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Survey on Wireless Fidelity (Wi-Fi) Based Indoor Location Technology for Mobile Devices

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***Abstract* - Implementing destination operations in a confined area may be revolutionized by indoor localization if the current inadequacies can be solved. Consequently, the development of a widespread indoor localization system (ILS) is now required. Cell phones and Internet-based indoor navigation could be used to achieve widespread use because cellphones are widely available and most buildings have WiFi. WiFi signal strength varies greatly depending on the environment and the configuration of the devices that use it. Because of this, a universal ILS that is widely accessible and does not need specialist hardware support remains a long way off in the future. Thus, this research examines the current level of WiFi-based algorithms for indoor positioning and their potential to be used in a wide variety of contexts. As a result, an ILS that relies on WiFi for availability is the fundamental objective of this study, and it aims to identify and recommend future research priorities. Using a real-world dataset, some experiments have been done to show how hard it is to put this kind of system into place.**

Keywords— Indoor Localization System, Wi-Fi, GPS, LAN, Mobile Devices etc.

I. Introduction

The primary purpose of an ILS [1] is to determine the location of a person while they are inside of another facility. Among the various uses for indoor localization [3], [4] are search and rescue, warehouse surveillance [2], and video games, to name just a few. Consequently, the possible uses of this area have piqued the interest of several academics during the past two decades. Because of the signal attenuation caused by objects such as walls, furniture, and people, GPS, which is frequently [14] used for outside locations, does not operate effectively in an indoor setting. Because of the growing need for indoor localization, a number of commercial solutions [9] have begun to appear. It became accessible in the United States and Japan in late 2011 with the release of Google Maps 6.0. As a result, many building owners [10] are reluctant to provide the details of their inside floor plans to the public. These programs [5], [11] such as the Tokyo subway subterranean area navigation app, enable passengers to traverse the huge internal expanses of major train stations. It is difficult to apply these applications [12] to other stations since they are not fine-grained and rely on some of these systems that have been tested over the years using a variety of different technologies for indoor locations. Early systems were preconfigured with dedicated infrastructure that allowed for remarkable precision. In addition, range-based localization [15] methods like AoA, ToA, TDoA, ToF, RTOF, and PoA have been employed by many early systems. Geometrical models are used to estimate the positions of at least three transmitters in each of these strategies. Such systems, on the other hand, need very precise antennae. Widespread use of ILS [16] requires the widespread use of common devices (such as smartphones) and common infrastructure, such as public offices, airports, and retail centers. Wireless LAN-based network [17] infrastructure is now commonplace in many public institutions, including colleges, hospitals, and government facilities. As a result, since no extra gear is needed, it may become widely available. A lot of effort is put into incorporating the same. An unknown location may be predicted using all-potential sites' fingerprints [18], which are collected by an app and sent to a remote server for examination. Aside from that, a test app collects RSS from an unknown place and delivers it to the server, where it is analyzed for fingerprint data saved on the server in order to determine the location. The accuracy of these approaches is largely dependent on the level of fingerprint effort. Video or image cameras can also be used for distance estimation.

