International Journal on Advanced Science Engineering Information Technology

Vol.12 (2022) No. 4
ISSN: 2088-5334

Hybrid Canny Zerocross Method for Edge Detection in Retina Identification Cases

Silfia Andini [a,*], Anjar Wanto [b], Retno Devita [a], Ruri Hartika Zain [a], Aulia Fitrul Hadi [a]

[a] *Universitas Putra Indonesia YPTK Padang, Jl Raya Lubuk Begalung, Padang, 25221, Indonesia*
[b] *STIKOM Tunas Bangsa, Jl Sudirman Blok A No. 1-3, Pematangsiantar, 21127, Indonesia*
*Corresponding author: *silfiaandini68@upiyptk.ac.id*

***Abstract*— Edge detection is fundamental to Figure processing. Edges include much information in a figure, including the object's location, shape, size, and information about its texture. Since edge detection is a critical component of Figure processing for object detection, comprehend algorithms for edge detection. This is because the edges define an item's contours, serve as a demarcation between the object and its backdrop, and serve as a demarcation between overlapping objects. That is, if the edges of an image can be identified accurately, all things can be found. The proposal of this paper is the use of the Canny Zerocross hybrid method to perform better edge detection based on comparative studies and the incorporation of the Canny way, which is considered one of the best edge detection methods, with the Zerocross way (cross zero) which is a derivative of the laplacian. In this paper, the research data used is the retinal image dataset—data obtained from STARE (Structured Analysis of the Retina). The Veterans Administration Medical Center in San Diego and the Shiley Eye Center (ECS) at the University of California provided Figures and clinical data from the retinal images. The experimental results of the comparative study show that the Zerocross edge detection technique is better than the Canny edge detection technique. Meanwhile, edge detection and image identification would be better when combining the two methods (hybrid) based on merging studies.**

***Keywords*— Edge detection; hybrid; canny; Zerocross; Retina.**

Manuscript received 4 Feb. 2022; revised 30 May 2022; accepted 3 Jun. 2022. Date of publication 31 Aug. 2022.

I. INTRODUCTION

Image has become an increasingly important medium for humans to observe information from the real world around them in recent years [1], [2], [3]. Images can be obtained using different observation and capture systems in various forms and ways [4]. Figure Engineering is a growing interdisciplinary subject that systematically studies various theories, technologies, and applications of images [5], [6]. The process combines basic science principles such as mathematics, computer science, and optics with accumulated experience in Figure applications, takes advantage of developments in electronics, integrates various Figure technologies, and discusses research and applications for the entire field of Figure [7], [8], [9]. Figure edges are groups of pixels with a high degree of dissimilarity that indicate crucial aspects of the image and carry information [10], [11], [12]. Edges are directly coupled with shape variations in the pixel intensity distribution [13], [14], [15]. Studies on extraction features, description, and recognition targets rely heavily on edge detection in image processing [16], [17]. Since it is a problem fundamental in both figure processing and vision of the computer, edge detection is a crucial difficulty in digital figure processing [18], [19], [20]. Edge detection is conducted on images with asymmetrical edges [21], [22].

Edge detection seeks to assess and group items in a picture, as well as to perform additional analysis on the image [23], [24], [25]. The term "edge detection" refers to two distinct processes: detection of first-order and second-order edges [24]. Several first-order approaches include the Sobel method [26], Roberts [27], Prewitt [28], and Canny [29]. While the identification of second-order edges, such as Laplacian Gaussian [30].

Edge detection techniques have been extensively developed to handle a variety of image identification difficulties [31], [32], [33], [34]. This is obvious from related investigations—introduced instruction in computer graphics, figure processing, and active contouring. The study of figure segmentation methods concentrated on picture segmentation techniques and segmentation techniques based on dynamic contour models. To begin, summarize the two primary methods of segmentation based on edges and regions, as well as their respective advantages and disadvantages. Then, investigate the segmentation approach based on the active contour model and compare different representative active contour models in detail. This research results in the development of a local binary fitting model and the enhancement and stimulation of the regional Gaussian distribution fitting energy model [35].

Identify and classify leaf diseases on banana plants to diagnose and get appropriate treatment for pests and diseases. In this automation process, Figure segmentation is a key component of analyzing Figures and extracting information. Therefore, to choose the most appropriate method of leaf segmentation, Numerous segmentation techniques are available, including thresholding adaptive, Canny, geodesic, color segmentation, fuzzy C-means, global thresholding, log, K-means, multi thresholding, region growing, Prewitt, Sobel, Robert, and zero-crossing were compared and analyzed. The results showed that the geodesic method had a significantly lower MSE [36].

Proposed a new hybrid detection to minimize spots on Figures, notably when concurrently weak/strong edges occur outside and inside heterogeneous areas. The combined methods are an improved polarimetric constant false alarm rate (IP_CFAR) edge detector and a weighted gradient-based (WG) detector. Based on these two detectors, a wavelet-based hybrid edge detection method is proposed combining its advantages and disadvantages. The experimental results show that the proposed method can overcome the problems experienced [37].

A two-dimensional visual Figure discriminator was experimentally demonstrated for edge detection by discussing two-dimensional optical edge detection using a photonic crystal plate in combination with a conventional optical imaging system. Integrating OID into traditional imaging systems enables the application of edge detection to objects of interest. 2DOID can reveal all edges of a 2D object with a single measurement, whereas 1DOID can only detect edges along one direction [38].

