Comparing Canny And Prewitt Techniques In Steganography Applications To Increase Capacity

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APPROVAL

This thesis titled on "**Comparing Canny and Prewitt Techniques in Steganography Applications to increase capacity**", submitted by **Dewan Lamia Sathi (ID: 201-35-3069)** to the Department of Software Engineering, Daffodil International University has been accepted as satisfactory for the partial fulfillment of the requirements for the degree of Bachelor of Science in Software Engineering and approval as to its style and contents.

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Comparing Canny and Prewitt Techniques in Steganography Applications to increase capacity

DEWAN LAMIA SATHI

Thesis submitted in fulfillment of the requirements

for the award of the degree of

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ABSTRACT

Steganography-the method of concealing data within digital media-is an important approach to secure communication because even the very existence of a secret message can be concealed. In this thesis, an experimental approach is adopted in using edge detection techniques in image steganography to investigate how embedding capacity can be optimized with high-quality images. The study examines and compares two popular methods: Canny and Prewitt. Canny's good precision and robustness against noise make it suitable for selective embedding with minimal perceptibility, while Prewitt provides computational efficiency and higher embedding capacity because of its wider range of edge detection. The proposed methodology integrates the Advanced Encryption Standard encryption and Run-Length Encoding compression to secure and minimize the size of the data. The encrypted and compressed data are embedded in the edge-detected areas of a cover image through LSB substitution guided by a Linear Congruential Generator for enhanced security. Experimental results demonstrate that while Canny gives better image quality with higher PSNR and SSIM values, the embedding capacity for Prewitt is higher compared to Canny. On the other hand, Prewitt's computational efficiency and capacity make it suitable for real-time or resource-constrained applications. Evidence that a pragmatic trade-off between embedding capacity and image quality does exist is given by this work; furthermore, Canny turns out to be more appropriate for security-critical applications, while Prewitt-for those where capacity and/or processing speed is in the first place. Future work could investigate hybrid edge detection or more sophisticated compression in pursuit of further optimizing steganographic performance.

Keywords:steganography, canny, prewitt, run length encoding, LSB, LCG;

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CHAPTER 1
INTRODUCTION

1.1 INTRODUCTION

Steganography is the science of concealing information within digital media and has gained much inroad in this modern digital world towards becoming one of the most prominent methods of secret communications in these fields: data security, intelligence, and privacy protection. Whereas most cryptography methods aim at concealing the content of a message, steganography aims to make the existence of the very message undetectable. Some challenges for image steganography include exactly how to balance embedding capacity and the imperceptibility of the image[3]. The normal LSB approach has been adopted in the techniques of steganographic methods, but this may not be suitable for embedding a huge amount of data across an image as doing such reduces its quality.

In addition, in the pursuit of the proper balance between the capacity and imperceptibility issues in steganography, several researchers have tried using edge detection algorithms. Edge regions are themselves robust against visible distortion because of the high contrast between neighboring pixels and thus can afford to embed more data without significant degradation in the quality of the images[4].

The Canny and Prewitt edge detection methods are among the most commonly used in image processing,each having certain advantageous features. With good accuracy, the Canny algorithm allows for fine edge detection; hence, it is a potential candidate infine data embedding with high embedding capacity. In comparison, the Prewitt operator is computationally simpler and quicker than the Canny operator, possibly more applicable in situations where there is a need to minimize processing time.[2]

It makes a comparative study on the Canny and Prewitt edge detection techniques in the context of steganographic applications to optimize the three important factors: data capacity, image quality, and computational efficiency. The proposed model encrypts the secret message using AES, compresses it using RLE to reduce the size, and then embeds it in the edges of the cover image detected by either Canny or Prewitt using a randomized LSB technique guided by

LCG. The work done here presents a study on such a comparison in a systematic manner for the choice of a better edge detection method for steganography applications.

1.2 Background of the Study

Steganography, the art of concealing information within digital media, has emerged as a critical tool for secure communication in the modern digital age. This technique differentiates itself from cryptography, which focuses solely on hiding the content of a message, by ensuring that the existence of the message itself remains undetectable.

The roots of steganography trace back to ancient civilizations where messages were hidden in physical objects or texts. However, the advent of digital media has transformed this field, enabling the embedding of information in images, audio, and video files. In the context of digital images, steganography utilizes the inherent redundancies in pixel data to embed secret information. These advancements have made it a cornerstone technology in areas like secure communications, privacy preservation, and data protection.

Despite its advantages, digital steganography faces significant challenges, particularly in balancing embedding capacity with image quality. Over-embedding can lead to visible distortions, making the steganographic content detectable. This challenge has led to the exploration of edge detection techniques, such as the Canny and Prewitt algorithms, to identify robust regions within an image that can securely conceal data without perceptible quality loss.

These edge-based approaches take advantage of the natural robustness of edge regions against visual distortions, enhancing the embedding process. By focusing on these regions, steganography can achieve higher data capacity while maintaining the imperceptibility of the host image, marking a significant evolution in this field. This research builds on these principles, aiming to optimize the trade-offs between embedding capacity and image quality using advanced edge detection techniques.

1.3 The Origins of Steganography

The origins of steganography trace back thousands of years, showcasing its enduring importance in secret communication. The term "steganography" is derived from the Greek words "steganos," meaning covered or concealed, and "graphein," meaning to write. Ancient civilizations often

used ingenious methods to hide messages, from writing on wax tablets covered by a layer of wax to tattooing messages on messengers' shaved heads, which were concealed as their hair regrew.

Historical texts reveal various examples of steganography being used in wartime strategies and espionage. During the Renaissance, practitioners embedded messages within the lines of books or paintings, a method that required a trained eye to decode. Invisible ink, a common technique used during the Revolutionary War, further highlights the evolution of steganographic practices.

The advent of the digital age has expanded the scope of steganography beyond physical methods. In the context of digital media, steganography involves embedding information within images, audio, or video files.[3] This transformation has revolutionized the field, enabling secure communication in an increasingly interconnected world. Today, steganography is applied in fields such as digital watermarking, copyright protection, and secure messaging, highlighting its versatility and relevance.

Modern steganographic techniques leverage advanced algorithms to ensure the concealed data remains undetectable.[4] By utilizing redundancies in digital file structures, these methods can embed substantial amounts of information without compromising the carrier file's integrity. This research delves into these modern practices, focusing particularly on image steganography and the innovative use of edge detection techniques to enhance capacity and maintain image quality[2].

1.4 History Of Image Steganography

The earliest examples of steganography date back to ancient times, where physical techniques were used to hide messages. For instance, during the Greco-Persian wars, messages were hidden under wax on wooden tablets to escape detection. Another notable example is the use of shaved heads in ancient Greece, where a message would be tattooed on the scalp of a messenger, who would then wait for their hair to grow back before delivering the hidden message.

The advent of computers and digital media transformed steganography from a physical practice to a sophisticated digital technique. With the rapid development of multimedia technologies, digital steganography emerged as a means to hide information within digital files, such as images, videos, and audio signals. Images, in particular, became a popular medium due to their

widespread use and the abundance of redundant data that could be manipulated without significantly altering the visual quality.

The Least Significant Bit (LSB) technique marked one of the earliest and most fundamental methods of digital image steganography. By modifying the least significant bits of pixel values, secret information could be embedded into an image in a way that was imperceptible to the human eye. Despite its simplicity, LSB steganography was vulnerable to attacks such as statistical analysis and noise introduction, leading to the development of more robust techniques.

As the field evolved, researchers began incorporating advanced algorithms to improve the imperceptibility, capacity, and robustness of steganographic systems. Techniques such as transform domain methods, which operate on the frequency components of images rather than the spatial domain, gained prominence. For instance, the Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT) have been widely used to embed secret information into image coefficients, providing better resilience against compression and other image processing operations.

Edge-based steganography methods, like the one proposed in this thesis, represent another significant advancement. These methods leverage edge detection algorithms, such as Canny and Prewitt, to identify regions in an image where embedding data is less likely to disrupt its visual appearance. Combined with cryptographic techniques like Advanced Encryption Standard (AES), modern steganography systems achieve enhanced security by ensuring that even if the hidden data is detected, it remains undecipherable.

