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The impact of the resolution of the measured object on the assessment of its perimeter

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Abstract
Automatic detection of objects is a part of visual systems supporting a quality control system of a manufacturing process. The paper concerns the influence of the resolution of images and the size of detected objects in pixels on measurements results. Test images of the objects of a known size were generated. The values of the perimeter of the objects were compared to the obtained values of measurements on the images with degraded resolution. The process of the degradation of the references images by successive downsizing the resolution, detection and measurements were performed applying automatic algorithm. The analysis of obtained results showed that the size of the analysed objects on the digital images plays an important role in reliability and accuracy of the measurement. The author concludes that, in order to avoid a bias in measurement caused by insufficient object resolution, the minimal acceptable size of objects on digital images in pixels should be recommended.

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1. Introduction

Digital images analysis is a part of many fields of science and has a wide application in various branches of manufacturing systems. Digital images are a source of information on the stage of designing ~~the~~ materials, where the quantitative analysis of a structure and its components provides information on the influence of a manufacturing process on the materials and their physical and mechanical properties. Appropriate detection of the selected components of the analysed structure is a necessary condition for reliable measurements. Digital image analysis and measurement of the selected objects is also an important part of a complex vision system for quality control. Digital measurements play an important role in the evaluation of a production process as well as in the assessment of the stage of the exploitation of the machine parts (Shirvaikar, 2006; Golnabi, 2007).

The problem of the proper detection is complex and involves numerous factors that have a strong impact on the quality of analysed images, such as the exposition of the objects, adjustment of the acquisition equipment, the parameters of the digitalisation, e.g. image resolution, bit depth, or file format (Gądek-Moszczak et al., 2019).

In the paper, the problem of the influence the size of analysed objects on the value of perimeter is considered. The author is convinced that the perimeter of objects is an appropriate parameter for analysis of the impact the level of image discretisation on the result of the measurements. Accurateness of its assessment depends on the proper detection, resolution of the image and complexity of the shape. An irregularly shaped object is exposed to a deformation in the discretisation process because the curve lines are represented as a combination of square pixels (Russ, 1995; Gonzalez, 2008). Depending on the software for image analysis assessment and applied algorithms for perimeter assessment, even in the high-resolution images, obtained values may differ in comparison to the reference values calculated according to appropriate for geometrical figure formulas.

Perimeter as one of the geometrical parameters is used directly to the quantitative description of objects and indirectly in an indication of the shape coefficient. The analysis of the shape of the objects is employed as one of the object recognition elements and may strongly influence on the final result of system efficiency and accuracy (Russ, de Hooff, 2000, Gądek-Moszczak et al. 2019).

2. Experimental

As the study is connected with the problem of accurateness of objects measurements, three sets of test images represent a different type of shape was generated.

Three types of the shape of objects were considered: a circular one, a rotated square and an irregularly shaped object. The square was rotated in 45° to show how the shape of this elementary geometric shape is degraded by insufficient resolution in the case where the straight line is crossing the image in a different orientation than rows or columns of the image matrix. The size of the generated initial images was 200x200 pixels.

Three sets of the images were generated by a gradual degradation of the resolution of the initial image in Aphelion software (Fig. 1, 2, 3). In order to exclude the influence the result of the detection on the measurement process, all images were binary, which simulated the stage of the processing the images after detection.

Three sets of the test images were analysed in order to assess the area of the objects *A*, maximal diameter *d* and perimeter calculated employing the Crofton method L_C and for comparison, the alternative method, very often applied in the image processing software, called for the needs of this study perimeter *L*.

The indication of the parameter value on the raster images is biased by the method of discretization of the object. This phenomenon is presented in Figure 4. The Presented study indicates the resolution of the objects as another factor that may affect the reliability of obtained perimeter values. Additionally, the applied methods of digital measurement influence obtained results; thus, this aspect was also taken into consideration.

