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MACHINE WHELL EDGE DETECTION MORPHOLOGICAL OPERATIONS

Pınar KARAKUŞ

Osmaniye Korkut Ata University, Engineering and Natural Sciences Faculty, Geomatic Engineering, Osmaniye, TÜRKİYE
pinarkarakus@osmaniye.edu.tr

Highlights

- Canny and Sobel edge detection algorithms were applied to determine the edges of different milling cutters used in machinability.
- According to MSE and PSNR results, the Canny algorithm gave better results than the Sobel algorithm.
- it was concluded that the images obtained from the applied morphological operations provided better performance than those not applied for both Canny and Sobel algorithms.

***Corresponding Author:** Pınar KARAKUŞ, pinarkarakus@osmaniye.edu.tr

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ABSTRACT: One of the critical issues of image processing, defined as obtaining useful information from the image and improving the quality of the image, is edge detection. How edge detection performance will be affected by adding morphological operators to edge detection algorithms is among the issues that have not been fully resolved. In the study, Canny and Sobel edge detection algorithms were applied to different milling cutters used in machinability. Morphological operators were applied to the determined edges, and their effects on the edges were examined. Mean Square Error (MSE) and Peak Signal Noise Ratio (PSNR) values were used to compare the performances of edge detection algorithms. According to MSE and PSNR results, it was seen that the Canny algorithm gave better results than the Sobel algorithm. In addition, it was concluded that the images obtained as a result of the applied morphological operations provided better performance than the images that were not applied for both Canny and Sobel algorithms.

Keywords: *Canny, Edge detection, Sobel, Morphological operations*

1. INTRODUCTION

The process of enhancing image quality and/or obtaining valuable information from an image is known as image processing. Image processing consists of three stages: pre-processing, enhancement, and information extraction [1]. Edge detection algorithms applied in extracting information from the stages used are one of the critical issues of digital image processing. Edge detection is defined as determining sharp discontinuities in an image and includes image segmentation, registration, feature recognition, and extraction operations. The edge, which has many definitions, is generally discontinuities that indicate sudden changes in pixel densities that characterize the boundaries between objects in a scene and/or between an object and its background [2]. In other words, it is a feature of the high-density pixel and the close neighborhood in the images. In this way, the object's shape in the image is formed by the edges, and the edge is used in image analysis to determine the region boundaries. In these analyses, the image's brightness is the main feature of calculating its edges [3]. The edge detection algorithms consist of a series of steps to obtain a digital image, calculate its density, and emphasize the boundaries of the zones [4]. In addition, many edge detection algorithms are used, such as Canny, Log, Zero Cross, Sobel, Roberts, and Prewitt [5-8]. One of these algorithms, the Canny algorithm, is ideal for determining complex shapes by accurately determining the edges of the object to be processed [9]. Therefore, the Canny algorithm has been used in applications in the field of medicine [10] and in applications in the field of aviation was used [11]. The Canny algorithm has the advantage of faster edge detection than operators such as Sobel, Prewitt, and Roberts [12].

Determining the edge detection performance by adding morphological operators to edge detection algorithms is among the issues still not fully clarified. In a study, they examined edge detection using mathematical morphological operators. They used erosion and dilation processes simultaneously. Their algorithm was applied to the grayscale image but could not obtain accurate results [13].

The study examined the effects of the operations performed to detect and improve the edge information in the image to understand the image and its information. For this purpose, images of different milling cutters used in machinability were converted to black and white and then median filtered. The edges were determined by applying Canny and Sobel edge detection algorithms to the

***Corresponding Author:** Pınar KARAKUŞ, pinarkarakus@osmaniye.edu.tr

median filtered images. The effects on the edges were examined by adding morphological operators, and images were obtained. Afterward, to numerically express which image achieved the best result from the images obtained, Mean Square Error (MSE) and Peak Signal Noise Ratio (PSNR) values were calculated, and the edge detection performances of the edge detection algorithms and applied processes were evaluated.

2. MATERIAL AND METHODS

2.1. Material

In the study, milling cutters with different sizes, given in Figure 1, were used. To avoid confusion, the milling cutters are named as shown in Figure 1. Images of milling cutters were obtained with a Nikon digital DSLR digital camera with 300 dpi, 500 ISO, and 32mm focal length [14]. While the images were being obtained, only the milling cutters were focused on, and the background was blurred.

