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Implementation of Motion Vector Steganography Method in Video

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ABSTRACT
The rapid development of information and communication technology has led to an increase in the exchange of digital data, particularly in the form of multimedia such as video. This condition creates a need for data security systems capable of maintaining the confidentiality of information from unauthorized parties. Steganography is one of the information security techniques that aims to hide secret messages within digital media without causing noticeable changes to the media. This study aims to implement the Motion Vector Steganography method on video media as an effective and secure technique for hiding secret messages. This method utilizes motion vectors generated during the video compression process, particularly in P-frames and B-frames, as the medium for message embedding. The research stages include analyzing video structure, embedding secret messages into motion vectors, and extracting messages from the stego video. The evaluation is conducted by comparing video quality before and after the embedding process using Peak Signal-to-Noise Ratio (PSNR) and Structural Similarity Index (SSIM) parameters, as well as testing the success of message extraction. The results show that the Motion Vector Steganography method is capable of hiding messages effectively without causing significant degradation in video visual quality. In addition, the embedded secret messages can be successfully extracted with a high level of accuracy. Therefore, this method can serve as an effective alternative solution for securing information in digital video media.
Keywords :Motion Vector Steganography, Video

INTRODUCTION

This study discusses the implementation of the Motion Vector Steganography method in video media as a technique for securing digital information. Motion Vector Steganography utilizes motion vectors generated during the video compression process to embed secret messages without causing significant visual changes. By leveraging the characteristics of motion vectors, the embedded messages become more difficult to detect, both visually and through simple analysis.

The main problem addressed in this study is how to implement the Motion Vector Steganography method in video and how message embedding affects the resulting video quality. In addition, it is necessary to analyze the success rate of the secret message extraction process from the stego video.

The objective of this research is to implement the Motion Vector Steganography method in video media, analyze video quality before and after the embedding process, and evaluate the success of extracting the embedded messages. The results of this study are expected to

contribute to the development of multimedia-based information security techniques, particularly in video media.

LITERATURE REVIEW AND PROBLEM STATEMENT

Previous studies have shown that steganography is an effective technique for securing digital information, particularly in multimedia such as images, audio, and video. Video steganography methods have evolved alongside video compression techniques, one of which involves the use of motion vectors. Several studies indicate that Motion Vector Steganography has advantages over pixel-based methods because it embeds messages in the compression domain, resulting in minimal visual changes that are difficult to detect. In addition, the use of motion vectors provides relatively high embedding capacity and better resistance to visual analysis compared to conventional steganography techniques.

However, there are still challenges in implementing Motion Vector Steganography, particularly in maintaining a balance between embedding capacity, video quality, and message extraction accuracy. Some studies show that uncontrolled message embedding can degrade video quality and reduce extraction accuracy. Therefore, further research is needed to implement Motion Vector Steganography in video and to analyze the impact of message embedding on video quality and extraction success, so that this method can be optimally applied as a multimedia-based information security technique.

METHOD

This study employs an experimental method aimed at implementing and evaluating the performance of the Motion Vector Steganography method for hiding secret messages in video media. The method consists of several interrelated stages, starting from data preparation to the analysis of test results.

The initial stage is data preparation, which includes selecting compressed digital video as the cover media. The video used has formats and codecs that support motion vector generation, such as MPEG or H.264, enabling the identification of I-frames, P-frames, and B-frames. In addition, a secret message in the form of text is prepared and converted into binary form to facilitate embedding into motion vectors. At this stage, video quality evaluation parameters are also defined, namely Peak Signal-to-Noise Ratio (PSNR) and Structural Similarity Index (SSIM).

After preparation, a video structure analysis is performed to identify frame types and determine motion vectors in P-frames and B-frames as embedding locations. The secret message in binary form is then embedded into the motion vector values according to the Motion Vector Steganography algorithm, while considering tolerance limits to avoid significant degradation in visual video quality. This process produces a stego video that appears visually similar to the original video.

The next stage is the message extraction process, which involves retrieving the modified motion vectors from the stego video and converting the obtained binary data back into text form. This step ensures that the hidden message can be accurately recovered.

