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"Revamping Raspberry Pi Wi-Fi for Motion Sensing"

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Abstract: A novel approach for motion sensing using Raspberry Pi's Wi-Fi signals. The system leverages the fact that Wi-Fi signals reflect and scatter off objects in their environment, causing slight variations in their characteristics. By analyzing the changes in the received Wi-Fi signal strength over time, the system can detect the presence and movement of objects within its range. The proposed solution utilizes the Raspberry Pi's built-in Wi-Fi module to transmit and receive Wi-Fi signals, and a custom software program to process the signals and perform the motion detection. The system is cost-effective, easy to deploy, and can be used for a wide range of applications, including home security, occupancy sensing, and environmental monitoring. The experimental results demonstrate the effectiveness and accuracy of the proposed system, making it a promising solution for motion sensing in various scenarios.

Keywords: – Raspberry Pi, Channel State Information, Motion Sensing, InfluxDB

I. INTRODUCTION

Wi-Fi signals are electromagnetic waves that can travel through space and are commonly used for wireless communication. They can also be used as a sensor to detect changes in the environment, such as motion or position changes. The Wi-Fi signal in a house or building can be compared to the rippling water in a swimming pool. Just as the water ripples and changes when someone enters the pool or moves through it, the Wi-Fi signal can also change and provide information about movement or position changes. This means that the signal can bounce off objects in the environment and create complex patterns that can be analyzed.

The time-series of channel state information (CSI) provides detailed information about the changes in the Wi-Fi signal as it interacts with the environment. Motion sensing using Raspberry Pi's Wi-Fi is a popular and cost-effective method of monitoring movement in a particular area. By using the Raspberry Pi's Wi-Fi module, it is possible to detect changes in the Wi-Fi signal strength caused by the movement of people or objects within the signal range. This technique is known as Wi-Fi sensing or Wi-Fi tracking and is used in various applications, including home security, occupancy detection, and retail analytics. The basic idea behind Wi-Fi sensing is that wireless signals are reflected and absorbed by objects in their path, causing changes in signal strength. By monitoring these changes, it is possible to detect movement and determine the location of the object.

The Raspberry Pi's Wi-Fi module can be used to perform this monitoring by constantly scanning for nearby Wi-Fi signals and analyzing their signal strength. This information can be processed using machine learning algorithms or custom scripts to detect and track movement.

II. WORK IN THIS AREA

[1] Depicts a model Wi-Motion, which is a recognition system that enables commercial Wi-Fi devices to identify user's activities using CSI measurements collected from commercial Wi-Fi devices, but the model is unable to detect performance of multiple users.[2] tells about a system mainly explores how to leverage PHY layer information to implement an advanced indoor fine-grained real-time passive human detection (FRID) that can be rapidly deployed, independent of indoor diverse scenarios and any calibration or re-calibration, but its major drawback is efficiency due to further calibration processes using phase variation and the system requires pre-learning of the environment for further calibration of the signals.[3] Details about a model Wi-Rol which is a device-free human sensing scheme which is able to precisely detect and interpret human motions within certain spatial region of interest (RoI) using only commodity Wi-Fi devices.

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Its major drawback is that change in in environment and other physical obstruction reduces the accuracy of the system. [4] Is a crowdsourcing-based system collect data from many mobile devices located across an indoor space, saving time and money. Its main drawbacks are time synchronization and unstable data sources which make the whole system less efficient and reduces the overall accuracy. [5] Tells us about a low-cost hand gesture recognition system utilizing Channel State Information (CSI) from a few subcarriers in prevalent Wi-Fi signals.

This information is sent through a lightweight signal segmentation algorithm and Convolutional Neural Network (CNN) that learns the gestures and successfully distinguishes them, but the performance of this model reduces if there are objects in the surroundings close to the subject, as it becomes difficult to distinguish motion.[6] talks about a model Wi-Sense a human activity recognition system that uses a convolutional neural network (CNN) to recognize human activities based on the environment-independent fingerprints extracted from the Wi-Fi channel state information (CSI), but this system fails to function when multiple users.[7] Is a model WiShape, a moving trajectory shape sensing system which leverages CSI to solve the limitation in floor plan construction for location-related motion sensing without the need of any sensors.