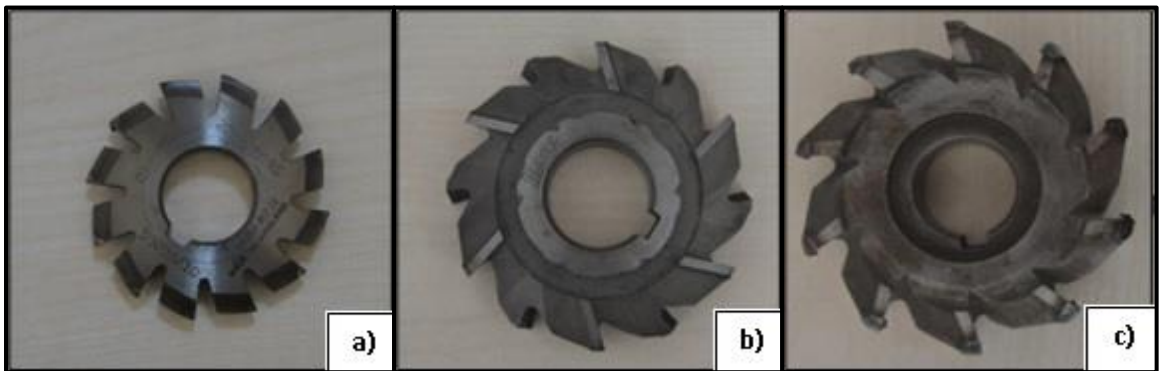


Figure 1. The milling cutters used in the examinations are a) milling cutters No. 1, b) milling cutters No. 2, and c) milling cutters No. 3

2.2. Methodology

2.2.1. Pre-processing

Pre-processing was the first stage in obtaining edges from the images obtained from milling cutters. At the pre-processing stages, the images obtained in RGB were first converted to black and white. In edge detection, the density of grayscale images is sufficient for the operation. Grayscale is called the value that represents the intensity of each pixel. The conversion from RGB to black and white image is given in Equality (1) [15].

$$Gray = Rx0.299 + Gx0.587 + Bx0.114 \quad (1)$$

As the second stage in image preprocessing, the Median filtering process, which is used to improve the quality of the image and eliminate the noise present in the image, was performed. With this process, the element in the middle of the list formed by sorting the grayscale values of the pixels in the neighborhood of a pixel from small to large and called the median is taken as the output value [16]. The most important feature of the median filter is that it protects the edges while eliminating noise. The process makes the image smoother, intensifying its pixels, mainly the background pixels close to each other [17].

2.2.2. Edge detection

2.2.2.1. Canny algorithm

First, The Canny algorithm eliminates noise by softening the black and white image. The results of the Canny algorithm vary depending on the specified threshold values. Appropriate threshold values should be determined depending on the study performed. The Canny edge detection algorithm has five stages, as indicated below [18-19];

- Using a Gaussian filter to improve the quality of the image by smoothing the image
- To find the gradients with the maximum response, use an edge detector.
- Suppressing non-maximal ones to mark locally maximum-valued edges by thinning the edges found in the previous step.
- Applying the double thresholding technique for more accurate determination of actual edges.
- The pixel merging process was used to determine the final edges by removing the weak edge pixels in the last step.

The Canny edge detection algorithm is based on some criteria. The first and most obvious is the low error rate. It is essential that the edges found in the images are not overlooked and those not edges are eliminated. Another criterion is that the edge points are well localized. For this process, the distance between the edge pixels found by the detector and the real edge pixels must be minimum [20].

2.2.2.2. Sobel algorithm

The Sobel operator is based on convolving the image in horizontal and vertical directions, as seen in Figure 2. a), b), and c) with a small, separable, and integer-valued filter. For this reason, there is also an ease of calculation [21]. One could think of this as an approximation of the first Gaussian derivative. This is the same as the first derivative of the Gaussian blurred image produced when applied with a 3x3 mask.

P_1	P_4	P_7
P_2	P_5	P_8
P_3	P_6	P_9

a)

-1	0	1
-2	0	2
-1	0	1

b)

-1	-2	-1
0	0	0
1	2	1

c)

Figure 2. a) Pixel matrix representation of the Sobel operator. b) A convolution matrix of 3*3 dimensions in the X-direction. c) A convolution matrix of 3*3 dimensions in the Y-direction.