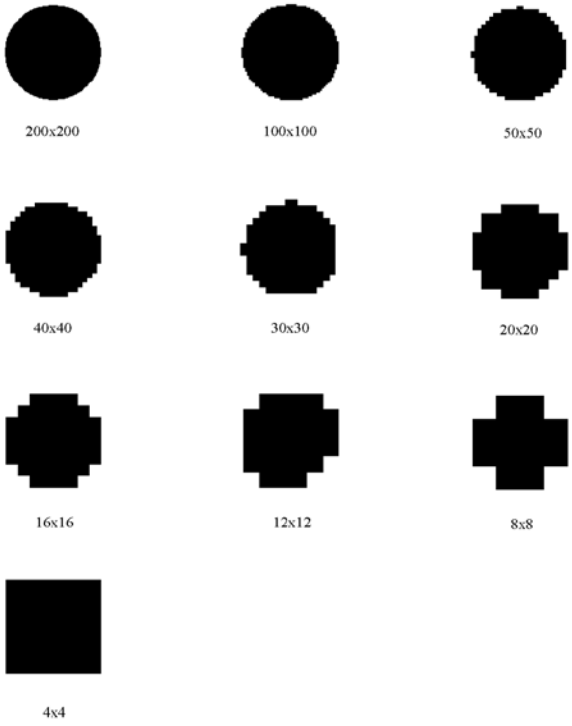

Fig. 1. Series of test images for circle

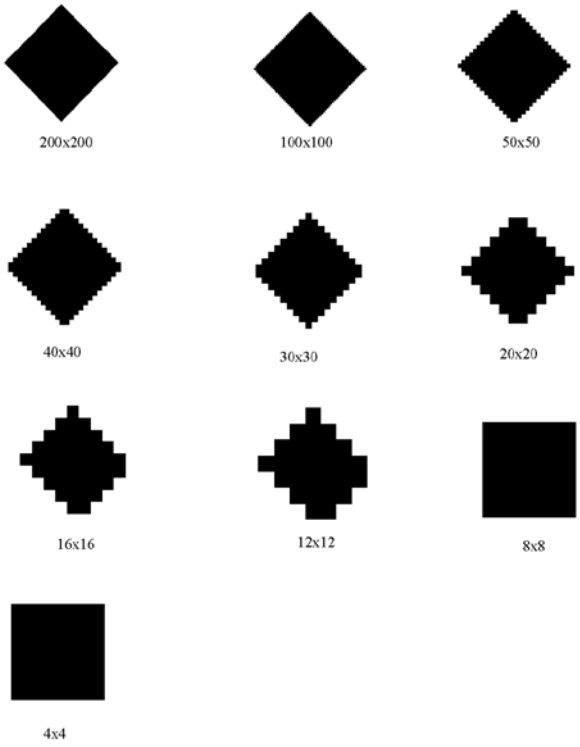

Fig. 2. Series of test images for rotated square (45°)

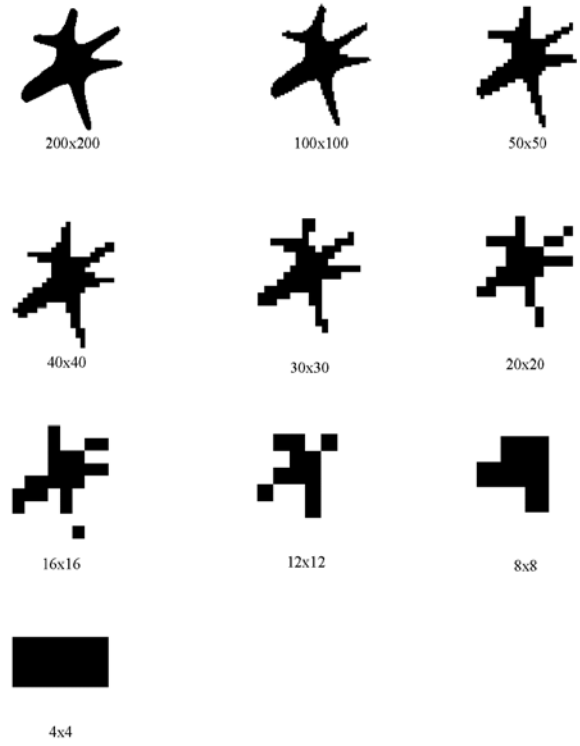

Fig. 3. Series of test images for irregular shape

Basically, two methods of perimeter estimation are known: the Crofton method, and a method based on the so-called 4 connected neighbourhood (Russ, 1995, Gonzales, 2008).

The Crofton method of perimeter measurement is based on determining the pixel of objects hit by secant, projected on the image from different angles. The boundary pixels of the objects that were first hit by the secant in four directions (fig. 5) are counted: parallel to the X-axis (N_0), perpendicular to the X-axis (N_{90}), oriented at 45° (N_{45}) and 135 ° (N_{135}). After inserting the obtained N values for each of the analyzed directions into the formula (1), the value of the perimeter's length is determined (Russ, de Hoff, 2000).

