finding the dispersion at one threshold value $t = 100$, Figure 3. For the above image (Fig. 3a) at $T = 100$, we get the background and foreground, (Fig. 3 b, c):



a) b) c)

Fig. 3. An example of finding the dispersion of image pixels by "Otsu":
a) full image with pixel colour values (P_{all}); b) foreground pixels (P_{FG}); c) background pixels (P_{BG})

In this example, the total number of pixels (P_{all}) is 16. The number of foreground pixels (P_{FG}) is 7, and the number of background pixels (P_{BG}) is 9. If we substitute these values into formula 3 and formula 4, we get the probability values (ω_{bg}) equal to 0.44 and (ω_{fg}) equal to 0.56. Now, to find the dispersion, we first find the mean of (x_{bg}) and (x_{fg}). To do this, add up the entire foreground and background pixel values separately and divide by the number. We get (x_{bg}) equal to 24, and (x_{fg}) 153.1. The dispersions (σ_{bg}^2) and (σ_{fg}^2) are calculated using formula 5. We get the values of 4 and 657.43. Then, using the results obtained in formula 2, we find the dispersion of colour values (σ_m^2) [14]. In this case, (σ_m^2) is equal to 369.9208. We can do the same for other values of t, Table 1.

The dispersion value remains the same from 28 to 120. If you see the dispersions above, they are smallest at $t = 28$ or, more precisely, between 28 and 120. Thus, the threshold is 28.

Different binarization methods have their own weaknesses: for example, the "Otsu" method can lead to the loss of small details and "sticking" of adjacent characters if the run value is chosen incorrectly (Fig. 4).

The main goal of the Otsu method is to find the optimal global threshold (t) for global binarization, but this method does not solve the problems of using global binarization. This can be seen from the example (Fig. 4).

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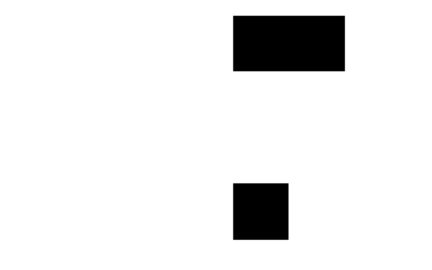
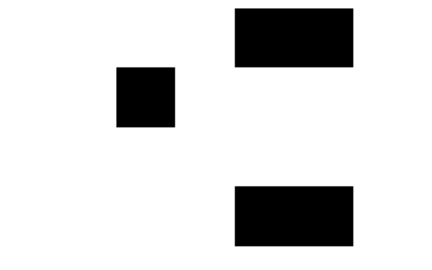
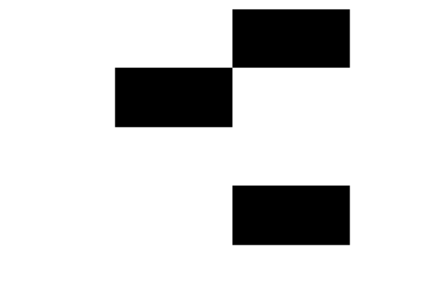
Table 1. *Detecting the binarization threshold with "Otsu"*

		
$t = 22,\ \sigma^2 = 4092{,}58$	$t = 23,\ \sigma^2 = 3667{,}6$	$t = 25,\ \sigma^2 = 2642{,}35$
		
$t = 26,\ \sigma^2 = 2009{,}93$	$t = 28,\ \sigma^2 = 371{,}55$	$t = 124,\ \sigma^2 = 1316{,}48$

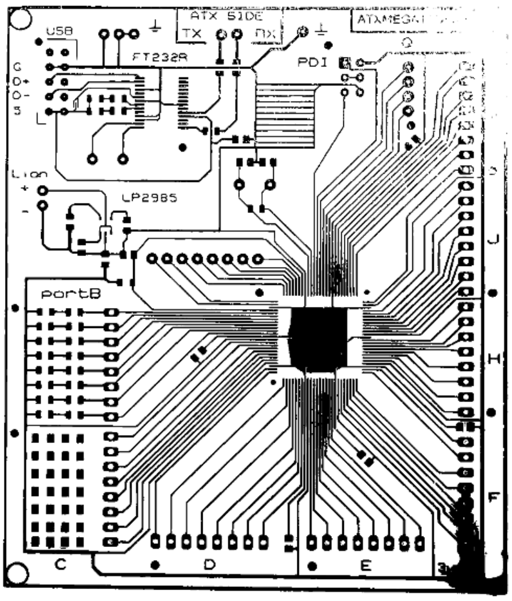


Fig. 4. An example of the "Otsu" method for image binarization

Development of a method for finding "Block size" in adaptive binarization

Adaptive binarization is a method of image binarization in which the binarization threshold changes depending on the local average pixel value in the neighbourhood of each pixel. Adaptive binarization is done by calculating the local average pixel value in a certain neighbourhood "Block size". Around each pixel, and then the threshold value is selected depending on this average value. If the pixel value is greater than the threshold, it is considered white, and otherwise, it is considered black [15].