The first derivative of the density in the horizontal and vertical directions is,

$$G_x = \frac{\partial f(x,y)}{\partial x} = P_9 + 2P_8 + P_7 - P_1 - 2P_2 - P_3 \quad (2)$$

$$G_y = \frac{\partial f(x,y)}{\partial y} = P_9 + 2P_6 + P_3 - P_1 - 2P_4 - P_7 \quad (3)$$

(2) and (3) are shown in the equation. The gradient size is;

$$G = \sqrt{G_x^2 + G_y^2} \quad (4)$$

It is calculated by.

2.2.3. Morphological operations

2.2.3.1. Dilation and erosion

The basic mathematical morphological operators are dilation and erosion. Other morphological processes are the synthesis of these two essential processes. Specifically, morphological processes enable the identification of geographical details and the determination of the boundaries of objects. Looking at the mathematical structure of morphological operations [20],

Let $f(x,y)$show the configuration element C of a black-and-white two-dimensional image. Dilation of a black-and-white image $F(x,y)$ by a black-and-white configuration element $C(s,t)$

$$(F\oplus C)(x,y) = max\{F(x-s,y-t) + C(s,t)\} \quad (5)$$

It is indicated by.

Erosion of a black-and-white image $F(x,y)$ by a black-and-white configuration element $C(s,t)$

$$(F\Theta C)(x,y) = \min\{F(x+s,y+t) - C(s,t)\} \quad (6)$$

It is indicated by.

The opening and closing of the grayscale image F(x,y) by the grayscale configuration element C(s,t) are indicated by the equations (7) and (8), respectively.

$$F \circ C = (F\Theta C)\oplus C \quad (7)$$
$$F \cdot C = (F\oplus C)\Theta C \quad (8)$$

Erosion is a reduction transformation that reduces the grayscale value of the image, while dilation is an expansion transformation that increases the grayscale value of the image. Both of them are sensitive to image edges whose grayscale value changes. Erosion filters the inner image, while expansion filters the outer image [22]. To achieve better morphological results, the dilation process is followed by the erosion process, which fills the gaps inside the objects whose edges are to be determined without any change in size and combines the isolated ones to form smooth boundaries [23]. Opening can be defined as first narrowing and then expanding; it eliminates noise and disconnected sections on the image. The closing process applied later can be defined as first expanding and then contracting; it is a morphological process that combines the remaining large parts and allows the disconnections to be combined [24,25].

3. RESULTS AND DISCUSSION

As a result of the image processing stages performed on the images of milling wheels given in Figure 1, the edges were tried to be determined. In the preliminary procedures carried out as the first stage of the investigations, RGB images were converted into black and white images (Figure 3). After that, a median filter was passed through the images converted to black and white to eliminate the salt and pepper noise effect and improve the image quality. It is stated in the studies that the median filter process does not cause any damage to the edges while eliminating noise [24,26,27]. In addition, the median filter is a linear filtering method that is more successful than linear filtering [28,29].

