

Wireless LAN/FM Radio-based Robust Mobile Indoor Positioning: An Initial Outcome

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Abstract

The location determination in an obstructed area can be extremely challenging especially if the Global Positioning System (GPS) is blocked. In such conditions, users will find it difficult to navigate directly on-site, especially within an indoor environment. Occasionally, this needs to integrate with other sensors in order to determine the location with greater intelligence, reliability and ubiquity. In this paper, we will utilise the function of a mobile sensing platform (MSP) by integrating a wireless local area network (WLAN) and FM radio. These positioning sensors will be switched based on the user's environment in order to ensure the robustness of the indoor positioning system. Finally, we will present our preliminary results to illustrate the performance of the system for an indoor environment set-up.

Keywords: *Wireless LAN , FM Radio, Indoor Positioning System*

1. Introduction

The navigation using Global Positioning Systems(GPS) is known to be able to operate in any location across the globe [1-4]. Presently, the development of GPS navigation systems has been advancing. Most of the current smart phones are equipped with the GPS function, which can be used to provide navigation assistance to the end user in an effective manner. However, the most severe limitations of GPS performance continue to exist. The accuracy of positioning deteriorates very rapidly when the user's receiver loses direct view of the satellites (which typically occurs indoors or in severely obstructed urban environments [5-11]). Therefore, the concept of an indoor positioning system has been introduced. This concept allows other technologies to be used for positioning determination. In order to do this, the utilisation of a mobile sensing platform (such as: Bluetooth, WLAN and a camera) can be used. The approach associated with a mobile sensing platform can help users to determine positioning with greater mobility and robustness [12-15].

Previously, there have been many types of research prototypes, which have relied on mobile indoor positioning. The system based on GSM signal strengths have been used to determine which floor of a building the user. However, accurate tracking within a floor of a building has not been achieved. Similarly, the short ranges positioning technology (Bluetooth and Near Field Communication) have been used to constrain the estimate of the user's location [16-18]. The disadvantage of this technology is it is require markers installation in each of environment. In contrast, there is approach that does not require the installation of additional infrastructure. This localization technique requires visual data. A major drawback to its use in a cell phone is that it requires the huge amount of environment picture to determine the location. In [19], the researcher has shown the integration of dead reckoning with WLAN which uses a particle filter to merge observations. They used a custom rigidly-mounted belt module with a WLAN radio and integrated mechanical sensor (such as two (2)

axis accelerometer, gyroscope, and pressure sensor). However, there is no deep explanation of their step counting algorithm or zero-reference determination for gyroscope. Indeed, their sensor mix is not sufficient for establishing global heading in the dead reckoning component without requiring the user to be facing the same direction every time the system is started. Although robust positioning is not new, most of the techniques shown above focus more on single positioning sensing and positioning integration between MSP with external device, rather than utilising a multisensory approach on MSP.

The structure of the paper is as follows. Section 2 will present the basic concept related to robust indoor positioning. Section 3 will present our problem formulation. Section 4 will present our proposed method. Section 5 will present our experiment setup. The details of our preliminary result will be covered in Section 6. Finally, a discussion and the future direction of the project will be provided in Section 7.

2. Concept of Robust Indoor Positioning on Mobile Sensing Platform

The concept of robust indoor positioning (see Figure 1 for fundamental system architecture) regards positioning determination across all environments [20-]. Usually, it requires a multi-sensor approach, augmenting standalone positioning with other signals, motion sensors, and environmental features.

