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VLC-Based Text, Audio, Image & Video Transmission & Receiver Over Small Distance

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Abstract: With the continuous rise in global internet usage, the need for dependable and high-speed connectivity has become more critical. Although Wi-Fi (Wireless Fidelity) is commonly used, it can become expensive and often suffers from reduced speed, especially when more than two routers are connected simultaneously. Light Fidelity (Li-Fi) presents a cutting-edge solution to these issues by enabling wireless communication through visible or infrared light, based on the principle of Visible Light Communication (VLC).This study proposes a system that facilitates the transmission of different data types—such as text, audio and images—using VLC technology. The data is sent via high-intensity LED arrays at the transmitting end, while a photodiode at the receiving end detects and converts the light signals back into data. The system's effectiveness is analyzed under varying conditions, including changes in transmission distance, light intensity, and signal quality. Li-Fi technology can deliver data at rates reaching up to 500 Mbps over short ranges using LED lights, or around 10 Kbps when standard lamps are used. Experimental findings validate the system's ability to transfer data efficiently under different environmental scenarios. Moreover, the concept is extended to demonstrate its potential in indoor location-based services, revealing its wide scope of application..

Keywords-- Li-Fi, Visible Light Communication (VLC), wireless communication, LED transmission, photodiode receiver, high-speed data transfer, indoor positioning, data transmission, light intensity, transmission distance, text/audio/image transfer, Wi-Fi alternative, infrared communication

I. INTRODUCTION

The increasing number of internet users worldwide has intensified the demand for faster and more reliable connectivity solutions. Traditional wireless technologies like Wi-Fi are widely adopted, yet they often become costly and exhibit decreased performance when multiple routers operate within the same network. To overcome these limitations, Light Fidelity (Li-Fi) has emerged as an innovative alternative. This technology facilitates wireless data transmission using visible or infrared light, implemented through the concept of Visible Light Communication (VLC) [1]. In the proposed system, the transmitter setup consists of a PC, Arduino Uno, UART interface, and high-intensity LED light, which collectively enable the modulation of data into light signals [1]. On the receiver side, a solar panel is used to detect incoming light signals, which are then decoded using an Arduino Uno, and the output is delivered through a PC or a speaker, depending on the data type. This setup supports the transmission of various types of content, such as text, audio, and images, and its performance is assessed under varying conditions including light intensity, transmission distance, and signal clarity [2]. The system demonstrates that Li-Fi technology can achieve high-speed data transfer—up to 500 Mbps with LEDs or 10 Kbps using standard lighting—making it a strong candidate for future wireless communication systems. Furthermore, its potential applications extend to indoor location-based services, showcasing the flexibility and scope of VLC-based communication [2].

II. LITERATURE REVIEW

R. A. A. Othman, D. A. Sagaran, M. Mokayef, and W. I. I. R. b. W. M. Nasir, in their work titled "Exploring Li-Fi for IoT Device Connectivity", evaluated the potential of Light Fidelity (Li-Fi) in Internet of Things (IoT) environments. Through enhanced light modulation techniques and improved receiver design, they developed a Li-Fi system tailored for small-scale data transmission typical in IoT applications. Their findings suggest that Li-Fi enables secure and rapid communication. Nonetheless, the study also raised concerns about scalability and interference from ambient light, which could affect performance in larger or more dynamic networks [1].

A. Assabir, J. Elmhamdi, A. Hammouch, and A. Akherraz "Enhancing Audio Communication via Li-Fi using PWM", investigated the application of pulse-width modulation (PWM) for transmitting sound over Li-Fi. By implementing PWM, they achieved effective light signal modulation, which led to improved audio clarity and minimized noise disruption. However, their research noted that system stability was impacted by inconsistent lighting and that precise alignment of components was essential for optimal results [2].

U. Pant, P. Gupta, A. Verma, P. Pant, A. Kumar, and V. Kumar Jadoun titled "Dual Mode Data Transfer through Li Fi in Smart Environments" focused on transmitting both analog and digital signals using LED-based systems. Particularly in renewable energy scenarios, they proposed a reliable communication protocol supporting both data types. The outcome showed that Li-Fi is capable of handling diverse signal forms, although its efficiency can be challenged by complex environmental factors [3].