The negatives of this model are that it has a high false alarm rate and it is limited to single users. [8] Is a system Wi-Vi. Wi-Vi enables a see-through-wall technology that is low-bandwidth, low-power, compact, and accessible to non-military entities. This system fails to detect humans when the concrete walls are thicker than 8''. [9] Is a fall detection system named WiFall. WiFall leverages Wi-Fi CSI for posture related motion sensing. Our system aims to detect the fall of the elderly, and can also identify other daily activities. The proposed system in [10] is an application that collects CSI data for feature extraction and runs error correction on the obtained data, but this application requires training to identify the spectrograms of CSI for different environments.

1. Proposed System

This paper proposes a novel motion sensing system that harnesses Wi-Fi signals and Channel State Information (CSI) to enable precise and real-time motion detection and tracking. The system is implemented on a Raspberry Pi, offering an affordable and accessible platform for a wide range of applications. By analysing the changes in CSI measurements obtained from Wi-Fi signals, the system can accurately identify and monitor motion within its coverage area. The system's architecture involves utilizing the capabilities of the Raspberry Pi, including the Wi-Fi interface and an antenna for signal reception. Through an efficient CSI extraction module, the system captures Wi-Fi signals and pre-processes them to extract CSI measurements. The data is then processed using a motion detection algorithm and pattern recognition techniques to differentiate between stationary and moving objects accurately.

Moreover, the system incorporates motion tracking capabilities to provide continuous updates on the position and trajectory of detected motion. This enables real-time monitoring of moving objects, making it suitable for applications such as smart homes, surveillance systems, human-computer interaction, and robotics. To evaluate the performance of the system, extensive experiments are conducted to validate its accuracy, reliability, and responsiveness. The experimental results demonstrate the system's effectiveness in detecting and tracking motion, highlighting its potential for practical implementation. In conclusion, this proposed motion sensing system utilizing Wi-Fi signals and CSI on a Raspberry Pi opens up new possibilities for affordable and accessible motion detection and tracking. With its wide range of applications and potential for real-time monitoring, the system showcases the power of leveraging existing infrastructure to enable smart and intelligent environments.

The major applications involve perimeter security to secure the perimeter of a facility by detecting any movement near the walls or fences, intrusion detection that can generate alerts at 4 different levels – ok, info, warn, critical depending on the scale of motion detected, retail analytics that can be used to analyze customer behavior in retail stores, such as how much time they spend in a particular section or how frequently they visit specific areas like a shopping mall, a college fest and so on. For advertising it can be used to advertise accordingly based on our Market Research thereby reducing the expenses for the same data and also as a smart home, such as smart locks, to enhance home security. For example, if the device detects motion when the homeowner is away, it can trigger the smart lock to lock the doors.

The proposed system for revamping Raspberry Pi's Wi-Fi signal for motion sensing is depicted in Figure 1. It consists of three major modules:

- Motion Monitoring
- Data Pre-processing
- Data Visualization

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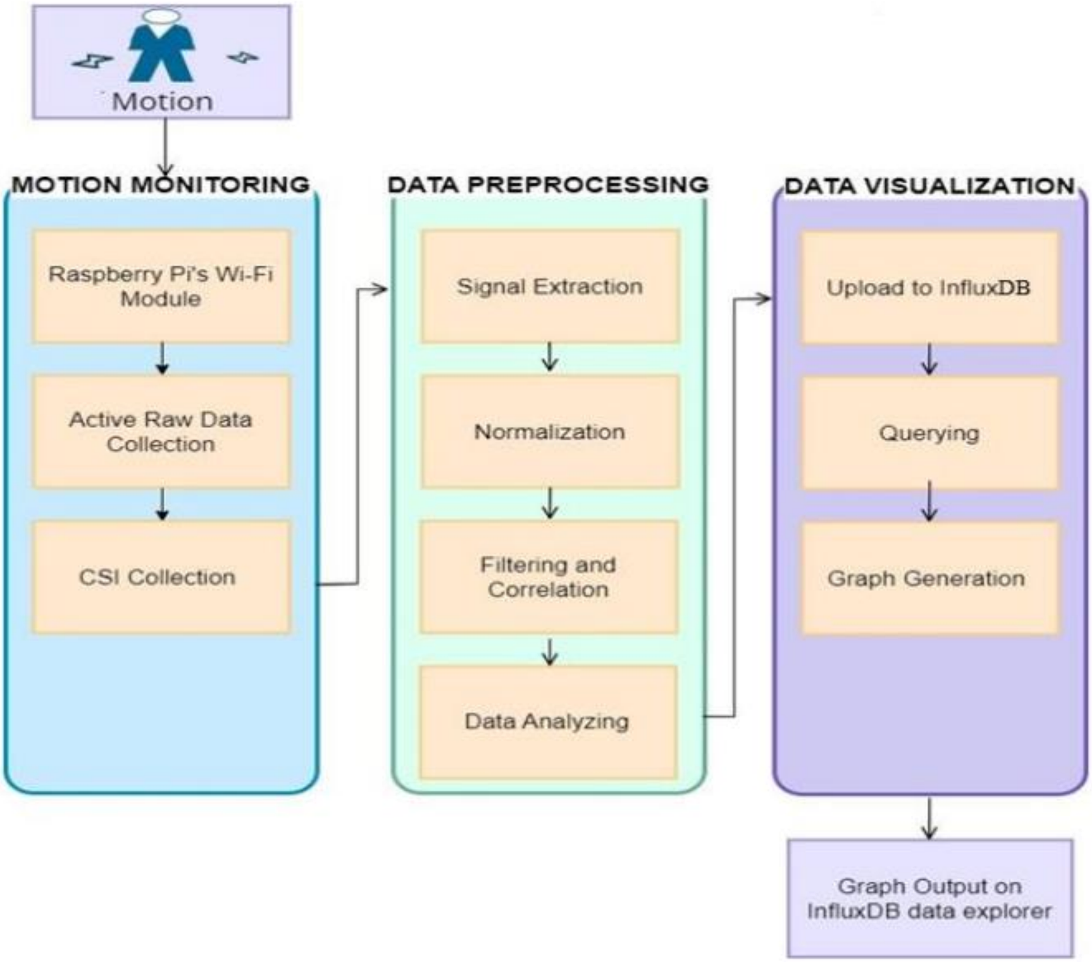

