

# A Survey on Various Edge Detection Techniques in Image Processing and Applied Disease Detection

Wan Muhammad Rahimi Wan Fadzli<sup>1\*</sup>, Ahmad Yusri Dak<sup>2</sup>, Tajul Rosli Razak<sup>3</sup>

<sup>1,2</sup>College of Computing, Informatics and Mathematics, Universiti Teknologi MARA Perlis Branch, Arau Campus, Arau, Perlis.

<sup>3</sup>College of Computing, Informatics and Mathematics, Universiti Teknologi MARA, Shah Alam, Selangor.

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## ARTICLE INFO

### Article history:

Received 30 January 2024

Revised 31 March 2024

Accepted 1 April 2024

Online first

Published 1 September 2024

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### Keywords:

Edge Detection  
Image Processing  
Gradient-based  
Gaussian-based  
Edge Detector  
Canny

### DOI:

10.24191/jcrinn.v9i2.415

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## ABSTRACT

This paper surveys various edge detection techniques in image processing, focusing on their applicability to disease detection. Many researchers encompass studies conducted in the context of various crops and fruits, shedding light on their effectiveness and adaptability. However, the more techniques are used and improved, less comparison has been made between them to look further at their challenges, such as noise sensitivity, scale variability, edge linking, and real-world variability. Also, the study will systematically survey and analyze literature on the ability of edge detection, including classical methods like Robert, Sobel, Prewitt, and Canny, as well as more advanced techniques such as gradient-based and Gaussian-based. This research aims to comprehensively understand the strengths and limitations of different edge detection techniques and can be used as a reference point for selecting and enhancing novel techniques in image processing. Overview, this paper makes a substantial contribution to the field by addressing both traditional edge detection in image processing and applied disease detection. It serves as a comprehensive guide, offering insights, practical advice, and a consolidated view of current research trends, and highlights the potential of edge detection in contributing to advancements in disease detection methodologies making it a valuable resource for researchers and practitioners.

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## 1. INTRODUCTION

In recent years, the field of image processing has witnessed an increase in research projects aimed at developing and enhancing edge detection techniques, focusing on their application in disease detection. Edge detection is a crucial step in image processing, serving as a foundation for various applications, including disease detection in crops and fruits. Gradient-based and Gaussian-based techniques are known for capturing and highlighting abrupt intensity changes in images. The two most popular techniques for edge detection are gradient-based first-order derivative and Gaussian-based second-order derivative, as classified in Fig. 1. Gradient-based techniques leverage the concept of gradients, representing the rate of change of intensity, to identify edges. Operators such as the Robert, Sobel and Prewitt operators compute the gradient of an image, emphasizing regions with significant intensity variations. These methods are

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<sup>1\*</sup> Corresponding author. *E-mail address:* wanmuhammadrahimi@gmail.com  
<https://doi.org/10.24191/jcrinn.v9i2.415>

computationally efficient and effectively detect edges, particularly in scenarios with well-defined boundaries. However, one notable challenge in gradient-based edge detection techniques is their sensitivity to noise.

On the other hand, Gaussian-based techniques focus on smoothing the image using Gaussian filters before detecting edges. The rationale behind this approach is to reduce noise and highlight subtle intensity changes. The Gaussian filter acts as a pre-processing step, enhancing the signal-to-noise ratio and facilitating more robust edge detection. The Canny edge detector, a widely acclaimed technique, combines Gaussian smoothing with gradient computation and non-maximum suppression to identify edges with high precision and low false positives.

