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INFORMATION TECHNOLOGY OF PRINTS PICTURES BINARIZATION OF COATING SURFACES ON A METALLIC PADDING

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Abstract. New information technology of binarization of colored snapshots of coating surfaces prints on a metallic padding is considered providing accuracy increase and reliability of objects of interest selection in low-contrast areas due to preliminary realization of brightness adaptive amplification and contrast of an initial picture. The advantage of the proposed information technology is a high level of the binarization process automation. Experimental results are considered on the example of coating surfaces porosity determination.

Keywords: binarization information technology, surface prints on a metallic padding, porosity calculation, brightness and contrast amplification, threshold binarization.

1. Introduction

One of the important characteristics considered when creating new coatings of metals is their porosity that significantly influences its corrosion resistance. The overlap method is worth to be selected among existing methods of porosity calculation that is quite simple but at the same time the most used one.

This method consists in putting the filter paper on the coating on a metallic padding soaked with a special solution that is rinsed with distilled water and dried on a clean glass after removal from the surface. As a result, the picture of the surface with pores prints is formed on the paper in a shape of dots or stains, visual analysis of which is used to calculate porosity [1]. The advantage of this method is a low cost of the experiment conduction and minimal requirements to a special equipment presence. At the same time, the necessity of a "manual" calculation of pores number is a significant disadvantage of the method that makes the process quite labor-intensive when there are a large number of pores.

The solution of this task can become more complicated with the presence of fuzzy areas on the print that leads to the evaluation accuracy decrease.

Binarization of the coating surface print picture that, as a rule, is in color is an important step during the process automation of the porosity determination. The presence of low-contrast areas and fuzzy fragments on it significantly complicates solving of the task of the threshold brightness level determination based on which pores will be separated from the background and decreases reliability and accuracy of the end result.

Thus, information technology of coating surfaces prints binarization should contain a stage of the initial picture preliminary processing providing amplification of its brightness and contrast for separation accuracy increase. To effectively solve this task the following requirements to the used methods are proposed: adaptiveness, minimal number (in ideal – absence) of controlling parameters that is important for reducing the time of their adjusting, absence of colored deviations (to escape incorrect identification of pores and background). Traditional methods of the brightness and contrast increase (gamma-correction, equalization and adaptive equalization of histogram, stretching the contrast [2]) do not satisfy the above-stated requirements.

In the works [3-5] adaptive methods of brightness and contrast increase were proposed that are based on the application of exponential conversions and static characteristics of both the picture as a whole, and its windows (non-overlapping fragments of the same size) of each color channel of an initial picture and satisfy all above-stated requirements.

The new information technology of coating surfaces prints pictures binarization on a metallic padding is considered in the paper providing an increase of determination reliability of their porosity during pictures processing containing low-contrast and fuzzy areas.

2. Section contents

The proposed in the paper new information technology of coating surfaces prints pictures binarization on a metallic padding consists of four basic stages:

1. Scaling of all color channels of the initial picture (it can be both colorful and halftone) on a segment [0,1].
2. Deleting in automatic mode the “extraneous information” (all possible identification inscriptions that were made on the paper during the formation of the coating surface print), detection of which, when present, is carried out visually.
3. Amplification of brightness and contrast based on the application of adaptive methods in order to increase binarization reliability. It happens due to increase of the accuracy during processing fuzzy and low-contrast fragments of the surface picture print.
4. Binarization realization based on the threshold brightness value that is calculated in automated mode.

After carrying out of these four steps the coating porosity value calculation takes place.

Let us take a closer look at the implementation of the last three stages.