This paper proposes a hybrid technique that combines the Canny and log operators. This paper also provides a comparison of the hybrid method with the conventional Canny edge detector technique and operator log operator concerning visual inspection, mean square error (MSE), Root mean square error (RMSE), Peak Signal to noise ratio (PSNR), and Bit error. The combination of these two methods produces good edge detection quality [39]. Furthermore, the research utilized an edge detection and thresholding hybrid approach to recognize fingerprint images and determine the similarity of fingerprint photos in the database to the fingerprint images under test. Thresholding Hybrid Laplacian from Otsu and Gaussian to obtain the results of background and object separation to identify smart fingerprint photos, with an average level of similarity of 87.94 percent. The calculating results demonstrate an extremely high degree of precision [40].

Based on the related studies described, this paper proposes a hybrid Canny Zerocross method in the case of retinal image identification, which is expected to solve edge detection problems better.

II. Materials and Method

A. Dataset

The research dataset used is the retinal image dataset, obtained from STARE (Structured Analysis of the Retina). The Veterans Administration Medical Center in San Diego and the Shiley Eye Center (ECS) at the University of California provided Figures and clinical data from the retinal images. The TopCon TRV-50 fundus camera is used to capture Figures at a 35° field of view. Figure in PPM format with a resolution of 700x605 pixels, which is then converted to JPG [41].

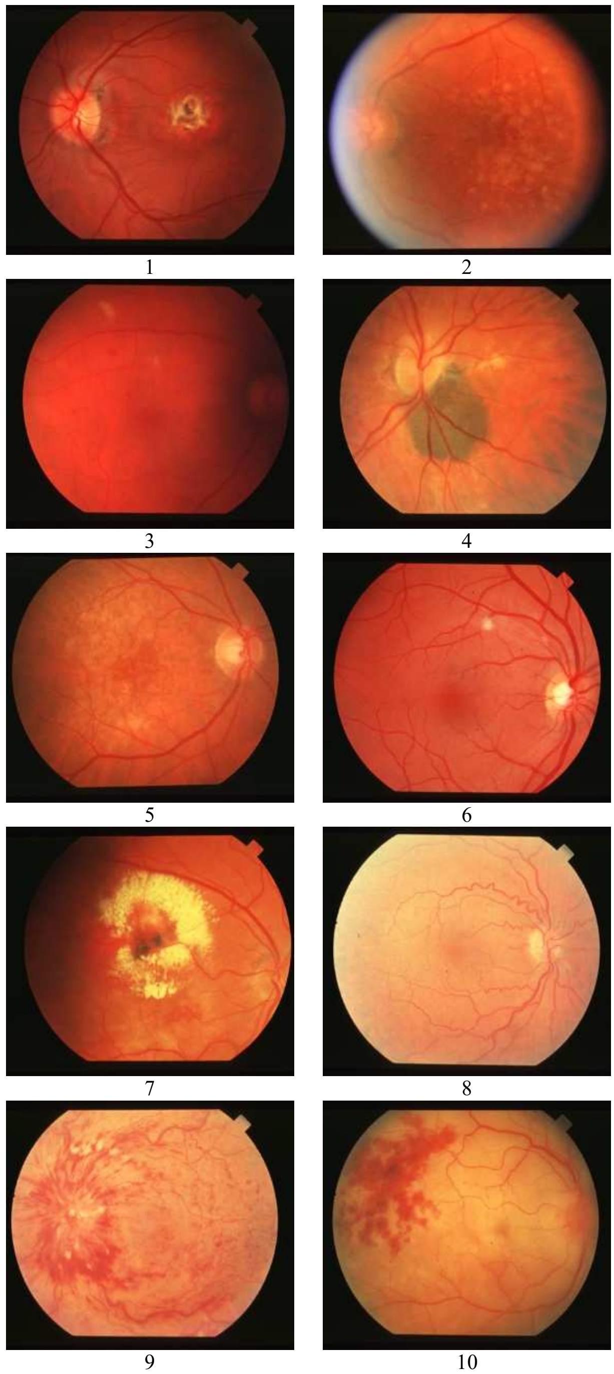


Fig. 1 Normal Image (Training Dataset)