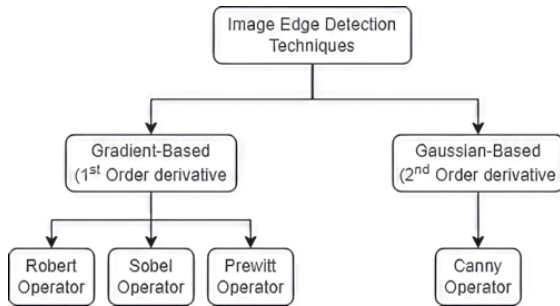


Fig. 1. Classification of edge detection technique

Many researchers have done several studies comparing the gradient-based and Gaussian-based techniques. These studies aim to determine the best technique when analyzing different shapes in image processing applications. Table 1 summarises gradient Gaussian-based techniques based on Mylsamy et al.'s performance analysis (Mylsamy et al., 2022). It reveals characteristics that impact their suitability for different applications. Gradient-based methods, including operators such as Sobel, Prewitt, and Roberts, emphasize intensity gradients, making them computationally efficient and particularly useful for real-time applications. However, the sensitivity to noise and challenges in maintaining edge continuity can limit their performance in complex scenarios.

On the other hand, Gaussian-based techniques, illustrated by operators like Canny, used a Gaussian smoothing step to reduce noise and enhance adaptability to varying scales. This additional processing, while providing noise robustness and improved edge linking, introduces a slightly bigger computational problem. The list of operators summarizes the various techniques available within each category, offering researchers a range of choices based on specific requirements. In the end, noise sensitivity is the key element when selecting between gradient-based and Gaussian-based edge detection methods with potential enhancement approaches. Table 1 illustrates a summary of Gradient-based and Gaussian-based techniques.

Table 1. Summary of Gradient-Based and Gaussian-based techniques

| Feature           | Gradient-Based Techniques  | Gaussian-Based Techniques  |
|-------------------|--|--|
| Main Principle    | Utilizes the image gradient (rate of change of intensity) to detect edges.                   | Applies Gaussian smoothing to the image to reduce noise before identifying edges.      |
| Operator          | Sobel, Prewitt, Roberts  | Canny  |
| Noise Sensitivity | Sensitive to noise, which can impact edge detection accuracy.                                | Less sensitive to noise due to the pre-smoothing step, improving robustness.           |
| Edge Linking      | It may produce fragmented edges, and linking edges can be challenging.                       | Capable of smoother edge linking, resulting in more continuous and connected edges.    |
| Scale Variability | They may struggle with scale variations and require multiple scales for optimal performance. | Addresses scale variability by employing Gaussian smoothing, making it more adaptable. |

|                        |   |  |
|------------------------|---|--|
| Real-World Variability | Performance may degrade in complex real-world scenarios with diverse textures and structures.         | Better handles real-world variability by reducing the impact of noise and enhancing edge continuity. |
| Hybrid Approaches      | Hybrid methods often integrate gradient-based and Gaussian-based techniques for enhanced performance. | Hybrid method can enhance noise resistance and edge localization precision.                          |

In summary, the table compares Gradient-Based and Gaussian-Based edge detection techniques, outlining key characteristics and operators associated with each approach providing insights into their respective strengths and limitations. Gradient-based methods, represented by operators like Robert, Sobel, and Prewitt, focus on utilizing intensity gradients to identify edges. These techniques are generally computationally efficient but can be sensitive to noise. On the other hand, Gaussian-based methods, represent by Canny, incorporate Gaussian smoothing for noise reduction before edge detection. While slightly more computationally complex, these techniques are less sensitive to noise and offer smoother edge linking.

The findings highlight the fundamental trade-offs between computational efficiency and noise resistance. Gradient-based techniques are well-suited for real-time applications but may struggle in noisy environments, while Gaussian-based methods prioritize noise reduction while increased computational complexity. The table highlights the demand selection based on the specific requirements of the application. Additionally, the discussion emphasizes the potential benefits of hybrid approaches that integrate the strengths of both techniques to achieve a balanced compromise between computational efficiency and robust edge detection.

## 2. EDGE DETECTION OPERATOR

Edge detection is vital in image processing for identifying crucial features. This study explains further details of operators Robert, Sobel, Prewitt and Canny, with each characteristic on determining edges within images and offering valuable insights for diverse applications. Table 2 compares various edge detectors based on practical performance analysis by Kumar et al. (2021).