2.1 Deleting “extraneous information"

This stage of the proposed information technology is carried out by the following way: if the value of an “extraneous information” is identified as a result of the visual analysis then the value of Δ_{di} is calculated by the following formula:

$$\Delta_{di} = \frac{0.333 + \left(\Delta_{max} + \overline{\Delta}\right)/\,2}{2}, \tag{1}$$

where Δ_{max} and $\overline{\Delta}$ – maximal and average difference between each pair of color channels, relatively; there is a condition for each pair of color channels: if the module of the intensity difference of their pixels exceeds the value Δ_{di} then in one of the channels the pairs of brightness of such pixels are changed to 1.

It is worth mentioning that in some cases the implementation of this method can decrease the accuracy of pores identification due to their incorrect interpretation as an “extraneous information”.

2.2 Adaptive methods of brightness and contrast increase

Brightness and contrast amplification is carried out on the basis of the brightness adaptive increase methods, adaptive spatial contrasting and adaptive histogram of correction proposed in the works [3-5].

Brightness adaptive increase includes the following stages.

1. Automatic evaluation of brightness V level for each color channel:

$$V = \sum_{j=1}^{N_w} \left(\left(I'\right)^{1-v_j} - \left(I'\right)^{\frac{\overline{i_j}+\overline{I}}{2}} \right), \tag{2}$$

where $\overline{i_j}$ – mean brightness of the j-th window; N_w – number of windows, and the value of I' is defined by the ratio:

$$I' = \left(\overline{I} + \frac{I_{min} + I_{max}}{2}\right)/\,2, \tag{3}$$

at this $\overline{I}$, I_{min}, I_{max} – mean, minimal and maximal levels of brightness, correspondingly, and v_j - evaluation of the brightness level, calculation of which is implemented using values of i_j^1, i_j и i_j^2:

$$i_j^1 = \overline{i_j^1}\left(1 - \frac{N_{i1}}{N_p}\right), \tag{4}$$

$$i_j^2 = \overline{i_j^2}\,\frac{N_{i1}}{N_p}, \tag{5}$$

where $\overline{i_j^1}$ и $\overline{i_j^2}$ – mean values by pixels brightness of the j-the window $w_{x,y}^j$, satisfying and not satisfying , correspondingly, the following condition:

$$w_{x,y}^j \geq \left(\overline{i_j} + \overline{I}\right)/\,2; \tag{6}$$

N_{i1} – number of pixels of the j-the window, complying with the condition (6); N_p – number of the window pixels. The value v_j is defined by the following way:

if $N_{i1} > 0$ and $i_j^1 \neq 0$, then

$$v_j = \left(i_j\right)^{\left(1-\mathrm{sgn}\left(i_j^1 - i_j^2\right)\frac{\min\left(i_j^1, i_j^2\right)\cdot\overline{i_j}}{\max\left(i_j^1, i_j^2\right)}\right)^{1+\mathrm{sgn}\left(i_j^1 - i_j^2\right)\cdot\overline{i_j}}}; \tag{7}$$

if $N_{i1} > 0$ and $i_j^1 = 0$, then

$$v_j = \left(i_j\right)^{1+\overline{i_j}^{\,1+\overline{i_j}}}; \tag{8}$$

if $N_{i1} = 0$, then

$$v_j = \left(i_j\right)^{1-\overline{i}_j^{\;1-\overline{i}_j}} . \tag{9}$$

If the condition $V \geq 0$ is good for all color channels then the brightness increase for the given picture does not take place.

2. Proportional increase of the brightness of each pixel of the present window $w^1_{x,y}$:

$$w^2_{x,y} = \left(w^1_{x,y}\right)^{1-p^1_{x,y}}, \tag{10}$$

where $p^1_{x,y}$ is calculated based on statistical characteristics of the present window and the selected color channel by the formulas:

$$p^1_{x,y} = \left(\frac{\left(w^1_{x,y}\right)^{max_p} + \left(1-w^1_{x,y}\right)^{max\left(i_w, 1-i_w\right)}}{2}\right)^{1+p^3_{x,y}}, \tag{11}$$