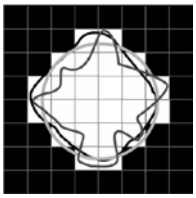

Fig. 4. Three different objects (shown as a continues lines) might be mapped on the discrete, raster image as the same shape (white area on the image)

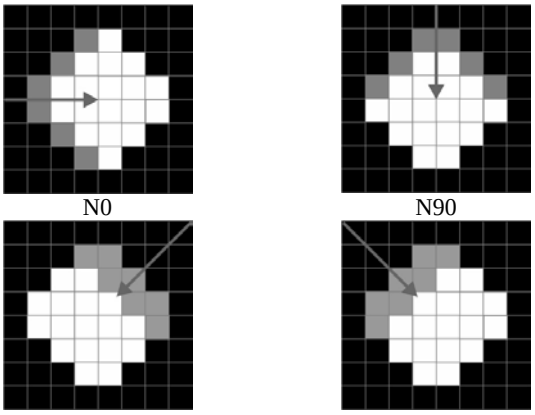

Fig. 5. Crofton's method of the object's perimeter measurement on the raster image

$$L_C = \left[N_0 + N_{90} + \frac{1}{\sqrt{2}}(N_{45} + N_{135})\right] \quad (1)$$

Perimeter L has been measured based on analysis of the neighbourhood of the boundary pixels of an object regarding 4 nearest neighbourhood pixels.

3. Results and discussion

Results of the measurements for three types of model objects with different shape were presented in Figures 4-6. The relationship between the maximum diameter d of the analysed object and the value of the Crofton perimeter L_C was presented. Additionally, the relationship between the Crofton perimeter and perimeter measured directionally by automatic algorithm considering 4 connected neighbourhoods of analysed pixel was investigated. The obtained results for objects on circle type shape were presented in Table 1, for rotated square in Table 2 and for irregular shape in Table 3. The analysis of the results for the circle shown, as it can be observed in Fig. 6 and recorded in Table 1, the decreasing number of pixels mapping the object has no significant effects on the relationship between the reference value of the perimeter and measured ones.

The discrepancy between the reference, calculated by analytic method, addressed for circle value and perimeter L remains the same, reaching over 27%.

For Crofton's perimeter L_C very high compliance with the reference, value is observed. The highest discrepancy of obtained value with calculated one reach 5.76% for the object with 101 pixels diameter. It is an effect of resolution degradation that strongly influence the shape of the object boundary and appeared "stairs effect".

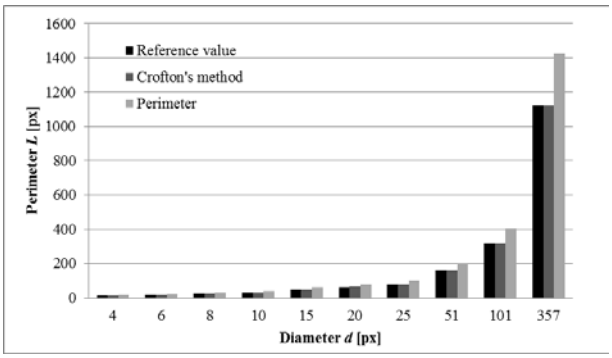

Fig. 6. Comparison of the results of perimeter measurement for circle.

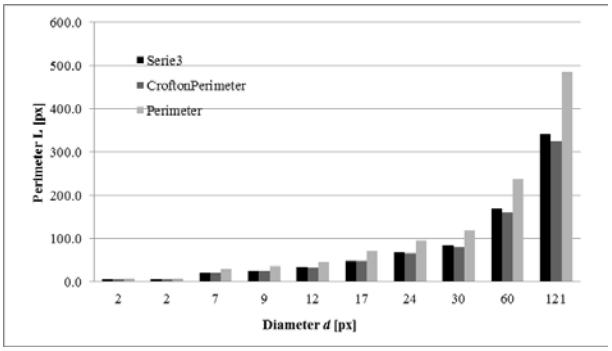

Fig. 7. Comparison of the results of perimeter measurement for rotated square shape

