**VLC SYSTEM FOR INDOOR POSITIONING SYSTEM**

**Abstract**

Visible Light Communication (VLC) has recently become recognized as a leading technology in the areas of wireless communication and indoor positioning, providing benefits for high levels of security and human safety. The goal of this study is to familiarize readers with VLC technology, as well as the system's transmitters (Tx), receivers (Rx), data packets, and outcomes.

**1. Introduction**

**1.1. Introduce about VLC technology:**

The positioning system aids in human control and coordinates calculation so that services based on coordinates can be provided. Two categories of positioning technologies exist:

* Global Positioning System: GPS is a reliable positioning system for outdoor conditions, but it is not accurate for indoor locations. Physical factors including obstructions, walls, ceilings, and various indoor maps severely reduce satellite signals, necessitating high localization.
* Indoor Positioning System: Wi-Fi technology is commonly used for indoor positioning. It can leverage the existing Wi-Fi infrastructure with reasonable cost and complexity. However, each technology has its own advantages and disadvantages, so when choosing to use a particular technology, trade-offs must be accepted.

Visible light communication (VLC) for indoor positioning has attracted interest and research recently. Due to their advantageous qualities, LED lights are typically the signals sent in VLC systems.

A wireless technique called Visible Light Communication (VLC) makes it possible to transmit high-speed data using visible light. By changing the light source's output intensity, this data is conveyed. A photodiode device receives the signals and transforms the information into representations that are clear and easy to understand.

VLC has several distinguishing features, including:

* Signal confinement: Light cannot penetrate through solid walls by its very nature. This improves network security by making it simple to contain the signal inside a single area.
* Why Non-line-of-sight independence: Because VLC systems use light, many people think that any blockage can impair their ability to transmit data. Line-of-sight is not necessary, though. It can nevertheless function in spaces that are severely impeded, according to research.
* Safety in potentially dangerous environments: In locations where RF transmissions are deemed hazardous, VLC can be employed as a workable alternative solution. These systems not only convey data using non-RF technology, but also use low-energy light sources, ensuring user safety. Hospitals, airlines, and mines are a few examples of these hazardous environments.

**1.2. System Structure for VLC:**

Consider a space, like a building, that is separated into various parts, each of which has several LED lights installed for lighting purposes. These spaces are modeled as illustrated in the diagram and are loosely referred to as rooms. An exclusive address termed (x, y, z) is given to each LED. The receiver may ascertain its precise location within the room using the coordinates of the LED's position. The receiver can send the LED IDs and their local coordinates to a server, which can then use them to determine the precise coordinates, once the local position is known.

A diagram of a device with a receiver

Description automatically generated

Figure 1. VLX System Model

Each LED needs a processing unit in order to translate the addresses and IDs into bits. For instance, the meter-based positional coordinates of LED B could be (3, 1, 3) and could be encoded as the bit string 110111. Based on a modulation method, the control circuit turns the LED's on/off state (High/Low). On-Off Keying (OOK) is a method for data modulation that is often employed. As a result, each LED transmits the information bits, which vary the light intensity.

**2. TX System**

**2.1. TX system**

The data transfer diagram for the LED light is shown in Figure 2. The sent value, which is the ID code, is first communicated as a 4-bit string. The length is then doubled to 8 bits by Manchester encoding, and a 6-bit preamble is added after that. We thus get a 14-bit string as a result. The ESP32 microcontroller serves as the LED's driver, continuously turning the light on and off using a technique called OOK modulation. The frequency of this OOK modulation can be changed via timer/counter interrupts. The predefined signal will be broadcast by the LED light. One thing to keep in mind is that in order to prevent the LED from flickering, we must select a frequency, and the brightness must be close to steady state in order to protect the user's vision.

A diagram of a computer

Description automatically generated

Figure 2. TX modulation diagram

**2.2. The On-Off Keying (OOK) modulation technique**

The On-Off Keying (OOK) modulation technique is employed in this VLC system. Pulse Width Modulation (PWM), Pulse Amplitude Modulation (PAM), Pulse Position Modulation (PPM), and Color-shift Keying (CSK) are just a few of the several modulation techniques used in VLC systems. We'll apply the OOK modulation approach in this investigation. The LED light is equivalent to a binary "1" bit when it is on. In contrast, a binary "0" bit signifies that the LED is off. This modulation technique has the drawback of causing flickering because it turns the light source on and off in accordance with the 0 and 1 bits. In order to get around this problem, the signal will be Manchester coded (where a "0" bit is represented as "01" and a "1" bit is represented as "10") before being modulated. This prevents flickering by producing a balanced code with an equal amount of 0s and 1s. When the LED is off in the OOK modulation method, it is not entirely off; instead, the light intensity is modified so that the receiver can still distinguish between the "0" and "1" bits during the decoding process. The human eye is unable to detect the intensity shift.

A diagram of a power supply system

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Figure 3. TX block diagram

**3. RX System**

**3.1. C-OOK modulation.**

Camera On-Off Keying (C-OOK) is a modulation system that utilizes the On and Off states of an LED light to transmit data, relying on the operation mechanism of the rolling shutter in the image sensor to facilitate the process. The full data packet should be able to be collected using only the length of the LED light shown in the photograph.

Image sampling, which turns the colored image into a binary image, starts the processing process. Detecting the Region of Interest (RoI) from the sampled image is the next stage. Before sending it to the preprocessing block to create a 1D array of brightness intensities in accordance with the image, the brightness intensity from the RoI segment is calculated. The array is then utilized to identify the preamable bit sequence for data storage using logical techniques.

A diagram of a process flow

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Figure 4. RX modulation diagram

The signal frequency must be higher than 100Hz to prevent flickering. Additionally, the camera's frame rate (sampling rate) must be at least twice as high as the transmitter's (Tx) frequency.

**3.2. Data packet structure.**

Figure 5 presents the packet structure of the transmitter (Tx), consisting of a 6-bit preamble and 8 bits of data. This data portion will contain the IDs of each room in the simulated house

A blue and black rectangle with a blue circle and a white rectangle

Description automatically generated

Figure 5. Data packet structure

**4. Result and Conclusion**

Figure 6 presents the experimental results in 4 different cases when performing 4Khz frequency.

**A group of images of different types of lines

Description automatically generated with medium confidence**

Figure 6. Experimental results in 4 different cases when performing 4Khz frequency

Figure 7 presents the errors in the transmission process at frequency 4KHz.

A graph of error

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Figure 7. Table of errors

**5. Future works:**

- Develop an app on Android or iOS to detect signals transmitted from the Tx.

- Develop a Tx transmitter with a more advanced microcontroller, flashing LEDs with different frequencies for each LED.

- Develop a system to accurately locate the receiver's position.

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