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PROBLEMS OF SOFTWARE PROCESSING OF DIGITAL PHOTOGRAPHY INTENDED FOR DETERMINING THE DIMENSIONAL ACCURACY OF A PRODUCT

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Abstract:
Some of the problems that arise during the processing of the acquired photo are analyzed in this paper. The most commonly used software tools in image processing require binary photography, and its conversion into the binary form is required first. Conversion problems, and their proper solution, are key steps for further machine determination of dimensional accuracy. Removing smudges on binary photos and rotating displays for photo overlap methods are the problems that are solved in the work, in order to successfully prepare the photo with software for further determination of the dimensional accuracy of the product. The knowledge gained in this paper will help scientists, and facilitate their.

Keywords: Digital photography; Image processing; Dimensional accuracy; Quality control

1. INTRODUCTION

Software processing of digital photos has a wide range of applications, processing within different software packages and using different methods, in order to use a quality processed photo for the desired purposes. Depending on the field of application, there are problems that researchers face and must be successfully solved in order for the software solution to make sense to be implemented in quality control systems.

A review of the literature will show some of the areas in which software systems have been implemented. The paper [1] presents a developed system in which a programmed algorithm for automatic detection of errors in the production of MPCG (Mobile Phone Cover Glass) is incorporated. In the food industry, in paper [2] photographs acquired by hyperspectral cameras are processed by software and used for automatic detection of errors in the food packaging process. In the field of mechanical engineering, the digital photo obtained during laser welding in paper [3] was processed by software and an algorithm was developed to monitor the accuracy of the product. For the quartz bar industry, by developing quality control, a method for detecting bubbles in quartz bars and evaluating their quality based on machine vision was developed in paper [4]. In all the mentioned works, the key part is the photo processing and their successful solution to the photo processing problem. The problems of photo binarization [5] must be properly solved so that it makes sense to use the photo in the further process. In the following, some of the solutions that the researchers used in their works will be presented. In paper [6] the Sauvola method was applied for adaptive photo binarization, while in paper [7] and [8] the Otsu method was used to solve the problem of binarization. Also in the paper [8] the problems of removing smudges and rotation of the display were considered. Methods for solving the problem of photo rotation are presented in [9] and [10]. As photo processing has become widely used as a means of reducing detection time and production effort in the paper [11], the study proposes an algorithm for photo processing that solves, among other things, the above-mentioned problems.

By researching the literature, it can be established that the field of application of digital photography is wide and that a large number of problems are encountered during the software processing of photographs. Therefore, the focus of this paper on the problems of software processing of photographs are intended to determine the dimensional accuracy of the product with regard to the required tolerance measurements.

2. PROBLEM DESCRIPTION AND RESEARCH GOAL

In the introduction, through a brief review of the literature, it was possible to see that the use of photography to determine the dimensional accuracy of the product with regard to the required dimension of the product is not widely used in science and industry. The reasons, among other things, lie in the problems that arise on the implemented hardware and software solutions of computer and machine vision. The implemented solution acquires and processes digital photos, which depends on the accuracy of product dimensions. Part of the surface of the photo that is not occupied by the product is unusable, it is removed during processing, which reduces the number of pixels in the photo and thus the tolerance limits because there are fewer pixels in the product. Photographs taken in color or in shades of gray (grayscale) must be converted into black and white binary form (0 and 1), which is a prerequisite for further processing with the most used software tools. The software loads the photo as a matrix with numbers, where each number in the matrix represents a pixel or a color of the photo. The problem arises when converting the photo into black and white binary form. Monochromatic photos have only black and white, which means that it is necessary to choose a shade of gray that will be the threshold value of black, and all other shades with a number greater than the threshold value are converted to white. Successful binarization solves an important prerequisite for further software preparation of the photo for the correct determination of the dimensional accuracy of the product. After binarization, smudges may appear on the photo caused by impurities, shadows, noises and other disturbances during photo acquisition or software processing. They can negatively affect the measurement of the properties of the parameters of the observed product region in the photo, which will be further used to determine the accuracy of the dimensions. Therefore, successful removal of smudges with binarization is an essential prerequisite for further determination of dimensional accuracy. With software packages, certain tools rotate the photo around its center, so it is necessary to crop the photo so that the product is exactly in the center. With the photo overlay method, in determining the dimensional accuracy of the product in the photo, it is important to center the product and orient it correctly so that the method is effective. Therefore, the mentioned problems of centering, cropping and rotation of the product in the photo are analyzed in this paper. The goal of this research is to gradually improve the algorithms for the above-mentioned problems of software photo processing, which will provide a quality solution and thus improve and facilitate the software preparation and processing of digital photos intended for determining the required dimensional accuracy of the product.