### 2.1 Robert Operator

The Robert edge operator (Roberts, 1965), a fundamental technique in image processing, is known for its simplicity and computational efficiency. Introduced as one of the earliest edge detection methods, the Robert operator focuses on detecting edges by employing a pair of 2x2 convolution kernels. These kernels, designed as simple difference filters, calculate gradients in the horizontal and vertical directions. Despite its straightforward implementation, the Robert operator has limitations regarding its edge detection capabilities. It tends to be less robust in the presence of noise and may produce relatively coarse results compared to more advanced techniques. While its simplicity makes it suitable for specific real-time applications where computational efficiency is critical, the Robert operator is often overshadowed by more sophisticated methods like the Canny operator which offers enhanced precision and adaptability. Researchers and practitioners often deliberate the trade-offs between simplicity and performance when selecting edge detection methods for specific applications.

### 2.2 Sobel Operator

The Sobel operator (Sobel & Feldman, 1973) is a famous edge detection method widely employed in image processing for its improved accuracy compared to regular techniques like the Robert operator. Introduced as a gradient-based operator, the Sobel operator enhances edge detection by convolving the image with a pair of 3x3 kernels, one for detecting changes in intensity along the horizontal axis and another for the vertical axis. This enables the Sobel operator to capture gradient information more effectively, especially in diagonal edge orientations. While it performs better in highlighting edges and reducing noise

than the Robert operator, it still has a general limitation. It may still present sensitivity to noise, and its effectiveness can vary based on the characteristics of the input image. Despite these considerations, the Sobel operator remains a valuable tool in image processing pipelines, finding applications in fields such as computer vision, medical imaging, and object recognition, where precise edge localization is essential. Researchers often appreciate its balance between computational efficiency and improved edge detection capabilities, making it a popular choice in diverse image analysis tasks.

### 2.3 Prewitt Operator

The Prewitt operator (Prewitt, 1970), a widely utilized gradient-based edge detection method in image processing, builds upon the foundational concepts introduced by the Sobel operator. Developed to enhance the Sobel operator's capabilities, the Prewitt operator employs a pair of 3x3 convolution kernels, one for detecting changes in intensity along the horizontal axis and another for the vertical axis. Similar to Sobel, these kernels emphasize gradient information and contribute to improved edge detection, particularly in horizontal and vertical orientations. While the Prewitt operator provides an advantageous middle ground between simplicity and accuracy, it shares some limitations with its predecessor. It may demonstrate sensitivity to noise, and the characteristics of the input image can influence its performance. Despite these considerations, the Prewitt operator remains a valuable tool for edge detection in various image analysis applications, contributing to computer vision, pattern recognition, and medical imaging. Researchers often choose the Prewitt operator for its ability to balance computational efficiency and enhanced edge detection capabilities, making it suitable for a broad range of image processing tasks.

### 2.4 Canny Operator

The Canny edge operator (Canny, 1986) is a well-established and widely utilized edge detection technique in image processing. Introduced by John Canny in 1986, this operator is renowned for its ability to perform high-precision edge detection with reduced sensitivity to noise. Several crucial steps are involved in the multistage approach of the Canny operator, which makes it unique. First, the image undergoes Gaussian smoothing to reduce noise and enhance the signal-to-noise ratio. Next, gradients are calculated using convolution with Sobel kernels, highlighting areas of rapid intensity change. Non-maximum suppression is applied to retain only the local maxima in gradient magnitude, leading to a thinned edge map. Finally, edge tracking by hysteresis helps connect weak to firm edges, resulting in a more robust and continuous edge map. The Canny operator's distinctive characteristics, including its ability to suppress non-maxima and preserve edge connectivity, make it a favoured choice for researchers and practitioners. The precision and adaptability have made it essential in various applications, from computer vision to medical imaging, and further refinements or enhancements to its computational efficiency make it the best edge detection method.