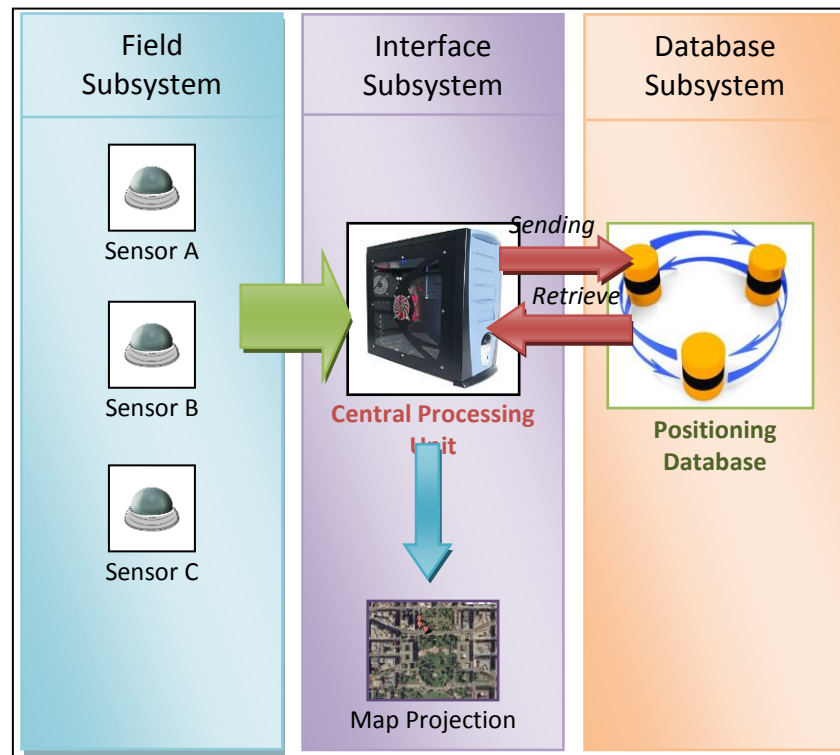


Figure 1. Fundamental System Architecture of Robust Indoor Positioning on Mobile Sensing Platform

This may be enhanced using three dimensional (3D) mapping, context awareness and cooperation between users. Robustness is maximised by harvesting as much information from the environment as possible and then selecting the most reliable measurements for

determining the position. According to Figure 1, the robust indoor positioning systems generally consist of three (3) subsystems, which are named as the field subsystem, the interface subsystem, and the database subsystem. In the normal situation, the transmitters will always continuously broadcast their signal within coverage. Any device which is equipped with special sensors within their coverage will receive a signal. The received signals by then will be processed by a central processing unit (where the positioning algorithm is installed), before it is compared with the surveying data in the database server. Finally, the output of the system will display the mapping location on a mobile device screen.

3. Problem Formulation

The core of the robust positioning is relying on positioning method integration. Although most of the positioning method integration seems successful in term of positioning accuracy and robustness, but it lacking when it comes to mobility, since most of it involve external hardware integration [25-29]. This solution is not tend very much to solve this issue, because it may make end users feel harsh on device integration. Thus, the positioning integration between MSP may solve this issue. In this paper, we aim to establish an indoor positioning system by utilising the WLAN and FM Radio function inside a mobile phone, since a mobile phone is a personal device which is used by the majority. The positioning method will be switched based on the type of environment in order to ensure the robustness of the indoor positioning system.

4. System Design

Generally, our system will determine positioning based on the availability of the signal. In detail, if the system is not within WLAN coverage, the system will prefer to process FM radio as alternative signal positioning. According to Figure 2, it shows the block diagram of WLAN/FM Radio based robust indoor positioning systems. Initially, the system will receive the WLAN and FM radio signal strength simultaneously. Those signals will be chosen by the system based on the how strong the received strength is. However, the signal strength also suffers in the obstructed environment since the signal will propagate and experience loss if there is a blockage between the AP and the mobile device receiver. Theoretically, the signal path loss obeys the distance power law as described below:

$$P_r(d) = P_r(d_0) - 10n \log \left(\frac{d}{d_0} \right) + X_\sigma \quad (3)$$

Where P_r is the received power; $P_r(d_0)$ is the received power at the d_0 (known as the reference distance), n is refers to the path loss exponent, which indicates the rate of the path loss which increases with distance. It depends on the surroundings, building type and other obstructions. In addition d_0 is the close-in reference distance (1m) and d is the distance of separation between the RF signal transmitter and the receiver (The transmitter could be AP and receiver could be mobile device receiver).