3. DESCRIPTION OF CONDUCTED EXPERIMENTAL RESEARCH

In this paper, the above-mentioned problems that arise during the software processing of the digital photograph will be considered on the acquired digital photograph of the rotor sample see Figure 1.

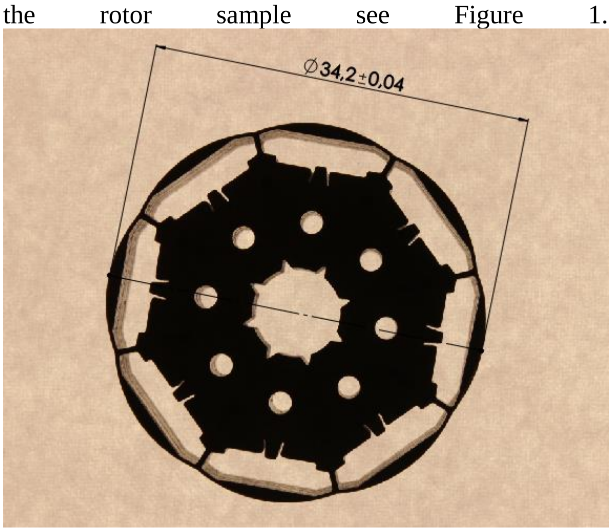

Figure 1 Digital photograph of the rotor

The diameter of the rotor is defined by the technical drawing, the samples of which are used during the first phase of preliminary research for the development of machine vision on the prototype machine for quality control, according to the project financed by the European fund for regional development (project code: KK.01.2.1.02.0062). For software processing, a digital photograph of the sample obtained in a laboratory environment using a Canon EOS 600D digital SLR camera, EF-S 18-55 IS II lens was used, see Figure 2.