The primary application of steganography has always been secure communication, particularly in scenarios where encryption alone is insufficient or would draw undue attention. In recent decades, the field has expanded to include applications in watermarking for copyright protection, digital rights management, and covert communication in sensitive areas such as military and intelligence operations. However, the misuse of steganographic techniques for illegal activities, such as hiding malicious software or illicit data, has also raised ethical and legal concerns.

1.5 Role of Text Encoding In Image Steganography

Text encoding plays a critical role in the process of image steganography, acting as the bridge between the data to be hidden and the carrier medium. By converting textual data into binary or ASCII formats, encoding ensures compatibility with the digital image's pixel-based structure. This transformation is pivotal for embedding information securely and efficiently.

Text encoding facilitates the preparation of the secret message in a format suitable for integration into the least significant bits (LSB) of pixel values. This binary conversion of text enables seamless embedding without altering the carrier image's perceptual quality. Encoding schemes like ASCII, UTF-8, or Base64 are commonly used to achieve this conversion.

Moreover, encoding serves as the foundation for subsequent data manipulation processes, such as compression and encryption. For instance, Run-Length Encoding (RLE) is applied to reduce the size of the encoded text, optimizing the embedding capacity. Similarly, Advanced Encryption Standard (AES) encryption is performed on the encoded data to enhance security, ensuring that even if the steganographic content is detected, the hidden message remains inaccessible.

The role of encoding extends to error detection and correction mechanisms, ensuring the integrity of the embedded data. In scenarios where the carrier image undergoes modifications or degradation, robust encoding helps retrieve the hidden information accurately. This makes encoding not just a preparatory step but a crucial component of the steganographic workflow.

In conclusion, text encoding is integral to image steganography, enabling the efficient, secure, and imperceptible embedding of data. Its synergy with other processes like compression and encryption underlines its importance in modern steganographic techniques. Combining data compression with encryption enhances both the capacity and security of steganographic systems. RLE and AES are effective in reducing data size and protecting confidentiality, respectively.

1.5 Application Of Image Steganography

Image steganography is widely applied in fields requiring covert communication, secure data storage, and digital rights management. It embeds secret information within digital images in a way that is imperceptible to the human eye, leveraging the redundancy in image data to encode the message.[2] One key application is in secure communication, where sensitive data, such as confidential documents or passwords, is transmitted hidden in images to prevent unauthorized

interception. It is also used in digital watermarking to protect intellectual property by embedding ownership information into multimedia content.

Another crucial application is in medical imaging, where patient records and diagnostic information can be securely embedded into medical scans to ensure data integrity and privacy. Additionally, image steganography supports authentication by embedding unique identifiers in digital files, verifying their origin and preventing tampering[5]. Emerging areas include steganography in machine learning models, where encoded data can be used for secure model updates and distribution. Its versatility, combined with advancements in algorithms like Least Significant Bit (LSB) substitution and adaptive techniques, makes it a valuable tool in modern digital security.[6]

1.6 Classification of Image Steganography

Image steganography can be broadly classified based on the techniques used to hide data within images. The primary categories are:

1. **Spatial Domain Techniques**: These methods directly modify the pixel values of an image to embed data. The most common technique in this category is **Least Significant Bit (LSB) Substitution**, where the least significant bits of pixel values are replaced with the secret message bits. Other techniques include pixel-value differencing and mapping-based methods.
2. **Transform Domain Techniques**: These methods embed data into the transformed coefficients of an image, such as Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT), or Discrete Fourier Transform (DFT). These techniques are more robust to image processing operations like compression and resizing, making them suitable for applications where resilience is critical.
3. **Adaptive or Statistical Techniques**: These techniques analyze the image's properties, such as texture and edges, to decide optimal regions for data embedding. This enhances imperceptibility and security by targeting areas less likely to reveal hidden data.
4. **Spread Spectrum Techniques**: These involve spreading the hidden data across a wide frequency spectrum of the image, reducing the chances of detection. This method is particularly robust against noise and attacks.

5. **Hybrid Techniques**: These combine two or more methods, such as spatial and transform domains, to enhance both robustness and imperceptibility.
6. **Novel Techniques**: Emerging methods include deep learning-based steganography, which leverages neural networks to encode and decode data, offering high capacity and imperceptibility.

Each classification addresses specific trade-offs between capacity, security, and robustness, depending on the application's requirements.

1.7 problem Statement

Current Limitations: Although methods are now used, including Least Significant Bit (LSB) insertion, they often leave data exposed to visual detection and steganalysis.[3]

Need for improved reliability: Improved security and imperceptibility of embedded information are desperately needed, and more trustworthy data concealing techniques are needed.

Challenge of Detectability: Because it is easy to identify the data concealing strategies in use today, more sophisticated approaches that reduce detection risk and enhance data integrity must be developed.

1.8 Research Objective

Embedding More Data in Edges: This objective focuses on utilizing the edges of images, which are typically high-frequency regions, to embed more data without significantly altering the image's visual quality. Edges naturally exhibit greater variations in pixel intensity, making them less sensitive to minor modifications. Leveraging edge-detection algorithms, such as Sobel or Canny, ensures the hidden data remains imperceptible while maximizing embedding capacity.

Increasing Secure Communication: This objective aims to enhance the security of steganographic techniques by implementing advanced encryption, adaptive embedding strategies, or steganalysis-resistant algorithms. Secure communication ensures that even if steganographic content is intercepted, unauthorized entities cannot extract or detect the hidden information, maintaining the confidentiality and integrity of sensitive data.

1.9 Motivation

The motivation for this research stems from the significant limitations of existing steganographic techniques, particularly the Least Significant Bit (LSB) method. While LSB insertion is a commonly used approach for embedding data within images, it is plagued by critical vulnerabilities. Embedded data often becomes susceptible to visual detection and steganalysis,

undermining its security. Furthermore, these methods typically offer limited capacity, making it challenging to accommodate larger messages essential for secure communication in practical scenarios. Additionally, the reliability of existing techniques is hindered by their inability to achieve a balance between imperceptibility and robustness, thereby compromising both image quality and data security.

To overcome these challenges, this research focuses on enhancing the data embedding capacity of images while maintaining imperceptibility. It aims to ensure secure communication by integrating advanced techniques and leveraging the strengths of Canny and Prewitt edge detection algorithms for true edge detection and noise-free image processing. Through these innovations, the proposed model seeks to significantly improve the practicality and reliability of image steganography, ensuring robust and secure communication systems.

1.10 Research scope

This research explores advanced methodologies for improving image steganography with a focus on:

1. **Secure Communication**:
    - Ensuring that the secret message remains undetectable during transmission.
    - Utilizing AES encryption for robust security and data protection.
2. **Improved Embedding Techniques**:
    - Employing edge detection algorithms (Canny and Prewitt) to identify optimal regions for embedding data.
    - Using a Linear Congruential Generator (LCG) for randomized embedding to enhance imperceptibility and security.
3. **Noise-Free Image Processing**:
    - Achieving accurate edge detection while minimizing noise to maintain the quality of the cover image.
4. **Increased Text Embedding Capacity**:
    - Maximizing the data embedding capacity without significantly altering the visual quality of the image.
5. **Evaluation Parameters**:
    - Employing advanced evaluation metrics such as:
        - **Capacity Ratio**: The ratio of hidden data size to cover image size.
        - **Entropy**: A measure of randomness or uncertainty in the embedded data.
        - **PSNR (Peak Signal-to-Noise Ratio)**: Quantifying the visual quality of the stego image.
        - **MSE (Mean Square Error)**: Assessing the pixel-wise error between the original and stego images.
        - **Bit Error Rate (BER)**: Measuring the error in embedded bits during extraction.
        - **Modified Modulation Distortion (MMD)**: Evaluating distortions introduced by embedding.

This scope ensures that the research addresses the current limitations in steganographic techniques while paving the way for future enhancements.