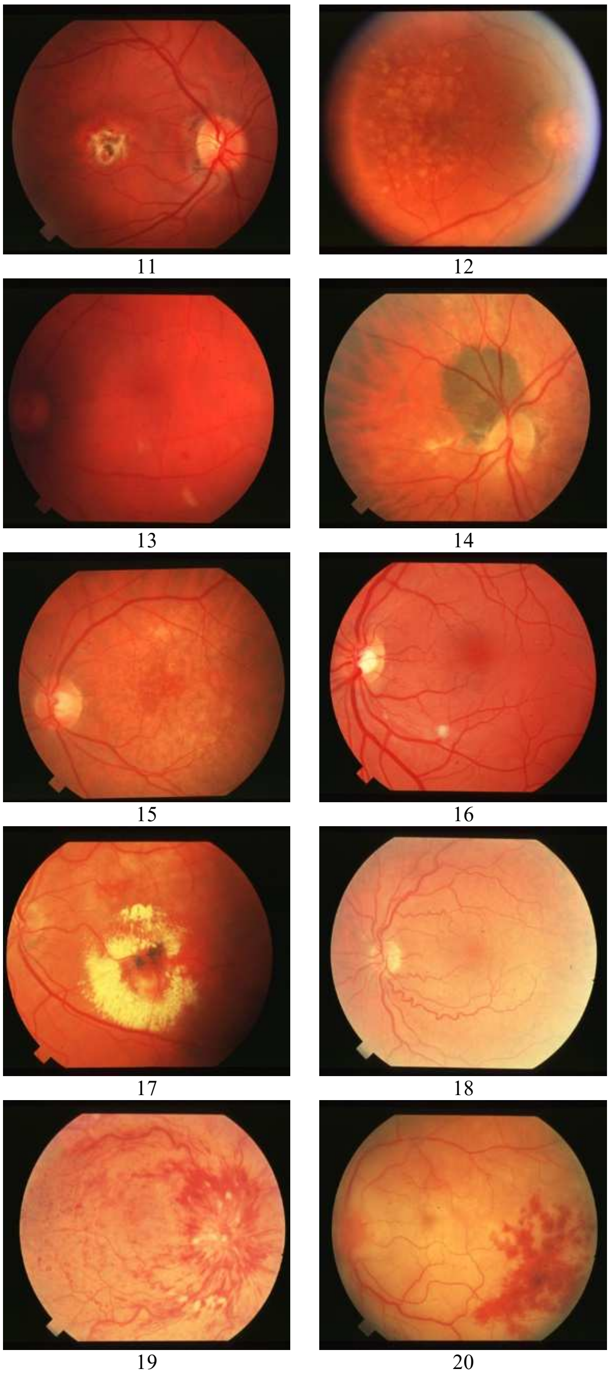


Fig. 2 Turnover Image (Test Dataset)

Figure 2 is a retinal dataset of 10 images that would be used as a training dataset. Based on these 10 images, another 10 images were added by rotating the position of the 10 normal images that had been obtained (Fig 2). 10 retinal image data that are rotated from normal images are used as a test dataset to obtain Precision results from the object identification process later [41].

B. Research Stages

The research stages in this study can be seen in fig 3.

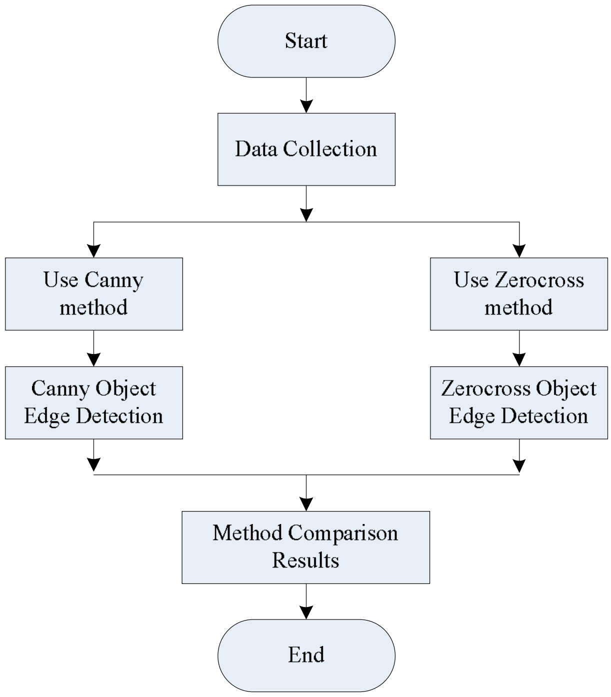


Fig 3. Research Stages

The research stage depicted in Figure 3 begins with the collection of data. Dataset utilized is a retinal dataset image composed of twenty images: ten normal images for training and ten rotational images for testing. The following step is to use the Matlab application to apply the Canny and Zerocross methods. Each retinal image dataset would be checked individually by entering the Matlab software code, and it would generate edge detection images of Canny and Zerocross objects for each trained and tested figure based on the program code entered in Matlab. The following stage is to study the object edge detection results obtained from each method to generate legitimate results comparison; now, the results of the two methods would be found out, and the optimum approach for edge detection would be determined.

III. RESULT AND DISCUSSION

Object identification using the Canny and Zerocross method edge detection processes on retinal images is carried out with the help of Matlab R2019a software. The dataset is initially partitioned into train also test subsets using the concepts described in Figure 1 and Figure 2.

Zerocross algorithms that generate a binary picture. Segment the image using the three ways to obtain the resulting image with the segmented object visible. It is necessary to notice an item gap enclosed by means of lines on a concealed gradient in the photographs. Segmentation aims to compare the three methods for identifying retinal pictures. Because the application would be used to make retinal image identification, a database is subjected to identification analysis. This is directly comparable to the results of the scanning. Tables II to VII provides the identification results for the three edge detection approaches (Canny, Zerocross, and Canny + Zerocross) based on Table I.

