Research Article

The Segmentation of Neutron Digital Radiography Image through the Edge Detection Method

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Abstract

The digital image processing is one way to manipulate one or more digital images. Image segmentation has an essential role in the field of image analysis. The aim of this study was to develop an application to perform digital image processing of neutron digital radiographic images, hoping to improve the image quality of the digital images produced. The quality of edge detection could be used for the introduction of neutron digital radiographic image patterns through artificial intelligence. Interaction of neutrons with the matter mainly by nuclear reaction, elastic, and inelastic scattering. A neutron can quickly enter into a nucleus of an atom and cause a reaction. It is because a neutron has no charge. Neutrons can be used for digital imaging due to high-resolution information from deep layers of the material. The attenuated neutron beam in neutron radiography are passing through the investigated object. The object in a uniform neutron beam is irradiated to obtain an image neutron. The technique used in segmenting the neutron radiography in this study was a digital technique using a camera with a charge-coupled device (CCD), which was deemed more efficient technique compared to the conventional one. Through this technique, images could be displayed directly on the monitor without going through the film washing process. Edge detection methods were implemented in the algorithm program. It was the first step to complement the image information where edges characterize object boundaries. It is useful for the process of segmenting and identifying objects in neutron digital radiography images. The edge detection methods used in this study were Sobel, Prewitt, Canny, and Laplacian of Gaussian. According to the results of the image that have been tested for edge detection, the best image was carried out by the Canny operator because the method is more explicit. The obtained edges were more connected than the other methods which are still broken. The Canny technique provided edge gradient orientation which resulted in a proper localization.
Keywords: *neutron radiography; digital image; edge detection*

Pola Citra Radiografi Digital Neutron Melalui Metode Deteksi Tepi

Abstrak

Memanipulasi satu atau beberapa citra dapat melalui pengolahan citra digital. Segmentasi citra yang merupakan proses pengolahan citra digital, memiliki peranan yang penting dalam analisis citra. Penelitian ini bertujuan untuk mengembangkan aplikasi pengolahan citra digital dari citra radiografi

digital neutron yang dapat meningkatkan kualitas citra yang dihasilkan. Kualitas deteksi tepi dapat digunakan untuk pengenalan pola citra radiografi digital neutron melalui aplikasi kecerdasan buatan. Interaksi neutron dapat dimanfaatkan untuk pencitraan karena memiliki informasi resolusi tinggi pada lapisan material yang dalam. Berkas neutron yang teratenuasi pada radiografi neutron melewati objek yang diteliti. Objek dalam berkas neutron diiradiasi untuk mendapatkan citra. Teknik yang digunakan dalam radiografi neutron pada penelitian ini adalah teknik digital yang merupakan cara yang lebih efisien jika dibandingkan dengan teknik konvensional. Teknik digital menggunakan kamera Charge Coupled Device (CCD) sebagai pengganti film. Melalui teknik ini, citra dapat ditampilkan langsung pada monitor tanpa melalui proses pencucian film. Pengolahan citra radiografi digital neutron menggunakan perancangan algoritma yang dibuat secara sistematis, terstruktur, dan rapi sehingga hasil program dapat diupayakan berjalan sesuai dengan apa yang diharapkan. Metode deteksi tepi yang digunakan pada penelitian ini adalah Sobel, Prewitt, Canny, dan Laplacian of Gaussian. Hasil citra terbaik yang dianalisis melalui deteksi tepi citra menggunakan operator Canny. Tepi citra yang dihasilkan melalui operator Canny saling terhubung lebih jelas, sedangkan operator lainnya masih terputus-putus.

Kata Kunci: : *radiografi neutron; citra digital; deteksi tepi*

I. INTRODUCTION

X-rays and Gamma rays are a beam of radiation created by the interaction of matter at the atomic level with the electron shell. They are mainly by three necessary processes: photoelectric effect, Compton scattering, and pair production. They intensively occur in the region of high electron-density because these are chiefly based on the interactions between photons and electrons [1]. Interaction of neutrons with the matter mainly by nuclear reaction, elastic, and inelastic scattering. A neutron can quickly enter into a nucleus of an atom and cause a reaction. It because a neutron has no charge. Incoherent scattering causes fast neutrons to interact. The probability decreases with the increasing atomic number [2].