$$p^2_{x,y} = p^3_{x,y} - min_{p3}, \tag{12}$$

$$p^3_{x,y} = sgn\left(p^4_{x,y}\right) \cdot \left|p^4_{x,y}\right|^{1-p^4_{x,y}} + sgn(V) \cdot |V|^{1-V}, \tag{13}$$

$$p^4_{x,y} = \left(w^1_{x,y}\right)^{1-w^1_{x,y}} - \left(i_w\right)^{1-i_w}, \tag{14}$$

$$i_w = \frac{0.5 + i_{max}/2 + \bar{i} + \bar{I}}{4}, \tag{15}$$

at that $max_p = max\left(p^2_{x,y}, 1-p^2_{x,y}\right)$; min_{p3} – minimal value according to matrix p^3; $\bar{i}$ – mean value of brightness of the present window.

3. Proportional change of pixels brightness of each window (increase and decrease for correcting the results of the previous step):

$$w^3_{x,y} = \left(w^2_{x,y}\right)^{\left(1-sgn\left(p^{aft}_{x,y}\right) \cdot \left|p^{aft}_{x,y}\right|^{1-p^{aft}_{x,y}}\right)}, \tag{16}$$

$$p^{aft}_{x,y} = \left(i_w\right)^{1-i_w} - \left(w^2_{x,y}\right)^{1-w^2_{x,y}} . \tag{17}$$

4. Final correction of brightness level for the selected color channel as a whole for reduction of the between-the-window “boundary” effect:

if $sgn\left(P_1\right) < 0$, then

$$I^2_{x,y} = \left(I^1_{x,y}\right)^{\left(1-P_1 \cdot \left(P_1\right)^{\left(I^1_{x,y} + min\left(I, 1-I\right)\right)/2}\right)}, \tag{18}$$

otherwise

$$I^2_{x,y} = \left(I^1_{x,y}\right)^{\left(1+P_1 \cdot \left(P_1\right)^{\left(\left(I^1_{x,y} + max\left(I, 1-I\right)\right)/2\right)^{1+\bar{I}-I^1_{x,y}}}\right)}, \tag{19}$$

where $I^1_{x,y}$ и $I^2_{x,y}$ – pixels brightness of input and output pictures for this step of the algorithm, correspondingly:

$$P_1 = \left|P_2\right|^{1+P_2}; \; P_2 = 0.5^{1-I'} - 0.5^{1-\bar{I}}$$

5. Correcting brightness decrease is implemented if the condition $V \geq 0$ is good for some color channels:

$$I^3_{x,y} = \left(I^2_{x,y}\right)^{1+\left(min\left(P_d, 1-P_d\right) - V^2 + V^1\right)/2}, \tag{20}$$

$$P_d = \frac{min\left(V^1, V^2\right)}{max\left(V^1, V^2\right)}, \tag{21}$$

at this V^1 и V^2 – values of automatic evaluations of the brightness level of the selected color channel I^1 and I^2 correspondingly.

The algorithm of adaptive spatial contrasting consists of the following steps:

1. Window conversion implementing the shift in brightness level to increase the contrast:

$$w^2_{x,y} = \left(w^1_{x,y}\right)^{\left(1-k_{x,y} \cdot w^1_{x,y}\right)}, \tag{22}$$

$$k_{x,y} = 10^{\left(lg\left(\bar{i}^{\,\bar{i}}\right) + w^1_{x,y} - \bar{i}\right)} . \tag{23}$$

As a result of the conversion (22) implementation for each pixel of the present window the shift of its brightness level takes place to the value of 1 or 0 depending on the $k_{x,y}$ coefficient that is calculated based on the pixel intensity and mean value of the window intensity that provides the contrast increase.