This method is used to binarize images with variable lighting or noise that can change the global binarization threshold. These properties of adaptive binarization are suitable for the use of these methods in the analysis and comparison of technical images in the production of images obtained with the help of technical vision systems. This method is used in many fields such as character recognition, image analysis, medical diagnostics, etc.

The main parameters for adaptive binarization are:

– a method for finding the average pixel value in the scanned area (Gaussian average);

– the size of the boring area "Block size".

Essentially, "Block size" is a matrix in which the pixel values are located (Fig. 5).

i

5	120	223	45	154	68
26	201	167	190	250	89
78	143	208	80	158	184
67	223	251	165	95	47
84	245	84	68	135	69
82	255	123	175	205	54

j

Fig. 5. Example of a 3×3 "Block size" area

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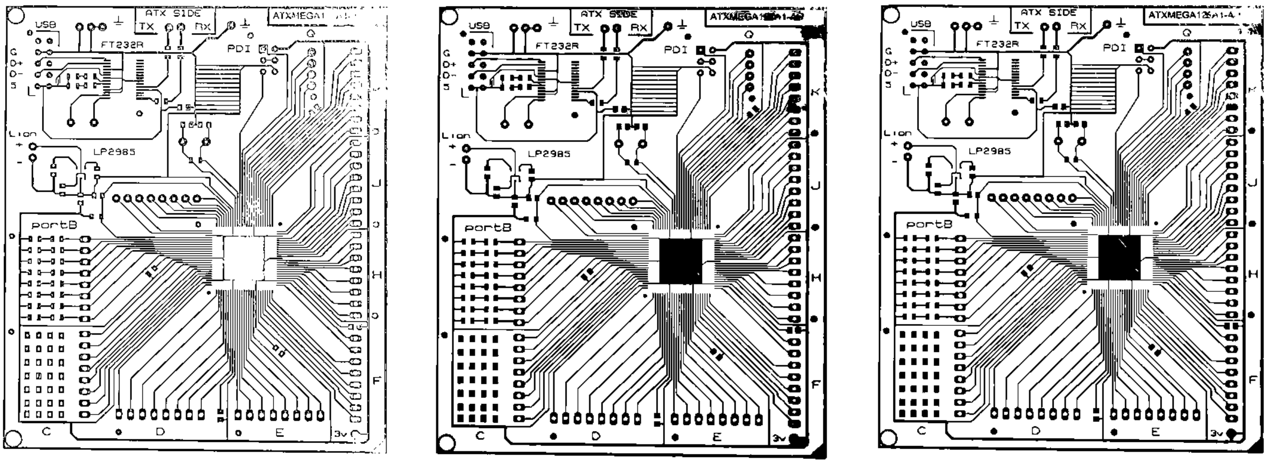
Depending on the size of this matrix, the ability to recognize small image elements in binarization changes. The larger the size of the "Block size" matrix, the more difficult it is to detail small elements, and vice versa, the smaller the size of the matrix, the more small elements can be found (Fig. 6) [16].



a) b) c)

Fig. 6. An example of finding the "Block size" area using the proposed algorithm: a) the threshold value of "Block size" is 23; b) the threshold value of "Block size" is 423; c) automatic finding of the value of "Block size"

Depending on the complexity of the image, it is necessary to select its own "Block size" values, which takes time during processing. Therefore, the development of an automated method for finding the "Block size" value for different images with different types of elements is an urgent task.

The "Block size" should always be an odd number to scan images with an arbitrary size.

To automatically select the "Block size" values, the following algorithm was built:

– find the global binarization threshold (t) using the Otsu method;

– binarize the image and find the standard deviation (σ);

– if the obtained value is even, subtract one, if the value is not even, leave it as it is, and substitute this value in the search for "Block size" (Fig. 7).