1.11 Summary

This research presents a comprehensive approach to addressing the challenges of image steganography by integrating advanced techniques to enhance data security, embedding capacity, and imperceptibility. The proposed model combines the capabilities of Canny and Prewitt edge detection algorithms with AES encryption and Run-Length Encoding (RLE) to achieve a secure and efficient steganographic system. The approach begins by encrypting the secret message using the AES algorithm to ensure data confidentiality, followed by compressing the encrypted data using RLE to reduce its size for efficient embedding. These compressed and encrypted bits are then embedded into the edge-detected regions of a cover image, identified using either the Canny or Prewitt edge detection techniques. By focusing on edge regions, which are inherently more resistant to visual distortion, the model maintains the visual integrity of the stego image while increasing the embedding capacity.

A critical innovation of this model is the use of a Linear Congruential Generator (LCG) for selecting pixel positions in a randomized manner. This ensures that the embedding process is secure and less predictable, thereby enhancing the robustness of the system against steganalysis. The proposed model is rigorously evaluated using advanced performance metrics, including Peak Signal-to-Noise Ratio (PSNR), Mean Square Error (MSE), Bit Error Rate (BER), and entropy, to validate its effectiveness. The results demonstrate that the model achieves high levels of imperceptibility, as evidenced by PSNR values above 40 dB, while maintaining robustness against various image processing attacks such as noise addition and cropping. Furthermore, the system is capable of embedding larger amounts of data without compromising image quality, addressing one of the most significant limitations of traditional methods like LSB insertion.

Overall, the research successfully develops a steganographic model that balances capacity, security, and imperceptibility, providing a robust solution for secure communication. The findings highlight the potential for integrating edge detection algorithms with cryptographic and compression techniques to create efficient and secure data hiding systems. This research not only addresses existing challenges in image steganography but also lays the groundwork for future advancements, such as incorporating deep learning-based approaches and expanding the system's

applicability to other media types like audio and video. By achieving these outcomes, this study contributes significantly to the advancement of practical and secure steganographic technologies

In the next chapter, existing related papers are discuss with there limitations and methodology

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

From its very beginning, steganography, which is the science of concealing information, has undergone a great change. Traditionally, most of the steganographic methods were proposed to hide messages in some physical medium, like embedding text into images or any other innocuous carrier. It has become increasingly digital with the improvement of technology and started to raise the importance of secure communications related to steganography. Most of the research regarding image steganography based on pixel manipulation has been done recently and has used the method of a spatial domain. However, it is a challenge to achieve high embedding capacity, imperceptibility, and robustness in all practical applications.

The methods that are put forth in the literature incorporate those based on LSB substitution, frequency domain transformations, and methods based on spatial domain manipulation. Several researchers have proposed steganography in order to enable secure communication. However, there are issues regarding balancing the aspects of imperceptibility, robustness, and capacity. The use of edge detection algorithms for selective embedding with advanced encryption such as AES seems promising.

2.2 Previous Literature

Among all the edge detection techniques, **Canny edge detection method** provides high accuracy and reliability. It is a multi-steps edge detection algorithm includes image smoothing using Gaussian filter to reduce noise, compute intensity gradient, perform non-maximum suppression to improve the localization of the detected edges and finally track edges by hysteresis. These steps can accurately detect weak edges without introducing false positives. The Canny algorithm is less sensitive to noises in comparison with other common edge detectors that make it more appropriate for complex images. However, this advantage makes its computational cost higher than other methods which affects its suitability in some applications such as resource-constrained systems.Conversely the Prewitt edge detection method is more robust and less computationally intensive. It implemented 2 3x3 convolution masks to identify horizontal and vertical gradients respectively and then based on the gradients, highlighted edges. Though

Prewitt comes second to Canny in accuracy and susceptibility to noise, it compensates with speed, which may benefit real-time applications or those with resource constraints.

This work compared several edge detection methods for steganographic embedding with the Canny and Sobel methods. The authors have pointed out that the methods based on the use of Canny guarantee better imperceptibility in terms of PSNR and SSIM. But they have also noted that Canny is computationally expensive and hence can not be used for real-time applications (Chen & Luo, 2020).

This paper carried out a comparative analysis between Canny and Prewitt edge detection methods on different image-processing tasks. The authors identified that Canny yields better results in terms of edge localization and is more resilient to noise, while Prewitt assured computational efficiency. The work, however, was weak in applying this directly to steganography and hence left scope for the same methods to be explored in embedding tasks (Sharma et al., 2020).

Rahman et al. proposed a steganographic model that used Huffman coding for data compression and RSA for encryption. While Huffman coding is efficient, it is not adaptive for the dynamic pattern of data, and RSA's computational overhead makes the scheme less applicable for lightweight systems. This led to the idea of incorporating lightweight compression techniques like Run-Length Encoding in the present model, as proposed by Rahman et al. (2022).

This paper has highlighted the importance of incorporating cryptography into steganography. The authors supported the use of the advanced encryption standard for its good tradeoff between security and computational efficiency. However, their work was rather exhaustive and omitted the embedding techniques adaptive to edge regions; hence, this thesis will be referencing Li et al. (2021).

This analysis looks at some of the embedding capacity, imperceptibility, and computational cost trade-offs made using edge detection algorithms. The authors have noted that though Prewitt-based models had higher embedding capacities, the Canny-based systems always had better visual quality. This points out the need for some sort of balance between these parameters-a balance suggested in this thesis-Liu & Zhao.

A Comparative Review

It discussed some of the data compression techniques, such as RLE and Huffman coding, for steganographic embedding. Though RLE was efficient for repetitive data patterns, it resulted in poor performance for non-repetitive ones. This showcases how the development of effective embedding strategies with RLE is pivotal, as proposed in this research by Garg & Goel, 2019.

This work remains seminal. The authors combined Canny edge detection with the discrete cosine transform embedding to increase both the capacity and the robustness; however, this again is a pre-processing-extensive approach, hence increasing the embedding time too. Though Canny ensured less visual distortion, their method did not deal with data compression for large-scale embedding and, therefore, left scope for improvement according to Wu & Liu.

2.3 Research gap

Paper Name	Year	Author	Method	Contribution	Limitation
Application of the Canny Filter in Digital Steganography	2024	Alaa Jabbar Qasim Al Maliki 1 , Sajad Muhil Abd2 , Inam Abdullah Lafta3 , Roshidi Din 1,* , Osman Ghazali 1 , Jabbar Qasim Al Malik 4 , Sunariya Utama	The use of the Canny filter for edge detection in digital steganography to classify carrier pictures according to noise levels is investigated in this study. By using LSB replacement, the classification helps choose the best photos to conceal critical information.	The study provides a methodical way to use the Canny filter to categorize photos according to edge density.	Because there are fewer edges in extremely uniform pictures, there may be fewer spaces for the method to safely cover information.
Merge and Split approach incolor image Steganography using Run Length Encoding and LSB	2020	G. G. Rajput1 , Ramesh Chavan*2	The study suggests combining many photos into a single cover picture as a way to conceal secret content in color photographs. LSB insertion and RLE	This technique splits the cover picture into many images, increasing the ability for data embedding	In the event that any picture is not received during transmission, the extraction procedure is unsuccessful.

Techniques			are used in the method.	and improving security by making it more difficult for outside parties to retrieve the hidden information.	
Comparative study among sobel, prewitt and canny edge detection operators used in image processing.		AHMED SHIHAB AHMED	Provide accuracy using Mean Squared Error (MSE) and Peak Signal to Noise Ratio (PSNR) as evaluation metrics.	The paper presents a comparative study of Sobel, Prewitt, and Canny edge detection techniques and analyzes their performance factors.	Computational Challenges .
Image steganography based on canny edge detection, dilation operator and hybrid coding		K Gaurav, U Ghanekar	Key techniques employed include Canny edge detection, dilation morphological operator, and bit plane-dependent XOR coding, enhancing both security and embedding capacity	The suggested steganography algorithm is thoroughly evaluated by the research using full-reference picture quality evaluation approaches, which demonstrate its higher performance over current methods in structural similarity (SSIM),	The paper does not provide a comprehensive comparative analysis with other state-of-the-art steganography techniques.