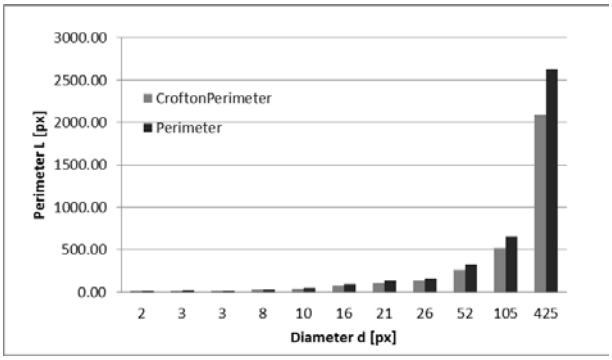

Fig. 8. Comparison of the results of perimeter measurement for irregular shape

Table 1. Comparison of the values of the measured perimeter for an object in the shape of a circle

Circle		The difference between reference values of the perimeter and obtained by digital measurement	
d [px]	*A* [px]	L_C [%]	*L* [%]
357	99999	3.09	27.38
101	7952	5.76	27.38
51	2038	0.14	27.38
25	480	1.34	27.38
20	318	1.32	27.38
15	176	0.45	27.38
10	79	0.43	27.38
8	52	0.45	27.38
6	30	0.31	27.38
4	12	0.11	27.38
2	4	0.01	27.38

Table 2. Comparison of the values of the measured perimeter *L* for the object in the shape of the rotated square

Square		The difference between reference values of the perimeter and obtained by digital measurement L_C and *L*	
d [px]	*A* [px]	L_C [%]	*L*[%]
121	7442	4.64	41.42
60	1800	5.66	41.42
30	450	6.12	41.42
24	312	3.56	41.42
17	162	1.25	35.53
12	72	7.51	45.58
9	45	3.01	41.42
7	28	2.39	39.06
2	4	14.44	40.24
2	4	14.44	42.01

Table 3. Comparison of the value of the measured perimeter for the irregular object

Irregular object		The difference between the obtained value of the perimeter L_C and *L*	
d [px]	*A* [px]	[%]	[px]
425	65180	26.06	543.68
105	4016	26.43	136.71
52	918	27.03	69.80
26	236	25.73	32.75
21	160	26.98	27.20
16	87	27.21	20.54
10	31	27.55	9.51
8	21	30.14	7.87
3	9	31.07	4.27
3	6	31.07	2.84
2	2	31.07	1.42

Degradation of the resolution for the object with the rotated rectangle shape caused revealed that diversity between the reference value of the perimeter and Crofton perimeter L_C increased for objects mapped by less than 28 pixels (fig. 7). The difference between the reference value and the perimeter *L* placed between the 35.53 and 45.58% (Table 2).

Due to irregularity of the last analysed object, the measured values of Crofton perimeter L_C and perimeter *L* were compared only with each other.

Results of the Crofton perimeter LC for a circle and square in general shown high convergence with the references values; therefore, for irregular object the divergences between the LC and L were analysed (Fig. 6, Table 3). The fluctuation between LC and L values were placed between the 25.73 and 31.07 %.

4. Summary and conclusion

The presented experiment aimed to show how the resolution of the image and the method of perimeter assessment strongly affects the result of digital measurement. The type of analysed shape has an influence on the result of resolution degradation and consequently on the result of the quantitative analysis. Based on obtained results the author concludes that analysis of digital images were the object is mapped by less than 100 pixels – for circular type of shape, and less than 30 pixels for rectangular type of shape is burdened with a measurement error ranging up to 14% for Crofton perimeter L_C, and up to 45% for perimeter *L*.

This study showed that the perimeter *L*, that is widely applied in image analysis software is biased and should be replaced by Crofton perimeter L_C.

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被测物体的分辨率对其周边评估的影响

關鍵詞
数字测量
解析度
图像处理
立体学

摘要
对象的自动检测是支持制造过程的质量控制系统的视觉系统的一部分。本文关注图像分辨率和像素中检测到的物体尺寸对测量结果的影响。生成了已知大小的物体的测试图像。将对象的周长值与分辨率降低的图像上获得的测量值进行比较。通过自动缩小分辨率，检测和测量来连续缩小参考图像的过程。对获得的结果的分析表明，数字图像上被分析对象的大小在测量的可靠性和准确性中起着重要作用。作者得出结论，为了避免由于对象分辨率不足而导致的测量偏差，应该建议以像素为单位的数字图像上最小可接受的对象尺寸。