During the radiation interaction either photoelectric effect or Compton, some of the photons interact with the matter and some pass on the through called attenuation. While x-ray attenuation depends on atomic number, neutron attenuated by only a few specific elements due to absorption and scattering [3]. X-ray and Neutron radiography, both are non-destructive and non-invasive methods given insight into the function of devices and their decay processes [4].

Neutrons have high-resolution information from deep layers of the material which can be used for imaging [5]. The 25 MeV thermal neutron has zero charges. Therefore the penetration depth in most metals is higher compared to 120 keV x-rays [6].

Through LI Hang's research, several hundred keV fast neutrons can penetrate some thermal neutron absorbers such as Cd. It was also feasible to investigate its use on some materials which are transparent to cold/thermal neutrons, such as Al [7]. Odin

proposed that the high sensitivity of neutrons to hydrogen content was possible to track water diffusion through 3 mm thick samples without any special preparation in a relevant time range [8].

The attenuated neutron beam in neutron radiography are passing through the investigated object. The object in a uniform neutron beam is irradiated to obtain an image neutron. Prokhorets obtained the neutron-radiography images using the transmission method. It shown the possibility of using the fast neutron for neutron-radiography imaging [9].

There are a number of method of neutron images producing including foils and x-ray film [10], computed radiography using image storage plates, real time scintillating screens with a CCD camera [11], neutron sensitive multi-channel plates [12], and other techniques.

The solution has been used for image recording through neutron scintillators coupled to Charge-Coupled Devices (CCD) video cameras and neutron imaging plates. The camera focused via a mirror on a scintillator screen [13]. A scintillator screen is used for converting the neutrons into optical light, while a mirror as additional components is used to prevent radiation damage of the camera [14].

Manipulation of one or more digital images can be involved by digital image processing. Digital image processing is the use of a computer algorithm to perform image processing on digital images [15]. Image segmentation has an essential role in the image analysis. It is used in pattern recognition and object detection, including the edge detection [16]. The image defined into meaningful parts or region by dividing spatial domain [15]. Edges is an image point where the gradient of image intensity function reaches its maximum local value [16].

Tremsin et al. [17], found that the artefacts of neutron radiography images should be treated properly. In addition, one should not confuse it for the real features of more complicated objects. It may not be easy to distinguish the edge effects from the various of attenuation coefficient in the sample. The application of micropore collimators can be a complimentary method in elimination of bright edges.

Hippmann proposed best suitable procedure for edge and line detection on large and small scales by using Qualitative Phase Contrast (QPC) imaging. It assesses low or nearly the same attenuation coefficient objects or composites resulting in a low absorption contrast. QPC imaging thus provides additional information such as enhanced contrast at edges and interfaces [18].

Some of the edges involve a step modification in intensity. Refraction or poor focus effect could lead to objects with boundaries by a gradual modification in intensity [19]. Edge detection has been developed for extracting edges from digital images by using techniques such as Roberts, Sobel, Prewitt, Kirsh, Robinson, Marr-Hildreth, LoG, and Canny edge detection [20].

Abubakar presented the study of Sobel, Canny, Robert, Prewitt, LoG (Laplacian of Gaussian) edge detection techniques for image segmentation. The experimental results obtained using the MATLAB version 7.12.0.635 (R2011a) software discussed highlight the performance of each method [21]. On another study, Krishnan et.al compared and analysed the performance of diverse edge detection techniques for recent digital image processing like Canny, Sobel, Prewitt, and LoG operator. The findings is that Canny provides better performance results under noise or complex images compared to other techniques [22]. In addition, the use of Canny technique could

also exploit the information detection of brain tumour source through Magnetic Resonance Image (MRI) by Parthasarathy. It well defined tumour detection [23]. To add, Andrushia proposed various edge detection algorithms for concrete crack detection. They are Prewitt, Sobel, Gaussian, Roberts, Canny, and Laplacian. The edge detection methods produced reasonably good outputs [24].