Fig 1: System Architecture

2. Methodolgy

Wi-Fi Module

This module is responsible for establishing a connection to a Wi-Fi network and transmitting data to other devices or the cloud. It includes hardware components such as Wi-Fi antennas and software components such as drivers to communicate over the network. The Wi-Fi module would play a critical role in transmitting the motion data to other devices or preferred database for further analysis.

Motion Monitoring Module

This module is responsible for detecting motion using Wi-fi signals and measuring motion in the surrounding environment. It involves collection of raw data and extracting the channel state information into the CSI Collection Bin.Fast Fourier Transform algorithm is a mathematical technique used to transform time-domain signals (such as motion data) into the frequency domain. Used to analyze the frequency components of the motion data and identify patterns or anomalies.

Data Preprocessing Module

This module is responsible for processing the raw data received from the motion sensing module and converting it into a usable format for other modules or analysis tools. It includes algorithms and software components that can filter, transform, or manipulate the data.

Filtering Algorithm

This algorithm is a technique used to remove unwanted or noisy components from a signal. Typically used to remove noise or other unwanted components from the motion data and improve the accuracy of the system.

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Correlation Algorithm

This algorithm is a mathematical technique used to measure the similarity between two signals. It is often used in signal processing applications to identify patterns or trends in a signal. A correlation algorithm could be used to identify patterns or correlations between different aspects of the motion data (such as motion amplitude and frequency) and improve the accuracy of the system.

Data Visualization Module

This module is responsible for providing a user interface for configuring the system and monitoring the motion data. Here we use InfluxDB Data Explorer, to analyze the output. The user interface module would be used to allow users to configure the system and view real-time or historical motion data. It can also generate alerts in four basic levels: Ok, Info, Warn, Critical, based on the scale of motion detected.