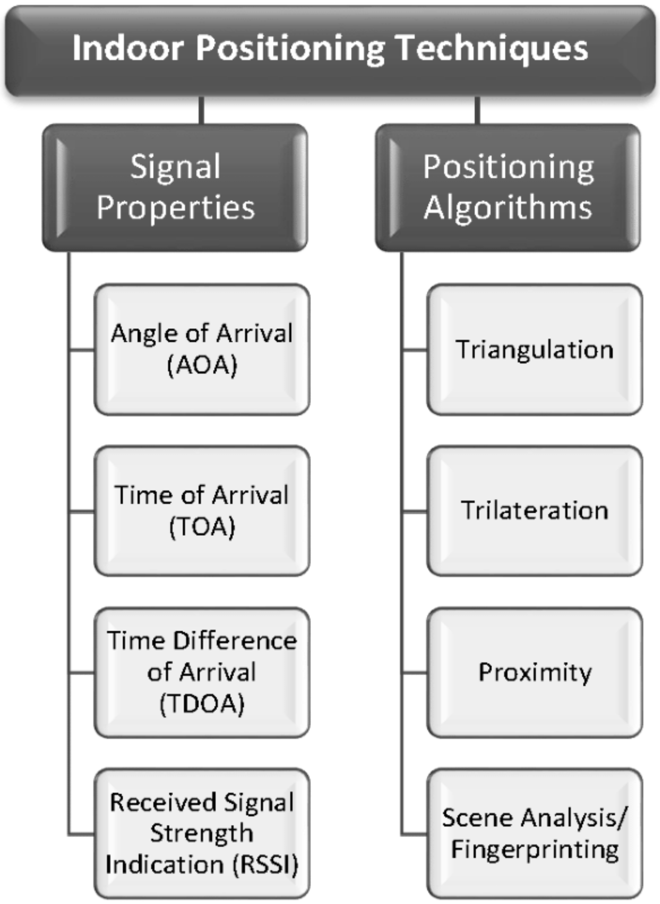

Figure 1: Classification of two types Indoor Positioning Technique.

These systems are categorized into two types based on the necessity for specialized infrastructure, as indicated in Figure 1. It is possible to further divide each group into two subcategories, depending on the technology they use. Because it requires additional hardware for localization, such as ZigBee, Bluetooth Low Energy, Visible Light Communication [6], [7], [13] or wearable sensing. However, the complexity and expense of installation are increased since these methods need suitable illumination. Users' privacy might be at risk because of this. If it is used to cover different parts of the buildings instead of employing the same technology throughout, the system's universality will be severely weakened. It is possible for all individuals, even the visually handicapped, to utilize indoor navigation software if the technology is widely available. In this context, researchers need to concentrate on the causes of the RSS vulnerability and provide fixes without requiring specific emitters. During implementation, a number of new research questions are raised. It is necessary to evaluate signal behavior in three distinct domains, including temporal, ambience, and device heterogeneity, before working with RSS fingerprints. Only a few studies have been done on heterogeneity in the devices themselves, but the challenge of localisation for busy public infrastructure in all three domains remains largely unsolved. Two major issues arise from this situation. We do not believe we will ever be able to create a universal ILS system that is as accurate as we would want. There is a lot of emphasis in the current survey papers. Many questions remain unanswered when it comes to a generalized ILS that could be used by all devices. The main contribution of this paper is always to deeply explain specific challenges and potential ideas for developing a WiFi-based ILS for smartphone users. This page also gives an overview of research into the different stages of a navigation system that light up wirelessly.

II. Different Methods of Indoor Positioning System

The productivity of interior destination infrastructure has been improved by combining a number of different localization systems and technologies. Furthermore, the use of a precise positioning method and the installation of expensive equipment for merging several non-radio technologies to improve the precision of location As a result, cutting-edge localization techniques including triangulation, scene analysis, and proximity have been developed in the search for a low-cost indoor positioning [19] system built using readily accessible technology. Indoor localization methods that assist first responders in difficult conditions such as darkness, smoke, etc. Aside from wireless signals, we would like to hear your thoughts on the importance of transportation data collected via device els. The device's sensors can track mobility data, including gait pattern [20], constant acceleration, and utter guidance. A study on distance measurement processes in real-time was also carried out. We are unable to compare the localization accuracy of different algorithms using a common technique. They also proposed developing a general population reference set of data to test the most recent real-time location machine learning. Researchers have looked into mathematical models for tracking a consumer in this area, but specific to the individual systems are more adaptable to changing environmental variables. Despite the fact that fingerprint-based localization processes utilize a variety of technologies to improve precision, this research ignores system ubiquity. The requirement to integrate many technologies and to be cost-effective has been noted in a few survey studies, but the research problems coming from an all-encompassing ILS remain mostly unexplored. This made us think about and talk about the real problems with implementing such a common ILS.

III. Problem Statement

An ILS using a WiFi fingerprinting-based ubiquitous ILS relies on RSSI and Channel State Information as two of the most important characteristics (CSI). RSSI is primarily a metric for assessing the strength of the received signal. When an electromagnetic wave travels across space, it experiences what is known as path loss, which reduces the signal strength at the receiver end as it moves further away. The Log Distance Path Loss Model may be used to illustrate the connection between RSSI as well as the proximity between both transceivers. It is defined as the propagation exponent, and A is the signal intensity measured at a distance of one meter. The propagation of wireless signals is also influenced by the CSI factor [21]. In the context of a communication channel, CSI refers to the properties of the broadcast signal that demonstrate how it propagates between transmitters and receivers. This effect is represented by Wi-combined Fi's effects of fade-out [22], scatter-out, and power decline with distance. The following formula is used to determine CSI [23] at the receiving end: There is a white Gaussian noise called N and the channel's frequency response is known as CSI.