The studies done by Abubakar, Krishnan, and Andrushia [21,22,24] are simple and use easy method that might possible to be used to enhance contrast at neutron digital radiography edges. So, it can be implemented to Tremsin and Hippmann's [17,18]. The present study, however, will use Canny, Sobel, Prewitt, Roberts, and LoG operator to extract the edges of neutron digital radiography images.

In this study, a significant improvement will be covered. The edge detection methods were applied to neutron digital radiography image due to low edge contrast as the problem of neutron radiography. The aim of this paper is to develop an application to perform digital image processing of neutron digital radiographic images, hoping to improve the image quality of the digital images produced. The quality of edge detection can be used for the introduction of neutron digital radiographic image patterns through artificial intelligence.

II. METHOD

The image used in this study was obtained by neutron digital radiography taken in BATAN Yogyakarta. The image is in grayscale bmp file format, because the inherent complexity of grayscale image is lower than colored image.

In this study, the detection of the shape of material is done by using optimized edge detection. It could not bother the color of image but to see actual shape of the material.

MATLAB is a very useful tool for image processing. Edge detection can use a special MATLAB function directly. The syntaxes are [25]:

```
BW=edge(I),
BW=edge(I,method),
BW=edge(I,method,thr,dir),
BW=edge(__,'nothinning'),
BW=edge(I,method,thr,sigma),
BW=edge(I,method,thr,h),
[BW,thrOut]=edge(___)
[BW,thrOut,Gv,Gh]=edge(___)
```

A binary image BW (edge map) is returned by `BW=edge(I)`. The specified edge detection algorithm used in this study were Roberts, Sobel, Prewitt, Canny, and Laplacian of Gaussian. By using those algorithms, `BW=edge(I,method)` detects edges in the image *I*. An edge detection algorithm may significantly reduce the amount of data to be processed due to less relevant information [26]. However, it still preserves the important structural properties of an image.

The edge detection should be tracked carefully by the edge detection algorithm. The false edges caused by noisy pixels also have to be eliminated by the edge detection algorithm. There are assumptions made in the edge tracing of images [27] namely (a) The gradient of edge pixels are stronger and greater than noise pixels, (b) The edge magnitude and orientation varies slowly along the edges

Roberts Operator

The Roberts cross gradient operator performs discrete differentiation. An input image has a spatial gradient that can be calculated absolutely by computing the total of squares of the different neighbouring pixels in the diagonal direction, as shown in Equation 1. It is the 3×3 pair convolution kernel. As shown in Equation 1, one is reasonable and the other rotated by 90^0 [28].

$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 0 \end{bmatrix} \quad \begin{bmatrix} 0 & 1 & 0 \\ -1 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \quad (1)$$

Normal   Rotated by 90^0

Roberts edge detection was used as the first comparison in this study. The functions of Robert edge detection are as follows:

```
project=guidata(gcbo);
I=get(project.axes2,'Userdata');
gray=rgb2gray(I);
BW=edge(gray,'Roberts');
set(project.figure1,'CurrentAxes',pr
oject.axes3);
set(imshow(BW));
set(project.axes3,'Userdata',A);
redo_Callback(hObject,    eventdata,
handles);
```

Sobel Operator

The Sobel operator is used to the opposite gradient in the horizontal and vertical direction of an image grid by introducing a minimal value of the filter. As shown in Equation 2, one kernel is standard and the other is rotated by 90^0 [28].

$$\begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \quad \begin{bmatrix} -1 & -2 & 1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} \quad (2)$$