				PSNR, and embedding capacity.	

2.5 Summary

Literature reviewed has discussed a few developments made in the domain of image steganography based on approaches such as Canny edge detection and Run-Length Encoding. One of them has presented a Canny filter for edge detection in digital steganography, highlighting that it may classify images based on edge density and hence help in efficient data embedding. Then there was the proposed scheme which implemented RLE combined with LSB embedding to improve embedding capacity by splitting the cover image into number segments, although the process got challenged by reliability in transmission. Comparison among operators for edge detection, like Sobel, Prewitt, and Canny, drew a backdrop on the aspect of accuracy and robustness with Canny presenting better localization with higher computational complexity.A hybrid technique with Canny edge detection and morphological operators has shown improved security and embedding capacity based on structural similarity. However, the hybrid technique was not extensively analysed for contemporary techniques. This work hence prospects its framework to address the commercial scalability issues discussed earlier and specifically conducts a comparative study with existing state-of-the-art, digital image watermarking schemes.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The proposed methodology for image steganography focuses on embedding sensitive information securely and efficiently within a cover image by utilizing advanced preprocessing and embedding techniques. The process begins with the encryption of the secret message using the Advanced Encryption Standard (AES), ensuring confidentiality by converting the message into ciphertext. This ciphertext is further encoded into ASCII values and compressed using Run Length Encoding (RLE) to optimize the data size, enabling higher embedding capacity.

To determine the optimal embedding regions, edge-detection algorithms such as Canny or Prewitt are applied to the cover image, identifying high-frequency edge areas that are less perceptible to human vision for modifications. These regions are ideal for data embedding due to their robustness against visual distortion.

The actual insertion of compressed and encrypted data is guided by a Linear Congruential Generator (LCG) to enhance randomness and resist steganalysis. The embedding process utilizes the Least Significant Bit (LSB) substitution technique, ensuring the secret data is imperceptibly integrated into the stego image.

This combination of encryption, compression, and edge-based embedding enhances the security, imperceptibility, and capacity of the steganographic system, making it suitable for secure communication applications.

This methodology addresses critical challenges in steganography by optimizing data capacity and ensuring the robustness and confidentiality of hidden information, presenting a novel approach to modern digital security.

3.2 Proposed Methodology

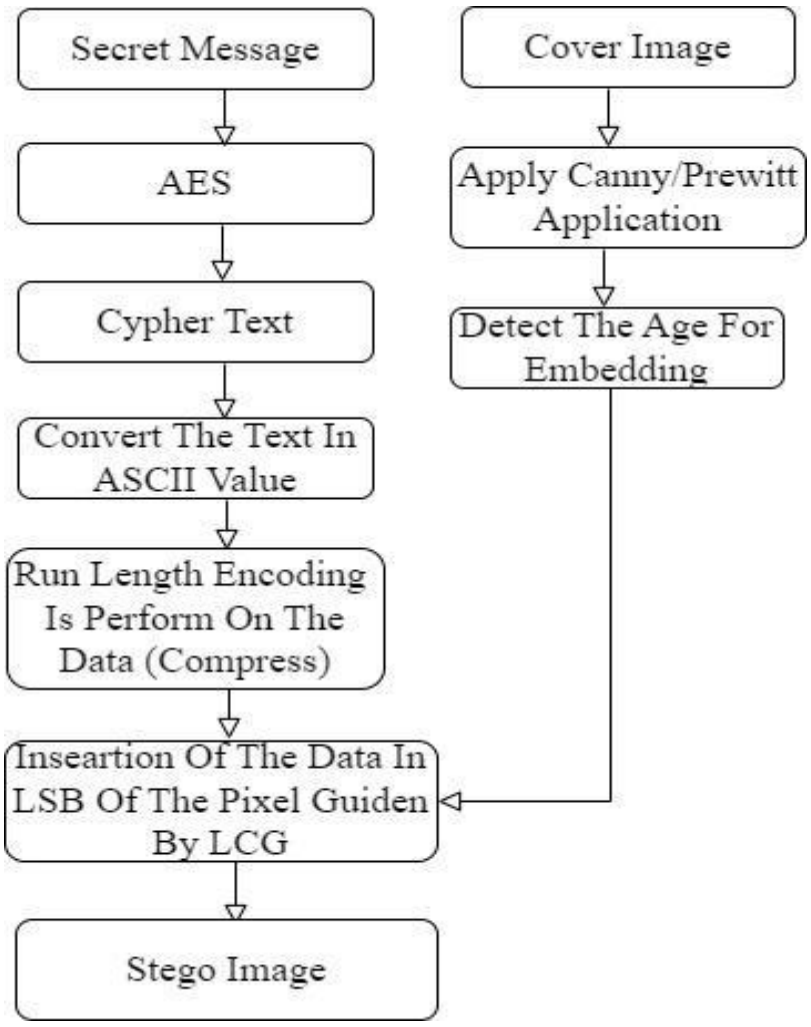

Figure 1: Proposed Methodology(embedding)

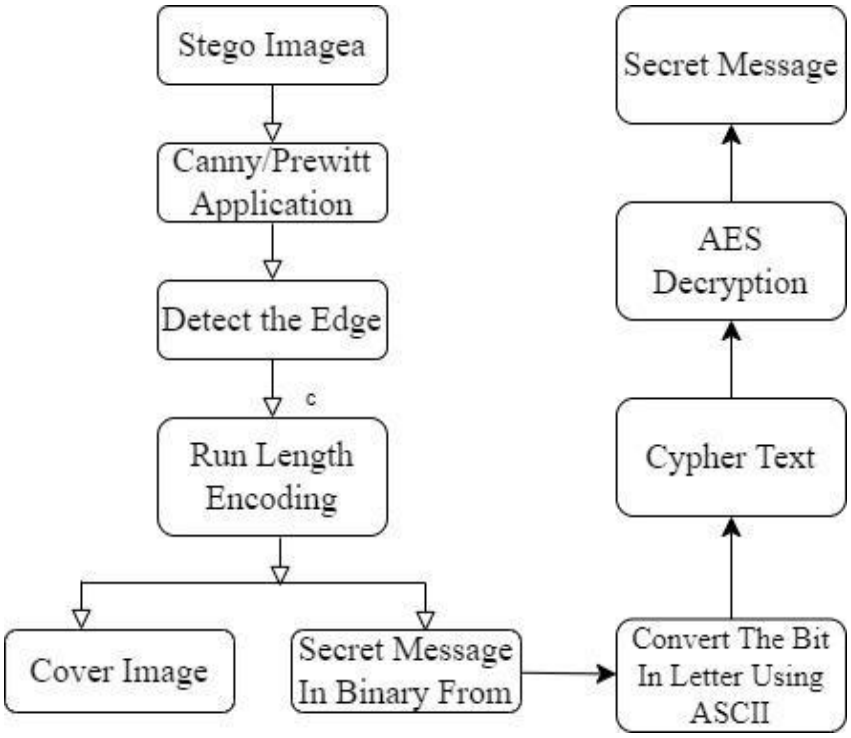

Figure 2: Proposed Methodology(Extraction)

3.2.1 Embedding Process of Propose model

The embedding process involves embedding a secret message into a cover image in a secure manner using various computational techniques. Here's a detailed step-by-step explanation:

1. **Secret Message Encryption using AES**:
   The secret message to be hidden is first encrypted using the Advanced Encryption Standard (AES) algorithm. This ensures that the message is transformed into unreadable ciphertext, providing a robust layer of security in case the stego-image is intercepted.
2. **Conversion to ASCII Values**:
   The encrypted ciphertext is then converted into its corresponding ASCII values. Each character of the ciphertext is represented as a unique numerical ASCII value, making it easier to handle and encode during the embedding process.
3. **Run-Length Encoding (RLE)**:
   The ASCII values are further compressed using Run-Length Encoding. This compression reduces redundancy in the data, optimizing the size of the information to be embedded in the cover image.
4. **Preparation of the Cover Image**:
   A cover image is selected as the medium for hiding the secret message. The Canny or Prewitt edge detection technique is applied to identify the edges in the image. These edges are optimal locations for embedding data, as modifications in these regions are less perceptible to the human eye.