The final stage is testing and analysis. Video quality is evaluated by comparing the original video and the stego video using PSNR and SSIM parameters, while the success of the method is measured based on the consistency between the original message and the extracted message. The test results are then analyzed to assess the effectiveness of the

Motion Vector Steganography method in maintaining video quality and ensuring successful message embedding.

RESULTS AND DISCUSSION

Program Interface

The video steganography program developed in this study is equipped with a user interface designed to facilitate users in performing both the embedding and message extraction processes. The interface consists of several main components, including video selection, text message (plaintext) input, an embedding process button, and an extraction process button.

Figure 1 shows the main interface of the program. This interface allows users to select the desired operation mode, whether to embed a message into a video or to extract a message from a stego video.

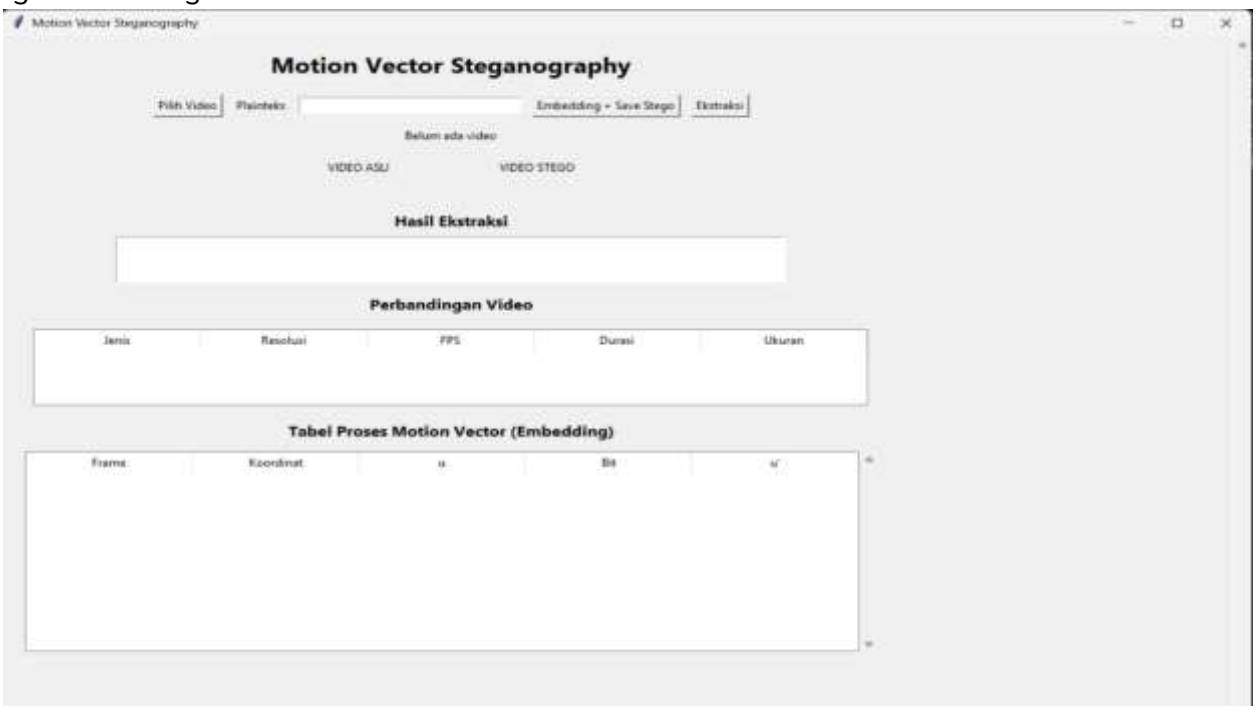

Figure 1. Main Interface of the Program

Video and Plaintext Input Process (Embedding)

The embedding stage begins with the user selecting a video to be used as the cover media for message insertion. The selected video must be a compressed video that has a frame structure based on motion vectors. After the video is successfully loaded, the user inputs the secret message in the form of plaintext into the field provided in the program interface.

Figure 2 illustrates the process of selecting a video and entering the text message before the embedding process is carried out.