S. S, R. B, P. L, S. S, S. M, and V. V "Audio Signal Transmission Using VLC-Based Li-Fi", examined the use of Visible Light Communication (VLC) for transferring audio content. Their system utilized filtering mechanisms to ensure accurate modulation and demodulation, resulting in low latency and high-quality audio transmission. Despite its benefits, the study highlighted limitations caused by environmental noise and changing lighting conditions, which can negatively impact audio clarity in low-light surroundings [4].

E. Ifada, N. T. Surajudeen-Bakinde, N. Faruk, A. Abubakar, O. O. Mohammed, and A. O. Otuoze presented their work titled "Advanced Li-Fi-Based System for Multitype Data Transmission", which focuses on building a robust Li-Fi framework for sending data like text and images. Using light modulation for transmission and decoding strategies at the receiver, they demonstrated the system's superiority over traditional Wi-Fi in terms of both speed and security. Nonetheless, challenges such as limited operational range and unstable performance in dynamic settings were noted [5].

M. Vasu, A. K. Mishra, U. S. Chauhan, D. Chandola, and S. Kapoor "Short-Range Image Transfer using Li-Fi Technology" explored how Li-Fi can facilitate image data transmission. By modulating LED light signals, their system successfully transferred images with low latency and high clarity over short distances. However, the study pointed out issues related to precise alignment and sensitivity to light interference, necessitating careful environmental control for optimal functioning [6].

I. Poonguhali, M. Anusha, V. Anciline, and D. Kavitha"VLC-Based Video Transmission Using LED Illumination", demonstrated how video signals could be transmitted using Visible Light Communication (VLC) through LED lighting. The video data was modulated into light and decoded using a photodetector at the receiver. The authors highlighted the advantages of VLC, such as its large bandwidth and immunity to electromagnetic interference. The successful demonstration showed promise for future use in areas like indoor wireless communication, secure data transfer, and smart transport systems [7].

III. METHODOLOGY

A. Audio Transmission

The audio transmission process starts by choosing or recording the desired sound to be transmitted. This audio file is initially sent to the microcontroller located on the transmitter side, where it undergoes encoding to prepare it for transmission [3]. After encoding, the microcontroller modulates the LED light by varying its brightness, converting the audio data into light pulses. These changes in brightness represent binary values corresponding to segments of the audio signal [3].

When the receiver is within the transmission range, a solar panel placed on the receiver side detects these modulated light signals. It captures the LED's flickering patterns, which are then forwarded to the receiver's microcontroller for processing. This microcontroller decodes the incoming signals and reconstructs them back into the original audio format [4]. The recovered sound is then played through a speaker for clear audio output. Additionally, a personal computer equipped with Visual Basic Runtime is connected to the system to simulate and manage audio playback, providing a better user experience for the received audio signal [4].

B. Text Transmission

In the process of transmitting text data, it begins by either typing or selecting the desired content on a device such as a computer or smartphone. This text is then forwarded to the transmitter's microcontroller, where it is converted into a suitable encoded format for light-based communication. The encoded data is then translated into a series of light pulses using an LED, which blinks in a specific sequence that represents the binary equivalent of the text (1s and 0s) [5].

On the receiver side, a solar panel is used to detect these modulated light signals instead of a traditional photodiode. When the solar panel is within the effective range of the LED, it captures the variations in light intensity. These signals are then passed to the receiver’s microcontroller, which decodes the binary information back into its original text form. Finally, the recovered text is displayed on an output device such as a monitor or mobile screen, allowing the message to be read clearly at the receiving end, thereby completing the transmission cycle [5].

C. Image Transmission

The image transmission process starts with selecting the desired image and resizing it to match the required display dimensions—for example, adjusting it to 128x64 pixels to fit a graphic LCD [6]. To streamline the data for transmission, the image is converted into a monochrome (black-and-white) format, which simplifies the data structure by reducing color complexity. This simplified image is then processed using specialized software, which transforms it into a numerical array indicating the intensity of each pixel [6].

This pixel data array is sent to the microcontroller on the transmitter side, where it is encoded into a format suitable for light-based transmission [6]. The encoded image data is then transmitted through the LED by rapidly modulating its light—each flicker corresponding to binary values representing the pixel data [7].

