Advances in Mathematics: Scientific Journal **9** (2020), no.6, 3721–3732
ISSN: 1857-8365 (printed); 1857-8438 (electronic)
https://doi.org/10.37418/amsj.9.6.50 Spec Issiue on ICAML-2020

EVALUATION AND ANALYSIS OF EDGE DETECTION TECHNIQUES ON LEUKEMIA IMAGES

R. KAUR [1] AND R. MAINI

ABSTRACT. Leukemia detection is a current area of research. The work focuses on the identification of the most suitable technique for the edge detection in the Leukemia images. Five different edge detection techniques are simulated in this work using different types of Leukemia images. Four types of Leukemia are considered and forty different Leukemia images (ten of each type) are taken for the purpose of simulation. The performance evaluation of edge detection techniques on different types of Leukemia images is assessed using various image quality metrics. The quantitative analysis is done based on the parameters PSNR, MSE and CoC. Qualitative analysis is also done for the evaluation purpose. Matlab 11b is used for the simulation. It has been observed from the test cases that Sobel operator produces better results for all the four types of the Leukemia images. The best results are produced for the images of CML type.

1. INTRODUCTION

The images have an important property of having discontinuities in the sharp edges. Intensities of the pixels change due to these discontinuities hence are important in defining boundaries of objects. The filters use this important property for the identification of the objects as described by Zhang and Zhao in [1]. The two important features describe an edge pixel, first and foremost the edge strength equal to the enormity of the gradient and secondly direction of the

[1] *corresponding author*

2010 *Mathematics Subject Classification.* 62H35, 62M40.
Key words and phrases. edge detection, AML, ALL, CML, CLL, leukemia.

edge, equal to the gradient's angle. Below general criteria is followed in the Edge detection as described by Zheng and Rao in [2]:

(i) Low error rate helps in identifying more edges accurately.
(ii) The operator should be able to detect an edge point that must be localized to the center of an edge.
(iii) The image noise should not create false edges and an edge should be marked once only.

2. Different types of edge detection techniques

Techniques used in the paper for edge detection are Roberts, Canny, Sobel, Fuzzy and Laplacian.

2.1. ***Roberts.*** Adjacent pixels are diagonally subtracted in Robert edge detection technique and then sum of squares of these differences is calculated. Discrete differentiation is used to approximate the image's gradient as introduced by L. G. Roberts, in [3]. The original image is convolved with the two kernels in Roberts operator shown below in equation:

$$Gx = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix} \quad \text{and} \quad Gy = \begin{bmatrix} 0 & 1 \\ -1 & 0 \end{bmatrix}.$$

Let $I(x, y)$ be a point in the original image and $Gx(x, y)$ be a point in image made by convolving with first kernel and $Gy(x, y)$ be a point in image created by convolving with second kernel. Using this we can define gradient as in equation below:

$$\nabla I(x, y) = G(x, y) = \sqrt{G_x^2 + G_y^2}$$

The gradient's direction can be defined as in below equation:

$$\Theta(x, y) = \arctan\left(\frac{Gy(x, y)}{Gx(x, y)}\right)$$

2.2. ***Canny.*** The Canny edge detection can be described by the following five steps:

I. For removing noise and for smoothing the image the Gaussian filter is used.
II. The concentration gradients of an image are calculated.

III. To purge the spurious squelch to edge detection the non maximum suppression is used.
IV. Double thresholding is applied to determine the potential edges.
V. Edge detection is concluded by suppressing the weak edges which are not coupled to the other sturdy edges as defined by X. Wang and J. Jin, [4]. Hysteresis is applied for stalking the edges.

2.3. ***Sobel.*** The Sobel edge detection is grounded on the operator used for the discrete differentiation. It calculates the gradient's approximation of the intensity function of the image. Sobel is computationally inexpensive as mentioned by Jin-Yu and Yan in [5], as it is grounded on convolving an image with the integer value filter which is small, separable and applied in both horizontal and the vertical direction.