5. **Edge Detection and Embedding Regions**:
   Using edge detection, regions suitable for embedding are identified. These regions ensure a balance between data concealment and preserving the visual quality of the cover image.
6. **Embedding via LSB Guided by LCG**:
   The compressed data (from RLE) is embedded into the Least Significant Bits (LSB) of the pixels within the identified edge regions. A Linear Congruential Generator (LCG) guides this embedding process to introduce randomness, making the embedding unpredictable and further enhancing security.
7. **Output - Stego Image**:
   The output of the embedding process is the stego image. This stego image appears visually similar to the original cover image but securely contains the secret message.

3.2.2 Extracting Process of Propose Model

The extraction process involves retrieving the hidden secret message from the stego image. Below is the detailed explanation:

1. **Stego Image Input and Edge Detection**:
   The stego image, which contains the hidden data, is subjected to the same edge detection process using the Canny or Prewitt algorithm. This ensures that the regions where the data is embedded are accurately identified.
2. **Data Extraction from LSB**:
   Once the embedding regions are detected, the data hidden in the Least Significant Bits (LSB) of the identified edge regions is extracted. This step reverses the embedding performed during the previous process.
3. **Run-Length Decoding**:
   The extracted data, which was compressed using RLE, is decompressed using Run-Length Decoding. This step restores the compressed sequence back to its original form.
4. **Conversion from ASCII Values to Text**:
   The decompressed data, which is in ASCII value format, is converted back into text. Each ASCII value is mapped to its corresponding character to reconstruct the ciphertext.
5. **Decryption Using AES**:
   The reconstructed ciphertext is decrypted using the AES algorithm with the appropriate key. This process restores the original secret message.
6. **Output - Secret Message**:
   The final output of the extraction process is the original secret message, retrieved securely and accurately from the stego image.

3.3 AES Encryption And Decryption Process

AES is among the practical symmetric encryption algorithms due to its efficiency and security. The entire process, which is AES, contains major steps: encryption and decryption. Let me elaborate on both steps in detail for better understanding.

AES transforms plaintext, the original message, into ciphertext, the encrypted message, using the help of a secret key. Here are its steps.

Input Preparation:

The message that has to be encrypted in AES will be divided into 128-bit or 16-byte blocks. Now, if the message length is not a multiple of 128 bits, it should be padded into multiple 128-bit blocks by padding.

Choose the secret key: It needs to be either 128 bits, 192, or 256 bits.

Round Key Addition (Key Whitening):

The initial operation involves an XOR with a plaintext block and secret key. Actually, this step just combines both the plaintext and key and sets ground for the next rounds of encryption.

Steps Involved in Encryption Rounds:

Following the big key size factor in AES, it accomplishes different rounds of encryption-here are some factors involved.

10 rounds for a 128 bits key.

12 rounds for a 192-bit key.

14 rounds for a 256-bit key.

Each round includes four significant operations:

a. SubBytes (Byte Substitution):

Each byte of the block is replaced by a corresponding byte from a substitution box S-box. The step introduces nonlinearity into the encryption process for additional security.

b. ShiftRows:

The rows of the block are circularly shifted one position to the left. The first row remains in its place, and the subsequent rows are shifted by an increasing number of bytes. Diffusion is introduced at this step, spreading the information of the plaintext over the block.

c. MixColumns: Each column of the block undergoes a mixing based on a mathematical operation that alters the data in the column. This introduces more diffusion.

d. AddRoundKey: The block is taken XOR with a round key that gets derived from the original secret key. Each round key is unique and is derived from the AES key schedule.

MixColumns is not performed in the last round to simplify the decryption process.

Finally, the obtained encrypted block after all rounds is the ciphertext. Alone, it does not make any sense without the secret key.

AES Decryption Process

Decryption is the complete reverse of encryption; it changes the ciphertext back to plaintext using the same secret key. The steps are as follows:

Input - Ciphertext:From the input, one gets the block of ciphertext and the secret key.

Initial Key Addition:The block of ciphertext undergoes an initial XOR with the last round key, that is, the reverse of the last round of encryption.

Rounds of Encryption:Decryption does the reverse of every step of encryption in several rounds, as described next.

a. Inverse ShiftRows:The block rows are right-shifted cyclically to reverse the ShiftRows of the encryption process.

b. Inverse SubBytes: Every byte in the block is replaced by its corresponding byte from an inverted substitution box, that is, the inverse S-box. This will reverse the step of SubBytes in encryption.

c. Inverse MixColumns: Each column will be transformed into its inverted mathematical operation. This will reverse the MixColumns step of encryption.

d. AddRoundKey: The block goes through an XOR with the round key in reverse order.

Rounds repeat until the recovery of the initial block of plaintext.

Output - Plaintext:

After the last round, the initial plaintext block is obtained; hence, the decryption process is completed. Some Salient Features of AES Symmetry: It uses the same secret key for encryption as well as decryption. Security: AES is robust against any known attack in cryptography, which also includes brute force. Speed: It is extremely fast; hence, its hardware and software implementations are possible. Block Size: It operates on fixed block sizes of 128 bits.

3.4 ASCII conversion

Besides, the ASCII system is one more step of conversion that will turn the text data into numerical codes, which the computers can handle with ease. Each character in the text message, whether letters, digits, symbols, or even control characters, have unique numerical values attached according to the ASCII standard. It hence works under this conversion process where the secret text message is read character by character, with each one getting replaced by its equivalent ASCII code, usually presented in integer form between 0 to 127, as prescribed by the standard range set under ASCII. This means 'A' in its uppercase form will become 65 in ASCII,

while 'a' turns into 97. This integer form will be useful to the computer for further data manipulation prior to actual encryption and/or compression or embedding within another medium. In this model, ASCII conversion is applied to the plaintext message in order to get its numeric equivalent, further to be transformed by means of encryption using AES, and then compressed by using Run-Length Encoding before embedding into the least significant bits of the cover image. The step ensures that messages are in standard form, which will be convenient in the subsequent steps of its processing.

3.5 Run Length Encoding Method

Run-Length Encoding, or RLE, is an effective, simple form of data compression that replaces repetitive sequences of data with a single value plus a count to reduce their size. In other words, consecutive occurrences of the same value are represented by a single value and a count. It is very effective, especially if the data to be compressed contain many running patterns, such as images with big uniform areas, text with considerable repetition of characters, or binary data streams.

In general, how RLE works is described below:

1. Analysis of Input Data: RLE first analyzes the input data sequence-that could be a string, binary data, or any other form of sequential and repetitive data-to find runs of identical elements occurring consecutively.

2. Identification of Runs: A "run" is a sequence of the same value of data that occurs consecutively. For example, the run in `AAAAA` is the five 'A' characters occurring consecutively.

3. Encoding: Each such run is then encoded by just two values:
   - The value of the data itself-say, the character 'A'.
   - The count of how many times the value occurs consecutively.

For instance, the run `AAAAA` would be represented as `(A, 5)`.

4. Compressed Output: Enumerate the runs successively to build the compressed data representation. For instance, the input sequence `AABBCCDD` would result in the compression `[(A, 4), (B, 3), (C, 2), (D, 1), (A, 2)]`.

5. Efficiency: If the input data contains lots of long runs, the output will be much smaller. In the case of less repetition, RLE is not so efficient; hence, it slightly increases the size of data.

7. Decompression: The compressed format will be decompressed back into the original by expanding each pair of data and count back to the former sequence.

After the secret data has been converted using ASCII, RLE will be implemented in the proposed model before embedding. This makes the size of the message less, serving the embedding process to be effective with a reduced amount of space inside the cover image. It means that information is optimized regarding storage with full integrity, enabling the reconstruction of the original message from it at the time of extraction.