TABLE I
IMAGE PAIRS OF TRAINING AND TESTING

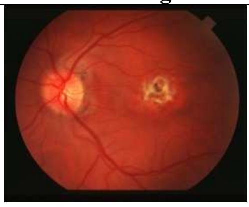
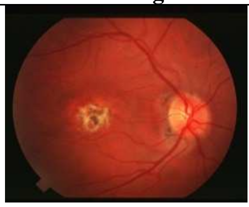
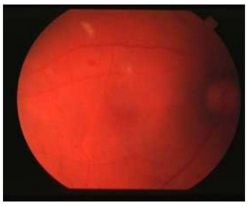
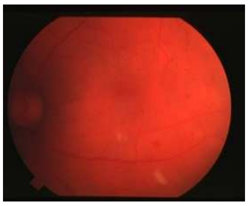
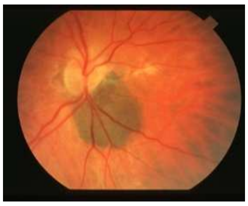
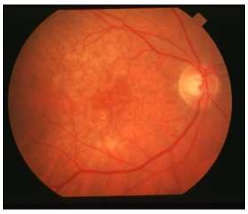
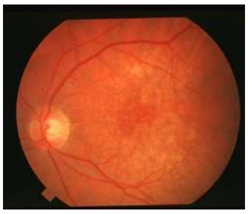
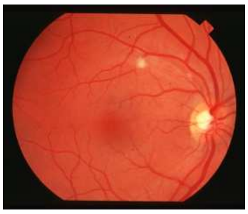
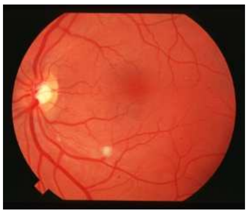
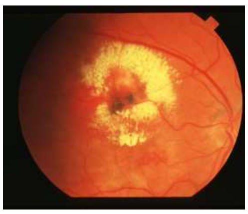
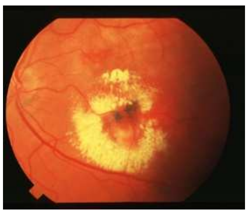
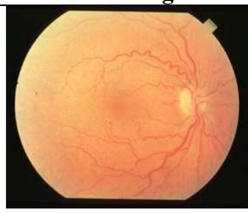
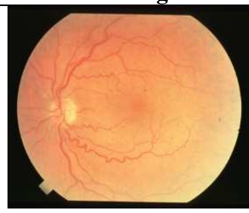
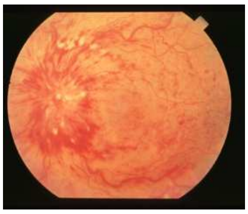
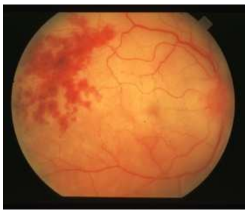
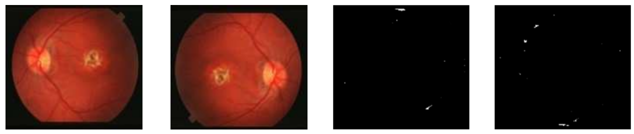
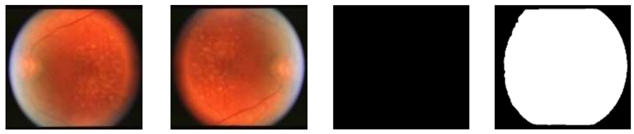
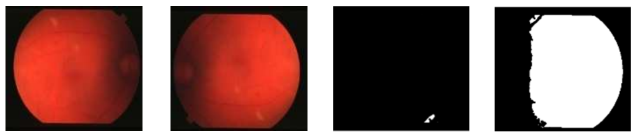
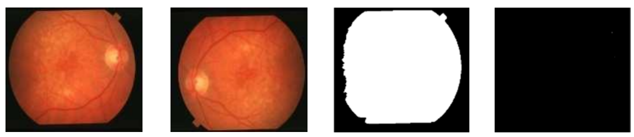
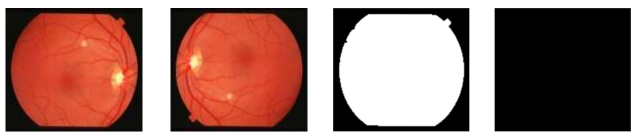
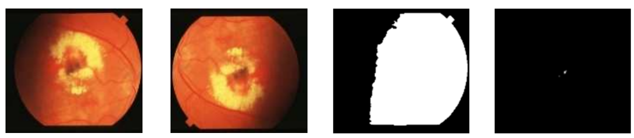
Training		Testing
 1	=	 11
 2	=	 12
 3	=	 13
 4	=	 14
 5	=	 15
 6	=	 16
 7	=	 17
 8	=	 18
 9	=	 19
 10	=	 20

TABLE II
RETINA IMAGE SEGMENTATION RESULTS WITH CANNY

Original Image	Processed Image	Segmentation (a)	Segmentation (b)
			
			
			
			
			
			
			

Original Image	Processed Image	Segmentation (a)	Segmentation (b)

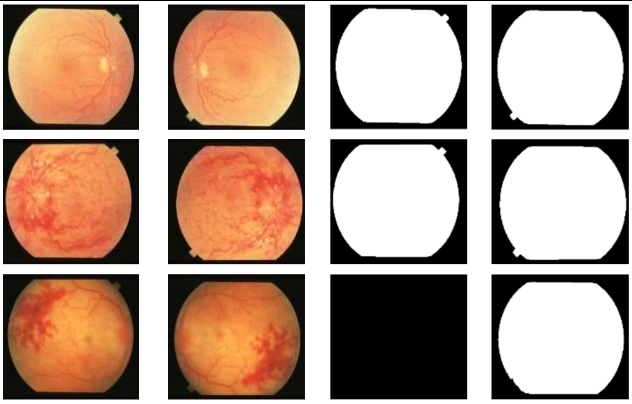


Table II is the result of segmentation using the Canny method on 20 retinal image objects (Table I). The segmentation results have analysis results ranging from pixel dimensions, precision, and error values. The complete results of the analysis using the Canny method, Table III illustrates this point.

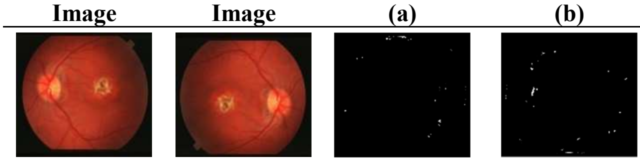
TABLE III
RETINA IMAGE PRECISION RESULTS WITH CANNY METHOD

No	Image Database (Pixel)	Image Test (Pixel)	Precision (%)	Error (%)	Results Identification
1	166	203	81,77	18,23	Suitable
2	2	100942	0	100,00	Not Suitable
3	278	74521	0,37	99,63	Not Suitable
4	99366	0	0	100,00	Not Suitable
5	96491	7	0,01	99,99	Not Suitable
6	99652	1	0	100,00	Not Suitable
7	73631	45	0,06	99,94	Not Suitable
8	100479	100479	100,00	0	Suitable
9	99851	99851	100,00	0	Suitable
10	0	98397	0	100,00	Not Suitable
Average			**28,22**	**71,78**	**30%**

According to Table III, the average precision value for Canny methods on the whole retinal image test findings is 28.22 percent. The Canny method accurately identified three retinal images out of ten trials and failed to correctly identify seven retinal images with a standard deviation score of 71.78 percent. The image database generates a minimum of 0 pixels and a maximum of 100479 pixels. Meanwhile, the image test generates a maximum of 100479 pixels and a minimum of 0. The overall success rate of identification using the Canny approach is 30%.