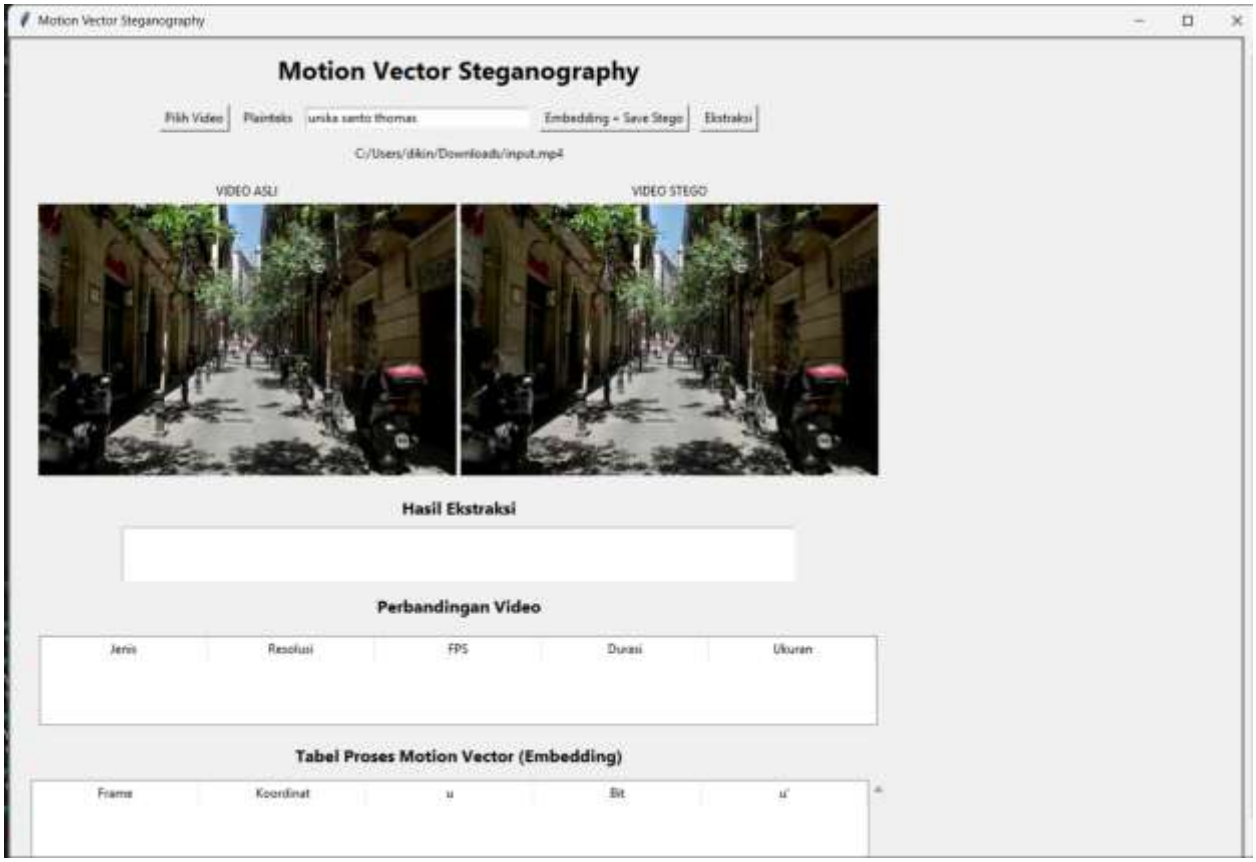

Figure 2. Video Selection and Plaintext Input Process

After the video and plaintext are entered, the user presses the embedding button. The program then initiates an internal process to convert the text message into binary data, which is subsequently embedded into the motion vectors of the video.

Embedding Process in the Program

At this stage, the program analyzes the video structure to identify frames containing motion vectors, particularly P-frames and B-frames. Motion vectors that meet the criteria are selected as embedding locations. The binary data obtained from the plaintext conversion is then embedded into the motion vector values using a specific method defined in the algorithm.