Two 3 x 3 kernels are used in the operator to calculate the approximation of derivatives. The kernels are convolved with original image. One is used for fabricating the vertical changes and one for horizontal changes. Assume I is the source image; Gy is the image comprising the derivative approximation for the vertical direction and Gx is for the horizontal direction. Sobel operator masks are shown as under in equation:

$$Gx = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} * I, \quad Gy = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} * I.$$

* denotes the convolution operation of signal processing in 2 dimensions.

2.4. ***Fuzzy.*** The membership function for the Fuzzy Logic can be described by indicating each neighborhood's degree of edginess as indicated in the equation

$$\mu_{Edge}(g(x,y)) = 1 - \frac{1}{1 + \frac{\sum_N |g(x,y) - g(i,j)|}{\Delta}}.$$

If the fuzzy concepts are used additionally for the modification of the membership values; only then this approach can be considered as a true fuzzy approach. The membership function is heuristically determined as mentioned in [6] by Gonzalez and Woods. The performance is limited but the function is fast.

TABLE 1. Two discrete approximations commonly used for Laplacian filter.

0	-1	0		-1	-1	-1
-1	4	-1		-1	8	-1
0	-1	0		-1	-1	-1

2.5. ***Laplacian.*** The Laplacian is 2-D isotropic's measure of second spatial's image derivative. Image $I(x, y)$ having intensity values of pixels has the Laplacian $L(x, y)$ defined in equation:

$$L(x, y) = \frac{\partial^2 I}{\partial x^2} + \frac{\partial^2 I}{\partial y^2}.$$

This is calculated using the Convolution filter.

As a set composed of discrete pixels is used to represent an input image, so discrete convolution kernel will be considered which help in approximating the 2nd derivatives, [7] by Torre and Poggio in Laplacian's definition.

Two small kernels ordinarily used are shown below:

Using an opposite sign convention is also valid equally. The negative peak is used for outlining the Laplacian as it is more common. To reduce effect of noise; image is smoothed by the Gaussian filter before applying the Laplacian filter.

3. DIFFERENT TYPES OF LEUKEMIA

Leukemia is usually classified into four types:

- Acute myeloid leukemia: AML
- Chronic myeloid leukemia: CML
- Acute lymphocytic leukemia: ALL
- Chronic lymphocytic leukemia: CLL

The main distinction between the above types is the rate of evolution and the location of the growth of the cancer.

3.1. ***ALL.*** Acute lymphocytic leukemia also well-known as acute lymphoblastic leukemia is a blood cancer's type that develops when leukemia cells start accumulating in bone marrow. ALL rapidly progresses and replaces the healthy cells which normally produces functional lymphocytes with the cells which do not mature properly called leukemia cells.

3.2. ***CLL.*** Chronic lymphocytic leukemia generally grows slower. Lymphocytes in this begins in bone marrow and extends into blood. Further it can spread into the other organs. CLL patient is not able to fight with infection as the normal blood cells are crowded by the abnormal lymphocytes. The abnormal lymphocytes in CLL take longer time for development and multiplication. Before becoming serious CLL may take many years .

3.3. ***AML.*** Acute myeloid leukemia is also famous as acute myelogenous leukemia and is a cancer of blood and bone marrow which is of fast-growing form. It is most widespread type of acute Leukemia. It occurs because the cells which are not completely mature starts being blasts. In AML these cells do not mature into WBC's and are not capable to fight against infections. In AML normal white blood cells are crowded out by the abnormal cells.

One of the main things that demarcates AML from the other main forms of leukemia is that it has eight diverse subtypes, which are based on the cell that the leukemia developed from.

3.4. ***CML.*** It is also identified as chronic myelogenous leukemia. Chronic myeloid leukemia is a type of cancer that disturbs the blood and bone marrow. It starts developing in bone marrow and then transmits to blood. Eventually it starts spreading to other body areas.

Chronic Leukemia type grows and spreads slowly.

4. Parameters for evaluation

Frequently used method for the quality assessment of the reconstructed images is the visual inspection method; in combination to objective measurements centered upon computations of pixel wise differences between the processed; and the original images. Quality evaluation of images is typically done using MSE or PSNR. These measures are stereotypically used for the evaluation in RGB system. Another metric for dealing with the color's scrutiny as ordinarily humans do is the Normalized color difference defined by Plataniotis, Lukac and Plataniotis in [8–10].