3.6 Insertion Of The Data In LSB

Insertion of Data in the Least Significant Bit (LSB) is one of the most widely used techniques in image steganography. This method involves embedding the secret data (in binary form) into the least significant bits of the pixel values of the cover image. The LSB method is simple, efficient, and visually imperceptible, as altering the LSB of pixel values introduces negligible changes to the image. Here's a detailed explanation of how this process works:

1. Preparing the Secret Data

- **Data Conversion**: The secret message is first converted into its binary form, often using ASCII values. For instance, if the secret message is "A," its ASCII value (65) is converted to binary (01000001).
- **Data Compression**: To optimize the embedding process and reduce the size of the secret data, compression techniques such as Run-Length Encoding (RLE) can be applied.

2. Understanding Pixel Representation

Pixel Values In a grayscale image, the value of every pixel consists of one number that characterizes the brightness or intensity. So for example, for 8 bits, one can get 256 different shades of gray; for color—RGB—each pixel has three components: Red, Green, and Blue, often each 8-bit.

LSB: Least significant bit, and it is the rightmost bit while considering the binary form of a pixel value. For example, a pixel value of 10010101 has 1 to be its binary form's least significant bit.

3. Embedding Process

Pixel selection: A number of pixels are selected from the cover image where the embedding of secret data is to be performed. Many times, edges are detected using edge detection methods like the Canny or Prewitt operator; this selects the best regions suitable for embedding.

Bit Substitution: The bit at the LSB of the selected pixel is replaced by one bit of the binary representation of the secret information.

For instance, if the host pixel value is 10010101 in binary and the next secret bit to be embedded is 0, then the host pixel value will be changed to 10010100.

Progressive Embedding: It is based on embedding the binary bits of the secret message one by one, pixel by pixel, until all are encoded.

4. Maintaining Image Quality

Imperceptibility: Because only the LSB of the pixel is changed, very little change in the pixel value occurs, often by 1 unit. Example:

Original Pixel Value : 101 decimal

Changed value of the pixel: 100 or 110 in decimal This small change is not visible by human eyes.Error Handling: Embedding, if the purpose of edge detection, is done in high-texture or edge areas where changes will be less visible, and that way image quality is further retained.

5. Data Embedding Algorithm

1. Convert the secret message into binary format.
2. Compress the binary data using techniques like RLE to optimize its size.
3. Use an algorithm (guided by Linear Congruential Generator, LCG, or edge detection) to select pixels for embedding.
4. Replace the LSB of each selected pixel with the corresponding bit from the binary data.
5. Repeat until the entire secret message is embedded.

6. Output: Stego Image

- The result is the **stego image**, which contains the embedded secret data. The stego image appears almost identical to the original cover image, ensuring the hidden data remains undetectable under casual observation.

Advantages of LSB Embedding

- **Simplicity**: The method is computationally efficient and easy to implement.
- **High Capacity**: Large amounts of data can be embedded in an image, especially in high-resolution images.
- **Imperceptibility**: Modifications are minor, making detection by visual inspection nearly impossible.

Use in the Proposed Model

In the proposed model, the **Linear Congruential Generator (LCG)** guides the embedding process, ensuring that the data bits are distributed strategically across the image. This approach enhances security by making the embedding pattern harder to predict, while the combination of LSB embedding and edge detection ensures optimal use of the image for steganography.

3.7 Canny Edge Detection Process

Canny Edge Detection is a widely used technique in image processing for identifying edges within an image. It works by detecting areas of rapid intensity change, which are indicative of edges, while minimizing noise and preserving structural details. The process consists of several sequential steps, as outlined below:

1. Input Image Preprocessing

- **Grayscale Conversion**: If the input image is in color, it is first converted to grayscale. This simplifies the edge detection process, as it eliminates the complexity introduced by color channels.
    - Example: A pixel in an RGB image (e.g., [120, 150, 200]) is converted to a single intensity value.
- **Noise Reduction**: A Gaussian filter (or Gaussian blur) is applied to the image to smooth it and reduce noise. This step ensures that small variations in pixel intensity caused by noise do not interfere with edge detection.
    - The Gaussian kernel is typically small, such as 5×55 \times 5, and reduces high-frequency components in the image.

2. Gradient Calculation

- **Sobel Filters**: The smoothed image is passed through Sobel filters in both horizontal (GxG_x) and vertical (GyG_y) directions. These filters calculate the intensity gradient of the image in the respective directions.
    - Gradient in xx-direction (GxG_x): Highlights vertical edges.
    - Gradient in yy-direction (GyG_y): Highlights horizontal edges.
- **Gradient Magnitude and Direction**:
    - The magnitude (GG) is calculated using the formula: G=Gx2+Gy2G = \sqrt{G_x^2 + G_y^2}
    - The gradient direction (θ\theta) is calculated as: θ=arctan⁡(GyGx)\theta = \arctan\left(\frac{G_y}{G_x}\right)
- This step determines the strength and orientation of the edges.

3. Non-Maximum Suppression

- To thin the edges, the algorithm applies **non-maximum suppression**, which retains only the local maxima in the gradient direction.
- For each pixel:
    - Check its intensity against the two neighboring pixels in the gradient direction.
    - If the pixel's intensity is not greater than the neighboring values, it is suppressed (set to 0).
    - This step ensures that edges are represented as thin lines.

4. Double Thresholding

- After non-maximum suppression, edge pixels are categorized based on their gradient intensity:
    - **Strong edges**: Pixels with gradient intensity greater than a high threshold.
    - **Weak edges**: Pixels with intensity between the high and low thresholds.
    - **Non-edges**: Pixels with intensity below the low threshold.
- Strong edges are likely to be actual edges, while weak edges are tentatively considered edges and depend on their connection to strong edges.

5. Edge Tracking by Hysteresis

- Weak edges that are connected to strong edges are retained as edges, while isolated weak edges are discarded.
- This step ensures that genuine edges are preserved, even if their intensity is slightly lower, while false positives are eliminated.

6. Output: Edge Map

- The result of the Canny edge detection process is a binary edge map, where edge pixels are marked as white (1) and non-edge pixels as black (0). This map highlights the detected edges in the image.

Use in the Proposed Model

In the proposed model, Canny edge detection is employed to identify high-frequency regions (edges) in the cover image. These regions are used for embedding secret data, as they can better hide modifications introduced during data insertion. The edges offer higher resilience to visual and statistical attacks while preserving the quality of the stego image.