Normal   Rotated by 90^0

Detection of Edge Sobel was used as the second comparison in this study. The functions of Sobel edge detection are as follows:

```
project=guidata(gcbo);
I=get(project.axes2,'Userdata');
gray=rgb2gray(I);
BW=edge(gray,'Sobel');
set(project.figure1,'CurrentAxes',pr
oject.axes3);
set(imshow(BW));
set(project.axes3,'Userdata',A);
redo_Callback(hObject,    eventdata,
handles)
```

Prewitt Operator

Prewitt operator is similar to the Sobel, but Prewitt is slightly simpler. It tends to produce somewhat noisier results [20]. The masks are as shown in Equation 3.

$$\begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix} \quad \begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix} \quad (3)$$

Normal   Rotated by 90^0

Prewitt edge detection was used as the third comparison in this study. The functions of Prewitt edge detection are as follows:

```
project=guidata(gcbo);
I=get(project.axes2,'Userdata');
gray=rgb2gray(I);
BW=edge(gray,'Prewitt');
set(project.figure1,'CurrentAxes',pr
oject.axes3);
set(imshow(BW));
set(project.axes3,'Userdata',A);
redo_Callback(hObject,    eventdata,
handles);
```

Canny Operator

Unlike Roberts and Sobel, the Canny operator is not easily affected by noise. It is one of the standard techniques in the industry field. It would be superior if the Canny worked well [20]. Detection of Canny uses two convolutions masks. They are the horizontal and vertical directions, as shown in Equation 4.

The Canny's algorithm requires the image to be filtered where the Sobel operator is applied onto it [29]. The blur edges and the unwanted edges is removed as the output of Sobel operator.

$$\begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix} \quad \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix} \quad (4)$$

Normal   Rotated by 90^0

Canny edge detection was used as the fourth comparison in this study. The functions of Canny edge detection are as follows.

```
project=guidata(gcbo);
I=get(project.axes2,'Userdata');
gray=rgb2gray(I);
BW=edge(gray,'Canny');
set(proyek.figure1,'CurrentAxes',pro
ject.axes3);
set(imshow(BW));
set(project.axes3,'Userdata',A);
redo_Callback(hObject,    eventdata,
handles);
```

Laplacian of Gaussian Operator

The Laplacian of Gaussian operator is a second-order derivative technique obtained by considering the difference of differences, called central differences. It has two effects. Its first effect is to smoothen the image, and the second is to compute the Laplacian, which yields a double-edge image. The digital implementation of the Laplacian function is usually made through the mask, as shown in Equation 5.

$$\begin{bmatrix} 0 & -1 & 0 \\ -1 & 4 & -1 \\ 0 & -1 & 0 \end{bmatrix} \quad \begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix} \quad (5)$$

$$\text{Normal} \qquad \text{Rotated by } 90^0$$

The Laplacian of Gaussian (LoG) combines Gaussian filtering and the Laplacian for edge detection. The LoG mainly uses two methods which are mathematically similar. In the first method, it convolves the image with Gaussian smoothing filter and compute it with the Laplacian result. This pre-processing step reduces the high frequency noise components prior to the differentiation step. In the second one, it shall convolve the image with the linear LoG filter [30].

Since both the Gaussian and the Laplacian are usually much smaller than the image, these methods usually require far fewer arithmetic operations. The 2D LoG equation centered on zero and with the Gaussian standard deviation σ has the form [31]:

$$LoG(x,y) = -\frac{1}{\pi\sigma^4}\left[1 - \left(\frac{x^2 + y^2}{2\sigma^2}\right)\right]e^{\frac{x^2+y^2}{2\sigma^2}} \quad (6)$$

The LoG operator become as simple as Laplacian operator shown in Equation 5.

Detection of LoG was used as the fifth comparison in this study. The functions of LoG edge detection are as follows.

```
project=guidata(gcbo);
I=get(project.axes2,'Userdata');
gray=rgb2gray(I);
BW=edge(gray,'log');
set(project.figure1,'CurrentAxes',pr
oject.axes3);
set(imshow(BW));
set(project.axes3,'Userdata',A);
redo_Callback(hObject,    eventdata,
handles);
```

III. RESULTS AND DISCUSSION

Neutron radiography is a non-destructive testing. As a result of interaction with matter, neutron penetrates the obejcts. It can transmit the material layers with certain thickness which depend on the specific attenuation properties of material [32].

