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Edge Detection Algorithm and Image Classification in Digital Image Processing

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ABSTRACT

Digital image processing is one of the fields that is constantly evolving in tandem with artificial intelegence and machine learning. The purpose of this study is to perform a systematic review of various methods used in digital citra classification and detection, as well as to compare the effectiveness of traditional algorithms like Sobel, Prewitt, and Canny with deep learning-based algorithms like Convolutional Neural Networks (CNN). The Systematic Literature Review (SLR) method is used to identify, evaluate, and analyze 78 related articles that provide preliminary data wit inclusive and exclucive criteria from 300 articles. The primary focus includes edge detection, citra-based object classification (fruit, leaf, face, and medical image), and fitness entrapping techniques such as GLCM, LBP, HSV, and fraktal. The study's findings indicate that deep learning, specifically CNN, consistently provides higher accuracy in classification than traditional methods, despite requiring a larger computer power**.** It is hoped that this research would serve as a guide for developing more effective and efficient digital image processing systems in a variety of application domains, including pharmaceutical, medical, digital safety, and creative industries.
KEYWORDS: edge detection; clasification; cnn digital image processing; deep learning

INTRODUCTION

A subfield of computer science called "digital image processing" is concerned with the computational processing, analysis, and interpretation of images (O'Mahony et al., 2020). Digital image processing is now a commonly created and used solution due to the growing requirement for automation and precision in a variety of industries, including industry , security, healthcare, and agriculture (Thesing et al., 2021). Edge detection, a method for locating object boundaries in an image, is a crucial step in image processing (Zulfikri et al., 2025). Segmentation, feature extraction, and object recognition all depend on edge detection (Mulyani et al., 2022). For this, several well-liked techniques are frequently employed, including sobel, canny, Prewitt, and Laplacian of Gaussian (LoG) (Harefa, 2020; Maximillian et al., 2023; Sulistyo et al., 2025). However, the type of image, the analysis's end aim, and the image's noise level all have a significant impact on the edge detection method selection(Yilmaz et al., 2020).

Additionally, using extracted features to classify photos into distinct groups is an essential step in the process (Fatimah & Agustin, 2025). Image classification techniques range widely, from deep learning algorithms like Convolutional Neural Networks (CNN)(Fuadah et al., 2022), which have shown excellent performance in the automatic classification of a variety of image types, including fruits, leaves, faces, and medical images(Firdaus et al., 2025; Liantoni Febri, 2022a; Saputra et al.,

2024; Zulfikri et al., 2025), to more conventional machine learning algorithms like K-Nearest Neighbor (KNN) and Support Vector Machine (SVM) (Naufal et al., 2021; Tan et al., 2024).

A systematic review is required to compile, contrast, and evaluate the patterns and efficacy of these techniques in light of the substantial research that has been done, with differing methodologies and outcomes(Habibi & Artha, 2023). Thus, in order to compare the effectiveness of conventional and contemporary methods in digital image processing, this study employs a Systematic Literature Review (SLR) technique to find and assess different edge detection and image classification algorithms.

1.1 Formulation of the Problem

In light of the background information provided, the research's problem formulation is as follows:

1. Based on the findings of a literature review, which edge detection and image classification techniques have been applied in digital image processing?
2. In the context of image processing and classification, how do deep learning algorithms (like CNN) fare in comparison to more conventional algorithms (like Sobel, SVM, and KNN)?
3. In the development of digital image processing systems, what are the most recent research trends and directions?

1.2 Research Objectives

The objectives of this research are to:

1. Identify and classify methods used in edge detection and digital image classification based on a relevant literature review.
2. Analyze and compare the advantages and disadvantages of traditional and deep learning algorithms in image processing.
3. Provide an overview of current developments in digital image processing research and potential future developments.

1.3 Advantages of Research

The following advantages are anticipated from this research:

1. For Scholars: to act as a resource for comprehending the state of research and current developments in digital image processing.
2. System developers can use this guide to choose the best edge detection and picture classification algorithms for their requirements.
3. For Education: Provides material to aid in learning and the creation of final projects pertaining to artificial intelligence and digital image processing.

1.4 Issue Restrictions

To concentrate on this investigation, the study is restricted to:

1. Concentrate on machine learning and deep learning algorithms for image categorization and edge detection techniques (Sobel, Prewitt, Canny, LoG, etc.).
2. Only works published in national or international journals or proceedings during the last ten years (if at all possible) are included in the reviewed literature.
3. This focuses on contrasting methods and evaluating outcomes rather than going into great detail about the technical parts of programming.