Table 2. A summary of various edge detectors

| Edge Detector    | Advantages  | Limitations   |
|------------------|---|---|
| Robert Operator  | Simple computation, computationally efficient   | Limited edge detection capabilities, sensitivity to noise                       |
| Sobel Operator   | Improved response to diagonal edges, reduced noise sensitivity                          | It may amplify noise, but it is not as effective for diagonal edges             |
| Prewitt Operator | Better detection of vertical and horizontal edges                                       | Limited adaptability to various edge orientations                               |
| Canny Operator   | High-precision edge detection, suppression of non-maxima, and connectivity preservation | Computational complexity, more parameter tuning required, may miss small edges. |

With its simple computation, the Robert operator is computationally efficient but limited in its edge detection capabilities, making it sensitive to noise. The Sobel operator improves edge detection, particularly for diagonal edges, yet may increase noise. Prewitt, highlighting vertical and horizontal edges, presents

limited adaptability to various edge orientations. In contrast, the Canny operator is a multistage process involving Gaussian smoothing, gradient calculation, non-maximum suppression, and edge tracking by hysteresis. While computationally more complex, the Canny operator excels in high-precision edge detection, suppressing non-maxima, and preserving edge connectivity. Many researchers favour the Canny operator for its comprehensive characteristics, making it a popular choice in image processing applications. Because of its characteristics, it can expand with further enhancements to the Canny operator, making it the best edge detection method, with potential improvements in computational efficiency and adaptability to diverse scenarios.

The findings from the table reveal distinct characteristics of each edge detection operator. The Robert operator, while computationally efficient, is limited in its edge detection capabilities and is sensitive to noise. Sobel and Prewitt operators improve on edge detection by emphasizing gradients in different orientations, but they may face challenges with noise and orientation adaptability. The Canny operator stands out as the most comprehensive edge detection technique, addressing many limitations of the other operators emerges as a robust and reliable choice for edge detection in diverse applications.

### **3. REVIEW OF LITERATURE SURVEY ON USED EDGE DETECTION AND APPLICATION IN DISEASE DETECTION**

In recent years, various edge detection methods have been proposed by researchers to enhance the accuracy and used for efficiency of image processing applications. Researchers Wang et al. (2022) introduced an improved Canny algorithm for packaging bag edge detection, utilizing Augmented Otsu for enhanced grayscale stretching and thresholding. This approach led to a 12.63% increase in information entropy, showcasing richer edge information. Building on this, X. Zhang & Yuan (2022) addressed irregular edges and noise in printed products by enhancing the Canny operator with a bilateral filter, resulting in improved positioning accuracy and continuous edges. Meanwhile, Ravivarma et al. (2021) opted for the Sobel algorithm due to its lower noise decline at higher levels. Towards overcome thick boundaries and broken edges, they introduced an extra mask and adjusted coefficients, achieving ideal edge detection.

Researchers Rahmawati et al. (2021) took a hybrid method by combining Prewitt and Canny methods for inverted image edge detection, achieving an average accuracy of 78.90% and an error rate of 21.10%. Similarly, Rubiagatra et al. (2023) proposed a novel ear biometric identification method using Gabor filters and Canny edge detection, showcasing excellent accuracy and robustness across a small dataset. Wei and Xu (2021) explored lane edge detection, replacing the Robert operator with the Canny algorithm in Hough transform, demonstrating improved real-time performance. Archana et al. (2021) introduced a Sobel 12D edge detection algorithm with additional direction templates, outperforming traditional Sobel operators.

In the context of image identification, Wanto et al. (2021) compared combined edge detection techniques, finding that Roberts and Canny outperformed Sobel and Prewitt with an accuracy of 92.84% versus 68.75%. Y. Zhang et al. (2021) tackled grid shadows in defect detection by combining Prewitt and Canny operators for improved foreground edge and higher defect recognition accuracy. Meanwhile, Fakhri et al. (2019) proposed a simple effective method for crack detection using Gaussian and Prewitt filters, outperforming manual and random forest methods. Guo et al. (2024) focused on scratch detection, presenting an improved Canny operator combined with probabilistic Hough transform, achieving an impressive accuracy of 97.96%. Researchers Syahfitri et al. (2023) proposed the Canny edge detection algorithm to identify density edges in kaffir lime peels and results tested that the right edge detection method in carrying out the edge detection process in the image of kaffir lime peel is the Canny edge detection Algorithm.