At the receiver's end, a solar panel is used to detect these flickering light signals instead of a photodiode.The solar panel captures the light variations and passes the signal to the receiving microcontroller. There, the binary data is decoded back into its original image form. Finally, the image is displayed on a graphic LCD, successfully recreating the visual content on the receiver side [7].

IV. Workflow And Data Preparation

A. Audio Source: The audio signal originates from a prerecorded sound file, typically in formats such as MP3 or WAV, which serves as the source for transmission via the Li Fi system.

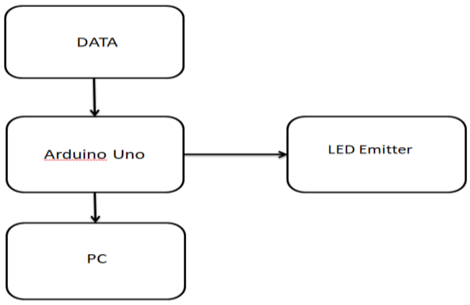

Fig1: Transmitter

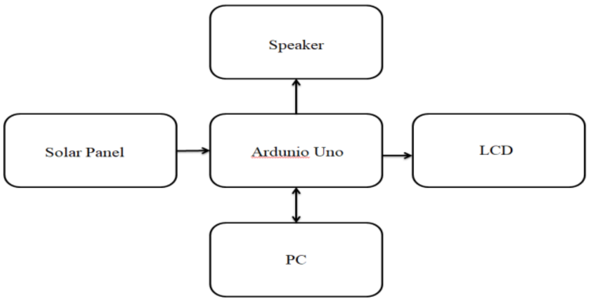

Fig 2: Receiver

B. Arduino Uno: The Arduino Uno functions as the central controller, handling the processing of data. It modulates the LED based on the incoming data signal, transforming it into corresponding light pulses for Li-Fi transmission. Additionally, it ensures proper synchronization among all components involved in the system.

C. LED Emitter: In this Li-Fi setup, the LED serves as the primary transmission medium. It translates the processed data signal into modulated pulses of light, which travel through a direct line-of-sight to the receiver. The brightness of the LED varies in response to the audio input, embedding the signal within the light stream for effective transmission.

D. PC(Transmitter): The transmitter-side PC is used to input the text data that needs to be transmitted. It sends the data to the Arduino Uno, which encodes it into a format suitable for Li-Fi transmission. The Arduino then modulates the LED to convert the encoded text into light pulses, which are transmitted over the air to the receiver.

E. Solar Panel: The solar panel at the receiver end acts as a light sensor, capturing modulated light signals from the LED and converting them into electrical signals for further processing.

F. Speaker: A solar panel at the receiver captures light signals and converts them into electrical signals. The Arduino Uno decodes these signals and sends the audio output to a speaker, allowing the received sound to be played clearly.

G. LCD: The LCD serves as the output display, showing the image received through Li-Fi after the Arduino decodes the signal captured by the solar panel.

H. PC(Receiver): On the receiving end, a personal computer (PC) is used to interpret the modulated light signals emitted by the LED. A solar panel captures these light pulses and converts them into electrical signals. These signals are then processed to reconstruct the original data.

Workflow:

1. Transmitter PC: The user inputs the data (text, image, audio, or video) on the PC, which is then processed and prepared for transmission.

2. Arduino (Transmitter): The Arduino receives the data from the transmitter PC and encodes it into a suitable format for Li-Fi transmission.

3. LED Emitter: The LED modulates its light based on the encoded data (text, image, or audio) and transmits the data through light pulses.

4. Solar Panel (Receiver): The solar panel at the receiver end detects the modulated light pulses and converts them into electrical signals.

5. Receiver Arduino: The Arduino at the receiver side decodes the received electrical signals back into the original data (text, image, or audio).

6. Output Device: The decoded data is then displayed or played back through the appropriate output device (PC for text and LCD for images, or speaker for audio).