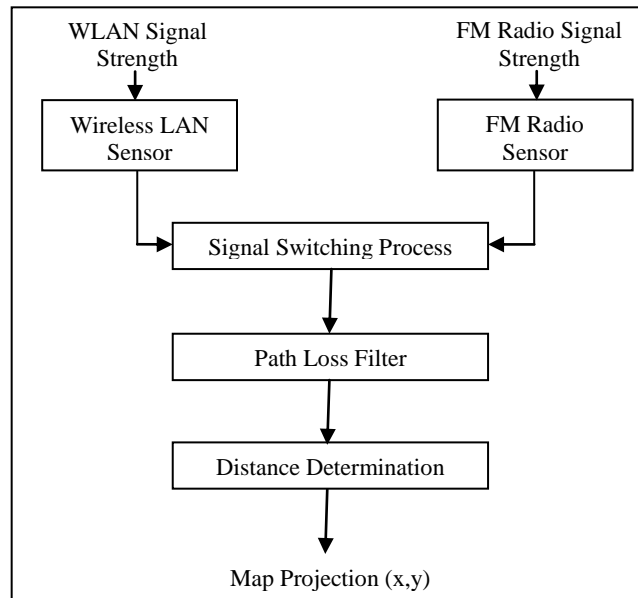


Figure 2. Block Diagram of WLAN/FM Radio based Robust Indoor Positioning.(the Basic Core of the System is based on RADAR [30], which is using KNN Nearest Neighbor [31] to Look-up Table during the off-line Phase)

The term X_σ is a zero mean Gaussian random variable with standard deviation σ . Equation (3) is modified to include the Wall Attenuation Factor (WAF). The modified distance power law is given as (4):

$$P_r(d) = P_r(d_0) - 10n \log \left(\frac{d}{d_0} \right) - T * WAF \quad (4)$$

Where, T is number of walls between the transmitter and receiver.

$$d = e^{\left(\frac{P_r(d_0) - P_r(d) - T * WAF}{10} \right)} \quad (5)$$

Equation (5) has been derived from equation (4). This equation is used to measure the distance between the access point and the mobile node. When the mobile device or node location has been calculated, the distance of every device or node will be calculated by using the Euclidean Distance equation (6).

$$\text{Distance} = \sqrt{(X_1 - X_2)^2 + (Y_1 - Y_2)^2} \quad (6)$$

The location server will calculate the distance for every device in the network and compare all the distance to determine the nearest device from the chosen mobile node. The nearest computation method is undertaken by the nearest neighbour(s) in signal space (NNSS). The idea is to compute the distance (in signal space) between the observed set of SS measurements, (ss_1, ss_2, ss_3) and the recorded SS, (ss'_1, ss'_2, ss'_3) at a fixed set of locations, and then pick the location which minimises the distance. In order to calculate based on three

(3) measurements, the equation (6) can be inherited to become equation (7) whereby D is the distance between the observed signal and the recorded signal:

$$D = \sqrt{((ss_1 - ss'_1)^2 + (ss_2 - ss'_2)^2 + (ss_3 - ss'_3)^2)} \quad (7)$$

5. Experiment Setup

We conducted the experiments at Level 2, N28, at the Universiti Teknologi, Malaysia, Johor whereby the total area was equal to approximately 120 m × 95 m, (for additional detail refer to Figure 3) by collecting WLAN and FM radio signal strength data along the corridor in four (4) orientations(see Figure 4).

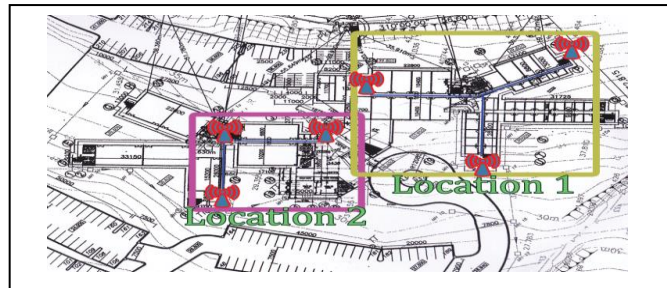


Figure 3. Experiment Location (Location 1, Location 2). The Icon of Wireless Transmitter is Refer to the Location of WLAN Access Point which Attached with FM Local Transmitter

The data recording, processing, and most positioning tests were performed by using HTC HD mini smart phones (see Figure 5), with platform Windows Mobile 6, equipped with Atheros AR5007EG wireless network adapters and stereo FM Radio. The FM tuner was controlled through a custom, low-level library written in C++, while the WLAN RSSI values were provided by the OpenNetCF SDF library [32]. A standard HTC headset has been used as an FM antenna. Due to the hardware design, the mobile device used in the experiment reported the Wi-Fi signal strength as one of six (6) levels. The FM RSSI, in turn, is represented with sixty three (63) levels; the maximum RSSI values, observed in the proximity of the transmitters, were below 45. In order to ensure a fair comparison of FM and WLAN, the precision of acquired FM RSSI samples were reduced to 6 levels as shown in Table 1.