TABLE IV
RETINA IMAGE SEGMENTATION RESULTS WITH ZEROCROSS

Original Image	Processed Image	Segmentation (a)	Segmentation (b)



Original Image	Processed Image	Segmentation (a)	Segmentation (b)

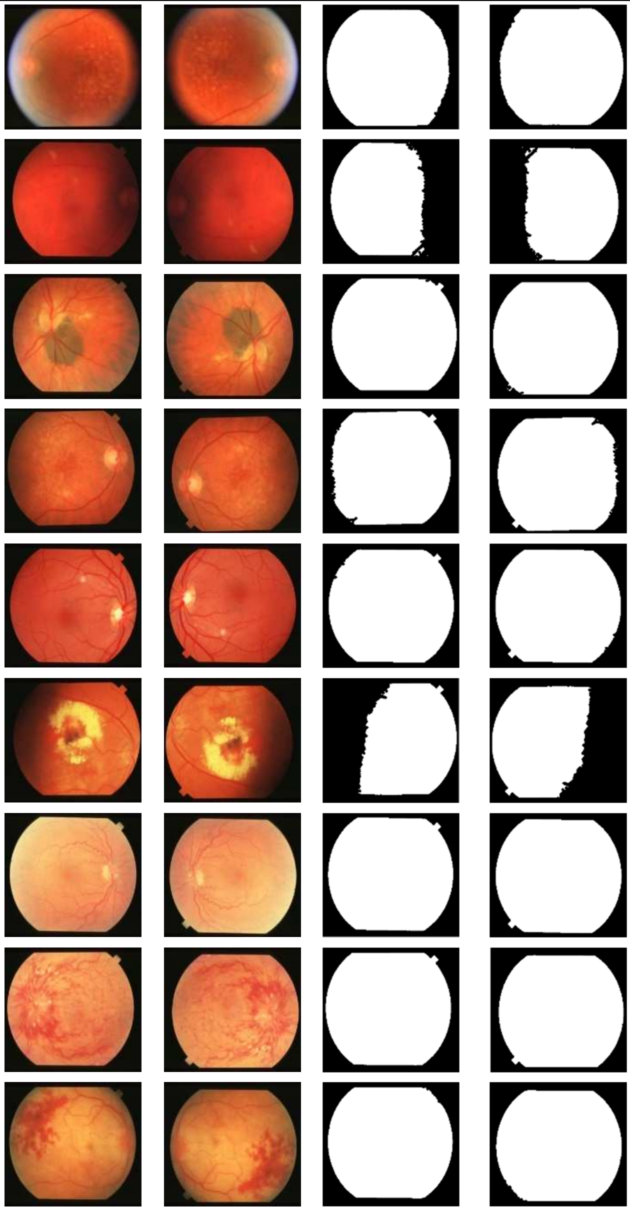


Table IV is the result of segmentation using the Zerocross method on 20 retinal image objects, where the segmentation results have analysis results ranging from pixel dimensions, precision and error values. Table v contains the complete findings of the analysis conducted using the Zerocross approach.

TABLE V
RETINA IMAGE PRECISION RESULTS WITH ZEROCROSS

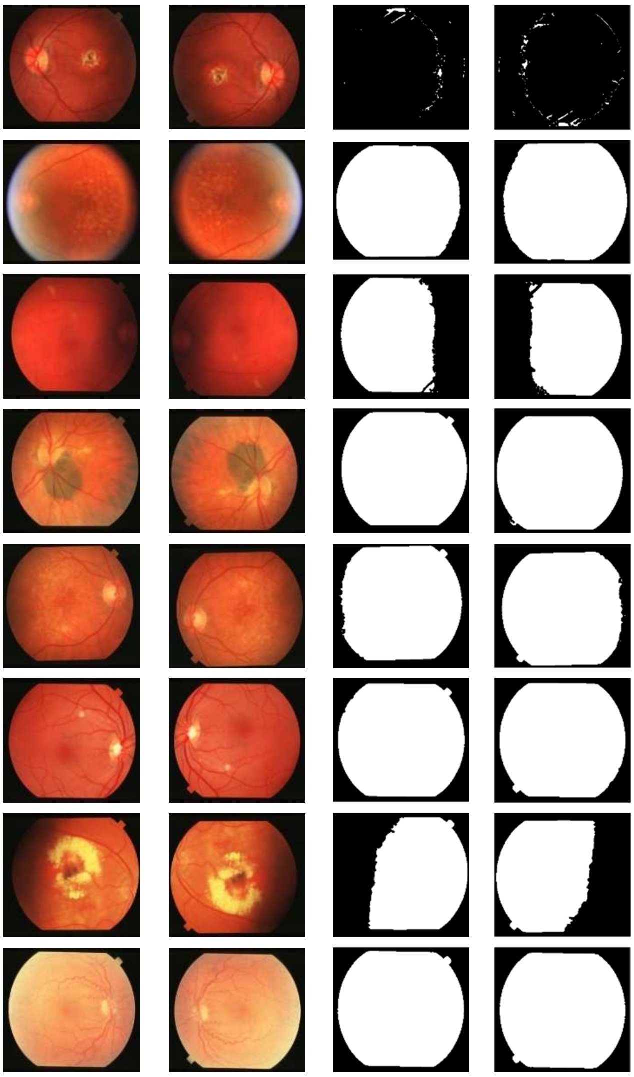
No	Image Database (Pixel)	Image Test (Pixel)	Precision (%)	Error (%)	Results Identification
1	245	401	61,10	38,90	Not Suitable
2	100190	100179	99,99	0,01	Suitable
3	73625	73594	99,96	0,04	Suitable
4	98487	98340	99,85	0,15	Suitable
5	95534	95490	99,95	0,05	Suitable
6	98817	98822	99,99	0,01	Suitable