Kartini is nuclear reactor located in BATAN, Yogayakarta regency. It is a TRIGA (Training Research and Isotope production General Atomic) categorized as inherent safety reactor. TRIGA Mark II is research reactor designed and manufactured by General Atomic [33]. It is utilized in various field such as Neutron Activation Analysis (NAA), radiography and tomography, education, and training [34].

The experiment was done using 300 digital neutron digital radiography images of a metal that had been normalized. The image was stored in the format of a bitmap (*.bmp) measuring 720 x 480 pixels. GUI MATLAB is used to implement the edge detection techniques, and the image of neutron digital radiography is tested, as shown in Figure 1. The problems and solutions are uttered in recognizable mathematical details [35].

Two axes are used in this GUI. The first GUI is database axes which store some images and the input image taken from open block. The second one shows the image after edge detection processing. The actual image and the processed images by using various kinds of edge detection techniques are shown in Figure 2.

The edges define the boundaries regions in an image by segmentation and object recognition. They can show where the shadows fall in an image or any other distinct change in the image intensity [36].
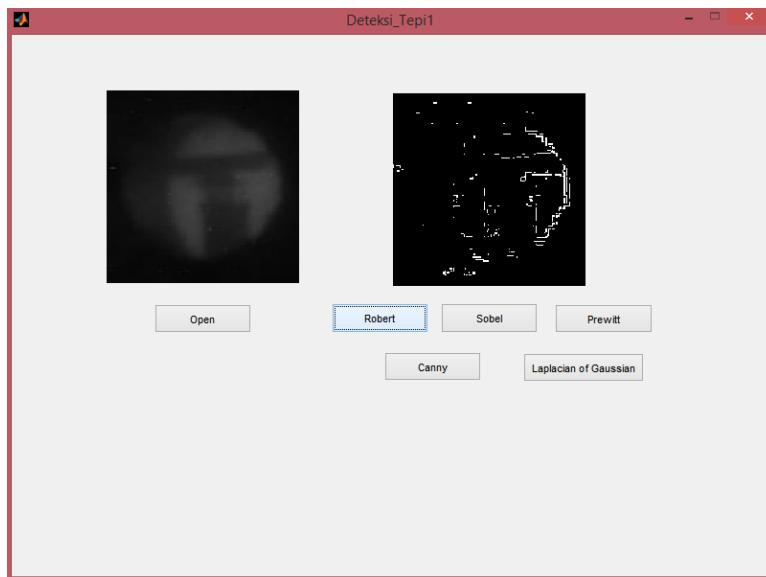