V. RESULT

A. Audio Transmission

In this setup Fig A. A smartphone plays music and is connected to the transmitter circuit via an aux cable. The audio signal is sent to a high-power LED, which modulates its brightness according to the sound waves, converting the audio into light pulses. These light signals travel through open space and are captured by a solar panel at the receiver end. The solar panel converts the light back into electrical signals, which are then fed to a speaker. The speaker reproduces the original sound, allowing the song to be heard clearly. This demonstrates real-time audio transmission using Li-Fi, where light acts as the medium for wireless sound transfer.

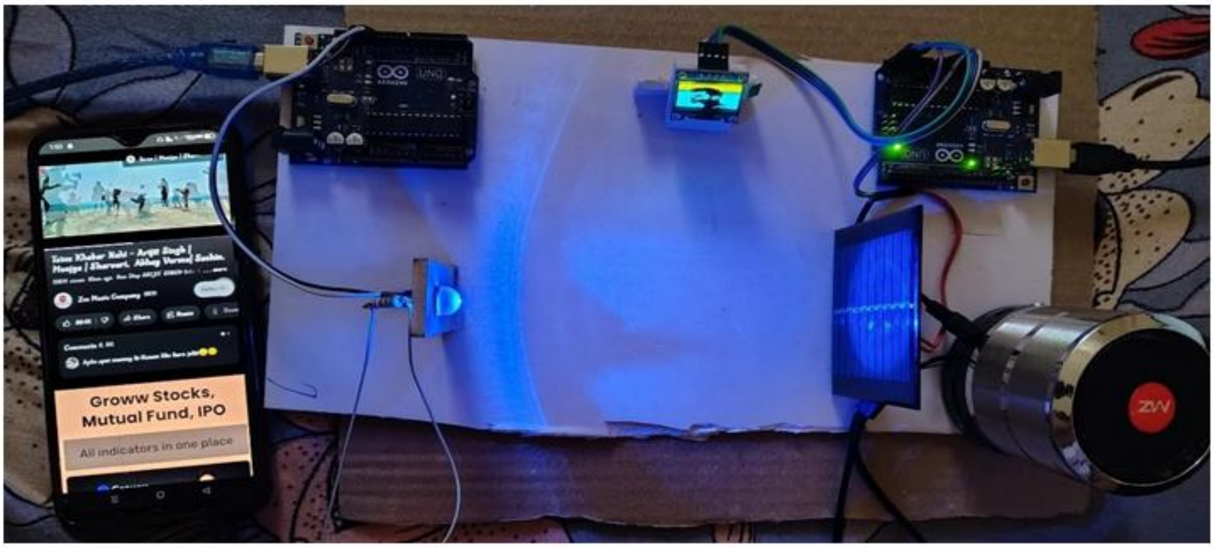

Fig A: Audio Transmission

B. Text Transmission

In this Fig B.1. Li-Fi-based text transmission system, the user first enters the desired text message on the transmitter PC using the Arduino Uno IDE. This text is sent to the Arduino Uno, where it is encoded into binary format to prepare it for optical transmission. The binary data is then used to modulate the brightness of a high-power LED, which blinks in a specific pattern representing the binary values (1s and 0s). This modulated light acts as the transmission medium and is sent across the communication path.