IV. Diferent Phases of Indoor Positioning System

Users that are willing to participate in data gathering may get RSS feeds for all of the accessible APs around any given location or reference point by using their mobile devices. The location points are selected based on the work's ground reality. Furthermore, data must be gathered from relevant sites in the experimental area. For example, RSS data was acquired for room-level localization from two places; one within the room and the other outside the room. They separated their trial area into two-by-two-square-meter grids and gathered RSS fingerprints from each grid to give fine-grained localisation.

Technology		Accuracy	Range	Suitable for
Wi-Fi		< 15 m	< 150 m	area detection
BLE	4	< 8 m	< 75 m	area detection
	5.1	< 1 m with line-of-sight		
UWB		< 30 cm	< 150 m	area detection
RFID		presence detection only	< 1 m	spot detection

Figure 2: Different phases of indoor positioning system

Fingerprints are tagged with location information in this manner of data gathering. The users collect data as they go about their regular routines, with their smart gadgets in hand. Their smart devices, at different points along the journey they take and the length of time they walk, record their RSS fingerprints and other pertinent data. Moreover, it is difficult to accurately identify open-source information because consumers are often uninformed of their participation in questionnaire surveys. As a result, these fingerprints have been incorrectly identified by the collective wisdom of the audience. It was able to accurately forecast the user's present position. The accelerometer sensor in cellphones collects data on a person's steps. There may be some variation in the number of footsteps and sensor readings from one user to the next. Here, we talk about another type of crowdsourcing in which a user manually enters the location of another user, like Lohan and others.

As a result of the restricted Wi-Fi signal coverage range and other interior environmental conditions, the signals from all APs are not heard at any given physical point. Before doing the analysis [8], the missing TR and TE values need to be filled in with interpolation.

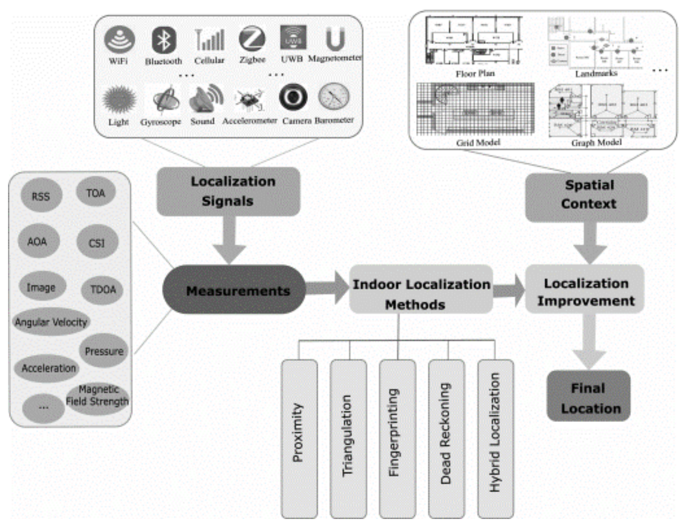

Figure 3: Different statistical approaches of indoor positioning system

When there are missing values, there are several strategies to deal with them, such as eliminating the feature, using mean, median, or mode, and so on. RSS values typically range from 0 to 120 dBm. Cooper ascribed an RSS value of 0 to unheard AP signals, while he awarded an RSS value of 0 to the lowest observed RSS value. During data collection, it is common to hear APs from neighboring structures or even hotspots. A lack of availability and inadequate signal strength may make certain APs unusable at all times. There are two types of signals: strong and weak. A number near to zero denotes the strong signal, while less than zero shows the weak signal (low distance sensitivity). Consequently, such signals must be disregarded while predicting location. Aside from being mobile and live for a brief period, Wi-Fi hotspots may be relocated. Predicting a location with these sorts of signal levels introduces errors due to noise.