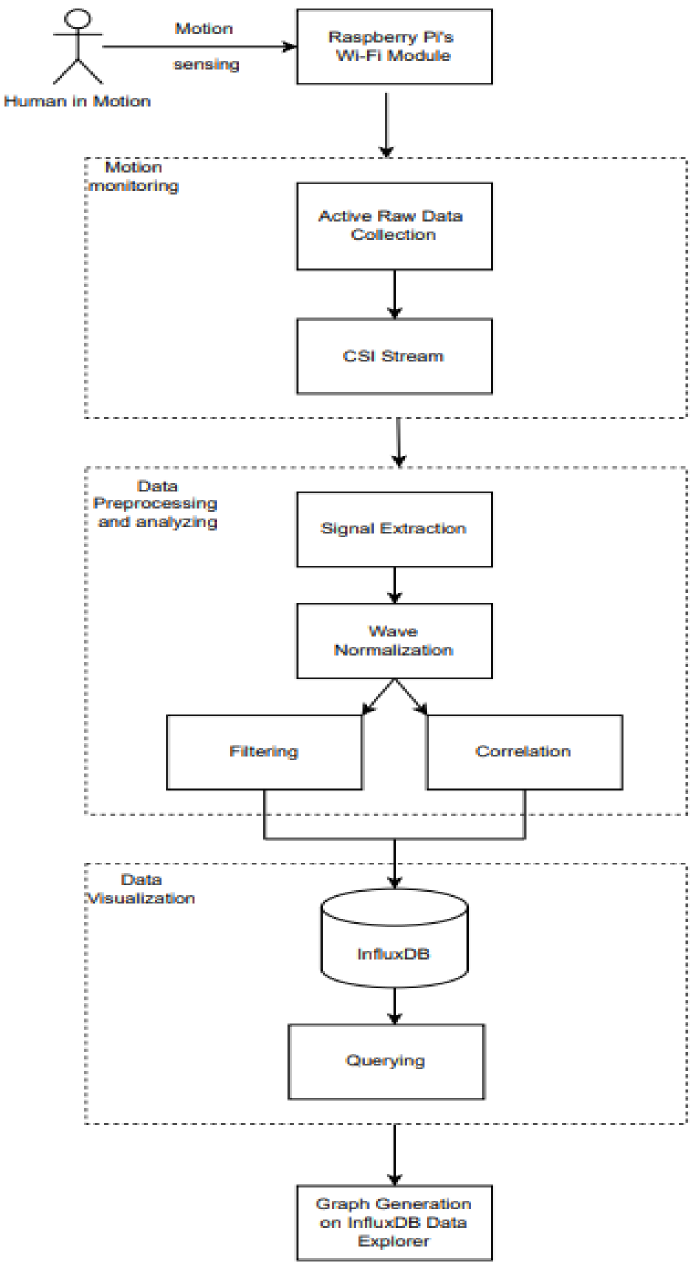

Fig 2: Data Flow Diagram

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III. PARAMETERS, RESULTS AND ANALYSIS

Table 1. Percentage of Accuracy

Domain	Total	Positives	Negatives	Percentage
Ground Floor (Apartment)	15	8	7	53%
5th Floor (Apartment)	50	34	16	68%
College Lab	54	30	24	55%
Independent duplex house	16	11	5	69%
Classroom college	50	40	10	80%

Results
Result 1

Figure 2: Graph generated for motion in a 5th floor classroom

In result 1 the system is deployed in a classroom with 8-10 people. During this time the surrounding environment has students come in and go out frequently. As you can see, most of the points plotted (Blue) on the graph are in the range of 2-5(out of 10). This tells us that the room has an active environment with people entering and exiting the room frequently.

This is a very similar situation to mediocre busy corner in a mall as the number of people entering and exiting is around 8-10 based on estimate. In a small experiment conducted during the time students were asked to exit the classroom which led to points being plotted into lower ranges (Red) and almost zero at one point which tells us that much less motion was being detected. After the students are let back into the classroom the graph starts to plot points in higher ranges (Green) signifying more and more motion being detected.