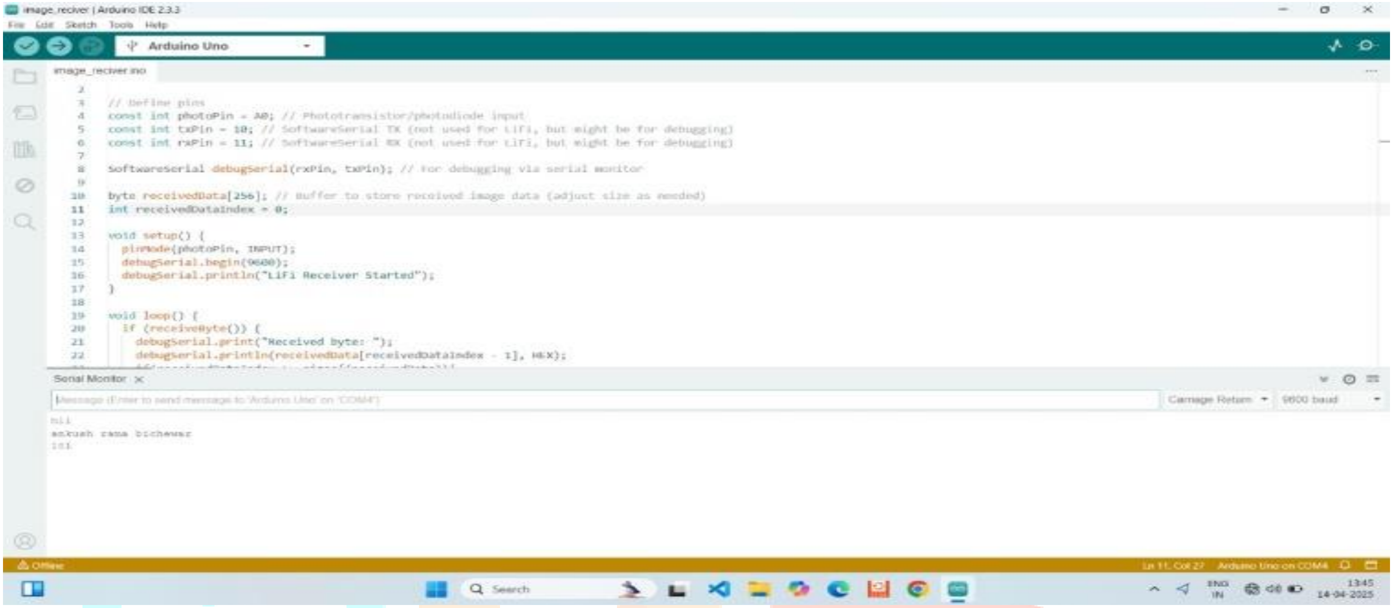

Fig B.1: Text Transmission

On the Fig B.2.Receiving end, a solar panel detects the flickering light and converts it into electrical signals. These signals are then processed by the receiver Arduino Uno, which decodes the binary back into readable text. Finally, the decoded message is displayed on the receiver PC's Arduino IDE, completing the text transmission wirelessly through visible light communication.