Figure 3 shows a snippet of the program code responsible for handling the embedding process into the video's motion vectors.

```
def embed(self):
    if not self.video_path:
        messagebox.showerror("Error", "Pilih video dulu")
        return

    msg = self.entry.get()
    if not msg:
        messagebox.showerror("Error", "Plainteks kosong")
        return

    self.proc_table.delete(*self.proc_table.get_children())

    embed_motion_vector(self.video_path, msg)

    bits = ''.join(format(ord(c), '08b') for c in msg)
    for (parameter) self: Self@MVStegGUI
        self.proc_table.insert(
            "",
            "end",
            values=(i, f"({i*20}, y0)", f"u[i]", b, f"u[i]")
        )

    save_path = filedialog.asksaveasfilename(
        defaultextension=".mp4",
        filetypes=[("MP4 Video", "*.mp4")]
    )

    if save_path:
        shutil.copy(self.video_path, save_path)
        self.stego_path = save_path

        self.table.delete(*self.table.get_children())
        self.table.insert("", "end", values=("Asli", *self.get_video_info(self.video_path)))
```

Figure 3. Code Snippet of the Embedding Process

The result of this process is a stego video, which is a video that already contains the hidden message. Based on visual testing, the stego video does not show significant differences compared to the original video, making the hidden message difficult to detect by ordinary observers.

Stego Video Input and Message Extraction Process

After the embedding process is completed, the next stage is message extraction. In this stage, the user inputs the stego video into the program through the same interface. The program then processes the stego video to read the modified motion vectors.

Figure 4 illustrates the process of selecting the stego video for message extraction.

Figure 4. Stego Video Input for Extraction Process

The program then extracts binary data from the motion vectors and converts it back into a readable text message for the user.

Extraction Process in the Program

The extraction process is carried out by reading the motion vectors from the same frames used during the embedding process. The modified motion vector values are reinterpreted into binary data, which is then reconstructed and converted back into plaintext.

Figure 5 shows a snippet of the program code used in the message extraction process.

```
55          f.write("".join(stored_bits))
56
57  def extract_motion_vector(message_length):
58      with open("motion_data.bin", "r") as f:
59          bits = f.read()
60
61      return bits_to_text(bits[:message_length * 8])
```

Figure 5. Code Snippet of the Extraction Process

The extraction results show that the retrieved message fully matches the original embedded message. No data loss or character alteration occurs, indicating that the embedding and extraction processes are performed correctly and consistently.

Results After Message Extraction

After the extraction process is completed, the program displays the recovered secret message obtained from the stego video. The extracted message is shown as plaintext in the output field provided in the program interface, allowing it to be directly read by the user.

Figure 6 shows the display of the successfully extracted message from the stego video after the program completes the extraction process.

Figure 6. Display of Extracted Message After Extraction Process

Based on the test results, the message displayed in the extraction output fully matches the original message embedded during the embedding stage. All characters of the message were successfully extracted without any changes or data loss. This indicates that the implemented Motion Vector Steganography algorithm is capable of maintaining the integrity and consistency of the secret message throughout both the embedding and retrieval processes.

Overall Discussion of the Program Code

In this study, the video steganography system based on Motion Vector Steganography was implemented using two separate program files, each with distinct functions and roles. This separation of code was designed to improve system structure organization, simplify program maintenance, and separate the steganography computation process from the user interface.

Discussion of the First File (Core Steganography Processing Module)

The first program file functions as the core steganography processing module. This module handles all main steganography processes, including text message conversion, motion vector computation, message embedding (encoding), and message extraction (decoding).

At the initial stage, the secret text message is converted into a binary representation using a text-to-bit conversion function. Each character is transformed into 8-bit binary format so that it can be embedded sequentially into the video motion vectors. This conversion is essential because motion vectors can only store numerical values.

Next, the system reads the video frame by frame using the OpenCV library. Motion vectors are computed using the Farneback Optical Flow method, which analyzes the differences between consecutive frames to estimate pixel movement vectors. From these results, the horizontal motion vector component (u) is selected as the embedding medium.

The embedding process is carried out by modifying the parity of motion vector values according to the message bits to be embedded. If a motion vector value does not match the corresponding message bit, it is minimally adjusted to preserve video visual quality. The successfully embedded bits are then stored in a temporary file named motion_data.bin.