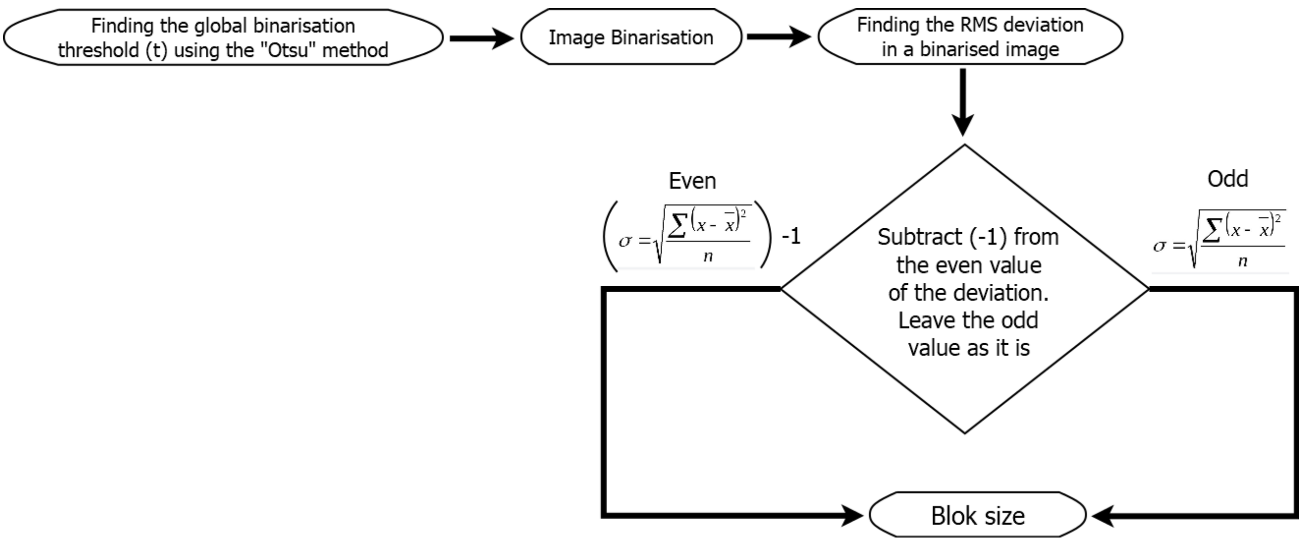


Fig. 7. Algorithm for finding the automatic value of "Block size"

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In this approach, we find the mean square deviation already in the binarized image, which provides information about the deviation of the background (e.g. white) and details (e.g. black) values of the image. This information can be used as the size of the scanning area "Block size".

Conclusion

The block size in binarization can affect the quality of the result. If the blocks are too small, some details may be lost, and if the blocks are too large, the result may be uneven. The optimal block size depends on the size of the image, the nature of the image, and the binarization method used. Typically, larger blocks are used for high-resolution images, such as medical images or high-quality images, while smaller blocks are used for low-resolution images, such as a webcam or mobile phone images.

Based on the results of the work, the following tasks were accomplished:

– the subject area was analyzed and the features of image binarization were considered;

– the threshold of binarization by "Otsu" was considered;

– an algorithm for finding the size of the scanning area "Block size" was developed.

The developed algorithm for finding the size of the scanning area "Block size" in the binarization of technological images of the topology of the SOE gives the following advantages (Fig. 8):

– automatic finding of the optimal scanning area Block Size;