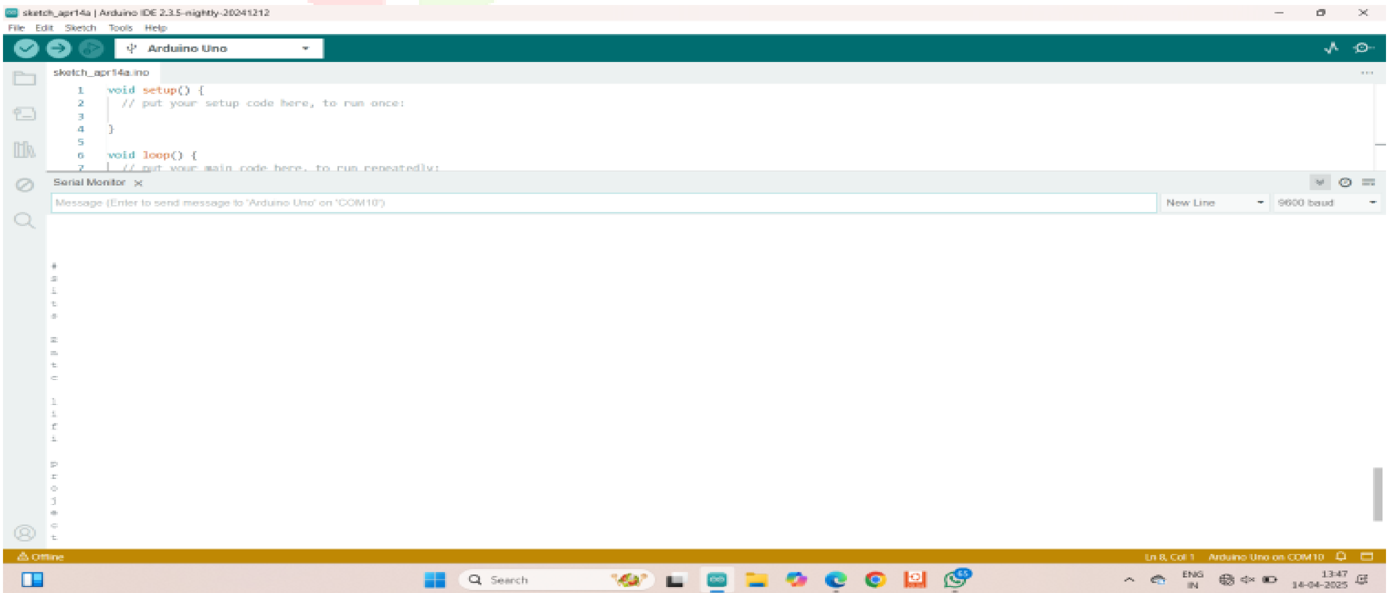

Fig B.2: Text Receiver

C. Image Transmission

At the Fig C.1.transmitter side, an Arduino Uno is connected to a white LED, which acts as the data transmitter. Data is first sent using the Arduino IDE from a PC. This data is in text or hexadecimal form, depending on what needs to be transmitted. When transmitting an image, a hexadecimal representation of the image is loaded into the Arduino program. Each pixel of the image is represented in hexadecimal and stored in a byte array. This array is associated with a unique identifier, such as 101 or 105, to allow for selective transmission of images. Once the data is ready, the Arduino transmits it through the LED using high speed on-off modulation. This rapid flickering is not visible to the naked eye but can be captured by the Solar Pannel at the receiver side. The Solar Pannel converts the light pulses into electrical signals. This forms the core of the Li-Fi technology—using light to carry information instead of radio waves.

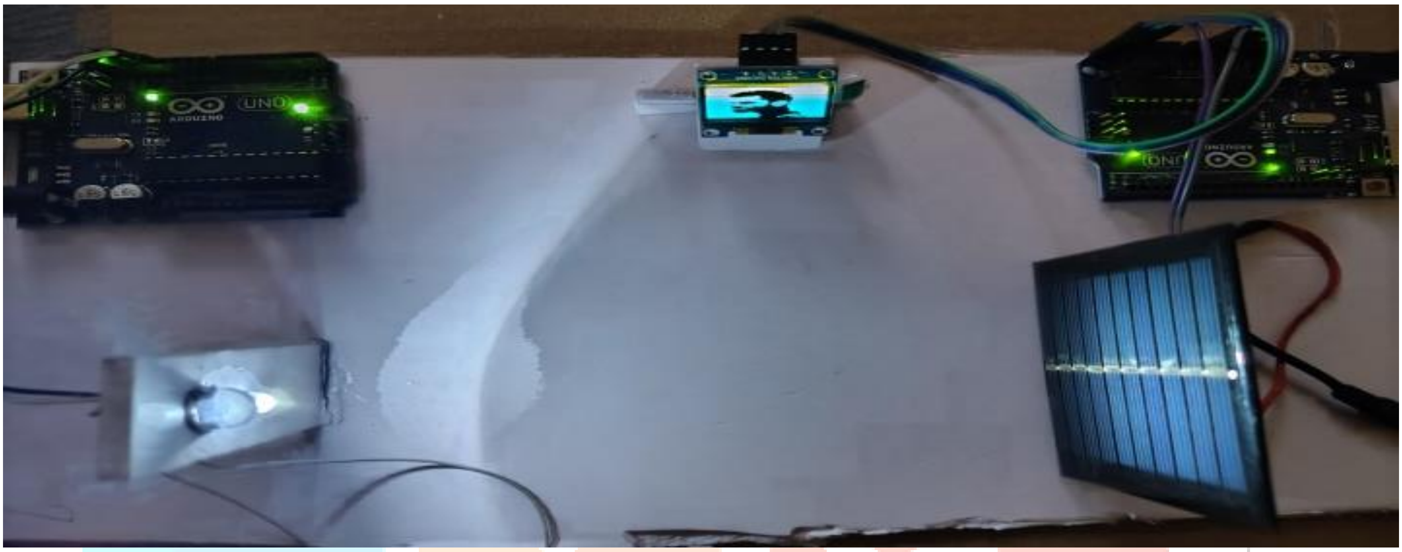

Fig C.1:Image Transmission

In this Fig C.2. Receiver side, another Arduino Uno is connected to a Solar sensor, which captures the light signals from the transmitter LED. The Arduino reads these electrical signals through an analog pin and converts them back into digital data. The received hexadecimal bytes are stored in an array in real time, as shown in the Arduino IDE serial monitor. In the serial monitor of the receiver, you can see text like "LiFi Receiver Started" and received values like "101", indicating the successful capture of the transmitted ID and image data.