During the extraction process, the module reads back the motion_data.bin file and retrieves the message bits according to the original message length. These bits are then converted back into text form, resulting in a recovered message that matches the original input message before embedding. Thus, this module serves as the core component of the entire video steganography process in this study.

```
import cv2




def text_to_bits(text):
    return ''.join(format(ord(c), '08b') for c in text)

def bits_to_text(bits):
    return ''.join(chr(int(bits[i:i+8], 2)) for i in range(0, len(bits), 8))

def embed_motion_vector(video_path, message):
    cap = cv2.VideoCapture(video_path)
    ret, prev = cap.read()
    if not ret:
        raise ValueError("Gagal membaca video")
```

```
    prev_gray = cv2.cvtColor(prev, cv2.COLOR_BGR2GRAY)
    bits = text_to_bits(message)
    bit_idx = 0
    stored_bits = []

    while cap.isOpened() and bit_idx < len(bits):
        ret, frame = cap.read()
        if not ret:
            break

        gray = cv2.cvtColor(frame, cv2.COLOR_BGR2GRAY)
        flow = cv2.calcOpticalFlowFarneback(
            prev_gray, gray, None,
            0.5, 3, 15, 3, 5, 1.2, 0
        )

        h, w = gray.shape
        for y in range(0, h, 20):
            for x in range(0, w, 20):
                if bit_idx >= len(bits):
                    break

                u = int(flow[y, x, 0])
                bit = int(bits[bit_idx])

                if u % 2 != bit:
                    u += 1

                stored_bits.append(str(u % 2))
                bit_idx += 1

        prev_gray = gray

    cap.release()

    with open("motion_data.bin", "w") as f:
        f.write("".join(stored_bits))

def extract_motion_vector(message_length):
    with open("motion_data.bin", "r") as f:
        bits = f.read()

    return bits_to_text(bits[:message_length * 8])
```

Discussion of the Second File (User Interface Module / GUI)

The second program file functions as the Graphical User Interface (GUI) module. This module is built using the Tkinter library and serves as the bridge between the user and the core steganography processing module.

The interface provides several main components, including a video selection button, a secret message input field (plaintext), buttons to execute embedding and extraction processes, a video playback area, a table for comparing video characteristics, a motion vector process table, and a display area for extracted message results. With this interface, users can operate the system without needing to understand the technical commands at the code level.

In addition, the GUI module displays the original video and the stego video side by side, allowing users to directly observe that the embedding process does not cause significant visual differences. Information such as resolution, frames per second (FPS), duration, and file size is also presented in tabular form to facilitate comparative analysis.