Shifting towards applications in agriculture of disease detection, starts from researchers Tangtisanon and Kornrapat (2020) utilized a Canny and Sobel model for curling leaf disease detection, achieving 96.6% accuracy with reasonable computation time. Moving to plant disease detection, Bonifacio et al. (2020) used

the Gray-Level Segmentation and Canny Operator for maize disease detection, attaining an overall accuracy of 92.50%. Similarly, Vijayan et al. (2021) applied Canny edge detection in tomato plant disease identification, achieving an average accuracy of 80%. Researcher Greeshma O. S (2021) proposed a CNN-based plant disease recognition model using edge detection, achieving an overall accuracy of 90%. Meanwhile, Yedukondalu et al. (2023) focused on early-stage disease detection in agriculture using the Canny edge detection algorithm. M.Manju et al. (2019) proposed an improved Canny edge detection method for plant disease identification, demonstrating a higher overall accuracy of 93.33%. Researchers Anitharani et al. (2022) incorporated Canny edge detection into plant leaf disease image detection and classification with CNN, achieving an average accuracy of 92%. In the context of paddy leaf disease, Dhiman and Saroha (2022) integrated the Canny operator with CNN for quick feature selection and achieved a total accuracy of 97.692%. Similarly, Jerome et al. (2023) used Sobel and Canny operators in a deep learning-based method for healthy and unhealthy plant leaf detection, achieving a high accuracy of 92%. Lastly, Taohidul Islam et al. (2019) introduced novel approaches for plant disease detection, incorporating Canny edge detection for extracting texture and shape information, with an achieved accuracy of 88%. These various methodologies collectively contribute to advancing the field of image processing and detection techniques in various areas.

Table 3. Analysis of various edge detection techniques used

| Authors                  | Robert Operator | Sobel Operator | Prewitt Operator | Canny Operator |
|--------------------------|-----------------|----------------|------------------|----------------|
| Wang et al. (2022)       |                 |                |                  | ✓              |
| X. Zhang and Yuan (2022) |                 |                |                  | ✓              |
| Ravivarma et al. (2021)  |                 | ✓              |                  |                |
| Rahmawati et al. (2021)  |                 |                | ✓                | ✓              |
| Rubiagatra et al. (2023) |                 |                |                  | ✓              |
| Wei and Xu (2021)        | ✓               |                |                  |                |
| Archana et al. (2021)    |                 | ✓              |                  |                |
| Wanto et al. (2021)      | ✓               | ✓              | ✓                | ✓              |
| Y. Zhang et al. (2021)   |                 |                | ✓                | ✓              |
| Fakhri et al. (2019)     |                 |                | ✓                |                |
| Guo et al. (2024)        |                 |                |                  | ✓              |
| Syahfitri et al. (2023)  |                 |                |                  | ✓              |

Table 4. Analysis of edge detection techniques applied in disease detection

| Authors                          | Plant/Disease | Edge detector | Advantages   | Limitations  | Accuracy |
|----------------------------------|---------------|---------------|--|--|----------|
| Tangtisanon and Kornrapat (2020) | Leaf          | Canny         | High precision. Canny provides accurate localization of edges, ensuring that the detected edges closely align with the actual boundaries in the image. | Canny involves multiple processing steps, including Gaussian smoothing, gradient computation, and edge tracking, which can be computationally intensive. | 96.6%    |
| Bonifacio et al. (2020)          | Leaf          | Canny         | It minimizes false positives by suppressing non-maxima, resulting in a reduced likelihood of detecting spurious edges caused by noise                  | While Canny is less sensitive to noise, it may still be affected by high levels of noise, impacting the accuracy of edge detection                       | 92.50%   |
| Vijayan et al. (2021)            | Leaf          | Canny         | Canny exhibits robust performance in diverse environments, allowing for effective edge detection across different image conditions,                    | Performance may be sensitive to the selection of parameters, such as the threshold values, requiring careful tuning for optimal results                  | 80%      |