4.1. ***Correlation Coefficient.*** For the purpose of envisaging the changes in the value of one variable upon changing the value of another variable; a statistical measure recognized as correltion coefficient which is used by Benesty in [11].

For computing the direction and strength involving a linear relationship between two variables r is used. r is calculated by using equation below.

$r = \frac{\sum x_i y_i}{\sqrt{\sum x_i^2}\sqrt{\sum y_i^2}}$

$x_i = X_i - \text{mean}(X_i)$

$y_i = Y_i - \text{mean}(Y_i)$

Here X and Y are the images under research.

Usually r ranges from $-1 \leq r \leq +1$.

4.2. ***MSE.*** Average of the squares of errors is measured in Mean Square Error. Essentially it indicates the difference between the article estimated and the estimator. Major source for the difference is the randomness. Equation below defines the MSE assumed an input image $I(xxy)$ and the processed image J.

$MSE = \frac{1}{xy}\sum_{a=0}^{x-1}\sum_{b=0}^{y-1}[I(a,b) - J(a,b)]^2.$

4.3. ***PSNR.*** PSNR stands for Peak signal to noise ratio. It is the ratio between the signal's maximum attainable power and the power of the corrupting noise that affects its representation. Logarithmic decibel scale is used for articulating the PSNR because of the vigorous range of the signals. Superior quality is indicated by the greater value for PSNR. PSNR is defined as given below by equation in dB.

$$PSNR = 10\log_{10}\left(\frac{Max_I^2}{MSE}\right).$$

Image's maximum possible pixel value is denoted by MaxI. Value of MaxI is 255 when 8 bits are used to represent pixels per sample. In absence of noise both images are identical and MSE is zero in this case as indicated by Salomon in [12].

5. Simulation

The work focuses on the application of the different edge detection operators on the different types of Leukemia images. Four types of Leukemia are taken into consideration and total forty images (ten images of each type) are taken for the analysis.

Main objectives of the analysis are:

I. To compare the performance of various edge detection techniques on different types of Leukemia images.

II. To identify the best operator suitable for edge detection for the Leukemia images.
III. To identify the suitable metrics for quantifying the performance of edge detection techniques.

To compare the results of various edge detection techniques five types of edge detection operators namely Canny, Sobel, Roberts, Laplacian and Fuzzy are considered. All these five types of operators are applied to the four types of Leukemia images namely AML, ALL, CML and CLL.

The steps followed in this process are:

Step 1: Maintain the four sets of Leukemia images namely ALL, CLL, AML and CML.

Step 2: Read the input image of one type of Leukemia from the first set.

Step 3: Convert the input image to the gray scale image.

Step 4: Apply all types of edge detection techniques to the input image one by one.

Step 5: Store the results for the individual images.

Step 6: If all the twenty images from the first set are used for the experimentation then pick the images from the next set and continue from step 3.

Step 7: Repeat the whole process for all the sets.

Step 8: Evaluate the results using parameters PSNR, MSE and CoC.

Step 9: Compare the results quantitatively as well as qualitatively.

6. Results and discussion

6.1. ***Qualitative Analysis.*** For the qualitative analysis the results of applying the five different filters on the four types of Leukemia images are shown. For the purpose of the visual comparison four images (one image of each category) are shown. The visual results are shown in Figure 1, Figure 2, Figure 3 and Figure 4 for the ALL, CLL, AML and CML respectively. From the analysis of Figures it is clear that the Sobel filter produces the best results. In fact its results can further be used for the identification of the type of the Leukemia as from the results the shape as well as the density of the nucleus is also clearly visible. The results of the Canny operator are also comparably good.