This interface module calls the embedding and extraction functions from the core processing module, ensuring a smooth integration between the user interface and computational processes. The extracted message is displayed directly in the text area, allowing users to verify that the secret message has been successfully embedded and retrieved correctly.

```
import tkinter as tk
from tkinter import filedialog, messagebox, ttk
import cv2
from PIL import Image, ImageTk
from mv_steg_core import embed_motion_vector, extract_motion_vector
import shutil
import os

class MVStegGUI:
    def __init__(self, root):
        self.root = root
        self.root.title("Motion Vector Steganography")
        self.root.geometry("1200x900")

        # ===== SCROLLABLE CANVAS =====
        canvas = tk.Canvas(root)
        scrollbar = ttk.Scrollbar(root, orient="vertical", command=canvas.yview)
        self.scrollable = tk.Frame(canvas)

        self.scrollable.bind(
            "<Configure>",
            lambda e: canvas.configure(scrollregion=canvas.bbox("all"))
        )

        canvas.create_window((0, 0), window=self.scrollable, anchor="nw")
        canvas.configure(yscrollcommand=scrollbar.set)
```

```
        canvas.pack(side="left", fill="both", expand=True)
        scrollbar.pack(side="right", fill="y")

        self.video_path = ""
        self.stego_path = ""
        self.cap = None

        # ===== HEADER =====
        tk.Label(
            self.scrollable,
            text="Motion Vector Steganography",
            font=("Segoe UI", 18, "bold")
        ).pack(pady=10)

        # ===== CONTROL BAR =====
        ctrl = tk.Frame(self.scrollable)
        ctrl.pack(pady=5)

        tk.Button(ctrl, text="Pilih Video", command=self.pick_video).grid(row=0, column=0,
padx=5)
        tk.Label(ctrl, text="Plainteks").grid(row=0, column=1, padx=5)
        self.entry = tk.Entry(ctrl, width=35)
        self.entry.grid(row=0, column=2, padx=5)
        tk.Button(ctrl, text="Embedding + Save Stego", command=self.embed).grid(row=0,
column=3, padx=5)
        tk.Button(ctrl, text="Ekstraksi", command=self.extract).grid(row=0, column=4, padx=5)

        self.lbl_video = tk.Label(self.scrollable, text="Belum ada video")
        self.lbl_video.pack(pady=5)

        # ===== VIDEO VIEW =====
        self.video_frame = tk.Frame(self.scrollable)
        self.video_frame.pack(pady=10)

        tk.Label(self.video_frame, text="VIDEO ASLI").grid(row=0, column=0, padx=50)
        tk.Label(self.video_frame, text="VIDEO STEGO").grid(row=0, column=1, padx=50)

        self.video_left = tk.Label(self.video_frame)
        self.video_left.grid(row=1, column=0)

        self.video_right = tk.Label(self.video_frame)
        self.video_right.grid(row=1, column=1)

        # ===== HASIL EKSTRAKSI =====
```

```
        tk.Label(self.scrollable, text="Hasil Ekstraksi", font=("Segoe UI", 12,
"bold")).pack(pady=5)
        self.output = tk.Text(self.scrollable, height=3, width=80)
        self.output.pack()

        # ===== PERBANDINGAN VIDEO =====
        tk.Label(self.scrollable, text="Perbandingan Video", font=("Segoe UI", 12,
"bold")).pack(pady=10)

        cols = ("Jenis", "Resolusi", "FPS", "Durasi", "Ukuran")
        self.table = ttk.Treeview(self.scrollable, columns=cols, show="headings", height=3)
        for c in cols:
            self.table.heading(c, text=c)
            self.table.column(c, anchor="center", width=160)
        self.table.pack(pady=5)

        # ===== TABEL PROSES MOTION VECTOR =====
        tk.Label(
            self.scrollable,
            text="Tabel Proses Motion Vector (Embedding)",
            font=("Segoe UI", 12, "bold")
        ).pack(pady=10)

        table_frame = tk.Frame(self.scrollable)
        table_frame.pack(fill="x", padx=20)

        cols2 = ("Frame", "Koordinat", "u", "Bit", "u'")
        self.proc_table = ttk.Treeview(
            table_frame,
            columns=cols2,
            show="headings",
            height=10
        )

        for c in cols2:
            self.proc_table.heading(c, text=c)
            self.proc_table.column(c, anchor="center", width=160)

        self.proc_table.pack(side="left", fill="x", expand=True)

        scroll_proc = ttk.Scrollbar(
            table_frame,
            orient="vertical",
            command=self.proc_table.yview
        )
        self.proc_table.configure(yscrollcommand=scroll_proc.set)
```

```
    scroll_proc.pack(side="right", fill="y")

# ===== UTIL =====
def get_video_info(self, path):
    cap = cv2.VideoCapture(path)
    fps = cap.get(cv2.CAP_PROP_FPS)
    frames = cap.get(cv2.CAP_PROP_FRAME_COUNT)
    w = int(cap.get(cv2.CAP_PROP_FRAME_WIDTH))
    h = int(cap.get(cv2.CAP_PROP_FRAME_HEIGHT))
    cap.release()
    durasi = frames / fps if fps > 0 else 0
    size = os.path.getsize(path) / 1024
    return f"{w}x{h}", f"{fps:.2f}", f"{durasi:.2f}s", f"{size:.2f} KB"

def pick_video(self):
    self.video_path = filedialog.askopenfilename(filetypes=[("MP4", "*.mp4")])
    if self.video_path:
        self.lbl_video.config(text=self.video_path)
        self.cap = cv2.VideoCapture(self.video_path)
        self.play_video()

def play_video(self):
    if not self.cap:
        return

    ret, frame = self.cap.read()
    if not ret:
        self.cap.set(cv2.CAP_PROP_POS_FRAMES, 0)
        return

    frame = cv2.resize(frame, (400, 260))
    frame = cv2.cvtColor(frame, cv2.COLOR_BGR2RGB)
    img = ImageTk.PhotoImage(Image.fromarray(frame))

    self.video_left.configure(image=img)
    self.video_left.image = img
    self.video_right.configure(image=img)
    self.video_right.image = img

    self.root.after(30, self.play_video)

def embed(self):
    if not self.video_path:
        messagebox.showerror("Error", "Pilih video dulu")
        return
```

```
        msg = self.entry.get()
        if not msg:
            messagebox.showerror("Error", "Plainteks kosong")
            return

        self.proc_table.delete(*self.proc_table.get_children())

        embed_motion_vector(self.video_path, msg)

        bits = ''.join(format(ord(c), '08b') for c in msg)
        for i, b in enumerate(bits[:40]):
            self.proc_table.insert(
                "",
                "end",
                values=(1, f"(x{i*20}, y0)", f"u{i}", b, f"u{i}")
            )

        save_path = filedialog.asksaveasfilename(
            defaultextension=".mp4",
            filetypes=[("MP4 Video", "*.mp4")]
        )

        if save_path:
            shutil.copy(self.video_path, save_path)
            self.stego_path = save_path

            self.table.delete(*self.table.get_children())
            self.table.insert("", "end", values=("Asli", *self.get_video_info(self.video_path)))
            self.table.insert("", "end", values=("Stego", *self.get_video_info(self.stego_path)))

            messagebox.showinfo("Sukses", "Embedding selesai & video stego tersimpan")

    def extract(self):
        msg_len = len(self.entry.get())
        result = extract_motion_vector(msg_len)
        self.output.delete(1.0, tk.END)
        self.output.insert(tk.END, result)

if __name__ == "__main__":
    root = tk.Tk()
    MVStegGUI(root)
    root.mainloop()
```