V. Data Analysis of Indoor Positioning System

The acquired data is processed in order to identify a meaningful distribution of RSS across different regions. As with other machine learning methods, statistical approaches are employed to determine the RSS pattern in order to predict an unknown position. In Fig. 3, the most common statistical methods for indoor location are shown. Research efforts in this field have embraced the fingerprint methodology as the primary location estimate method. It has been used in a variety of technologies, including Wi-Fi and RFID, acoustic, visible light, and magnetic fields. It is better to use WiFi-based fingerprinting because of its widespread use in interior areas. RADAR was first proposed in the early 2000s as a real-time monitoring and traceability network built on wireless LAN devices. This is a game-changing piece of research in the field. This system's localization method also includes the Rician distribution model and Rayleigh fading model. Using less computing power, the Horus system is a popular alternative. Many scholars have applied this technique during the last few decades. When it comes to dealing with the many reasons for wireless channel changes, numerous modules in Horus have been presented to obtain improved accuracy. In addition to this, recent research has shown that inertial sensors may make it easier to find where something is.

The Pedestrian Dead Reckoning (PDR) technique is often used by inertial sensor-based localization systems. A PDR calculates the distance traveled from a predetermined starting point. Smartphone inertial sensors have been used to track people. User displacement has been calculated using a wide range of complicated human mobility information, including stride length estimation and heading direction estimation, as well as the trajectory of the user's walk, run, stairs, or elevator. Among smartphone users, SmartPDR is a well-known technique for PDR. In order to estimate a position, SmartPDR makes use of a number of different models. The most prevalent mistakes in inertial measurements include thermo-mechanical noise, bias stability, and biases. It has also been shown to be a good way to make localization more accurate. Wi-Fi channel data was collected with precision and accuracy using CSI to investigate flaws. In order to figure out the localization error caused by pedestrian movement, they looked at how it affected the accuracy of localization. However, these methods need a significant amount of calibration work in order to use wardriving to create a fingerprint database. But the crowdsourcing strategy, which uses smartphones to build a fingerprint database, has greatly reduced the fingerprint method's main problems, such as the cost of time and people.

Zee is a technology that provides a negligible open source methodology for collecting wireless internet connection speed and gravitational location information. It has also been implemented by Zee to indicate the uncertainty of position prediction. Also, with LiFS, a fingerprint database is built using user trajectory data, which is then mapped to the floor layout. A "stress-free" floor design has been developed to reflect the actual walking lengths between any two spots in a large, three-dimensional environment. As a result, they create a stress-free environment. Locating a target location is done using LiFS's closest neighbor technique. In addition to the abovementioned methods, various geometrical models have been used to locate an unknown place. Instead of relying on the previously recorded fingerprint data, a Weighted Path Loss (WPL) model was used to estimate an unknown position. Places where WiFi snifers may gather RSS feeds from different access points. The LDPL model was used to create an RSS map. Additionally, there is a more advanced model known as the ray-tracing model. On the other hand, these models require prior knowledge of AP sites. They used an optimization technique in conjunction with the LDPL prototype in their proposed model, which people with depression may experience, to solve the feed reader calculations. Configuration, on the other hand, relies on GPS data that can only be accessed in specific locations, such as a building's hallway or near a doorway. Aside from that, EZ's complicated way of calculating and figuring out where it is has led to many false room detections. It recently developed a localization model from RSS for LDPL exponents and uncertain transmit power. Different geometric models have been used in this area, including the RSS-based model, which is centered upon that connection between broadcast and glorified. There are systems like CUPID, Guoguo, and Cricket, all based on arrival angle. All of the algorithms have been rolled into one innovative WiFi-based system. Using the CF method, each subarea's RSS distance function has been ft. Multiple online positioning phases, each of which makes use of a different location search algorithm, have been developed in order to meet the requirements of defining the small intervals of a sensor and locating the correct position within a sub region. This step is important, as it is part of the larger process of putting a device online. For the purpose of performing indoor localization, a method known as RSS-based trilateration can be utilized. The raw data was the very first thing that they investigated. Because of this, model-based techniques often need extra infrastructure, changes to the products, and knowledge of how the hardware needs to be set up in order to work.