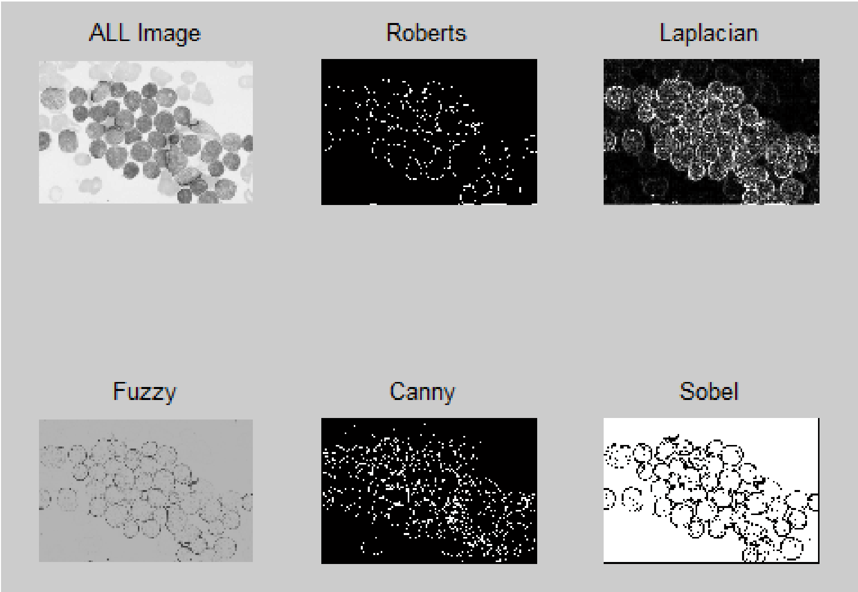

FIGURE 1. Different edge detection techniques applied to the ALL Image

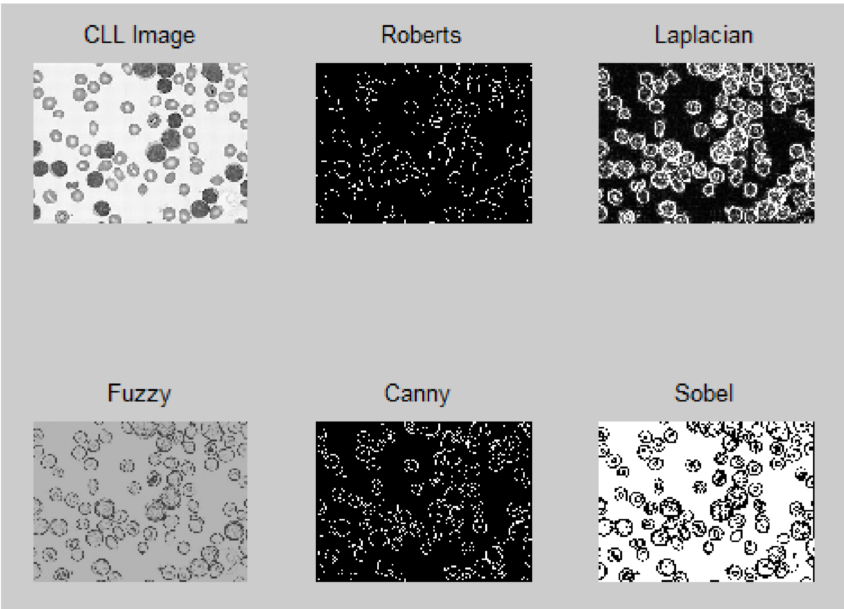

FIGURE 2. Effects of different edge detection techniques applied to the CLL Image