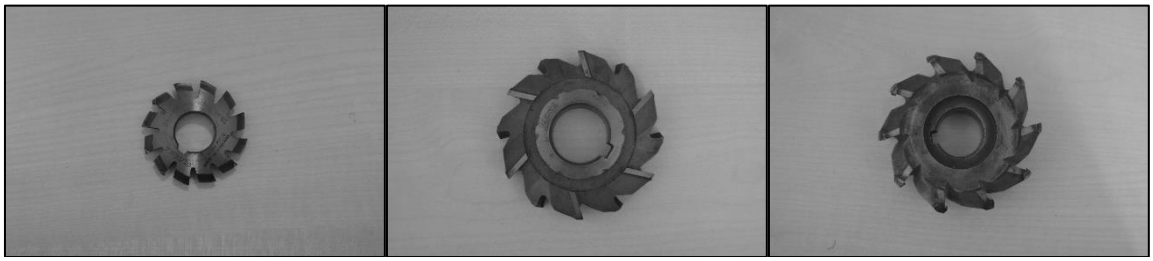


Figure 3. Black and white images

After the preprocessing operations were performed to obtain better results in edge detection operations, Canny and Sobel edge detection techniques were applied to the images, and an attempt was made to determine the edges. During these processes, Canny and Sobel detection techniques and more accurate determination of the edges [30-32] and the effect of providing threshold values were also examined. Due to the nature of the algorithms used [30,31], two threshold values, Low and High, in the interval 0<Low<High<1 for Canny [33,34] and the single threshold value for Sobel [35] has been applied. After all the different threshold values were applied, the morphological operator determined the edges. As a result of these operations, the effects of different threshold values and the processing ends of edge detection algorithms on edge detection have been observed. In the operations performed with the Canny algorithm, first of all, the Low value was selected as 0.075 to determine the High value that would give the best result and different High values. Then morphological operators were applied to this value. When the obtained images were examined, it was observed that a clear edge did not form on the three pocket knives until the 0.475 High value for the 0.075 low value, and the edges became more apparent with the decreasing High value. However, it has been determined that the edges deteriorate after a certain reduction value from the High value for each milling cutter, and different High values for each milling cutter give good results. After that, different Low values were selected according to the determined High value, and the most appropriate Low value was determined. The images obtained from these operations and the morphological operators applied are given in Tables 1 and 2. When the images were examined, it was determined that different threshold values gave better results for each milling cutter. The threshold values that provide the best results in the Canny algorithm and behind the applied morphological operations are from milling cutter No. 1 to milling cutter No. 3, respectively. [0.045,0.095], [0.065,0.105], [0.045,0.085] The conclusion has been reached that it is.

Table 1. The results for different High values of 0.075 and Low value selected in determining the edges of different milling cutters with the Canny algorithm