Recently, researchers have turned to the Fresnel zones concept to pinpoint the target's elliptic area. Due to NLoS propagation, there are several transmission pathways from the transmitter to the receiver in the inside environment. In each Fresnel phase, the NLoS route and the LoS path are phased differently. Fresnel zones are defined using mathematical calculations based on the difference between the Fresnel phases of a target. The Fresnel zone model is used to calculate the elliptic area. In order to test the viability of their approach, they put it into action with the Elp of the environment; we can figure out some useful features for localization and other device less sensing applications.

Conclusion

The purpose of this research is to pique interest in wireless ILS as well as the challenges involved in new research. In addition to a concise explanation of the various stages of an ILS, this section also includes a definition of the issue at hand as well as a summary of previous research. We hope to make a significant contribution by classifying the challenges of conducting research in ILS from the point of view of the prevalence of the system. Nearly every indoor localization application, such as navigation, asset monitoring, and emergency evacuation, calls for this. The inherent difficulties in research and the potential future scope are extensively examined. As mentioned, the main problems are building and devising algorithms with exact locations using trained and tested datasets under a variety of scenarios. These problems must be dealt with an ILS that works on a large scale and gets good localization accuracy in crowded indoor areas.

Future Work

Changes to the WiFi network architecture, such as adding, replacing, dropping, and moving access points, may adversely affect the operation of a localization system. Some WiFi APs in one location may be offline during emergencies such as freoutbreaks. Such situations need a change in the training approach to include localization services. Because of this, it is necessary to find a way to transfer the existing training model into the new feature space. It takes a long time and a lot of effort to gather a large number of training fingerprints. A study is thus required to estimate the least amount of fingerprint gathering needed to cover the whole area. In order to make the system more effective and accurate, it is necessary to gather unlabeled fingerprints from unidentified individuals. Further research is needed in order to improve the system's performance. Keeping the community characterized and cleaning it up are two of the most important things to think about when it comes to keeping people safe and stopping the spread of diseases during a pandemic (such as COVID-19). The movement patterns of a crowd may be studied using indoor localisation methods. As a result, methods for reducing crowd size may be studied, as well as potential hot areas for crowd formation. At public venues like train stations, airports, and retail malls, for example, a large throng may develop in front of an LED display screen. There is a chance to prevent the development of the crowd if another LED display panel is installed nearby, analyzing the movement of the crowd. The most important requirement for any localization system is the precision of the tracking or localization. High localization accuracy may improve a system. As a result, other characteristics like scalability, resilience, energy efficiency, and affordability are typically disregarded. Wireless signal channels become increasingly congested if a big localization region becomes overcrowded. The process of localisation may thus need additional computations or studies. If you're going to be expanding the scope of your translation efforts, you'll need a system that can handle it. Because the client-side mobile device lacks powerful computing power and lengthy battery life, a localization algorithm should be simple enough to run on the server end. As a result, in order to use less power, a system must be energy efficient. ILS is mostly used to monitor and navigate people in real time. Consequently, a system with low network latency and high efficiency is necessary. To do this, the server and client should only send each other a small amount of data that has already been processed.

References

[1] Shang, Shuang, and Lixing Wang. "Overview of WiFi fingerprinting-based indoor positioning." IET Communications (2022).

[2] Kawecki, Robert, Sławomir Hausman, and Piotr Korbel. "Performance of Fingerprinting-Based Indoor Positioning with Measured and Simulated RSSI Reference Maps." Remote Sensing 14.9 (2022): 1992.

[3] Noble Mary Juliet, A., et al. "Wi-Fi-Based Indoor Patient Location Identifier for COVID-19." Computer Networks and Inventive Communication Technologies. Springer, Singapore, 2022. 503-511.

[4] Kabir, Alamgir, et al. "Light Fidelity (Li-Fi) based Indoor Communication System." 2022 International Conference on Advances in Computing, Communication and Applied Informatics (ACCAI). IEEE, 2022.

[5] Ahammed, Md Tabil, et al. "Design and Implementation of Programmable Logic Controller Based Automatic Transfer Switch." Journal of Artificial Intelligence, Machine Learning and Neural Network (JAIMLNN) ISSN: 2799-1172 2.02 (2022): 41-51.