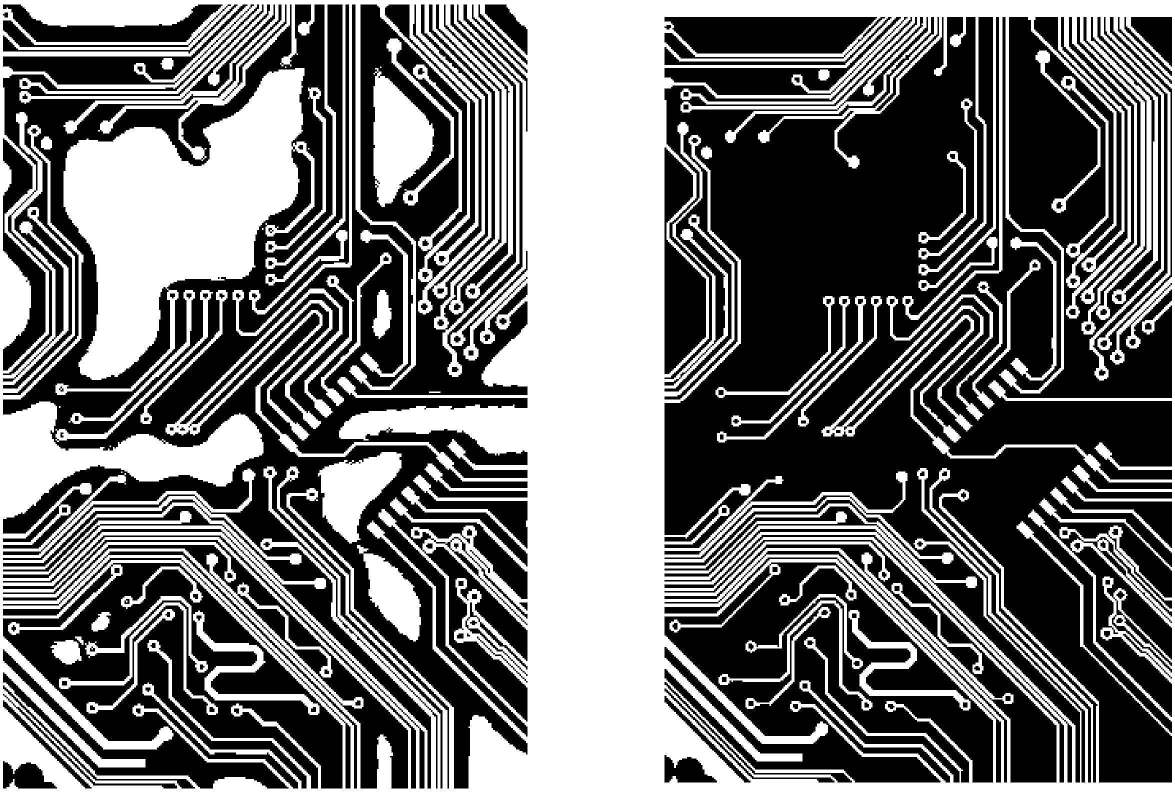
– resistance to image noise without the use of smoothing filters;

– detection of details in areas of contrast difference.

The sense of using the mean square deviation in the binarized image as the window size in adaptive binarization is as follows:

– this approach allows us to obtain a global binarized image with an automatic "Otsu" threshold;

– use of the mean square deviation in the binarized image as it gives the difference between the size of the background and the image elements.



a) b)

Fig. 8. Results of the algorithm:
a) global binarization; b) adaptive binarization with automatic adjustment of the scanning area size

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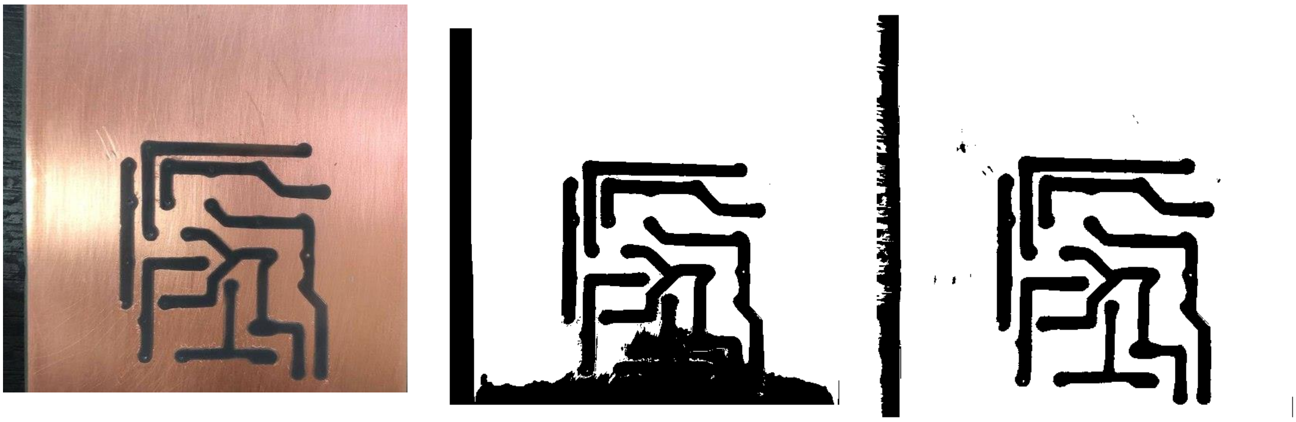
Thus, we get the average optimal value for binarization (Fig. 9):

– reduction of noise influence;

– reduction of contrast drop;

– the ability to find more details.



a) b) c)

Fig. 9. Results of improved binarization: a) real image; b) binarized image;
c) binarized image using the proposed algorithm for automatic sizing of the scanned area value

With the use of an automatic scanning window, such processing becomes faster and more accurate.

