Wi-Vi and Li-Fi based framework for Human Identification and Vital Signs Detection through Walls

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Abstract

Human motion detection and identification are becoming vital for building applications in smart homes. Traditional human activity recognition mechanisms use unique devices to track human motions having low resolution with less accuracy. The Wi-Fi signals in our homes can be extended to provide virtual human visualization through walls, as well as the ability to provide vital signs of persons behind walls. So in this paper, we have discussed the Wi-Vi and Li-Fi based framework that can identify moving humans behind opaque obstacles and in what ways does Vital Radio provide information about their physical health conditions and thus increasing the Wi-Vi detection accuracy using Li-Fi.

Keywords

Wi-Fi, Vital Radio, Wi-Vi, VLC, Li-Fi,

1. Introduction

The normal Wi-Fi router is not only used as a data transmitter router, but it can be used in several intelligent systems for smart health solutions. Wi-Fi can be upgraded to Wi-Vi which is cheaper and it can act as X-rays that can track a person's movements by sending some reverse radio signals as pings. Wi-Vi depends upon the Wi-fi signals which are based on MIMO (Multi Input Multi Output) antenna to capture the motion of objects behind the obstacles. Wi-Vi works in two basic modes, as a gesture detection framework, and as a moving object detection interface. Here, the main hurdle is to abolish reflections coming back and concentrate on the reflections coming from behind the obstacles [1].

Analyzing the reflections from objects behind the obstacle/wall is tough as the strength of the signal keeps on decreasing after getting reflected by objects. Because of this, small changes in signals are hard to analyze. Only a little patch of the entire signal gets transmitted to the entire site and the rest gets reflected by the obstacles [2]. Therefore, in order to resolve this issue, we are proposing a new technology which is capable of doing multi-tasking at a single time i.e., providing vision through the walls and also detecting vital signs of the person behind the wall.

LiFi is a fully networked wireless system based on Visual Light Communication which includes multiple access points and bi-directional multiuser communication. LiFi uses visible light, and visible light has spectrum 10,000 times greater than radio spectrum thus it has a higher range of frequencies. For LiFi, a transceiver for transmission which encompasses a modulation technique to carry data using light and receiver to receive the data is needed.

The important key ideas in this paper are is that how RF signals get cancelled when they get reflected from a stationary object. The receiver antenna works on the mobile object creating a discrepancy between the signals that can be refined to determine the motion of the target. This whole process is called MIMO inference.

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Secondly, the Vital-Radio is a wireless device that keeps eye on the heart and breathing rate of a human [3]. It is capable to operate in the presence of multiple people in the room and can detect the breathing and heart rate of each and every person.

For the creation of smart cities, IoT has been originated as a key source. Many theft incidents have been reported in big cities after which IoT came into the picture. IoT was the major advancement in smart home systems with the help of which we can monitor our home from anywhere around the globe. Using our designed framework, the efficacy of the IoT framework can be escalated substantially.

No doubt we have been surrounded by an enormous amount of data available but to use it in a booming and useful manner so artificial intelligence is the domain which not only made us possible to utilize the data but also to generate references, predictions, models, analysis, stats, probabilities and speculations etc based on data access.

2. Previous Work

2.1. Ultra-Wideband Systems

Earlier various attempts have been made in order to develop a system that can provide vision through walls but they include heavy-weight radars and costly material. This system has only been provided to the military for security operations. They are largely focused on simulations. The main problem in these types of systems was the Flash effect which decreases the accuracy of the subject. To eliminate this issue, very short pulses were used of the order of about 1 nanosecond. Also to provide isolation for reflected signals, linear frequency chirp can be used. But all these processes require ultra-wide bands (UWB) which are of the order of 2GHz [1]. Hence due to which its setup becomes heavier and bulkier. Also, this wall sensing technique can be used separately for 1-Dimensional or 2-Dimensional detection. Whereas in our proposed system, it is lighter and very much affordable in price and hence can be used easily.

2.2. WISEE

Presently there are many such devices that can detect human gestures such as commercially available Xbox, or games, etc. Also by using sensors by placing them on the human body or camera-based systems, we can detect human gestures. Some of the recent works operate in the range of 2.4GHz to identify human activities using the Micro-Dopler effect [2]. However, our framework is the most advanced device in this domain which even works in non-line of sight cases without using any device attached to the subject and also effectively works behind the obstacles.