2. Correcting window conversion implemented by the formulas:

$$w^3_{x,y} = \left(w^2_{x,y}\right)^{\left(p^1_{x,y}\right)^{p^1_{x,y}}}, \tag{24}$$

$$p^1_{x,y} = \left|\left(p^2_{x,y}\right)^{p^2_{x,y}} + sgn\left(\bar{i} - 0.5 \cdot i_{max}\right) \cdot \left(\bar{i}^{\bar{i}} - 0.5 \cdot i_{max}\right)\right|, \quad (25)$$

$$p^2_{x,y} = \left(1 - w^2_{x,y}\right)^{1-\bar{i}}. \quad (26)$$

3. Controlled correction of the pixels intensity levels using statistical characteristics of the present window and selected color channel in total:

$$w^4_{x,y} = \left(w^3_{x,y}\right)^{\left(\left(1-\bar{I}\right)^{\bar{I}} + P_{add} + \left(\bar{i}\right)^{w^3_{x,y}}\right)}, \quad (27)$$

where P_{add} – chosen empirical values allowing to control the level of the received picture intensity that is formed based on the automatic evaluation of the brightness level (2). At this, negative values of the P_{add} parameter lead to the output picture brightness increase and positive – to decrease.

Adaptive histogram correction includes the following steps.

1. If the condition is implemented:

$$i_{min} \neq i_{max}, \quad (28)$$

then the proportional increase of pixels brightness takes place that also leads to contrasting:

$$h^2_j = \left(h^1_j\right)^{1-sgn\left(h^1_j - i_h\right) \cdot \left(d_j\right)^{\left(h^1_j\right)^{d_j}}}, \quad (29)$$

where h^1_j, h^2_j – elements of the intensity levels vectors contained in histogram of the present input and output window for this stage of pictures, correspondingly; d_j and i_h are calculated by the formulas:

$$d_j = \frac{\left|h^1_j - i_h\right|^{1-\left|h^1_j - i_h\right|}}{max\left(i_h, 1 - i_h\right)^{1-max\left(i_h, 1-i_h\right)}}, \quad (30)$$

$$i_h = \left(\overline{i_h}\right)^{1-sgn\left(d_1\right) \cdot \left|d_1\right|^{\left(\overline{i_h}\right)^{\left|d_1\right|}}}, \quad (31)$$

$$d_1 = i_m^{1-i} - i_m^{\bar{i}}, \quad (32)$$

$$i_m = \left(i_{min} + i_{max}\right)/2, \quad (33)$$

at that, $\overline{i_h}$ – mean value by the vector h^1, and $i = \left(i_m + \bar{i}\right)/2$. If the condition (28) is not implemented then h^2 is formed by the following way:

$$h^2_j = h^1_j - min_1 + i_{min}, \quad (34)$$

where min_1 in case of the condition implementation:

$$i_{min} \neq 0, \quad (35)$$

is calculated by the formulas:

$$min_1 = \left(i_{min}\right)^{1+\left(d_{min}\right)^{\left(i_{min}\right)^{d_{min}}}}, \quad (36)$$

$$d_{min} = \frac{\left|\bar{i} - i_{min}\right|^{1-\left|\bar{i} - i_{min}\right|}}{i_{max}}, \quad (37)$$

$$i_{max} = max\left(\bar{i}, 1 - \bar{i}\right)^{1-max\left(\bar{i}, 1-\bar{i}\right)}. \quad (38)$$

When the condition (35) does not work, then $min_1 = 0$.

2. If $r > 1$ then scaled extension of the histogram of the present window is carried out:

$$h^3_j = h^2_j \cdot r^2 - h^2_1 \cdot \left(r^2 - 1\right)2, \quad (39)$$

$$r = \frac{max_1 - min_1}{h^2_{max} - h^2_1}, \quad (40)$$

at this h^2_{max} and h^2_1 – the first and last elements of the h^2 vector and max_1 value, if $i_{max} \neq 1$ then:

$$max_1 = \left(i_{max}\right)^{1-\left(d_{max}\right)^{\left(i_{max}\right)^{d_{max}}}}, \quad (41)$$

$$d_{max} = \frac{\left|\bar{i} - i_{max}\right|^{1-\left|\bar{i} - i_{max}\right|}}{i_{max}}, \quad (42)$$

and otherwise $max_1 = 1$.