The disadvantages of this method include the following:

– slower than conventional global binarization;

– the deviation parameter, and thus the threshold finding, depends on global binarization.

The use of the proposed algorithm allows to improve the quality of image processing, reduce noise and improve the resolution when detecting small image elements (e.g., thin conductors in the topology of the DP). The developed software will also allow faster processing and comparison of technical images (Fig. 10).

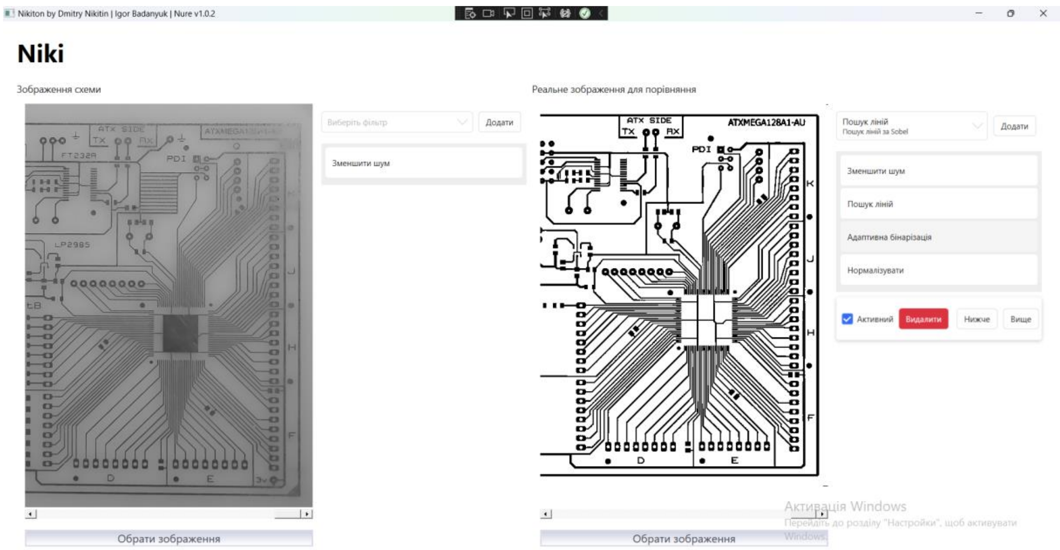


Fig. 10. The developed software

References

1. Arianna Martinelli, Andrea Mina, Massimo Moggi. (2021). The enabling technologies of industry 4.0: examining the seeds of the fourth industrial revolution. *Industrial and Corporate Change*, Volume 30, Issue 1, P. 161–188. DOI: https://doi.org/10.1093/icc/dtaa060

ISSN 2522-9818 (print)
ISSN 2524-2296 (online) *Innovative technologies and scientific solutions for industries. 2023. No. 1 (23)*