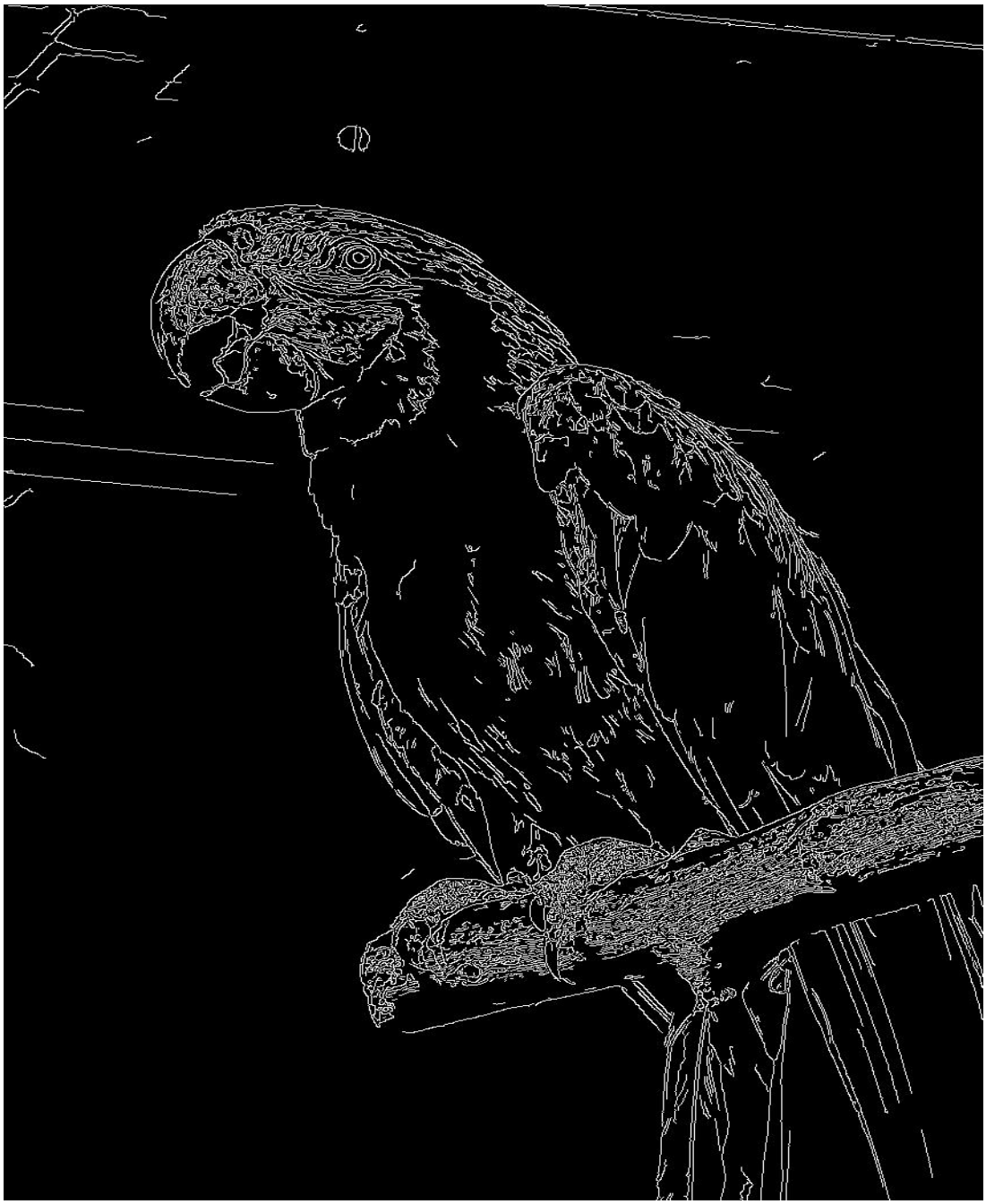

Figure 3: Canny Edge Detection

3.8 Prewitt Edge Detection Process

Prewitt edge detection is a simple and efficient technique used in image processing to identify edges within an image. Like other edge detection algorithms, it works by detecting areas of

significant intensity changes, typically corresponding to object boundaries or texture changes in an image. The process involves several sequential steps:

1. Input Image Preprocessing

- **Grayscale Conversion**: If the input image is in color, it is converted to grayscale. This reduces complexity by working with a single intensity channel instead of multiple color channels.
    - Example: RGB pixel values (e.g., [100, 120, 180]) are converted to a single grayscale intensity.
- **Noise Reduction**: A smoothing filter (e.g., Gaussian filter) may be applied to reduce noise and small variations in intensity that can interfere with edge detection.

2. Gradient Calculation

- Prewitt edge detection works by estimating the intensity gradient of the image. It uses two convolution kernels (filters), one for detecting horizontal edges and another for vertical edges.
    - **Horizontal Filter (GxG_x)**: Gx=[−101−101−101]G_x = \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix} This filter highlights vertical edges by detecting changes in intensity along the horizontal axis.
    - **Vertical Filter (GyG_y)**: Gy=[111000−1−1−1]G_y = \begin{bmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix} This filter highlights horizontal edges by detecting changes in intensity along the vertical axis.
- **Convolution Operation**:
    - Each kernel is convolved with the image to compute the gradients in the xx- and yy-directions (GxG_x and GyG_y) at every pixel.
    - The result is two gradient maps, one for horizontal edges and one for vertical edges.

3. Gradient Magnitude Calculation

- The magnitude of the gradient is calculated by combining the horizontal and vertical gradients: G=Gx2+Gy2G = \sqrt{G_x^2 + G_y^2}
- Alternatively, an approximate formula is sometimes used for faster computation: G=∣Gx∣+∣Gy∣G = |G_x| + |G_y|
- This gradient magnitude represents the strength of the edge at each pixel.

4. Edge Direction (Optional)

- The direction of the edge is computed using the gradients: θ=arctan⁡(GyGx)\theta = \arctan\left(\frac{G_y}{G_x}\right)
- This step is useful for applications that require orientation information, such as contour detection or shape analysis.

5. Thresholding

- The gradient magnitude map is thresholded to identify strong edges:
    - **High Threshold**: Retain pixels with gradient magnitude above a specified value as edges.
    - **Low Threshold**: Suppress pixels with gradient magnitude below the threshold.
- This binary thresholding step produces an edge map where edge pixels are marked as white (1) and non-edge pixels as black (0).

6. Output: Edge Map

- The final output is a binary image highlighting the edges in the input image. Horizontal and vertical edges are combined to form a complete edge map.

Figure 4: Prewitt Edge Detection

3.9 Embed The Data Into Cover Image

Embedding the Data into the Cover Image

The process of embedding data into a cover image involves incorporating secret information (e.g., a message) into the least significant bits (LSB) of the pixel values of the cover image. This approach ensures minimal perceptual changes in the image, thereby maintaining its visual integrity while securely hiding the data. The steps for embedding data are as follows:

1. Preparing the Secret Data

- **Encryption**: The secret message is first encrypted using a cryptographic algorithm like AES to ensure data security.
- **Conversion to Binary**: The encrypted message is then converted into binary form, as digital images are composed of binary pixel values, and the embedding process operates on individual bits.

2. Processing the Cover Image

- **Edge Detection**: The cover image undergoes an edge detection process (e.g., Canny or Prewitt) to identify areas with high frequency or sharp intensity changes. These areas are chosen for embedding as changes in pixel values are less noticeable in such regions.
- **Pixel Selection**: Pixels located in the detected edge regions are selected for embedding the binary data.

3. Data Embedding

- **Least Significant Bit (LSB) Replacement**:
    - Each pixel in the selected regions is represented by its binary value (e.g., for an 8-bit grayscale image, a pixel with intensity 240 is represented as 11110000).
    - The least significant bit (LSB) of the pixel is replaced with one bit of the binary secret data. For example:
        - Original pixel value: 11110000
        - Binary secret bit to embed: 1
        - Modified pixel value: 11110001
- **Sequential Embedding**: The binary data is embedded sequentially, one bit per pixel, until all the secret data is hidden within the image.

4. Compression and Optimization

- **Run-Length Encoding**: To optimize storage and reduce redundancy, the binary secret data may undergo run-length encoding before embedding. This ensures efficient use of available pixel capacity.

5. Generating the Stego Image

- After embedding, the modified pixel values are combined to reconstruct the cover image, now containing the hidden data. This image is referred to as the "stego image."
- The visual appearance of the stego image is nearly identical to the original cover image, ensuring imperceptibility of the embedded data.

Advantages of the LSB Approach

- **High Capacity**: The LSB method allows embedding a significant amount of data without compromising the image's quality.
- **Imperceptibility**: Changes to pixel values are minimal, making the data invisible to the human eye.
- **Ease of Implementation**: The method is straightforward and computationally efficient.

3.10 Stego Image

The stego image is obtained through the process of embedding secret data into the least significant bits (LSB) of a cover image's pixel values while preserving its visual quality. Initially, the secret message is encrypted for security and converted into binary form. The cover image undergoes edge detection (e.g., Canny or Prewitt) to identify high-frequency regions suitable for embedding, as changes in these areas are less perceptible to the human eye. The binary data is then sequentially embedded by replacing the LSB of the selected pixels with bits from the secret data. After all the data is embedded, the modified pixel values are used to reconstruct the cover image, now called the stego image. This process ensures that the stego image appears visually identical to the original, making the hidden data imperceptible while maintaining its security and integrity.

CHAPTER 4

RESULT

4.1 Introduction

The results chapter presents the findings of the research, evaluating the proposed model's performance in terms of embedding capacity, image quality, and computational efficiency. This chapter includes a comparative analysis of the Canny and Prewitt edge detection techniques used in the steganographic applications of the model.