|                              |      |               |  |  |         |
|------------------------------|------|---------------|--|--|---------|
| Greeshma (2021)              | Leaf | Canny         | The non-maximum suppression step thins the detected edges, preserving only the local maxima in gradient magnitude and contributing to more accurate edge localization.                     | The algorithm's multistage process may require significant memory, making it less suitable for resource-constrained environments                     | 90%     |
| Yedukondalu et al. (2023)    | Crop | Canny         | Canny provides consistent results across different images and scenarios, making it a reliable choice for edge detection in diverse applications.   | Canny may struggle to accurately represent complex junctions where multiple edges intersect, potentially leading to incomplete edge detection.       | -       |
| M.Manju et al. (2019)        | Leaf | Canny         | Canny maintains edge connectivity by employing hysteresis during the tracking phase, ensuring that weak edges are connected to solid edges   | The algorithm may be affected by variations in illumination, causing challenges in detecting edges consistently across different lighting conditions | 93.33%  |
| Anitharani et al. (2022)     | Leaf | Canny         | Canny operates through a comprehensive multistage process, including Gaussian smoothing, gradient calculation, non-maximum suppression, and edge tracking, leading to improved performance | Canny may struggle to detect edges with low contrast, leading to potential omissions in the presence of subtle intensity changes                     | 92%     |
| Jerome et al. (2023)         | Leaf | Sobel & Canny | The Gaussian smoothing in Canny allows the algorithm to adapt to different scales, making it effective in detecting edges of varying widths  | In specific scenarios, Canny may produce fragmented edges, especially when dealing with noisy images or images with intricate textures               | 92%     |
| Dhiman and Saroha (2022)     | Leaf | Canny         | Canny incorporates automatic thresholding, reducing the need for manual parameter tuning and making it user-friendly   | The algorithm is primarily designed for thin edge detection and may encounter challenges when dealing with vast or textured edges                    | 97.692% |
| Taohidul Islam et al. (2019) | Leaf | Canny         | The algorithm includes Gaussian smoothing, enhancing its robustness against noise and providing a smoother gradient magnitude  | While Canny is less sensitive to noise, it may still be affected by high levels of noise, impacting the accuracy of edge detection                   | 88%     |

#### 4. CONCLUSION

In conclusion, this paper briefly introduced various edge detection techniques and a review of their applicability to disease detection. It also reviewed the gap for edge detection techniques and various edge operators through a comprehensive comparative analysis, the paper highlights the refine characteristics, advantages, and limitations of operators such as Robert, Sobel, Prewitt, and Canny in Table 1 and Table 2 to give a more precise idea for researchers to evaluate and identify the best operators and techniques according to their application in edge detection. It led to the findings that Canny operator stands out as the most comprehensive edge detection technique. The literature review tables in Table 3 and Table 4 contribute valuable insights into the real-world applicability of different edge detection methods, providing a comprehensive understanding of their usage across various circumstances. The findings emphasize the characteristic trade-offs between computational efficiency and precision, highlighting the importance of customized selection based on specific application requirements that led to the potential of edge detection

in contributing to advancements in disease detection methodologies. The paper's main message indicates on the critical role of edge detection in image processing and the need for a thorough understanding of various techniques that can be applied in disease detection. By highlighting the adaptability and effectiveness of the Canny operator, the paper offers useful vision and gap to both researchers and practitioners for making a significant contribution to the existing knowledge in the field.

## 5. ACKNOWLEDGEMENTS/FUNDING

The authors would like to acknowledge the support of College of Computing, Informatics and Mathematics, Universiti Teknologi Mara (UiTM), Cawangan Perlis, Kampus Arau and College of Computing, Informatics and Mathematics, Universiti Teknologi MARA, Shah Alam, Selangor, Malaysia.

## 6. CONFLICT OF INTEREST STATEMENT

All authors declare that they have no conflicts of interest to disclose.

## 7. AUTHORS' CONTRIBUTIONS

**Wan Muhammad Rahimi Wan Fadzli** conceptualised the central research idea, provided the theoretical framework from existing research, carried out the research, wrote and revised the article. **Ahmad Yusri Dak** and **Tajul Rosli Razak** designed the research, supervised research progress, anchored the review, revisions and approved the article submission.

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