Fig:C.2 :Image Receiver

When the receiver recognizes the ID 101 or 105, it maps this ID to the corresponding pre-saved hexadecimal image data. The Arduino uses this data to render the image on a color LED display. As seen in the image, the display successfully shows the face image transmitted from the other side. This verifies the end-to-end communication of image data via Li-Fi

D. Video Transmission

In Fig. D.1. A Li-Fi video transmission simulation using MATLAB, the process begins with converting a video into individual image frames. This is done using the VideoReader function, which allows the video to be read frame by frame. Each frame is extracted using readFrame and saved as a separate image using imwrite. The frames are systematically named (e.g., 000001.jpg, 000002.jpg) to preserve the correct sequence, which is crucial for accurate video reconstruction. This step results in a folder containing all the frames that represent the original video.

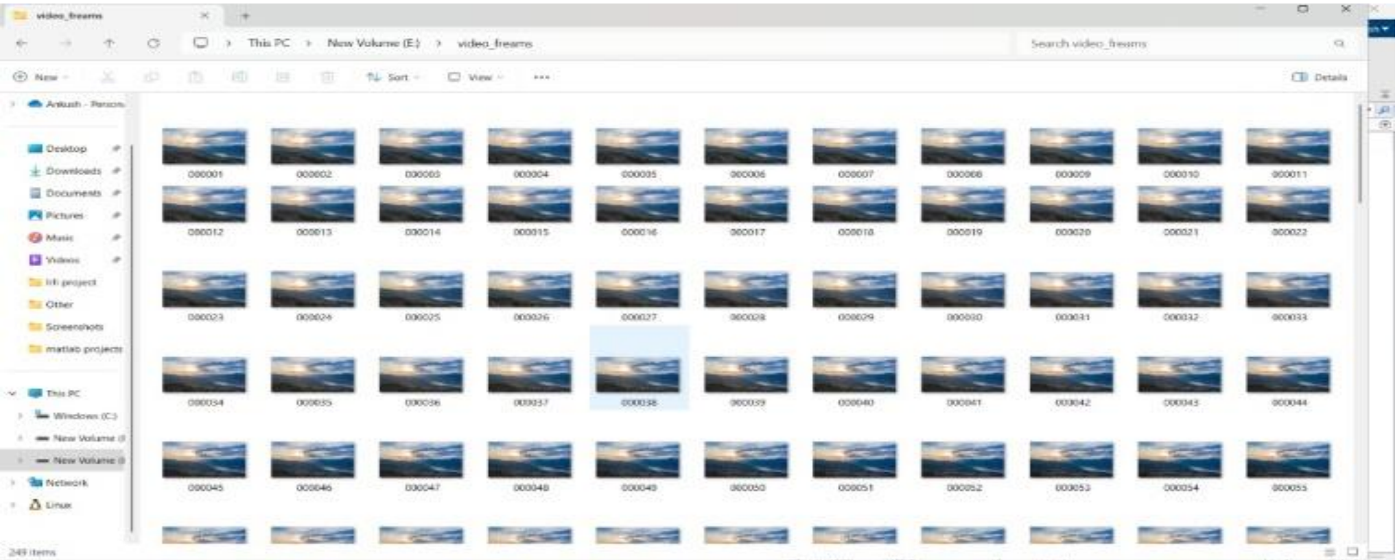

Fig D.1 Video Transmission

Fig D.2 shows The next step is to reconstruct the video from these images using the VideoWriter object. A script reads the image files in numerical order using imread and writes them into a video stream using writeVideo. Maintaining the correct order ensures that the playback sequence and timing remain accurate. After all frames are written, the video file is closed and saved.