3. All levels of pixels brightness of the present window change to corresponding to them levels of brightness contained in vector h^3 (or h^2 if the second step was skipped), but the output picture forms as a result of this.

2.3 Application of adaptive methods of brightness and contrast increase in the proposed information technology.

Brightness and contrast amplification in the proposed information technology is carried out based on the above-mentioned adaptive methods of the brightness and contrast increase by the following way.

1. Adaptive increase of brightness.
2. If the brightness increase was implemented then

adaptive histogram correction is applied to the received picture.

3. The method of adaptive spatial contrasting is used for a picture received after previous steps.

4. The method of adaptive histogram correction is applied to the picture received after the 3rd step.

5. At the last stage the output picture formation takes place by fusion of images received as a result of two previous steps implementation:

$$I^5_{x,y} = (0.5 - \Delta_1) \cdot I^4_{x,y} + (0.5 + \Delta_1) \cdot I^3_{x,y}, \quad (43)$$

$$\Delta_1 = sgn(\Delta_2) \cdot |\Delta_2|^{1-|\Delta_2|}, \quad (44)$$

where $I^3_{x,y}$, $I^4_{x,y}$ and $I^5_{x,y}$ pixels with x, y coordinates of the selected color channel of the 3rd, 4th and 5th steps correspondingly; Δ_2 – difference of mean values according to the chosen color channel of output pictures for the 3rd and 4th stages.

As a result of experiments conduction the dimension of windows when applying adaptive increase of brightness and spatial contrasting was chosen to be equal to 3x3 pixels and when using adaptive histogram correction – coinciding with the dimension of the picture.

2.4 Implementation of binarization

After the brightness and contrast increase the picture binarization is carried out by dividing it by brightness level using the further presented algorithm.

1. If the initial picture – colorful, then halftone picture is formed by the following method:

a) the selection of the final brightness value is implemented based on the minimal value of intensity for each of color channels for all pixels the intensity value of which does not exceed the T_1 value and at this the T_1 value is calculated by the formula:

$$T_1 = \left(\overline{I} / 2 + \overline{I_1}\right) / 2, \quad (45)$$

where $\overline{I_1}$ – mean brightness of pixels that does not exceed $\overline{I}$ (mean value) for the most informative color channel;

b) for pixels, brightness of which does not meet the above-mentioned condition, the choice of the final intensity value takes place based on the mean brightness value for each of the color channels;

c) for each pixel of a halftone picture of I^1 received after the implementation of previous steps, the conversion takes place allowing to improve the separation between pores and background and to form final halftone picture of I^2:

$$I^2_{x,y} = \left(I^1_{x.y}\right)^{1-T_1+I^1_{x,y}}. \quad (46)$$

2. Binarization of a halftone picture of I^2 using threshold T_2 based on the expression (45).

The choice of the most informative color channel depends on the initial picture and is carried out based on the visual analysis (although in most of the cases it is recommended to choose the red color channel).

2.5 Porosity determination

After implementation of the binarization of the surface print picture the calculation of its porosity takes place in automated mode. For this, the following conditions are carried out:

1. An automatic rotation of the received surface print is implemented in such a way that one of its sides (usually the print looks like a triangle) is parallel to abscissa axis.

2. A part of the picture is selected that is the print of the coating surface. At this several boundary lines and columns of the received fragment are neglected (set by the user).

3. The coating surface porosity P is calculated by the formula:

$$P = \frac{N_b}{N_w} 100\%, \quad (47)$$

where N_b и N_w – number of black and white pixels of the print correspondingly.