[6] Ibrahim, Md, et al. "Designing a Top as Based Suspended Square Core Low Loss Single-Mode Photonic Crystal Fiber Optics Communications." 2022 International Conference on Advances in Computing, Communication and Applied Informatics (ACCAI). IEEE, 2022.

[7] Ibrahim, Md, et al. "Design a Novel Top as Based Suspended Core Single Mode Photonic Crystal Fiber Optics Communications." 2022 International Conference on Advances in Computing, Communication and Applied Informatics (ACCAI). IEEE, 2022.

[8] Ahammed, Md Tabil, et al. "Analysis of Energy Consumption for a Hybrid Green Data Center." 2022 International Conference on Innovations in Science, Engineering and Technology (ICISET). IEEE, 2022.

[9] Lee, Yu-Cheol. "SRS: Spatial-tagged radio-mapping system combining LiDAR and mobile-phone data for indoor location-based services." Advanced Engineering Informatics 52 (2022): 101560.

[10] Wainer, Gabriel, and Moayad Aloqaily. "Machine learning-based indoor localization and occupancy estimation using 5G ultra-dense networks." Simulation Modelling Practice and Theory 118 (2022): 102543.

[11] Prathibha, Soma, et al. "Detection Methods for Software Defined Networking Intrusions (SDN)." 2022 International Conference on Advances in Computing, Communication and Applied Informatics (ACCAI). IEEE, 2022.

[12] Shawon, Md Sajjad Hossain, et al. "Voice Controlled Smart Home Automation System Using Bluetooth Technology." 2021 4th International Conference on Recent Trends in Computer Science and Technology (ICRTCST). IEEE, 2022.

[13] Ferdous, Md Jannatul, et al. "Design and Analysis of A High Frequency Bow-tie Printed Ridge Gap Waveguide Antenna." Journal of Image Processing and Intelligent Remote Sensing (JIPIRS) ISSN 2815-0953 2.02 (2022): 26-38.

[14] Ahammed, Md Tabil, et al. "Design of Porous Core Fiber for Terahertz Regime using Zeonex." 2021 4th International Conference on Computing and Communications Technologies (ICCCT). IEEE, 2021.

[15] Rizk, Hamada, Ahmed Elmogy, and Hirozumi Yamaguchi. "A Robust and Accurate Indoor Localization Using Learning-Based Fusion of Wi-Fi RTT and RSSI." Sensors 22.7 (2022): 2700.

[16] Sircoulomb, Vincent, and Houcine Chafouk. "A Constrained Kalman Filter for Wi-Fi-Based Indoor Localization with Flexible Space Organization." Sensors 22.2 (2022): 428.

[17] Alitaleshi, Atefe, Hamid Jazayeriy, and Javad Kazemitabar. "Affinity propagation clustering-aided two-label hierarchical extreme learning machine for Wi-Fi fingerprinting-based indoor positioning." Journal of Ambient Intelligence and Humanized Computing (2022): 1-15.

[18] Pol, Vidya. "A Comparison and Analysis of Wireless Fidelity to Light Fidelity and its Combination of Networks."

[19] Khokhar, Zulqarnain, and Murtaza Ahmed Siddiqi. "Machine learning based indoor localization using Wi-Fi and smartphone." J. Independ. Stud. Res. Comput. 18.2 (2021).

[20] Hosseini, Komeil Shah, et al. "Improving Multi-floor WiFi-based Indoor positioning systems by Fingerprint grouping." 2021 5th International Conference on Internet of Things and Applications (IoT). IEEE, 2021.

[21] Fedosova, Irina, Olha Pronina, and Olena Piatykop. "Exploring Wi-Fi-based Indoor Positioning Techniques for Mobile App." 2021 IEEE International Conference on Information and Telecommunication Technologies and Radio Electronics (UkrMiCo). IEEE, 2021.

[22] Madjarov, Ivan, Jean Luc Damoiseaux, and Rabah Iguernaissi. "Towards Designing a Li-Fi-Based Indoor Positioning and Navigation System in an IoT Context." Future of Information and Communication Conference. Springer, Cham, 2021.

[23] Sun, Honglei, et al. "CLRS: A Novel CSI-Based Indoor Localization Approach by Region Sectioning." 2021 International Wireless Communications and Mobile Computing (IWCMC). IEEE, 2021.