METHODOLOGY

2.1 Type of Research

This research is a Systematic Literature Review (SLR), a qualitative research method used to identify, evaluate, and synthesize various scientific literature relevant to the topic of digital image processing, specifically in terms of edge detection and image classification. The SLR was

conducted systematically with clear stages and criteria to ensure objective, structured, and replicable results.

2.2 Research Stages

This SLR was conducted through the following five main stages:

1. Identifying the Topic and Research Question
   Determining the focus of the SLR study, namely edge detection and digital image classification methods and a comparison of machine learning and deep learning approaches.
2. Determining Inclusion and Exclusion Criteria
   Used to filter articles relevant to the study focus.
3. Literature Search
   Searching articles from various reliable scientific sources.
4. Study Quality Evaluation
   Assessing the validity and contribution of articles that passed the initial selection.
5. Data Extraction and Analysis
   Collecting primary data and analyzing it to answer the research questions.

2.3 Literature Search Sources and Strategy

The literature search was conducted through several scientific databases and digital repositories, such as:

1. Google Scholar
2. IEEE Xplore
3. ScienceDirect
4. SpringerLink
5. ResearchGate
6. Garuda Ristekdikti

Keywords used in the search included:
"digital image processing," "edge detection algorithms," "image classification," "CNN for image," "SVM image classification," "comparative study of deep learning, machine learning, image processing," and "SLR in computer vision."

2.4 Inclusion and Exclusion Criteria

Table 1

Inclusion and Exclusion Criteria

No.	Inclusion	Exclusion
1	Articles published in the last 5 years (2020–2025)	Articles published before 2020
2	Relevant to the topic of edge detection and image classification	Not relevant or only discussing general basic theory
3	Using machine learning or deep learning methods	Does not include experiments or test results
4	Articles in Indonesian or English	Articles with limited or incomplete access

2.5 Data Analysis Techniques

Data extracted from each article includes:

1. Name and year of publication
2. Research objective
3. Method used (edge detection/classification algorithm)

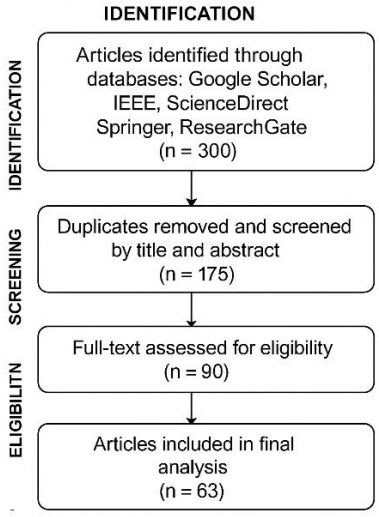
4. Dataset used
5. Test results (accuracy, precision, recall, etc.)
6. Strengths and weaknesses of the method

The data is then compiled into a comparison table and analyzed qualitatively to identify patterns, trends, and research gaps.

RESULTS AND DISCUSSION

1.1 Literature Review Results

Based on the literature search and selection process using the PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analys) approach, 63 scientific articles were selected for further analysis. These articles were published between 2020-2025 and come from various domains such as agriculture, health, forensics, education, and the creative industry.



Picture 1. Prisma Diagram

From the literature analysis, the reviewed studies can generally be grouped into two main focuses:

1. Image Edge Detection

   Edge detection is used for the initial segmentation of objects in images, particularly in cases such as leaves, faces, and money (Jing et al., 2022). The most commonly used algorithms include:

   a. Sobel: easy to implement and quite effective for initial object boundary detection (Alfita et al., 2022; Gansar Suwanto et al., 2021; Kong et al., 2023; Lynn et al., 2021; Maximillian et al., 2023; Owotogbe et al., 2020; Peng-o & Chaikan, 2021; Ranjan & Avasthi, 2023; Santoso et al., 2019; Singh, 2021; Tian et al., 2021).
   b. Prewitt and Canny: more sensitive to noise but provide sharper edge detection results (Alfita et al., 2022; Avci, 2022; Idris et al., 2022; Janna, 2025; Kumar Shah et al., 2020; Lynn et al., 2021; Maximillian et al., 2023; Owotogbe et al., 2020; Putra & Susilawati, 2021; Sulistyo et al., 2025; Tenekeci et al., 2025; Wang & Sun, 2021; Zangana et al., 2024).
   c. Laplacian of Gaussian (LoG): used for complex imagery (Ansari et al., 2017; BenHajyoussef & Saidani, 2024; Harefa, 2020; Haryono, 2020; Moelya et al., 2024; Sholehurrohman & Habibi, 2023; Sinaga et al., 2021; Yuan et al., 2024).

d. Some studies also use bio-inspired algorithms such as Ant Colony Optimization (ACO) to improve edge detection accuracy (Benhamza et al., 2013; Chaudhari & Gulve, 2025; David et al., 2022; Liantoni Febri, 2022; Rizan, 2025; Tenekeci et al., 2025; Zhang et al., 2015).