2.6 Results of the experiments

Experimental results were gained during processing of various RGB pictures of coating surfaces prints on a metallic padding received to calculate porosity by the method of overlapping, the example of which is shown on fig. 1. Given example has a greenish background due to insufficient washing with distilled water (unfortunately not seen on the figure) that has led to the necessity to choose green color channel during binarization.

The picture shown on figure 1 contains small blurring (upper part of the picture) and also prints of pores that are hardly distinguishable from the background, an example of which can be the fragment selected with a circle (shown in large scale on figure 6). Figure 2 presents histogram of the initial picture that indicated its insufficient contrast.

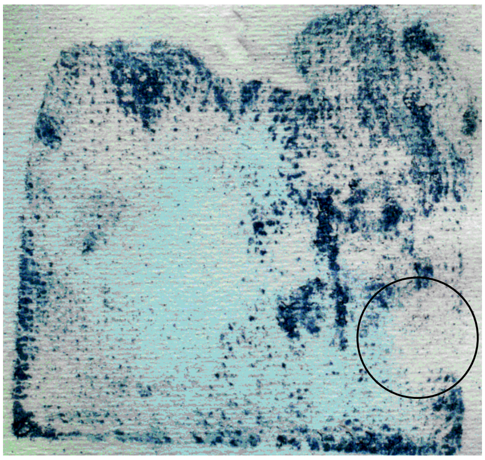

Fig. 1. Initial RGB picture.

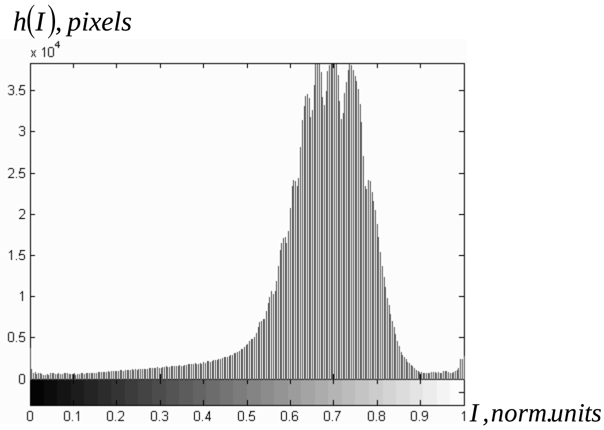

Fig. 2. Histogram of initial picture

When implementing binarization of the given picture (after conversing it to the halftone one based on the maximum of the brightness values for each pixel) by traditional approaches, the example of which can be the method of Huang and Wang [6] (fig. 3) a significant deviation of an intensity distribution takes place that leads to incorrect interpretation of the background as pores. Given circumstance indicates about inexpediency of use of traditional approaches during binarization of similar picture.

Fig. 3. The results of the initial picture binarization by method of Huang and Wang

Figure 4 presents the results of the brightness and contrast increase on the initial picture and figure 5 is the histogram corresponding to it.

Comparison of pictures histograms (fig. 3 and fig. 5) presented on figure 1 and figure 4 shows that the maximum has moved from the values of 0.65-0.75 to 0.75-0.9 of normal units that indicates the brightness increase and the histogram dynamic range extension – about the contrast increase.

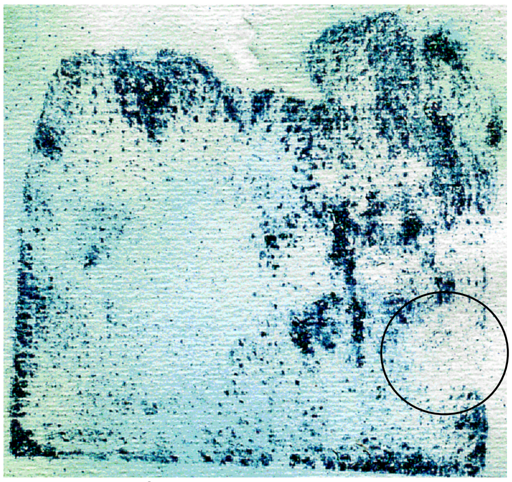

Fig. 4. Results of the brightness and contrast increase for the picture shown on figure 1.