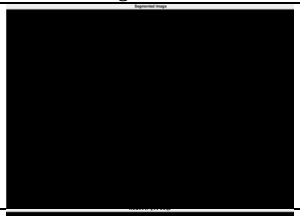
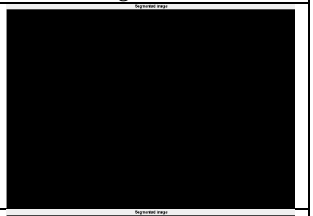
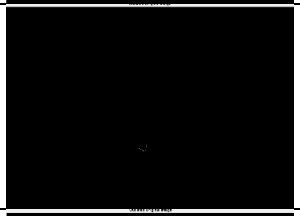
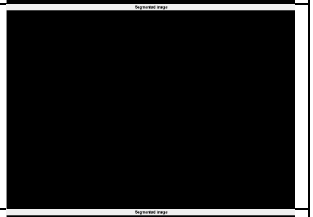
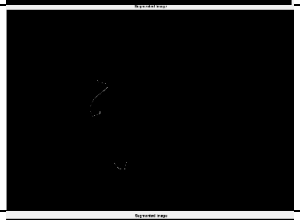
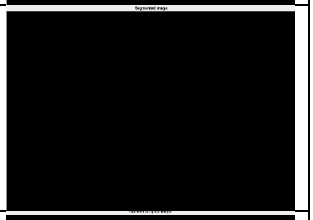
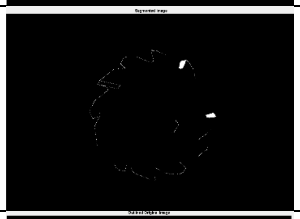
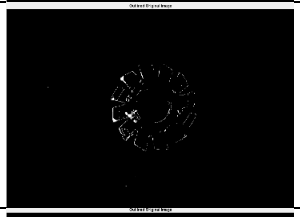
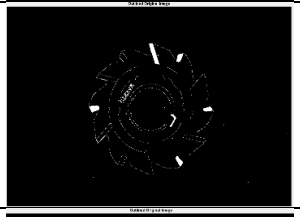
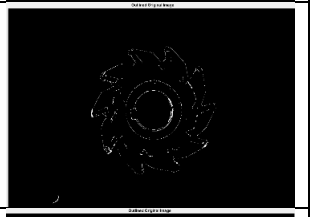
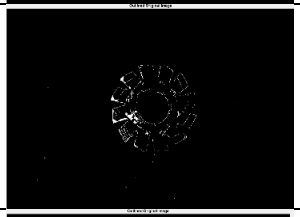
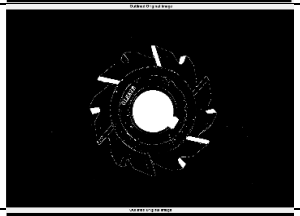
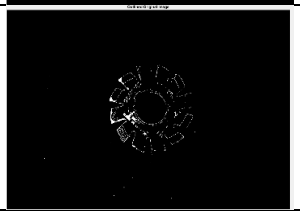
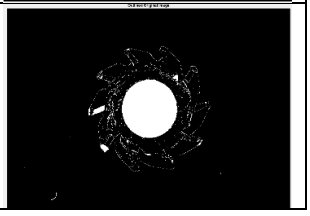
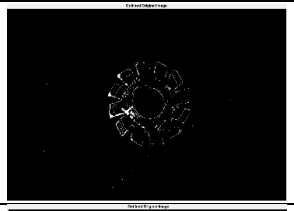
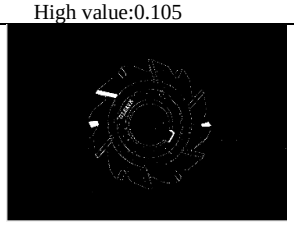
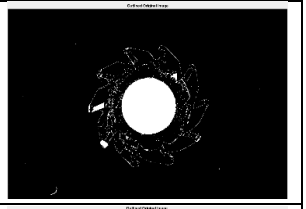
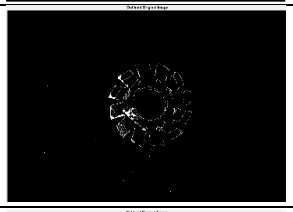
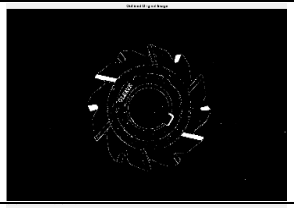
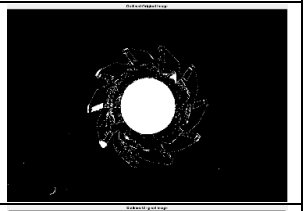
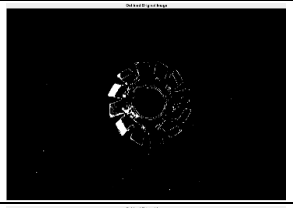
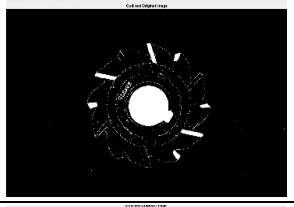
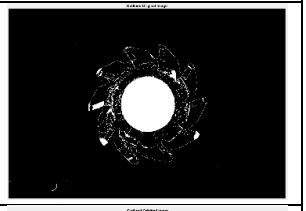
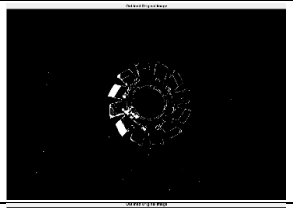
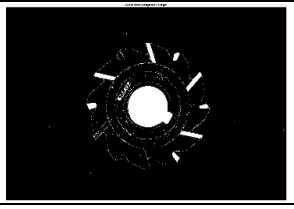
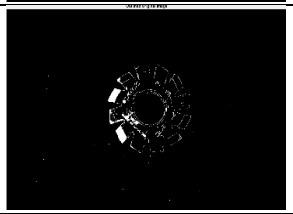
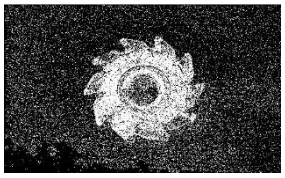
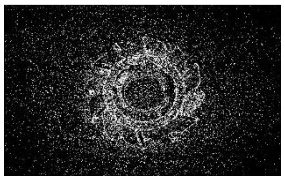
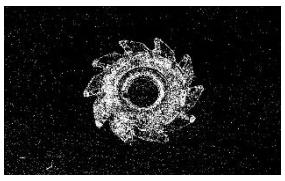
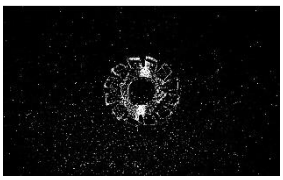
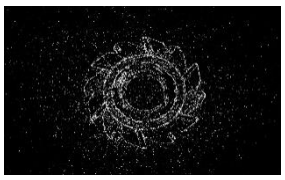
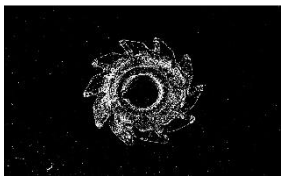
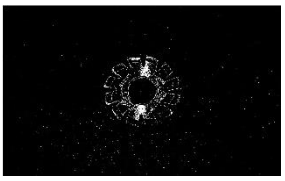
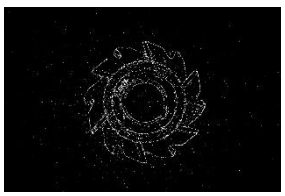
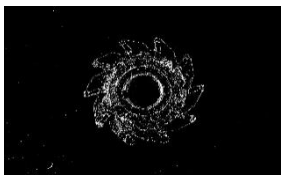
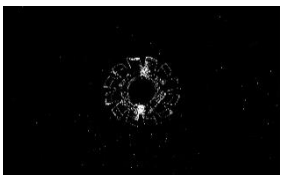
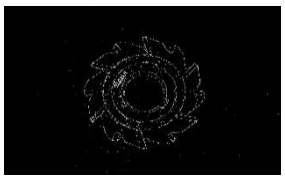
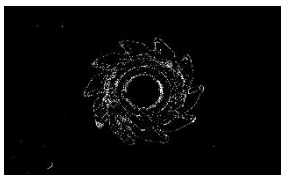
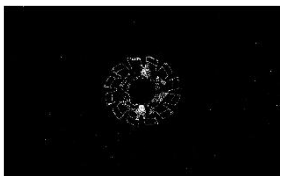
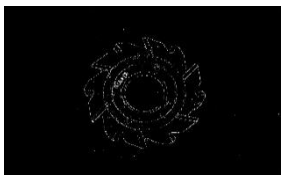
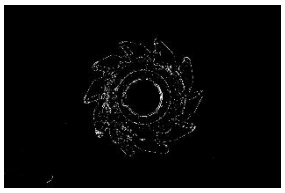
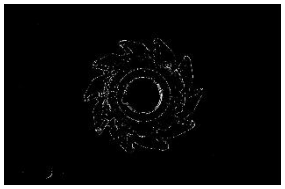
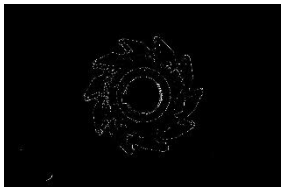
Canny			
Low value: 0.075			
High values	Milling cutter No.1	Milling cutter No.2	Milling cutter No.3
0.975			
0.875			
0.575			
0.475			
0.175			
0.105			
0.095			
0.085			