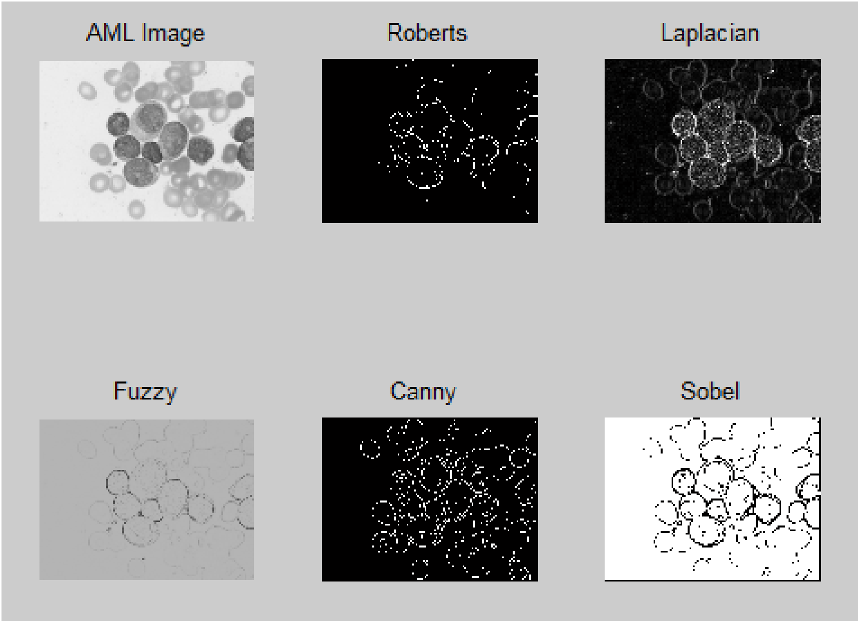

FIGURE 3. Results of different edge detection techniques applied to the AML Image

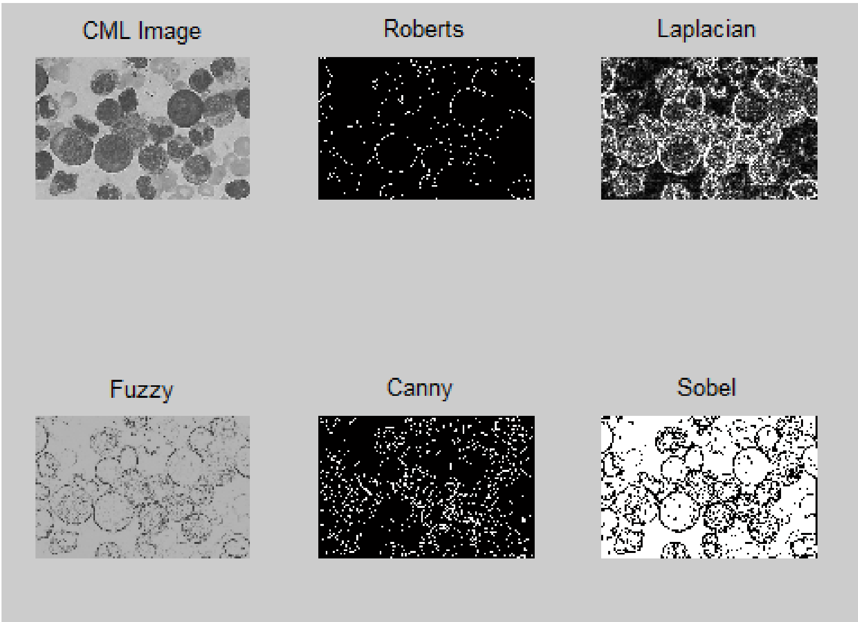

FIGURE 4. Effects of different edge detection techniques applied to the CML Image

TABLE 2. MSE in different Leukemia image types corresponding to the different edge detection techniques

Sr. No.	***Edge detector/ Image type***	***Canny***	***Robert***	***Sobel***	***Laplacian***	***Fuzzy***
1	ALL	3.3207 * e+004	4.1148 * e+004	3.0553 * e+004	4.1003 * e+004	4.0890* e+004
2	CLL	3.6831 * e+004	4.5423 * e+004	3.4055 * e+004	4.5272 * e+004	4.5167* e+004
3	AML	3.3434 * e+004	4.1402 * e+004	3.0788 * e+004	4.1256 *e+004	4.1139* e+004
4	CML	1.6667 * e+004	2.1274 * e+004	1.5441 * e+004	2.1174 *e+004	2.1100* e+004

6.2. ***Quantitative Analysis.*** The consolidated results for the forty images taken as input are shown in Table 2, Table 3 and Table 4 for MSE, PSNR and CoC respectively.

From the analysis of Figures and Tabular data it is clear that the most promising results are produced by Canny and the Sobel filter when applied on the CML images. In fact Sobel filter is better. Even if we compare for all the image types the results produced by the Sobel filter are better because a 2-D spatial measurement of gradient is performed on an image and therefore an emphasis is laid on the regions having high spatial frequency corresponding to edges. Typically in an input grayscale image at each point it finds the approximation of absolute gradient magnitude.