Figure 2 Used equipment during acquisition

The digital photography was processed within two different software packages (Matlab and R studio). Already when opening a digital photo within the software package, problems arise caused by the high resolution of the photo, which greatly slows down the use of certain software tools. Since the photo was acquired in color, it must first be converted into a monochrome photo. This is followed by the binarization of the photo, which was done in one software package using Otsu's method and the Adaptthresh method, which uses an adaptive gray border. Another software package performed binarization using 11 different methods (Bernsen, Niblack, Sauvola, Wolf, Nick, Gatos, Su, Trsingh, Bataineh, Wan and ISauvola). Photo binarization was performed according to the default settings of each individual method within the software package. Due to the problems that arise when connecting tools from different libraries, the binarized photos obtained using the mentioned 11 methods were saved in JPEG format and were analyzed and processed in the first software package. For each binarized photo, the number of pixels that make up the surface of the rotor, as well as the number of pixels located on the largest horizontal part of the rotor (width) and on the largest vertical part of the rotor (height) were determined using software tools. As the rotor sample was acquired by equipment whose lens has a central projection, in Figure 1 you can see the appearance of the third dimension, which creates smudges on the binarized photos that cause problems and must be removed as well as other smudges caused by impurities on the surface, noises and other errors created upon acquisition. To solve the mentioned problem, the smudges removal tool was used within the software using the automatic settings of the tool. The number of pixels removed was then calculated. As with some binarization methods there are smudges that are larger and cannot be removed by the automatic settings of the tool used, by combining different tools available in the used programs ('bwconncomp', 'regionprops', 'labelmatrix', 'ismember'), used within the loop, simple algorithms have been developed to remove smudges, then the total number of removed pixels is calculated. After that, the total number of pixels in the surface of the rotor after the smudges were removed, and the width and height of the rotor were calculated. Since the number of calculated pixels of the rotor surface differs with the binarization methods used in the obtained photos, a problem arises when choosing a method that gives accurate results, which is also a key prerequisite in determining the dimensional accuracy of the rotor. In order to analyze the problem, the mean value of the number of smudges free rotor pixels from all 13 methods used is calculated. The deviations of all methods are calculated in relation to the mean values. The width and height of the rotor are calculated with the mean value of the number of pixels of the rotor without smudges, and the results obtained with other methods are analyzed. With each binarization method, for the obtained value of the number of pixels of the rotor, a software algorithm is used to determine which threshold shade of gray color during binarization corresponds to the value of the obtained pixel numbers. An algorithm is then programmed so that every pixel with a shade of gray that is less than the smallest threshold shade of gray is converted to black, and every pixel whose shade of gray is greater than the highest threshold shade of gray is converted to white. While all other shades of gray remain unchanged. In this way, the layout of the pixels in the photo can be visually seen, and by calculating the size of the pixels in the processed photo, it can be concluded whether there are dimensional deviations or whether the dimensions of the product are within the tolerance limits. Photographs processed in this way can be used to determine the dimensional accuracy of the product using different methods. With the overlay method, the photo is binarized with a shade of gray according to the above-calculated mean value of the shades of all methods used, and the smudges removed where the photo processed in this way is overlapped over the reference photo and the dimensional accuracy of the product is determined. In order to solve the problem, it is necessary to position the product in the same position and the same orientation as the product in the reference photo. Therefore, it is necessary to find the center of gravity and the center of the product. The position of the edge pixels of the rotor at the top, bottom, left and right sides was determined by the algorithm of the repeating loop, and thus the center was calculated. In another way, the edge pixels were determined using a software tool that automatically calculates them, as well as a software tool for determining the center of gravity of the rotor. With the rotor, in case the stains are not well removed, the problem arises that the center of gravity of the product and the center of the product are not in the same place. When rotating the photo, it is important that the product is in the center and that the photo has the same width and height. In order to properly prepare the photo, cropping was done according to the required conditions. When rotating a photo, there is a deviation in the number of pixels depending on the angle of rotation. In terms of the number of pixels of the total area, the deviations are not significant, while the problem occurs at the edges of the product where, after rotation, large changes in the arrangement of pixels on the edge can be observed. The analysis of the problem is considered by rotating the photo by half a degree and by one degree. By analyzing and researching the above-mentioned problems, the goal is to find an algorithm that will facilitate the software processing of digital photography to determine the required dimensional accuracy of the product.

4. RESULTS OBTAINED

Photo binarization was performed with 13 different methods within 2 different software packages. Software tools were used to calculate the number of pixels representing the surface of the rotor, as well as the number of pixels in the width and height. The results are shown in Table 1, where it can be seen that the Adaptthresh method has an area of 13625262 pixels which is the most, while the Gatos method has the least (828255 pixels). The width and height of the Adaptthresh, Bernsen and Niblack methods differ greatly compared to the other methods.

Table 1 Features of the rotor after binarization

Binarization methods	**Area (pixels)**	**Width (pixels)**	**Height (pixels)**
Otsu's	2562799	2242	2246
Adaptthresh	13625262	4607	3455
Bernsen	8961137	4607	3455
Niblack	9537052	4607	3455
Sauvola	1113171	2241	2245
Wolf	1318170	2241	2245
Nick	967796	2240	2244
Gatos	828255	2241	2245
Su	1558446	2240	2244
Trsingh	1067834	2241	2244
Bataineh	2660714	2242	2247
Wan	2058419	2243	2246
ISauvola	1108493	2241	2245

The reason for the large deviation in the surfaces is the appearance of smudges, i.e. pixels that are not an integral part of the rotor surface. Table 2 shows for each method the number of pixels removed using the software tool Bwareaopen according to the default settings of the tool. Since it is impossible to remove all smudges with the mentioned tool, pixels that are not part of the rotor surface were removed by the software tools mentioned above. Table 2 shows the total number of removed pixels.