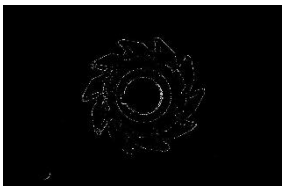
Table 2. The results obtained for different Low values at the High value determined by the Canny algorithm of different milling cutters

Canny					
Milling cutter No.1		Milling cutter No.2		Milling cutter No.3	
High value:0.095		High value:0.105		High value:0.085	
0.085		0.095		0.075	
0.075		0.085		0.065	
0.065		0.075		0.055	
0.055		0.065		0.045	
0.045					

After the edges are determined as a result of the Canny algorithm and threshold values applied in the study, a single threshold value is used in the Sobel operator, and the other edge determination algorithm is applied after the edges are determined as a result of threshold values applied [36]. Different values have been applied for the Sobel operator by starting from the threshold values of [0.5] and increasing them at certain rates. The threshold values applied and the images obtained as a result of the morphological operations applied after are given in Table 3. When the obtained images were examined, it was determined that the optimal threshold value for the images belonging to each milling cutter was [1.75]. However, after that, it was tested on the images of milling cutter No. 3 to examine how increasing the threshold value by a little more would affect determining the edges. When the images were examined, it was observed that the edges began to deteriorate when the threshold value rose above the value of [1.75]. Compared to the Sobel algorithm, it can be seen that the Canny operator can provide clear edges and that there are more object details in the images [37,22,38]. [22] showed that the Canny algorithm can determine smoother and thinner edges than Sobel. [39] in their studies, they stated that the Canny edge detection method is better in terms of performance than other edge detection methods, but it contains complex processing steps.