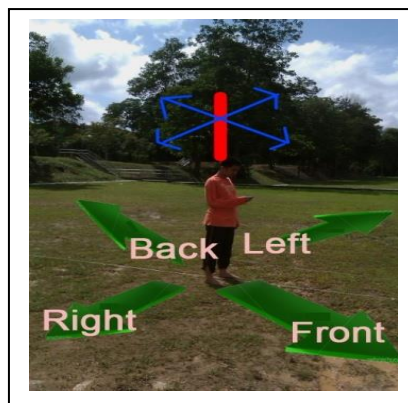


Figure 4. Four (4) Type of Orientations during WLAN Data Collection [34]



Figure 5. An HTC HD Mini Device used as a Data Collector

Note that this conversion has an adverse effect on FM positioning accuracy and has been applied only for comparison with WLAN. While FM transmitters were distinguished by their radio frequency, the different WLAN access points were recognised by their MAC addresses. The RSSI values received from different access points were assumed to be independent since the interference did not have an important influence on the system [33].

6-level FM RSSI	Original FM RSSI	WLAN RSSI
0	0	No signal
-90	1 to 9	Very low
-80	10 to 19	Low
-70	20 to 29	Good
-60	30 to 39	Very good
-50	40 to 49	Excellent

Table. 1. Mapping of FM and WLAN RSSI (HTC HD Mini)

6. Preliminary Results

In this section, we will discuss our preliminary results. Basically, these are based on our WLAN data collection. The data will be used to test the proposed system. By referring to Figures 6, 7, 8 and 9, it shows the RSSI strength compared to the distance between the mobile node and the access points in different user orientations. As we can see from this figure, the trend of RSSI is normal, where by the value decreases if the distance increases and this trend is almost the same in Figures 10, 11, 12 and 13.

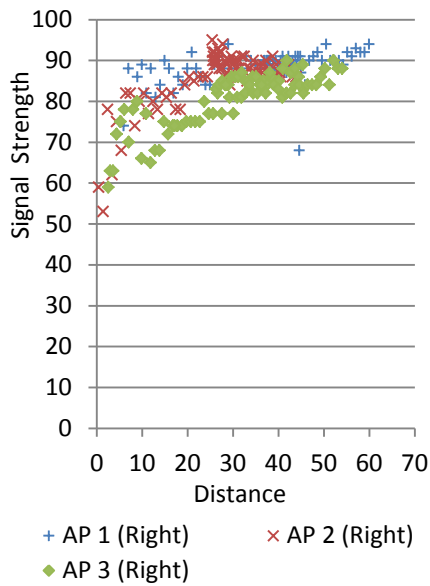


Figure 6. Distance and RSSI during Data Collection in Location 1 (User Orientation: 0°). (Note: Signal Strength in -dBm and Distance in Metres)

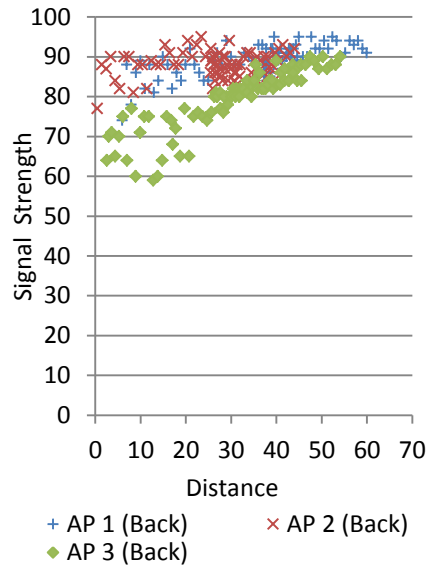


Figure 7. Distance and RSSI during Data Collection in Location 1 (User Orientation: 90°). (Note: Signal Strength in -dBm and Distance in Metres)

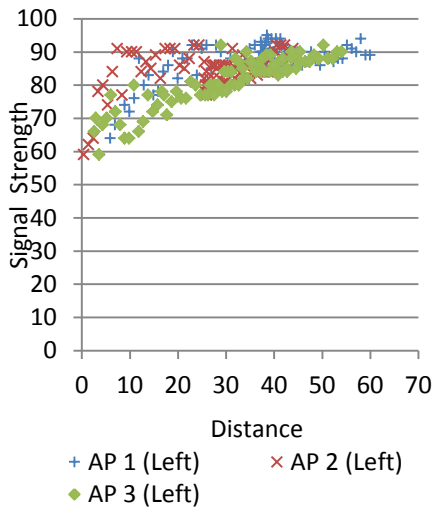


Figure 8. Distance and RSSI during Data Collection in Location 1 (User Orientation: 180°). (Note: Signal Strength in -dBm and Distance in Metres)