Table 2 The number of pixels of the smudges

Binarization methods	**Bwareaopen default**	**Total number of the smudges**
OTSU's	21136	21136
Adaptthresh	34382	10862125
Bernsen	1538055	6395664
Niblack	556805	6962227

Sauvola	126840	1394263
Wolf	289595	1184584
Nick	108742	1533448
Gatos	28681	1672989
Su	156732	939738
Trsingh	100972	1421742
Bataineh	10090	18281
Wan	111640	772626
ISauvola	122162	1398941

Table 3 shows the pixel counts of the rotor surface for each method after the smudges have been removed. The Wan method has the rotor surface with the most pixels, while the Trsingh method has the smallest surface. Their difference gives a deviation of 341469 pixels. Using the algorithm, the threshold shade of gray color corresponding to the calculated surfaces was calculated, for each method it is shown in Table 3. With the Wan method, the threshold shade is 162 and with Trsingh 57. Table 3 shows the pixel numbers representing the width and height of the processed rotor. With the Adaptthresh, Bernsen and Niblack methods, the width and height decreased significantly after removing the smudges. By calculating the mean value of the number of pixels of the rotor surface of all 13 methods, a surface with a number of pixels of 2572525 pixels is obtained, which corresponds to a shade of gray of 107. Then the photo is binarized according to the calculated mean value of the gray color shade, spots are removed and the width containing 2242 pixels and the height with 2246 pixels are calculated (Table 3).

Table 3 Features of the processed rotor

Binarization methods	**Processed rotor (pixels)**	**Shades of gray**	**Width and height**
OTSU's	2541663	97	2242x2246
Adaptthresh	2763137	143	2243x2247
Bernsen	2565473	105	2242x2246
Niblack	2574825	108	2243x2246
Sauvola	2507434	75	2241x2245
Wolf	2502754	71	2241x2245
Nick	2501244	69	2241x2245
Gatos	2501244	69	2241x2245
Su	2498184	66	2241x2245
Trsingh	2489576	57	2241x2244
Bataineh	2658815	126	2243x2247
Wan	2831045	162	2244x2249
ISauvola	2507434	75	2241x2245
Mean	2572525	107	2242x2246

In order to visually display the pixels that are within the limits of deviation and their position, each shade of gray color smaller than 57 and larger than 162 was converted into white color using the algorithm, while the other shades of gray color remained unchanged (Figure 3).

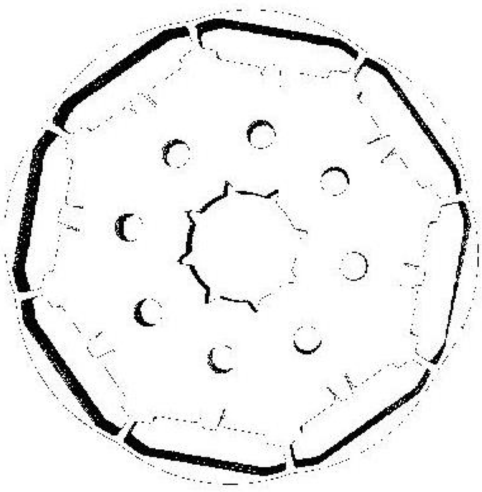

Figure 3 Display of shades of gray from 57 to 162

Another way to visually display pixels within deviation limits is by using the enlarged view of the left edge (Figure 4). The black color represents the surface of the rotor, while the shades of gray are the deviation limits.