2. Núbia Carvalho, Omar Chaim, Edson Cazarini, Mateus Gerolamo. (2018). Manufacturing in the fourth industrial revolution: A positive prospect in Sustainable Manufacturing, *Procedia Manufacturing,* Volume 21, P. 671–678. DOI: https://doi.org/10.1016/j.promfg.2018.02.170
3. Mohammad Fakhar Manesh; Massimiliano Matteo Pellegrini; Giacomo Marzi; Marina Dabic. (2020). Knowledge Management in the Fourth Industrial Revolution: Mapping the Literature and Scoping Future Avenues, *IEEE Transactions on Engineering Management,* Volume: 68, Issue: 1, P. 289–300. DOI: 10.1109/TEM.2019.2963489
4. Andronie, Mihai, George Lăzăroiu, Mariana Iatagan, Iulian Hurloiu, and Irina Dijmărescu. (2021). "Sustainable Cyber-Physical Production Systems in Big Data-Driven Smart Urban Economy: A Systematic Literature Review" *Sustainability 13*, no. 2: 751 p. DOI: https://doi.org/10.3390/su13020751
5. Nevliudov, I., & et al. (2021). Development of a cyber design modeling declarative Language for cyber physical production systems, *J. Math. Comput. Sci.,* 11(1), P. 520–542.
6. Theo Lins, Ricardo Augusto Rabelo Oliveira. (2020). Cyber-physical production systems retrofitting in context of industry 4.0. *Computers & Industrial Engineering.* Volume 139. DOI: https://doi.org/10.1016/j.cie.2019.106193
7. Igor Gruzman. (2013). Threshold binarization of images based on the skewness and kurtosis of truncated distributions. Optoelectronics Instrumentation and Data Processing 49(3). P. 215–220. DOI: 10.3103/S8756699013030011
8. B. Gatos, K. Ntirogiannis, and I. Pratikakis. ICDAR 2009 document image binarization contest (DIBCO 2009). *ICDAR*, 2009. P. 1375–1382. DOI:10.1109/ICDAR.2009.246
9. N. Stamatopoulos, B. Gatos, G. Louloudis, U. Pal, and A. Alaei. ICDAR 2013 Handwriting Segmentation Contest. *12th International Conference on Document Analysis and Recognition (ICDAR).* 2013. P. 1402-1406. URL: https://www.academia.edu/19693205/ICDAR_2013_Handwriting_Segmentation_Contest
10. K. Ntirogiannis, B. Gatos, and I. Pratikakis. Performance Evaluation Methodology for Historical Document Image Binarization, *IEEE Transactions on Image Processing,* vol. 22, no.2, 2013. P. 595–609. DOI: 10.1109/TIP.2012.2219550
11. T. Romen, Sudipta Roy, O. Imocha, Tejmani Sinam, Kh. Manglem, "A NewLocal Adaptive Thresholding Technique in Binarization" *IJCSI International Journal of ComputerScience Issues,* Vol. 8, Issue 6, No 2, November 2011. URL: https://arxiv.org/ftp/arxiv/papers/1201/1201.5227.pdf
12. Rukhsar Firdousi, Shaheen Parveen, "Local Thresholding Techniques in Image Binarization", *International Journal Of Engineering And Computer Science* ISSN: 2319-7242 Volume 3 Issue 3 March, 2014. P. 4062–4065. DOI: 10.5121/cseij.2016.6101
13. T. Romen Singh, Sudipta Roy, O. Imocha Singh, Tejmani Sinam, Kh. Manglem Singh "A New LocalAdaptive Thresholding Technique in Binarization" *IJCSI International Journal of Computer ScienceIssues,* Vol. 8, Issue 6, No 2, November 2011. DOI: https://doi.org/10.48550/arXiv.1201.5227
14. Er. Nirpjeet kaur, Er. Rajpreet kaur "A review on various methods of image thresholding" (*IJCSE*). URL: http://www.enggjournals.com/ijcse/doc/IJCSE11-03-10-095.pdf
15. Graham Leedham, Chen Yan, Kalyan Takru, Joie Hadi Nata Tan and Li Mian "Thresholding Algorithms for Text/Background Segmentation in Difficult Document Images" *Seventh International Conference on Document Analysis and Recognition (ICDAR 2010).* DOI:10.1109/ICDAR.2003.1227784
16. Niblack (1986), An Introduction to Digital Image Processing, P. 115–116. URL: Prentice Hall. https://homepages.thm.de/christ/Start/01Lehre/11Bildv/aktuell/BVpix&refs/AdOculos%20-%20Digital%20Image%20Processing%20.pdf

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Відомості про авторів / About the Authors

Баданюк Ігор Олександрович – Харківський національний університет радіоелектроніки, аспірант кафедри комп’ютерно-інтегрованих технологій, автоматизації та мехатроніки, Харків, Україна; e-mail: ihor.badaniuk@nure.ua; ORCID ID: https://orcid.org/0009-0008-9137-4847

Невлюдов Ігор Шакирович – доктор технічних наук, професор, Харківський національний університет радіоелектроніки, завідувач кафедри комп’ютерно-інтегрованих технологій, автоматизації та мехатроніки, Харків, Україна; e-mail: igor.nevliudov@nure.ua; ORCID ID: https://orcid.org/0000-0002-9837-2309

Нікітін Дмитро Олександрович – Харківський національний університет радіоелектроніки, старший викладач кафедри комп’ютерно-інтегрованих технологій, автоматизації та мехатроніки, асистент, Харків, Україна; e-mail: dmytro.nikitin@nure.ua; ORCID ID: https://orcid.org/0000-0002-5591-4438

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Badanyuk Igor – Kharkiv National University of Radio Electronics, Postgraduate Student of Computer-Integrated Technologies, Automation and Mechatronics, Kharkiv, Ukraine.