TABLE 3. PSNR in different Leukemia image types corresponding to the different edge detection techniques

Sr. No.	***Edge detector/ Image type***	***Canny***	***Robert***	***Sobel***	***Laplacian***	***Fuzzy***
1	ALL	2.9184	1.9873	3.2803	2.0027	2.0146
2	CLL	2.4686	1.5581	2.8089	1.5725	1.5826
3	AML	2.8889	1.9606	3.2470	1.9759	1.9883
4	CML	5.9122	4.8524	6.2441	4.8729	4.8880

TABLE 4. CoC in different Leukemia image types corresponding to the different edge detection techniques

Sr. No.	***Edge detector/ Image type***	***Canny***	***Robert***	***Sobel***	***Laplacian***	***Fuzzy***
1	ALL	-0.0491	-0.0121	-0.0291	-0.0095	0.2841
2	CLL	0.0073	-0.0047	-0.0041	-0.0241	0.4422
3	AML	-0.0536	-0.149	-0.0382	-0.0236	0.1789
4	CML	-0.1290	-0.0145	-0.0820	-0.1236	0.1044

7. CONCLUSION AND FUTURE WORK

From the results produced it is proved that the Sobel filter gives the best results for all types of the Leukemia images. This is because the Sobel Filter finds the absolute gradient's magnitude at each point in the input grayscale image. Comparable results are produced by the Canny filter also. Stated results can be verified from the tables (Table 2 to Table 4) used for the performance metrics. This work can be extended by adding the effect of noise in the four types of images and then applying the edge detection techniques.

REFERENCES

[1] R. ZHANG, G. ZHAO, L. SU: *A new edge detection method in image processing*, Proceedings of IEEE, International Symposium on Communications and Information Technology, **1** (2005), 445–448.

[2] Y. ZHENG, J. RAO, L WU: *Edge detection methods in digital image processing*, Proceedings of 5th International Conference on Computer Science and Education, 2010, 471–473.

[3] L. G. ROBERTS: *Machine perception of 3-D solids*, Publisher Optical and Electo-Optical Information Processing, MIT Press, 1965.

[4] X. WANG, J. JIN: *An Edge Detection Algorithm Based on Improved CANNY Operator*, Proceedings of Seventh International Conference on Intelligent Systems Design and Applications, 2007, 623–628.

[5] Z. JIN-YU, C. YAN, H. XIAN-XIANG: *Edge detection of images based on improved Sobel operator and genetic algorithms*, Proceedings of International Conference on Image Analysis and Signal Processing, 2009, 31–35.

[6] R. C. GONZALEZ, R. E. WOODS: *Digital Image Processing (2nd ed)*, Prentice Hall, 2002.

[7] TORRE, T. A. POGGIO: *On edge detection*, IEEE Trans. Pattern Analysis Machine Intell., **8**(2) (1986), 187–193.

[8] K. N. PLATANIOTIS, A. N. VENETSANOPOULOS: *Color Image Processing and Application*. Springer, New York, USA, 2000.

[9] R. LUKAC, B. SMOLKA, K. MARTIN, K. N. PLATANIOTIS, A. N. VENETSANOPOULOS: *Vector filtering for color imaging*, IEEE Signal Processing Magazine, **22**(1) (2005), 74–86.

[10] R. LUKAC, K. N. PLATANIOTI: *A taxonomy of color image filtering and enhancement solutions*, Advances in Imaging and Electron Physics, W. Hawkes, E., **140** (2006), 187–264.

[11] J. BENESTY, J. CHEN, Y. HUANG: *On the Importance of the Pearson Correlation Coefficient in noise reduction*, IEEE Transactions on Audio, Speech and Language Processing, **16**(4) (2008), 757–765.

[12] D. SALOMON: *Data Compression: The Complete Reference*, Fourth edition, Springer-Verlag London Limited, 2007, 281.

COMPUTER ENGINEERING
PUNJABI UNIVERSITY PATIALA, INDIA
Email address: rupinderkrsandhu@gmail.com

UCOE
PUNJABI UNIVERSITY PATIALA, INDIA