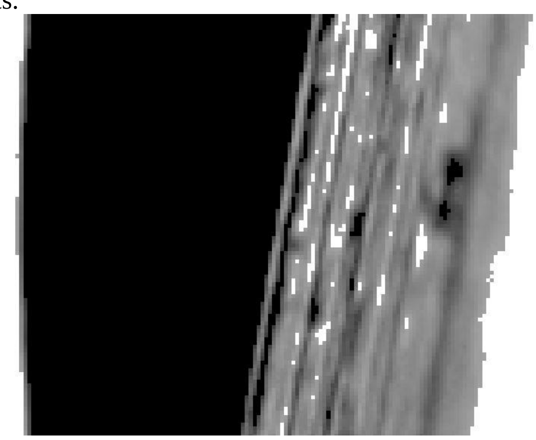

Figure 4 Enlarged view of the rotor with the deviation limits

When rotating a photo display, it is crucial that the rotor is cut so that it is in the center of a digital photo that has the same width and height. Table 4 shows the coordinates of the center of the rotor, on the basis of which the center of the photo is determined and the photo is cropped to dimensions 2261x2261, which is arbitrarily chosen and must be more than the dimensions of the rotor and an odd number. The coordinates of the center of gravity of the rotor are shown in Table 4 and differ slightly from the coordinates of the center of the rotor.

Table 4 Coordinates of the center of gravity and the center of the rotor

	X	**Y**
Center of gravity	2085.4	1796.2
Rotor center	2086.5	1796.5

With rotation, there is a problem where the pixels are not properly distributed along the edge of the rotor. Figure 5a shows an enlarged part of the rotor that has not been rotated, while Figure 5b shows the same enlarged part of the rotor that has been rotated by 22° clockwise.

a **b**

Figure 5 Non-rotated and rotated part of the photo

In order to analyze the problem that arises in digital photos when rotating the photo of the rotor will be rotated 180º clockwise and vice versa. Then the number of pixels in the surface of the rotor and the number of pixels on the outer edge of the rotor are calculated. Figure 6 shows the dependence of degrees of rotation on the number of pixels in the rotor surface, while Figure 7 shows the dependence of degrees of rotation on the number of pixels on the outer edge of the rotor.

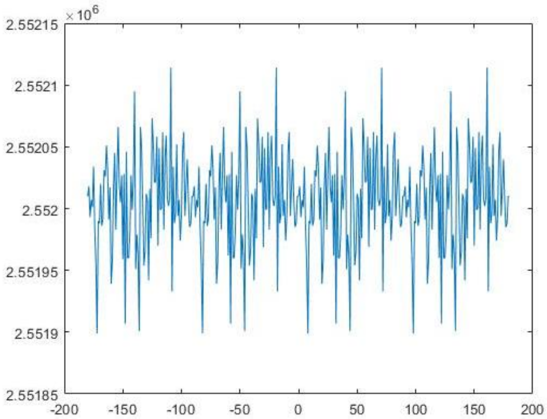

Figure 6 Diagram of the dependence of the number of surface pixels on the angle of rotation

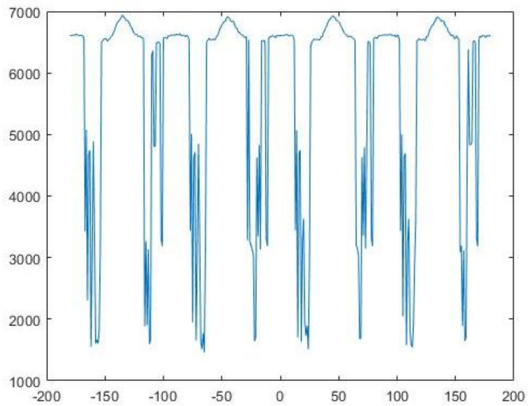

Figure 7 Diagram of the dependence of the number of edge pixels on the angle of rotation

By analyzing Figures 6 and 7, the values of the pixels with the highest value and with the lowest value are determined. The difference between the largest and smallest rotor surface is shown in Table 5, where the first row represents the difference in surface where the angle increased by 0.5 degrees, and the second row is the difference in surface with an increase in angle by 1 degree. The results of the number of edge pixels were analyzed in the same way.