2.3. Infrared and Thermal Imaging

Thermal imaging and infrared imaging have been developed to increase man's capability to see in foggy or smoky areas. In order to detect obstructions in the visible range of their sensors, the system captures thermal power-based signals. Due to the short frequency of this system, we cannot see through opaque obstructions, while the system presented in this paper works at about 12.5 cm [5].

2.4. Wi-Vi

Wi-Vi is a low powered and low-cost device that is accessible to average users. It works with the help of wifi router present in our home as it requires only a few MHz of bandwidth to operate. It performs wall imaging without any other device needed from the other side of the wall and hence extends the human vision beyond the electromagnetic range to allow us in identifying objects in the dark or smoke. However, the displayed results are of low resolution and object detection cannot be

achieved if the wall is thicker than 8 inches. Whereas in our framework, providing better resolution and detection of objects can even be done by walls thicker than 8 inches.

2.5. Deep learning models

The deep learning models have been proven to be an efficient response in human-centred computing in fog and mobile edge networks. Some algorithms like fuzzy c-means clustering have also provided support in healthcare in tumor identification methods [10,16]. Also, there are some crowdsourcing methods based on human-centric computing which uses mobile devices that can also be used for the training and testing of these models to give highly accurate results [11].

3. Proposed Framework

The proposed framework in this paper is collectively a combination of wi-vi, vital radio and li-fi. As the old wi-vi system has some drawbacks, using li-fi along with it can metamorphose it completely. Higher display resolution can be accomplished easily with the data transmitting power of li-fi signals.

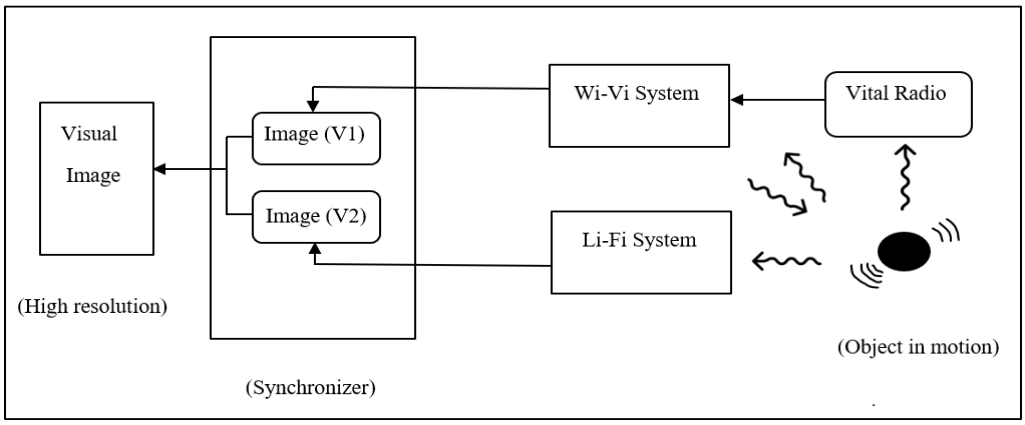

Figure 1: System Overview

When a Wi-Fi signal is passed through opaque obstacles very few signals pass through the wall and gets reflected by moving object [9]. Also few signals spread evenly in the entire room and get reflected by walls. Because of these reflections, it is difficult to detect minute human gestures. To overcome this issue[4], Wi-Vi uses a MIMO antenna to get accurate results. The whole system including antennas is very economical, effective and uses low bandwidth to operate. Based on the Wi-Vi concept, a device has been developed called Vital-Radio which is used to track and analyze the heartbeat and breathing rate of a human. This device does not need any additional equipment attached to the human body and it even works with multiple persons inside a close room (having good accuracy in 8 metres or less) [3,12,13].

A room having the availability of LED lights or bulbs will act as a source for li-fi, and reflected signals from the objects will provide highly accurate data to the system, which will sync the data collected by wi-vi and vital radio. After analyzing and performing Eigen decomposition on the vectors from data collected by the system, the results will be displayed which will be more accurate than what the single wi-vi system could have provided.