Figure 7 and figure 8 show binarization results carried out for a selected fragment (fig. 6) directly and after their processing by the described methods correspondingly.

Consideration of the received results shows that the brightness and contrast increase of the initial picture has allowed selecting a significantly larger number of hardly distinguishable pores (fig. 8).

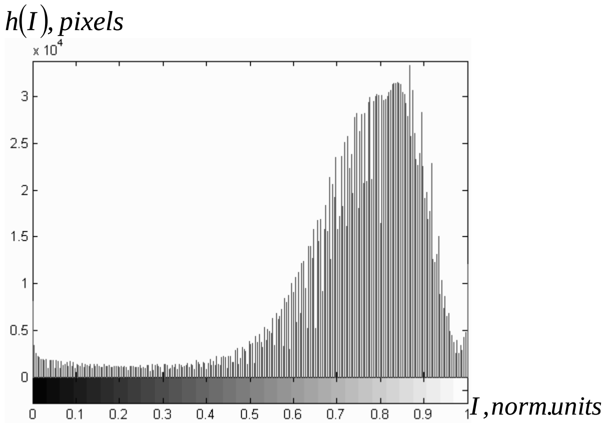

Fig. 5. Histogram of the picture on figure 4.

In total, after binarization for the picture shown on fig. 1 it was received 8% less of black pixels than for the picture shown on figure 4.

Relatively little percent of difference is explained by an integral increase of pores localization reliability in various areas. Although accuracy increase by 8% is not significant but when defining porosity of various fragments of a sample surface shown on the picture (fig. 1) it will be more significant.

Fig. 6. Selected fragment on figure 1

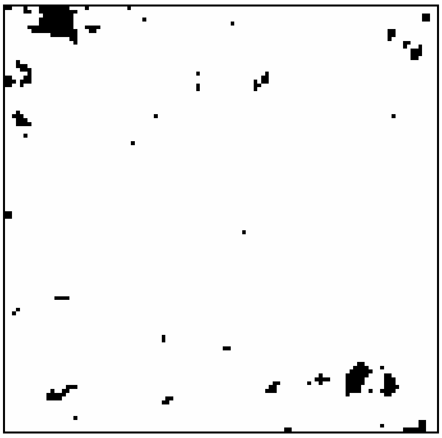

Fig. 7. Binarization result of the selected fragment of the picture on figure 1

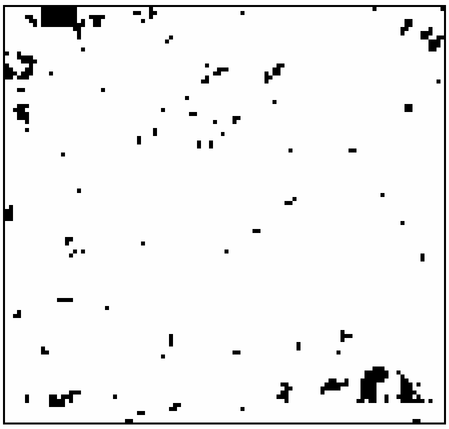

Fig. 8. Binarization result of the selected fragment of the picture shown on figure 4

3. Conclusion

In the proposed information technology it was a success in raising the reliability of the pictures binarization containing low-contrast and fuzzy areas due to amplification of brightness and contrast of the coating surface picture prints on a metallic padding. It contributes to a more accurate determination of a coating porosity after binarization implementation.

The advantage of the proposed information technology is a high level of the binarization process automation (manual control exists only during implementation of the second step and when selecting the most informative color channel, brightness and contrast amplification is carried out totally automatically). A quite high calculation complexity of the brightness and contrast amplification methods should be attributed to disadvantages.

A perspective trend of further researches is the activities implementation automation level increase needed for the calculation of porosity after the initial picture binarization.

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