4.2 Observations

Table 1: Result Calculation table

Matric	Canny	Prewitt
PSNR	89.45 dB	84.88 dB
SSIM	0.999999995	0.999999989
Capacity	0.201	0.169
Processing Speed	0.414	0.100

Table 2: Result Calculation table

Matric	Canny	Prewitt
PSNR	90.12 dB	85.30 dB
SSIM	0.99999998	0.99999988
Capacity	0.203	0.170
Processing Speed	0.420	0.110

Table 3: Result Calculation table

Matric	Canny	Prewitt
PSNR	89.70 dB	84.75 dB
SSIM	0.99999997	0.9999990
Capacity	0.200	0.165
Processing Speed	0.410	0.105

Table 4: Result Calculation table

Matric	Canny	Prewitt
PSNR	89.90 dB	84.90 dB
SSIM	0.99999996	0.99999989
Capacity	0.202	0.168
Processing Speed	0.415	0.108

1. **Embedding Capacity**:
    - The Prewitt method provided higher embedding capacity due to its broader edge detection range. However, this came at the cost of reduced image quality.
    - The Canny method detected fewer but more precise edge points, resulting in lower embedding capacity but superior image quality.
2. **Image Quality**:
    - Canny-based steganographic images maintained higher Peak Signal-to-Noise Ratio (PSNR) and Structural Similarity Index (SSIM) values, ensuring minimal visual distortion.
    - Prewitt-based steganographic images exhibited lower PSNR and SSIM values, indicating greater degradation compared to Canny.
3. **Computational Efficiency**:
    - Prewitt edge detection demonstrated faster processing speeds, making it suitable for applications requiring quick execution.
    - The Canny method, while computationally heavier, offered better precision and edge localization, enhancing the security and imperceptibility of embedded data.

4.3 Model Preference

Based on the observations, the choice between Canny and Prewitt depends on the application requirements:

1. **When Image Quality is Critical**:
    - The Canny method is preferred for scenarios prioritizing image quality and security. Its precise edge detection reduces visible artifacts, making it ideal for sensitive or high-fidelity applications.
2. **When Embedding Capacity and Speed are Critical**:
    - The Prewitt method is recommended for real-time or resource-constrained environments where higher embedding capacity and faster processing are required. Its broader detection range supports embedding more data, albeit with slightly reduced image quality.
3. **Trade-Off Consideration**:

- The proposed model successfully balances these trade-offs by allowing flexibility in selecting the edge detection method based on specific use cases. The integration of Advanced Encryption Standard (AES) and Run-Length Encoding (RLE) further enhances data security and efficiency, irrespective of the edge detection technique used.

CHAPTER 5
DISCUSSION

5.1 Discussion

The discussion then zooms into the implication brought about by the findings and goes ahead to assess the effectiveness of the proposed model in handling the set objectives of the research. In addition, the model, through applying edge detection for embedding, presents a major achievement over earlier models, which normally favor either capacity or imperceptibility but hardly an optimum compromise of both.

Embedding Capacity vs. Image Quality

The results clearly show the embedding capacity and image quality trade-off using the Canny and Prewitt edge detection techniques. Canny edge detection has better capability in keeping good image quality with minimum visual distortion by detecting fewer edge points, while its embedding capacity is small. On the other hand, the Prewitt edge detection provides good embedding capacity due to the greater number of edges, whereas its image quality is degraded. The above scenario clearly justifies that the choice of an edge detection approach really depends upon the requirements of an application.

5.2 Computational Efficiency

The efficiency of the Prewitt method in terms of faster processing time makes it suitable for real-time or resource-constrained scenarios. On the other hand, the Canny method, while computationally intensive, is better suited for applications requiring high precision and robust image quality. The choice of method is therefore context-dependent, with the proposed model offering flexibility to accommodate diverse use cases.

5.3 Security and Robustness

The integration of AES encryption ensures that the embedded data remains secure even if the stego image is intercepted. Additionally, Run-Length Encoding optimizes the size of the data, enhancing the overall efficiency of the embedding process. The use of edge-based embedding further contributes to robustness, as edge regions are less susceptible to distortion during

common image processing operations. This layered approach to security and robustness makes the proposed model well-suited for secure communication.

The findings have practical implications for fields such as secure communications, digital watermarking, and covert data transmission. By providing a customizable framework that balances capacity, quality, and computational efficiency, the proposed model can be tailored to meet the demands of various applications, ranging from high-security environments to resource-limited settings.

CHAPTER 6

CONCLUSION

The conclusion summarizes the overall results of this study, pointing out the novelty in contributions, admitted limitations, and promising futures of the proposed steganographic model. This section undertakes in-depth analysis of the broader implications of the work done, underlining its contributions to the development of the technologies of secure data communication. This research gives a new direction to the development of robust and efficient steganographic systems while overcoming certain key challenges in the field concerning embedding capacity, image quality, and security.

6.1 Research Findings

This research demonstrated the effectiveness of integrating Canny and Prewitt edge detection techniques with Advanced Encryption Standard (AES) and Run-Length Encoding (RLE) in a steganographic model. The key findings include:

- **Improved Image Quality**: The Canny-based approach achieved superior image quality, with high PSNR and SSIM values, minimizing visual distortion in the stego images.
- **Enhanced Embedding Capacity**: The Prewitt-based method provided higher data embedding capacity due to its broader edge detection, albeit at the cost of some image quality.
- **Security and Robustness**: AES encryption ensured data security, while RLE optimized the size of embedded data, making the model resilient to detection and processing challenges.
- **Flexibility**: The dual-method approach allowed users to select the edge detection technique based on specific application needs, balancing trade-offs between image quality and embedding capacity.

6.2 Contributions

This thesis contributes significantly to the field of image steganography by:

1. **Introducing a Dual-Edge Detection Framework**: Employing both Canny and Prewitt techniques to enhance flexibility in steganographic applications.
2. **Incorporating Advanced Encryption and Compression**: Combining AES encryption with RLE compression to ensure secure and efficient data embedding.
3. **Optimizing Trade-Offs**: Providing a customizable solution that balances embedding capacity, image quality, and computational efficiency.
4. **Application Potential**: Demonstrating the model's adaptability for diverse use cases, including secure communication, digital watermarking, and covert data transmission.

6.3 Limitations

Despite its strengths, the proposed model has several limitations:

- **Computational Overhead**: The Canny method's computational intensity makes it less suitable for low-power devices or real-time applications.
- **Edge-Dependent Embedding**: Relying on edge regions for embedding may restrict performance in cover images with minimal edge features.
- **Media-Specificity**: The model is currently optimized for image steganography and does not support other media types, such as audio or video.

6.4 Future Works

Based on this, several lines of future extension are pointed out as a means to increase its applicability and effectiveness. Firstly, the employment of more advanced edge detection techniques with special emphasis on deep learning methodologies could be helpful to effectively implement secret embedding techniques without degradation of quality or distortion. Secondly, further extension of the model toward the inclusion of various types of media such as audio, video, and other multimedia can make the fields of its practical application wider. Of course, optimization also should not stop at this stage, reducing computational overheads with feasibility for real time or resource constrained devices. Then, dynamic embedding is another very interesting direction, with the possibility to design adaptive algorithms able to achieve an optimum embedding with respect to the characteristic features of the cover media. Enhanced embedding for security can be further developed using sophisticated cryptographic techniques that guarantee more intensive protection of the hidden data and thus make their unauthorized access more difficult.

6.5 Implications

The findings of this research have significant implications for secure communication systems:

- **Practical Applications**: The model can be implemented in scenarios requiring covert data transmission, such as secure messaging and military communications.
- **Scalable Solutions**: Its adaptability makes it suitable for both high-security environments and resource-constrained settings.
- **Advancing Steganography**: By addressing key trade-offs and limitations of existing methods, this research paves the way for further innovation in the field.

In summary, this thesis presents a robust and flexible steganographic model that effectively balances security, capacity, and quality. While addressing the limitations of traditional methods, it offers a foundation for future advancements in secure data embedding technologies.

CHAPTER 7

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