No	Image Database (Pixel)	Image Test (Pixel)	Precision (%)	Error (%)	Results Identification
7	72786	72836	99,93	0,07	Suitable
8	99712	99717	99,99	0,01	Suitable
9	99047	99049	100,00	0,00	Suitable
10	97585	97589	100,00	0,00	Suitable
Average			**96,08**	**3,92**	**90%**

Average Precision value for the entire retinal test image results obtained using the Zerocross method is 96.08 percent, as shown in Table v. In nine of the 10 trials, the Zerocross method properly identified nine retinal pictures and incorrectly specified only one, with a mean value of error 3.92 percent. Database image produces a minimum of 245 pixels and a maximum of 100190 pixels. In terms of the amount of pixels formed in the test image, the minimum and highest values are 401 and 100179. The overall success rate of identification utilizing the Zerocross approach is 90%.

TABLE VI
RETINA IMAGE SEGMENTATION RESULTS WITH HYBRID METHOD (CANNY + ZEROCROSS)

Original Image	Processed Image	Segmentation (a)	Segmentation (b)



Original Image	Processed Image	Segmentation (a)	Segmentation (b)

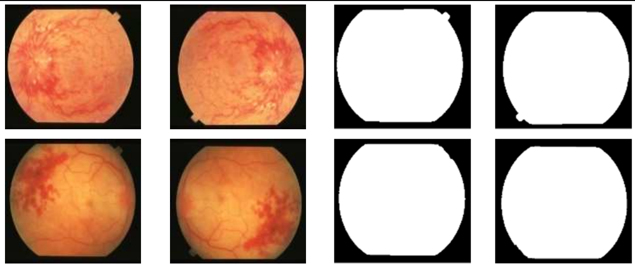


Table VI is the result of segmentation using the Hybrid (Canny + Zerocross) method on 20 retinal image objects. The segmentation results have analysis results ranging from pixel dimensions, precision, and error values. The complete results of the analysis using the Hybrid method (Canny + Zerocross), table vii illustrates this point.

TABLE VII
RETINA IMAGE PRECISION RESULTS WITH HYBRID METHOD (CANNY + ZEROCROSS)

No	Image Database (Pixel)	Image Test (Pixel)	Precision (%)	Error (%)	Results Identification
1	1402	2035	68,89	31,11	Not Suitable
2	102430	102406	99,98	0,02	Suitable
3	76139	72739	95,53	4,47	Suitable
4	100798	100695	99,90	0,10	Suitable
5	98184	98177	99,99	0,01	Suitable
6	101116	101106	99,99	0,01	Suitable
7	75063	75041	99,97	0,03	Suitable
8	101954	101951	100,00	0,00	Suitable
9	101299	101300	100,00	0,00	Suitable
10	99792	99837	99,95	0,05	Suitable
Average			**96,42**	**3,58**	**90%**

Average Precision value for the entire retinal test image findings obtained utilizing the Hybrid (Canny + Zerocross) approach is 96.42 percent, as shown in Table vii. In nine of the ten trials, the Zerocross method properly identified nine retinal pictures and incorrectly specified only one, with a mean value of error 3.58 percent. The image database generates a minimum of 1402 pixels. The maximum is 102430 pixels, while the minimum and maximum are 2035 pixels and 102406 pixels, respectively. The overall success rate of the hybrid technique (Canny + Zerocross) is 90%.

The comparison of each approach using ten trials of retinal pictures and the average value of error and precision for each technique are presented in the form of a graph in Fig 4.

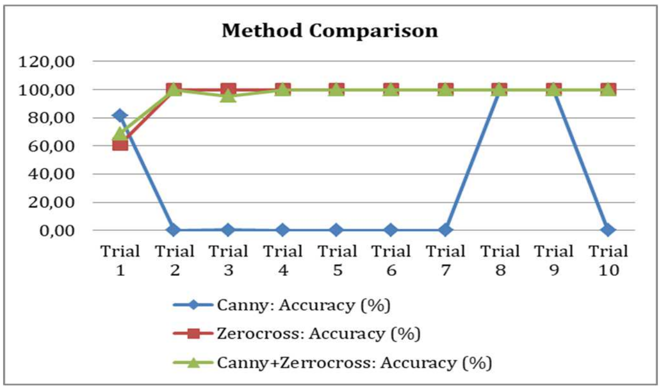


Fig. 4 Comparison Graph of 3 Methods (10 Trials)

Based on Fig. 4, the graph of the accuracy level of the Zerocross and Canny + Zerocross methods is relatively stable and consistent compared to the accuracy level of the Canny method, whose differences are pretty significant. However, overall, the accuracy rate of the Canny + Zerocross method is better than the other two methods.