Nevliudov Igor – Doctor of Technical Sciences, Professor, Kharkiv National University of Radio Electronics, Head of Department of Computer-Integrated Technologies, Automation and Mechatronics, Kharkiv, Ukraine.

Nikitin Dmytro – Kharkiv National University of Radio Electronics, Senior Lecturer of the Department of Computer-Integrated Technologies, Automation and Mechatronics, assistant, Kharkiv, Ukraine.

ОБРОБКА ТОПОЛОГІЧНИХ ЗОБРАЖЕНЬ ДЛЯ КОМПЛЕКСНОГО АНАЛІЗУ ДЕФЕКТІВ І ВІДХИЛЕНЬ ЗА ДОПОМОГОЮ АДАПТИВНОЇ БІНАРИЗАЦІЇ

Предметом дослідження статті є підготовка для розпізнавання та порівняння реальних топологічних зображень друкованих плат (ДП) за допомогою адаптивної бінаризації зображення з "автоматичним вікном" (ділянки для сканування зображення "Block size"). **Мета** роботи – удосконалення методу адаптивної бінаризації для зображень, отриманих системами технічного зору за допомогою розробки автоматичного алгоритму виявлення необхідного значення вікна бінаризації зображення. **Завдання**: дослідити предметну сферу для аналізу технічних зображень топології ДП; описати знаходження глобального порога бінаризації (t) за допомогою методу "Otsu"; провести глобальну бінаризацію зображення; розрахувати середнє квадратичне відхилення бінаризації; обробити здобуті результати для знаходження необхідного значення "Block size"; перевірити розроблений алгоритм у програмному забезпеченні. **Результати**: реалізовано та перевірено алгоритм обробки зображень з автоматичним налаштуванням вікна бінаризації "Block size"; розроблено програмне забезпечення з використанням запропонованого алгоритму та порівняно роботу глобальної бінаризації з удосконаленим методом знаходження значень ділянки для сканування зображення "Block size"в обробці дрібних елементів топології ДП. Це вирішить такі питання: видалення шуму із зображення (шум може виникати з причини поганої якості сканування або фотографії, а також через наявність дрібних плям на поверхні друкованої плати); сегментація зображення – поділ його на окремі елементи, такі як контури, зони й текст (цей процес може бути автоматизований за допомогою програмного забезпечення для обробки зображень); виявлення елементів – знаходження та відокремлення окремих елементів, зокрема резисторів, конденсаторів та інших компонентів, зображених на топології; відновлення елементів – використання програмного забезпечення для відновлення форми й розмірів окремих елементів (цей процес може бути автоматизований з використанням моделей глибокого навчання, які можуть розпізнавати різні типи елементів); аналіз топології – використання результатів обробки зображення для аналізу топології друкованої плати (це може передбачати перевірку з'єднань, вимірювання розмірів елементів і перевірку сумісності зі схемою пристрою). **Висновки**: за результатами роботи розроблено алгоритм автоматичного налаштування розмірів сканувальної ділянки "Block size" для бінаризації технологічних зображень топології ДП; визначено такі переваги розробленого алгоритму: автоматичне знаходження оптимальної сканувальної ділянки "Block size"; опір шумам зображення без використання згладжувальних фільтрів; знаходження деталей у зонах перепаду контрасту.

Ключові слова: обробка технологічних зображень; адаптивна бінаризація; метод "Otsu"; топологія ДП; знаходження "Block size".

Бібліографічні описи / Bibliographic descriptions

Баданюк І. О., Невлюдов І. Ш., Нікітін Д. О. Обробка технологічних зображень для комплексного аналізу дефектів і відхилень за допомогою адаптивної бінаризації. *Сучасний стан наукових досліджень та технологій в промисловості*. 2023. № 1 (23). С. 164–173. DOI: https://doi.org/10.30837/ITSSI.2023.23.164

Badanyuk, I., Nevliudov, I., Nikitin, D. (2023), "Topological image processing for comprehensive defect and deviation analysis using adaptive binarisation", *Innovative Technologies and Scientific Solutions for Industries*, No. 1 (23), P. 164–173. DOI: https://doi.org/10.30837/ITSSI.2023.23.164