To have smooth functioning of every component of the system, it is necessary to remove the possible shortfalls that might interrupt the whole process. Two important concepts which must be focused on and should be taken care of are the flash effect and nulling.

3.1. Removing Flash-Effect

Due to continuous reflection from walls and objects, the reflected signal transmitted by the moving object is much stronger than the signal received by the receiver antenna. To resolve this issue Wi-Vi uses interference nulling to increase the sensitivity for the reflections. Also, Wi-Vi uses power boosting the signal so that the reflected signal can provide accurate results.

3.2. Nulling

In earlier systems, to nullify the reflected signal, multiple antenna arrays were used. But in Wi-Vi, antenna arrays are avoided to get a sharper and improved resolution, as a large antenna array with bulkier elements would require MIMO nulling at each of the antenna using the nulling algorithm. So to overcome this, Wi-Vi uses Inverse Synthetic Aperture Radar (ISAR) which has only a single receiving antenna. Using this single antenna, ISAR makes only one movement at a time. When the subject starts moving, ISAR filters the consecutive signals from adjoining positions in the space and hence it calculates the exact location of the person at that present time.

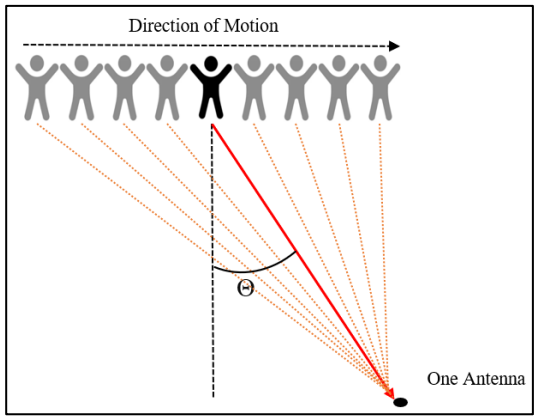

Figure 2: ISAR

3.3. Detecting Human Movement and Vital Signs

Using Wi-Vi, several moving objects /humans can be tracked. To detect human movement, a series of antennas can be tracked, just as with individual humans. However, each human emulates its antenna array. Because Wi-Vi has only one antenna, the received signal can be accessed via the antenna array of the moving person. Furthermore, multiple people increase the noise notably. Wi-Vi uses Smoothed Music Algorithm to avoid this problem. This algorithm calculates a correlation matrix (w x w) on R[n]. The noise is removed and the strongest eigenvectors are maintained by performing eigen-decomposition on R[n] [1]. In this case, this corresponds to some moving eigen-vectors and DC values. In the case of vital radio, it uses Wi-Vi to access the physical health of every person in the room and has the capability to record the vital signs of multiple users at a time. Also, the recent advancements in vital radio make use of air pressure around the subject to get more accurate data of his/her health.

3.4. Li-Fi (VLC)

Light Fidelity is a modern-day technology that encompasses a surplus amount of power. Major incentives it offers are reliability which enables interference-free communication, more efficiency, and cheaper. In terms of localization, it is far easier for setting up. Less latency is a key benefit of LiFi thus it can help in AR and VR technologies [7]. It is free from any form of interference thus it is eco-

friendly. In the case of security, it provides an approach for monitoring and authentication, there are invisible artefacts that block illumination which makes it safe to use [8]. In the viewpoint of demonstration, a small scale LiFi prototype is explained below –

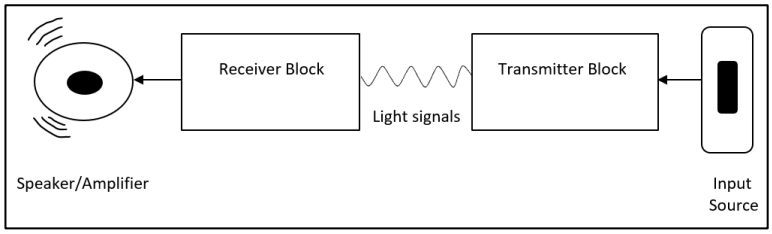

Figure 3: Li-Fi Prototype

3.4.1. Transmitter

For data transmission from one end one audio jack of 3.5mm, one DC battery of 9V, one resistor of 100-220ohm, and white coloured Led of 2 watts. An input source will send the audio signal through LED at photodiodes in the solar panel located at the receiver end in the form of an electrical signal.