Table 5 Maximum deviations of the number of surface and edge pixels during rotation

	Area difference	**Edge difference**
0.5 degree	234	5600
1 degree	215	5479

5. SUMMARY

The researched problems arising from the software processing of the digital photograph intended to determine the dimensional accuracy of the acquired rotor enabled valuable knowledge that will greatly help scientists in this type of research. When binarizing according to the default settings of the tool, there were large deviations in the results of certain methods, which were obvious errors. Methods such as Adaptthresh, Bernsen, and Niblack led to a large increase in the number of pixels because the selected grayscale threshold included a large number of background pixels in the surface of the object. On the other hand, the Sauvola, Wolf, Nick, Gatos, Su, Trsingh and ISauvola methods apparently excluded a large number of pixels from the rotor surface that belong to it. The main reason for poor results is improperly acquired digital photography because the appearance of shadows or the third dimension causes problems that cannot be completely removed by software. The default settings of certain methods can also be the cause. With the tool used to remove smudges, in addition to the automatic settings, the settings for the number of pixels of the smudges to be removed are also set. With certain binarization methods, the connected area of smudges are so large that in case of their removal, certain rotor surfaces will also be removed, therefore special algorithms were programmed to avoid the mentioned problem and calculate the surface of the rotor without smudges. Whereby a new problem arises in the case of serial production of a large number of samples and/or using different acquisition devices, the processing of the photo would become time-consuming and complicated because the mentioned algorithm would have to be modified and adapted to the observed photo. With certain methods, in addition to the removal of smudges, it was necessary to add pixels that are part of the rotor and were deleted during binarization. Therefore, in Table 2, the last column shows the total number of smudges that were removed by the Bwareaopen tool and the added smudges calculated by the algorithm. As there are large deviations in the number of pixels of the rotor surface of all methods, the mean value of the number of pixels of the rotor surface has the largest diameter of the rotor of 2246 pixels. This for the actual rotor diameter of 34.2mm tolerance limits ± 0.04mm gives a projected pixel size of 15.23 μm which means that the deviation within ± 2 pixels meets the tolerance requirements. Looking at Table 3, it can be concluded that the deviations of the other methods are greater than ±2 pixels, which in this case would not meet the tolerance requirements. As the rotor has the largest dimensions of

2246, the photo is cropped to 2261x2261 so that during rotation the pixels are not lost, which can move and increase in size due to the initial orientation and shape of the rotor. It is also crucial to position the center of the rotor in the center of the photo because with most software tools the rotation of the photo display is performed around the center, otherwise the rotor rotates eccentrically and gives incorrect results when overlapping photos. Which leads to the conclusion that the photo should be cropped to an odd number of pixels in order to be able to determine the central pixel around which the rotation is performed. As the shape of the rotor is symmetrical with slots equally spaced every 45º, it is sufficient to rotate the display only ±22.5º. When rotating the photo display, it can be concluded that the minimal deviations in the number of pixels are on the surface of the rotor. By rotating by ± 180º, the number of pixels on the surface of the rotor is periodically changed every 90º, which is also the case with the number of edge pixels. While rotation greater than ±10º results in large deviations in the number of pixels on the edge of the rotor, which creates major problems when the edge is the variable with which dimensional accuracy is determined.

As in this paper, for consideration of certain problems of software photo processing, a photo acquired using a central projection lens was used and the processing was performed using default (automatic) software settings, therefore, future extended research will use photography acquired with better quality equipment, a camera with a larger-sized and higher-resolution monochrome sensor fixed on a stationary tripod, an orthogonal projection lens with a shorter minimum focus length, and illumination under the sample that has parallel light radiation as well as other recommended features in the paper [12]. The software tools and their different photo processing settings explored in this paper will also be explored. Since the rotor is circularly symmetrical, it is crucial in future research to program a binarization algorithm that will have the condition that the binarized rotor must have its center of gravity and center on the same pixel, as well as the condition that the width and height must have the same number of pixels. On the basis of future research, new valuable knowledge and conclusions would be reached, which will facilitate the software processing of photographs intended for determining the dimensional accuracy of products and would give better results.

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