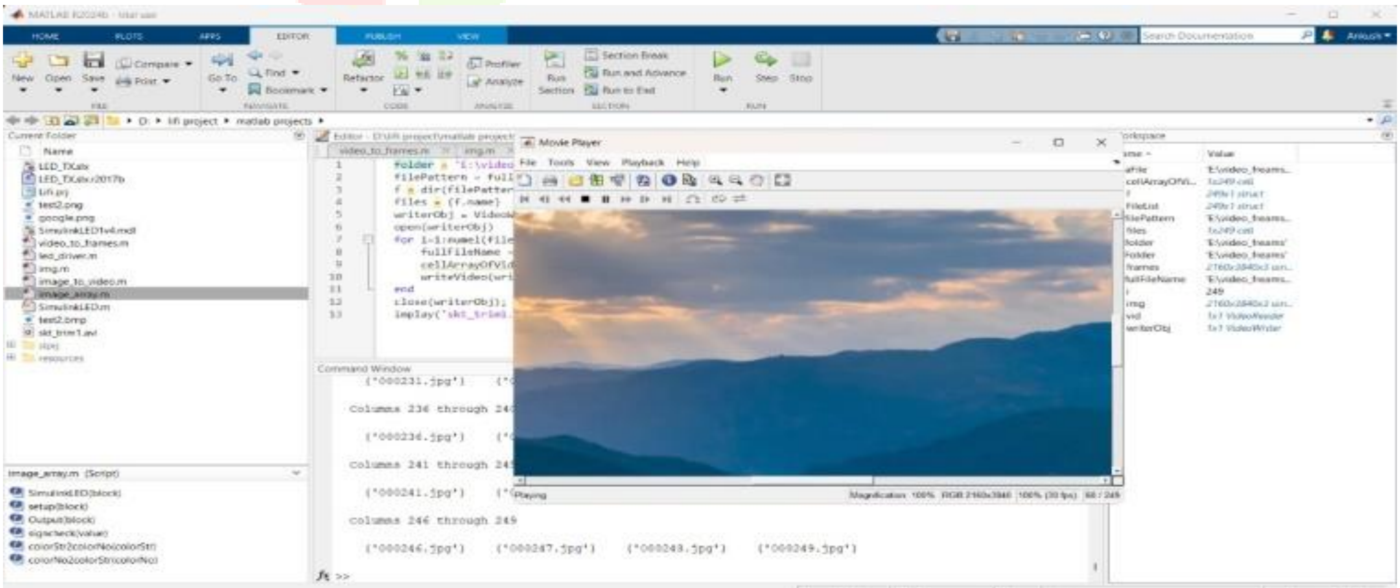

Fig D.2 Video Transmission

Two scripts, video_to_frames.m and image_to_video.m, handle these tasks automatically. MATLAB also displays related variables such as frame resolution, frame count, and file paths in its workspace. The GUI and video player offer visual feedback, confirming that the reconstructed video matches the original, ensuring data integrity through the Li-Fi transmission process.

VI. CONCLUSIONS

This paper investigated the potential of Li-Fi (Light Fidelity) technology as a ground breaking solution for wireless communication. By leveraging visible light for data transmission, Li-Fi presents several benefits over conventional radio-frequency communication systems such as Wi-Fi, including faster speeds, enhanced security, and reduced interference. The proposed system demonstrates the capability to transmit diverse data types—audio, text, and images—through a unified design involving two Arduino Uno boards, a high-power LED transmitter, and a solar panel receiver.

The system effectively manages and transmits data, highlighting Li-Fi's potential to deliver reliable communication with low latency. The use of light for data transmission makes Li-Fi an appealing alternative in scenarios where radio-frequency communication is impractical or limited. Additionally, the ability to handle multiple data types within a single system simplifies the design process, making it both efficient and cost-effective.

Despite its promising features, Li-Fi faces certain challenges such as the need for line-of-sight communication and its vulnerability to interference from environmental factors. However, the successful transmission of data across varying distances shows that Li-Fi holds significant potential for applications in industries such as healthcare, industrial automation, and smart homes. Further development and research are essential to overcome these limitations and improve the technology's reliability and range.

In conclusion, Li-Fi stands as a promising alternative to traditional wireless communication, offering faster speeds, better security, and increased flexibility. With ongoing advancements, it has the potential to become a major player in the future of wireless data transmission.

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