2. Image Classification

The primary goal of image classification is to group objects in an image into specific classes. The approaches used vary widely, including:

a. Traditional Machine Learning: K-Nearest Neighbor (KNN), Support Vector Machine (SVM), Naive Bayes, and Random Forest. These methods are commonly applied to images of fruit, leaves, and faces, with accuracy results varying between 70–90% depending on the quality of the extracted features (Amrullah, 2025; Farid Naufal, 2021; Fatimah & Agustin, 2025; Hartono et al., 2020; Hassan et al., 2020; Hossen et al., 2025; Jing et al., 2022; Mapoka et al., 2024; Muchtar et al., 2024; Naufal et al., 2021; Sanu, 2025; Tan et al., 2024; Winanti et al., 2023; Yilmaz et al., 2020).

b. Deep Learning: Convolutional Neural Networks (CNN) have become the dominant method in modern image classification. CNNs are used to classify oranges, fish, faces, and even skin cancer. CNN models generally achieve higher accuracy than traditional methods, averaging above 90% (Ardhito et al., 2024; Aryawan et al., 2023; Hassan et al., 2022; Intyanto, 2021; Jing et al., 2022; Karypidis et al., 2022; Paramastri et al., 2024; Rijal et al., 2024; Rumui et al., 2025; Xian et al., 2024; Yilmaz et al., 2020).

1.2 Comparative Analysis of Algorithms

Table 2

Algorithm Type Advantages Disadvantages

No.	Algorithm	Type	Advantages	Disadvantages
1	Sobel	Edge Detection	Simple, fast implementation	Less sensitive to smooth contours
2	Prewitt	Edge Detection	Simple, fast implementation	Less sensitive to smooth contours
3	Canny	Edge Detection	Sharp and accurate results noise-resistant	Higher complexity
4	SVM, KNN	Traditional Clasification	Suitable for small datasets, easy to interpret	Performance decreases on large and complex data
5	CNN	Deep Learning	High accuracy, automated feature extraction	Requires large data sets and high computational requirements
6	Random Forest	Ensemble Learning	Stable, not prone to overfitting	Less suitable for highly variable images

1.3 Discussion

Based on the analysis, it can be concluded that:

1. Edge detection remains a crucial stage in image processing, especially in preprocessing before classification. The Canny method generally provides the best results in complex cases.

2. Deep learning, particularly CNNs, demonstrates significant advantages in classification accuracy compared to traditional methods. However, using CNNs requires large training data and adequate hardware.
3. Recent research shows an increasing trend in the use of hybrid methods, which combine several algorithms to improve performance, for example, CNN + SVM or CNN + PCA.
4. There is still room for development for the application of image processing in the context of real-time, limited resources, and local applications (such as the classification of local plants, batik, or waste).

CONCLUSION

Based on the results of a literature review of 50 scientific articles related to edge detection and digital image classification, the following conclusions were obtained:

1. The most frequently used edge detection methods in digital image processing are Sobel, Prewitt, and Canny. Among these methods, Canny provides more precise results and is robust to noise, but requires more computational time than Sobel and Prewitt.
2. In terms of image classification, deep learning approaches, particularly Convolutional Neural Networks (CNN), generally demonstrate higher accuracy and performance than traditional algorithms such as K-Nearest Neighbor (KNN), Support Vector Machine (SVM), and Naive Bayes.
3. There is an increasing trend in the use of hybrid methods, namely a combination of edge detection and classification techniques based on machine learning and deep learning to improve system accuracy and efficiency.
4. Various types of image objects have been studied, such as images of fruit, leaves, faces, food, money, and medical images, demonstrating the broad application of digital image processing in various fields.
5. Although deep learning methods excel in terms of performance, their implementation still presents challenges, particularly related to the need for large datasets and high computational resources.

Recommendations

Further research should consider a hybrid approach combining edge detection and deep learning to improve both efficiency and accuracy.

1. Standardized local datasets for specific objects such as Indonesian plants, batik, or domestic waste are needed to encourage the adoption of image processing technology at the national level.
2. The development of lightweight and efficient CNN-based models (such as MobileNet and SqueezeNet) should be encouraged, particularly for real-time applications on computationally limited devices like smartphones and embedded systems.
3. This literature review could be expanded to include aspects of image segmentation, data augmentation, and model evaluation using more comprehensive metrics (F1-score, confusion matrix, etc.).

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