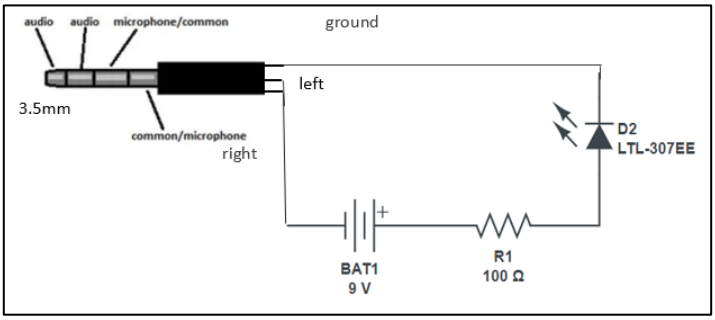

Figure 4: Li-Fi Transmitter and Receiver

3.4.2. Receiver

At the receiving end one solar panel, one audio jack of 3.5mm and a speaker or one device for storing the data transmitted. The next solar panel will detect those electrical signals received from the transmitter and will send signals into the output source (storing device/speaker/amplifier). Thus the data transmission takes place.

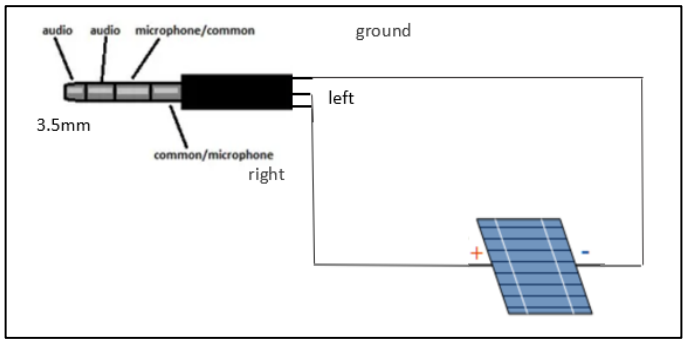

Figure 5: Li-Fi Receiver

4. Applications

4.1. Healthcare

Assume a case if someone wants to check the heart rate of another person in a different room. Then Wi-Vi and Vital Radio both perform combinational. As explained above, it will analyze two consecutive signals. After this process continues a heart rate pattern can be derived and used for checking health quality.

In the case of Hospitals, nowadays LEDs are used thus using Li-Fi simultaneously with a visual image received from our system, it can give more clarified results to enhance the accuracy of the whole structure.

4.2. Defence

In the case of Military operations, no doubt Wi-Vi is and will be a mega asset but by using described framework operations can easily be accomplished. Some SSL protocols can also be involved in this framework [14].

4.3. Smart Traffic Management

For road traffic in tunnels, the proposed framework will give drivers an image of both rear and front view which results in less noise pollution in crowded and over jammed places.

4.4. Smart Homes

Many theft incidents have been reported in big cities after which IoT came into the picture. Consider a scenario in which a person from his office can have an eye on his residency by viewing visual representation generated by our framework further helpful in thief detection. Therefore elevating the efficiency of IoT [15] based smart home systems.

4.5. Autonomous Cars

In the case of smart vehicles, our framework will be useful as its data can be collected for training and testing using different algorithms of machine learning resulting in a model which can be used with artificial intelligence for predicting the dense traffic area resulting in to increase in accuracy of autonomous cars [17].

5. Conclusion

Wi-vi, vital radio and li-fi used separately have many drawbacks like resolution, accuracy, etc., but combining them all in one framework can metamorphose their shortfalls. In a room having the availability of an LED light/bulb, the amalgamation of Li-Fi with the other two technologies will boost the precision power of detection and identification of Wi-Vi and Li-Fi based framework's. The framework is very effective in Human-based identification and in the detection of its vital signs having a much higher resolution than each of them when used solitary. Hence this low-cost framework can be used in the public sector and also by the general public for private use.

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