Figure 1. Implementation of Edge Detection Algorithms Program

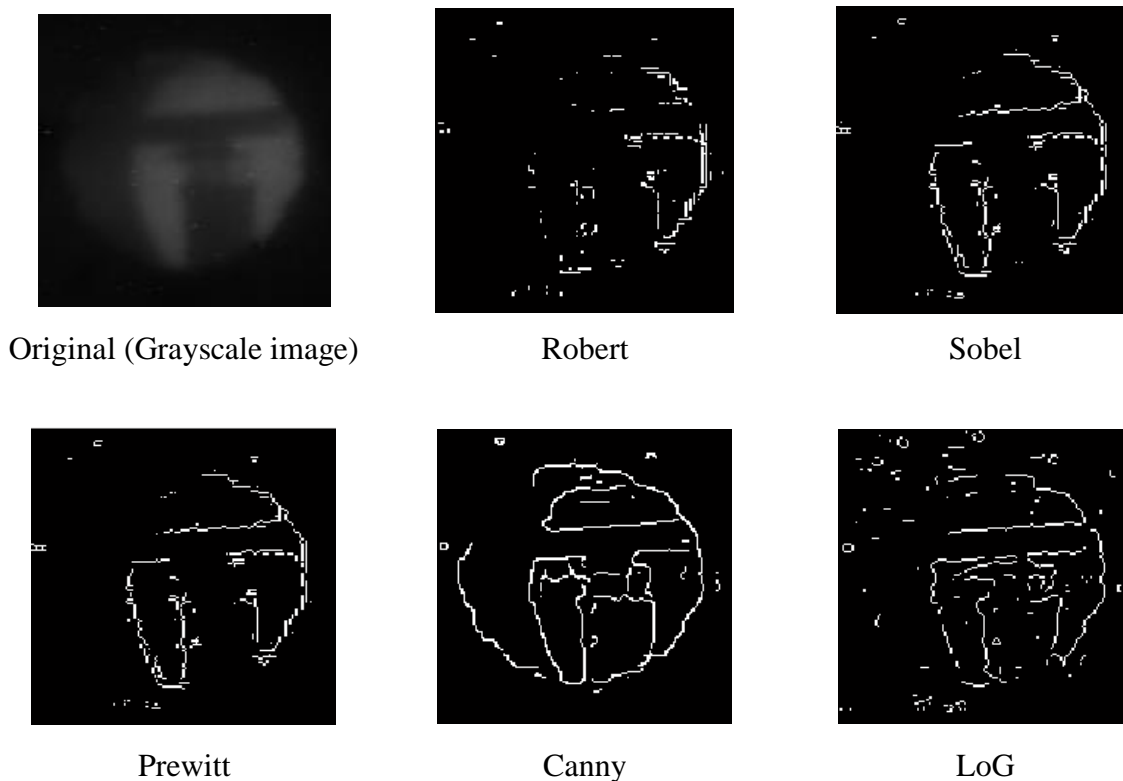| Original (Grayscale image) | Robert | Sobel |
| Prewitt | Canny | LoG |

Figure 2. Original Image Compared to Various Kinds of Edge Detection Techniques

From the experiment, the Robert operator is rapid to compute, while the Sobel is slower than the Roberts operator. The images processed with Robert technique, however, is close to the ones produced by Sobel one. As seen, the edge quality of the pixels are degraded due to the jerky effect on the edges. In contrast, although the Sobel operator had a larger convolution kernel which smooths the input image to a greater extent, when it comes to locating the intricate edges, a Sobel operator is not accurate [37]. Katiyar and Arun through their studies supposed that the Sobel is weaker than Prewitt.

The resulting image processed using Robert and Prewitt detect the various features and stadium. However, they fail when the features are smaller and the range of threshold is very low [38].

Compared to the other techniques, seen from Figure 2 that Canny operator detected the edges of the object image in a more clearly manner without any discontinuity. Satbir Kaur and Ishpreet Singh have studied a comparison between edge detection techniques, proving that Canny technique can extract the features in the image without disturbing its features [39].

The Robert, Sobel, Prewitt, and LoG operator are less sensitive to noise. Compare to Canny operator, LoG has great extent in removing noise after twofold differentiation. Unfortunately, the LoG operator is unable to find edge orientation while the Canny provides edge gradient orientation, which results in proper localization. Li Bin and Mehdi Samiei Yeganeh proposed that the LoG operator is rarely used for direct edge detection because it often produces the edge of second pixels full [40].

Edge detection can be brought to medical image enhancement research area to produce a more efficient medical radiographic images. The Canny operator is advisable and recommended for a detailed framework of human anatomy. MRI and X-Ray images often consist of the important and meaningful edges, i.e. bones.

IV. CONCLUSION

In this study, the various edge detection method for image segmentation was applied to neutron digital radiography image using MATLAB software. The algorithm works well on the neutron digital radiography image. From the experiments, Canny and LoG produce almost similar edges, while Robert is much closer to Sobel and Prewitt. Compared to the other techniques, Canny is deemed better producing optimal performance.

ACKNOWLEDGMENT

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