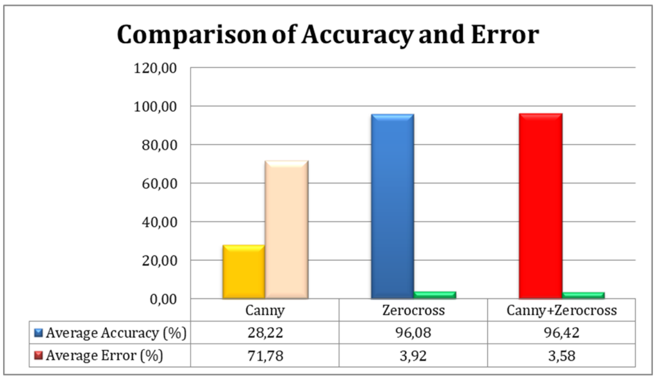


Fig. 5 Comparison Results of 3 Methods (Precision and Error)

On the basis of the facts shown in Fig 4 and 5, it can be inferred that the Canny + Zerocross method combination (Hybrid Canny Zerocross) is more accurate than the Canny and Zerocross methods alone. This is demonstrated by the Figure picture recognition results, which reached 96.42 percent, a modest improvement of 0.34 percent over the Zerocross method, which achieved an average Precision of 96.08 percent. Additionally, the Hybrid Canny Zerocross approach is superior in terms of the number of pixels used to identify retinal pictures.

IV. Conclusion

According to the experimental results and analysis of the research, identifying objects using the edge detection process on retinal pictures with the Canny + Zerocross approach performs better than using the Canny or Zerocross methods alone. As may be observed, the resulting segmentation produces more discernible results. Combining the two methodologies can aid in identifying retinal picture objects with varying shapes and dimensions.

Acknowledgment

The authors are grateful to Universitas Putra Indonesia YPTK Padang for all the assistance during the completion of this study.

References

[1] D. Chen *et al.*, “Deep learning and alternative learning strategies for retrospective real-world clinical data,” *npj Digital Medicine*, vol. 2, no. 1, pp. 1–5, 2019.

[2] M. Haenlein, E. Anadol, T. Farnsworth, H. Hugo, J. Hunichen, and D. Welte, “Navigating the New Era of Influencer Marketing: How to be Successful on Instagram, TikTok, & Co.,” *California Management Review*, vol. 63, no. 1, pp. 5–25, 2020.

[3] S. Rahmawati, R. Devita, R. H. Zain, E. Rianti, N. Lubis, and A. Wanto, “Prewitt and Canny Methods on Inversion Image Edge Detection: An Evaluation,” *Journal of Physics: Conference Series*, vol. 1933, no. 1, p. 012039, 2021.

[4] Y.-J. Zhang, “Development of Image Engineering in the Last 20 Years,” *Encyclopedia of Information Science and Technology, Fourth Edition*, pp. 1319–1330, 2018.

[5] Y.-J. Zhang, *Image Engineering. In: Handbook of Image Engineering*. Springer, Singapore, 2021.

[6] Y.-J. Zhang, “Image Engineering,” in *Handbook of Image Engineering*, Springer, Singapore, 2021, pp. 55–83.

[7] A. Distante and C. Distante, *Handbook of Image Processing and Computer Vision*, vol. 1. 2020.

[8] Y. Xu *et al.*, “Artificial intelligence: A powerful paradigm for scientific research,” *The Innovation*, vol. 2, no. 4, pp. 1–20, 2021.

[9] F. Zangeneh-Nejad, D. L. Sounas, A. Alù, and R. Fleury, “Analogue computing with metamaterials,” *Nature Reviews Materials*, vol. 6, no. 3, pp. 207–225, 2021.

[10] L. H. Gong, C. Tian, W. P. Zou, and N. R. Zhou, “Robust and imperceptible watermarking scheme based on Canny edge detection and SVD in the contourlet domain,” *Multimedia Tools and Applications*, vol. 80, no. 1, pp. 439–461, 2021.

[11] R. Ranjbarzadeh, S. B. Saadi, and A. Amirabadi, “LNPSS: SAR image despeckling based on local and non-local features using patch shape selection and edges linking,” *Measurement: Journal of the International Measurement Confederation*, vol. 164, p. 107989, 2020.

[12] S. Aouat, I. Ait-hammi, and I. Hamouchene, “A new approach for texture segmentation based on the Gray Level Co-occurrence Matrix,” *Multimedia Tools and Applications*, vol. 80, no. 16, pp. 24027–24052, 2021.

[13] M. Mittal *et al.*, “An Efficient Edge Detection Approach to Provide Better Edge Connectivity for Image Analysis,” *IEEE Access*, vol. 7, pp. 33240–33255, 2019.

[14] J. Ma, X. Jiang, A. Fan, J. Jiang, and J. Yan, “Image Matching from Handcrafted to Deep Features: A Survey,” *International Journal of Computer Vision*, vol. 129, no. 1, pp. 23–79, 2021.

[15] Z. Wei and G. H. Liu, “Image retrieval using the intensity variation descriptor,” *Mathematical Problems in Engineering*, vol. 2020, pp. 1–12, 2020.

[16] M. Gholizadeh-Ansari, J. Alirezaie, and P. Babyn, “Deep Learning for Low-Dose CT Denoising Using Perceptual Loss and Edge Detection Layer,” *Journal of Digital Imaging*, vol. 33, pp. 504–515, 2020.

[17] S. Sengupta, N. Mittal, and M. Modi, “Improved skin lesion edge detection method using Ant Colony Optimization,” *Skin Research & Technology*, vol. 25, no. 6, pp. 846–856, 2019.

[18] C. J. J. Sheela and G. Suganthi, “Morphological edge detection and brain tumor segmentation in Magnetic Resonance (MR) images based on region growing and performance evaluation of modified Fuzzy C-Means (FCM) algorithm,” *Multimedia Tools and Applications*, vol. 79, no. 25–26, pp. 17483–17496, 2020.