Table 3. The results obtained in the Sobel algorithm for different Threshold values of different milling cutters

Sobel			
Threshold values	Milling cutter No.1	Milling cutter No.2	Milling cutter No.3
0.50			
0.75			
1.00			
1.25			
1.50			
1.75			
2.0			
2.25			

2.50			

In the threshold values determined in the study, the edge detection algorithms and the morphological processing applied to MSE and PSNR regression models were used to compare the image edge detection quality of the images obtained. In these models, MSE refers to the average value of the sum of squares of the difference between the processed and original image pixels. The magnitude of the MSE represents the difference between the original grayscale image and the processed grayscale image. The higher value of MSE means better edge detection results [3,7]. The term PSNR refers to the maximum possible error of an image. In addition, it is seen that the smaller the obtained PSNR value, the better the edge detection operator is [3,7].

The study calculated MSE and PSNR for images obtained from Canny and Sobel algorithms at the threshold values that give the best image, both with and without morphological operators applied. For this purpose, the effect of both the Canny and Sobel algorithms and the morphological operator have been observed. Accordingly, the MSE and PSNR equations used are given in Equation (9) and Equation (10). MSE and PSNR results obtained from the equations used are given in Table 4 and Table 5.

MSE [40]

$$MSE = \frac{1}{M*N}\sum_{i=1}^{M}(f'(i,j) - f(i,j))^2 \quad (9)$$

Here, $f'(i,j)$ and $f(i,j)$ are the image to be evaluated and the original grayscale image, respectively. "M" and "N" represent the length and width of the image, respectively. The symbol "$\sum$" means addition.

PSNR [41];

$$PSNR = 10\,log_{10}\frac{255^2}{MSE} \quad (10)$$

Here, 255 is the maximum pixel value of the image, and MSE is the mean square error.

Table 4. Without morphological processing

Sobel			Canny		
	MSE	PSNR		MSE	PSNR
Milling cutter No.3	19791.28	5.17	Milling cutter No.3	19852.47	5.15
Milling cutter No.2	19592.35	5.21	Milling cutter No.2	19611.89	5.21
Milling cutter No.1	18699.80	5.41	Milling cutter No.1	18728.23	5.41

Table 5. Morphologically processed version

Sobel			Canny		
	MSE	PSNR		MSE	PSNR
Milling cutter No.3	19997.8688	5.12	Milling cutter No.3	20117.2846	5.10
Milling cutter No.2	19734.6844	5.18	Milling cutter No.2	19750.0511	5.18
Milling cutter No.1	18818.3281	5.38	Milling cutter No.1	18873.8014	5.37

When the results given in Tables 4 and 5 are examined, the effect of applying morphological processing on edge detection was observed in both Canny and Sobel algorithms. In both methods, the results with and without morphological processing were examined. It was observed that the MSE value

obtained after the morphological process was applied was higher, and the PSNR value was lower. It was determined that the morphological process gave better results in edge detection [3,7]. In addition, when the results were examined in terms of the algorithms used, it was observed that they gave almost similar results in terms of PSNR values, regardless of the morphological operations. Still, the Canny algorithm was lower in some cases. It was determined that the MSE values obtained for the Canny algorithm were more significant than those obtained for the Sobel algorithm, regardless of the morphological operations. These results show that the Canny algorithm is better than the Sobel algorithm in edge detection [3,7]. Many studies have similarly observed that the Canny algorithm gives better results in edge detection than the Sobel algorithm [37,22, 38,39].

4. CONCLUSIONS

The study examined the effects of the commonly used Canny and Sobel edge detection algorithms on image performance and the morphological operations applied to these methods. Images belonging to three different milling cutters were used in the investigations. The determination of the edges and the MSE and PSNR calculations were performed in the Matlab program. According to the MSE and PSNR results obtained, it has been determined that the Canny algorithm gives more results than the Sobel algorithm. In addition, it has been concluded that the images obtained from the applied morphological operations in both Canny and Sobel algorithms provide better performance than the unapplied images.

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