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Result 2

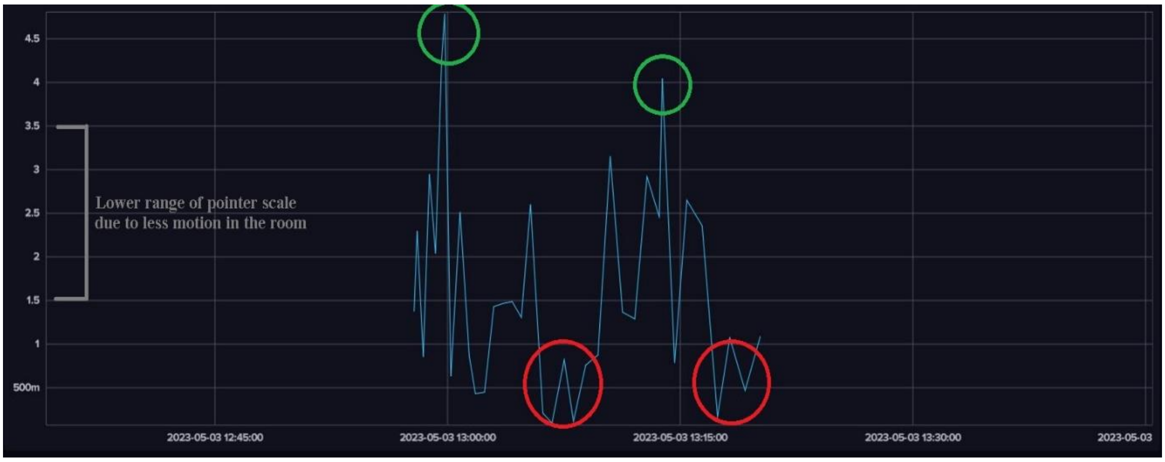

Figure 3: Graph generated for 5th floor presentation room

In result 2 the system was deployed in the presentation room. Initially only 3 members were present in the room which led to lower range values. Entrance of 5 panel members into the presentation room caused motion detection to spike first (Green). As soon as the room had settled down and presentation continued the graph was plotting slightly lower values during which motion detection falls to very low values first (Red). Followed by a moment where a panel member approached the Raspberry Pi very closely causing a second spike in motion detection second (Green). Once the panel exited the presentation room the motion detection fell to lower values again second (Red).

Result 3

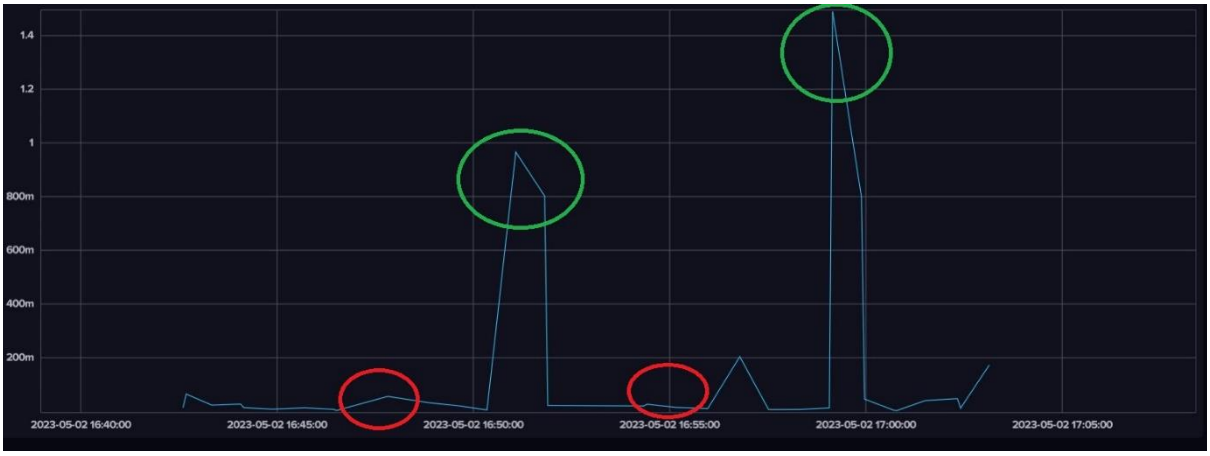

Figure 4: Graph generated for 1st floor bedroom in an independent house

In result 3 the system was deployed in a room in an independent house. Due to the presence of a singular person in the room very minimum values of motion were detected first (Red). The person present in the room was asked to walk around the room causing a spike in motion detection first (green). Then a brief period of resting saw the motion detection plummet due to no motion being detected in the room second (Red). Then followed by another momentary walk around the room leading to the second spike in motion detection second (green).

IV. CONCLUSION

In conclusion, our proposed system is to use the Raspberry Pi's Wi-Fi Chip to sense and study the motion of a group of individuals. Wi-Fi sensing using a Raspberry Pi for motion detection has proven to be a reliable and cost-effective method for improving home security and automation. By analysing changes in Wi-Fi signal strength, the Raspberry Pi can accurately detect motion in a specific area, making it an ideal solution for indoor motion detection. Moreover, this method

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of motion detection is non-intrusive and can be easily concealed, making it an ideal solution for homeowners who prefer a more discreet security system. Additionally, the use of Wi-Fi sensing avoids the need for additional hardware or cables, making it a more convenient solution for homeowners. The implementation of Wi-Fi sensing using a Raspberry Pi can also be integrated with other smart home technologies, allowing for seamless automation and control. This can include sending alerts to a smartphone, activating other smart home devices, or even triggering an alarm system. In conclusion, Wi-Fi sensing using a Raspberry Pi is a valuable tool for improving home security and creating a smarter, more efficient living space. While it may not be the most advanced method of motion detection, it offers a practical and convenient solution for homeowners looking to enhance their home security and automation.

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