[19] R. G. Zhou, H. Yu, Y. Cheng, and F. X. Li, “Quantum image edge extraction based on improved Prewitt operator,” *Quantum Information Processing*, vol. 18, no. 261, pp. 1–24, 2019.

[20] P. Jayapriya and S. Hemalatha, “Detection of Maize Stem and Leaf Diseases using Edge Detection Method to Prevent the Crops from Diseases,” *Journal of Xi'an University of Architecture & Technology*, vol. 12, no. 7, pp. 1052–1064, 2020.

[21] M. Gandhi, J. Kamdar, and M. Shah, “Preprocessing of Non-symmetrical Images for Edge Detection,” *Augmented Human Research*, vol. 5, no. 1, pp. 1–10, 2020.

[22] V. R. Balaji, S. T. Suganthi, R. Rajadevi, V. Krishna Kumar, B. Saravana Balaji, and S. Pandiyan, “Skin disease detection and segmentation using dynamic graph cut algorithm and classification through Naive Bayes classifier,” *Measurement: Journal of the International Measurement Confederation*, vol. 163, p. 107922, 2020.

[23] B. Watkins and A. van Niekerk, “A comparison of object-based image analysis approaches for field boundary delineation using multi-

temporal Sentinel-2 imagery," *Computers and Electronics in Agriculture*, vol. 158, no. November 2018, pp. 294–302, 2019.

[24] M. Versaci and F. C. Morabito, "Image Edge Detection: A New Approach Based on Fuzzy Entropy and Fuzzy Divergence," *International Journal of Fuzzy Systems*, vol. 23, pp. 918–936, 2021.

[25] Y. Liu, M.-M. Cheng, D.-P. Fan, L. Zhang, J.-W. Bian, and D. Tao, "Semantic Edge Detection with Diverse Deep Supervision," *International Journal of Computer Vision*, vol. 130, pp. 179–198, 2022.

[26] G. Chen, Z. Jiang, and M. M. Kamruzzaman, "Radar remote sensing image retrieval algorithm based on improved Sobel operator," *Journal of Visual Communication and Image Representation*, vol. 71, no. 102720, pp. 1–8, 2020.

[27] M. Yasir *et al.*, "Automatic Coastline Extraction and Changes Analysis Using Remote Sensing and GIS Technology," *IEEE Access*, vol. 8, pp. 180156–180170, 2020.

[28] Erwin and T. Yuningsih, "Detection of Blood Vessels in Optic Disc with Maximum Principal Curvature and Wolf Thresholding Algorithms for Vessel Segmentation and Prewitt Edge Detection and Circular Hough Transform for Optic Disc Detection," *Iranian Journal of Science and Technology, Transactions of Electrical Engineering*, vol. 9, pp. 1–12, 2020.

[29] B. Iqbal, W. Iqbal, N. Khan, A. Mahmood, and A. Erradi, "Canny edge detection and Hough transform for high resolution video streams using Hadoop and Spark," *Cluster Computing*, vol. 23, no. 1, pp. 397–408, 2020.

[30] Y. Cho *et al.*, "Keypoint Detection Using Higher Order Laplacian of Gaussian," *IEEE Access*, vol. 8, pp. 10416–10425, 2020.

[31] A. Wanto, S. D. Rizki, S. Andini, S. Surmayanti, N. L. W. S. R. Ginantra, and H. Aspan, "Combination of Sobel+Prewitt Edge Detection Method with Roberts+Canny on Passion Flower Image Identification," *Journal of Physics: Conference Series*, vol. 1933, no. 1, p. 012037, 2021.

[32] Z. Selmi, M. Ben Halima, U. Pal, and M. A. Alimi, "DELP-DAR system for license plate detection and recognition," *Pattern Recognition Letters*, vol. 129, pp. 213–223, 2020.

[33] X. Wu, D. Sahoo, and S. C. H. Hoi, "Recent advances in deep learning for object detection," *Neurocomputing*, vol. 396, pp. 39–64, 2020.

[34] W. Cao, Q. Liu, and Z. He, "Review of Pavement Defect Detection Methods," *IEEE Access*, vol. 8, pp. 14531–14544, 2020.

[35] X. Ye and Q. Wang, "Active Contour Image Segmentation Method for Training Talents 0f Computer Graphics and Image Processing Technology," *IEEE Access*, pp. 1–1, 2020.

[36] S. Deenan, S. Janakiraman, and S. Nagachandrabose, "Image Segmentation Algorithms for Banana Leaf Disease Diagnosis," *Journal of The Institution of Engineers (India): Series C*, vol. 101, no. 5, pp. 807–820, 2020.

[37] J. Shi, H. Jin, and Z. Xiao, "A novel hybrid edge detection method for polarimetric SAR images," *IEEE Access*, vol. 8, pp. 8974–8991, 2020.

[38] M. A. Kats, "Dark field on a chip," *Nature Photonics*, vol. 14, no. 5, pp. 266–267, 2020.

[39] P. Dubey, P. K. Dubey, and S. Changlani, "A Hybrid Technique for Digital Image Edge Detection by Combining Second Order Derivative Techniques Log and Canny," *IEEE Xplore*, pp. 1–6, 2020.

[40] S. Sumijan, S. Arlis, and P. A. W. Purnama, "Fingerprint Identification Using the Hybrid Thresholding and Edge detection for the Room Security," *TEM Journal*, vol. 9, no. 4, pp. 1396–1400, 2020.

[41] "Structured Analysis of the Retina." [Online]. Available: https://cecas.clemson.edu/~ahoover/stare/. [Accessed: 02-Mar-2021].