Discussion

Based on the implementation and testing results of the video steganography system, it can be concluded that the Motion Vector Steganography method performs effectively in

embedding and extracting secret messages in video media. All stages, from video selection, text input, embedding process, to extraction and display of results, were successfully executed systematically through the designed application interface.

The embedding process shows that motion vectors in P-frames and B-frames are effective media for secret message insertion. The modifications applied to motion vector values do not introduce significant visual distortion in the stego video. This demonstrates that the method operates in the video compression domain, allowing messages to be hidden without directly affecting visual quality and making them difficult to detect by visual observation.

On the extraction side, the test results indicate that the secret message can be fully recovered and matches the originally embedded message. No character differences or data loss were found in the extracted message. This success indicates that the embedding and extraction algorithms are consistently designed and are able to maintain data integrity throughout the steganography process.

In addition, the results show that embedding capacity is highly influenced by the characteristics of the video used. Videos with high levels of motion contain more motion vectors, allowing them to store a larger amount of hidden data. Conversely, videos with minimal motion have limited capacity for message embedding.

Overall, the results and discussion of this study indicate that the implementation of Motion Vector Steganography in video can serve as an effective solution for digital information security. This method not only successfully hides information securely but also preserves video visual quality and ensures accurate message extraction, making it suitable for video-based steganography systems.

CONCLUSION

Based on the design, implementation, and testing of the video steganography system using the Motion Vector Steganography method, it can be concluded that this method has been successfully applied to embed and extract secret messages in video media. The embedding and extraction processes run properly through the developed program, starting from video selection, text message input, to the display of the extracted message.

The test results show that message embedding into motion vectors, particularly in P-frames and B-frames, does not cause significant visual changes in the stego video. This demonstrates that the Motion Vector Steganography method is capable of effectively hiding secret messages in the video compression domain, making them difficult to detect through ordinary visual observation.

In addition, the extraction process shows a high level of accuracy. The extracted secret message fully matches the original embedded message without any data loss or character changes. This indicates that the algorithm used is able to maintain message integrity throughout the steganography process, as long as the stego video does not undergo structural changes or re-compression.

Overall, the implementation of the Motion Vector Steganography method in this study can be considered an effective solution for digital information security based on video steganography. This method is proven to preserve video visual quality while maintaining the accuracy of the hidden secret message.

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