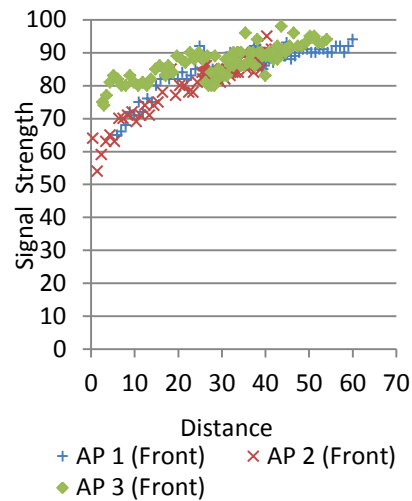


Figure 9. Distance and RSSI During Data Collection in Location 1 (User Orientation: 270°). (Note: Signal Strength in -dBm and Distance in Metres)

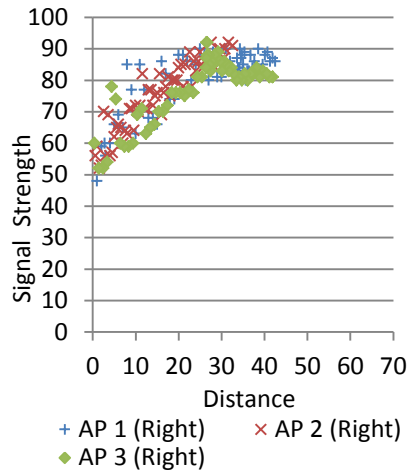


Figure 10. Distance and RSSI During Data Collection in Location 2 (User Orientation: 0°) (Note: Signal Strength in –dBm and Distance in Metres)

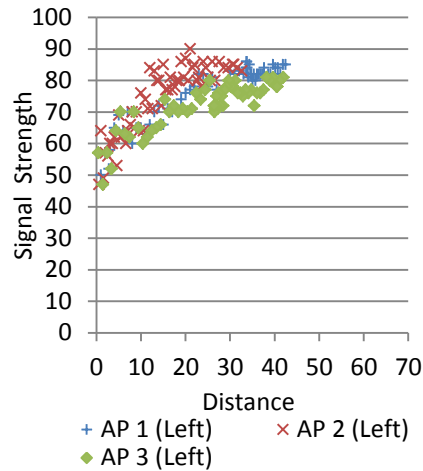


Figure 11. Distance and RSSI During Data Collection in Location 2 (User Orientation: 180°). (Note: Signal Strength in –dBm and Distance in Metres)

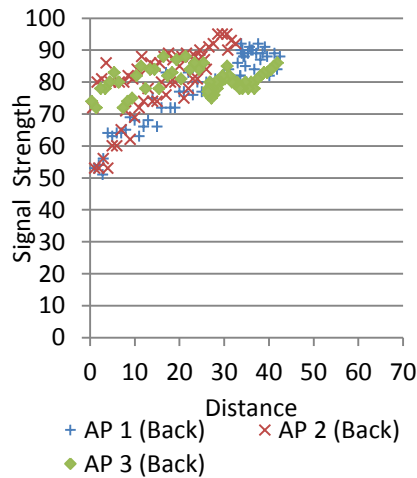


Figure 12. Distance and RSSI During Data Collection in Location 2 (User orientation: 90°) (Note: Signal Strength in –dBm and Distance in Metres)

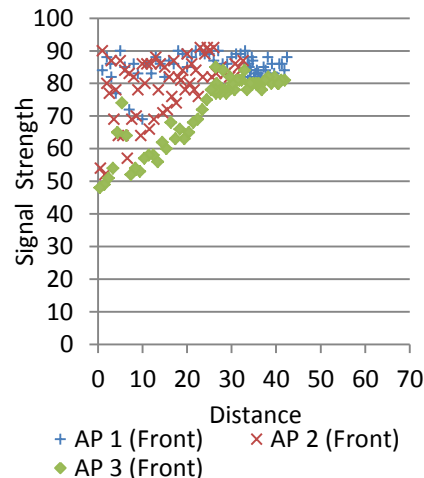


Figure 13. Distance and RSSI During Data Collection in Location 2 (User Orientation: 270°). (Note: Signal Strength in –dBm and Distance in Metres)

The wide difference in signal strengths between points at similar distances is explained as follows: the layout of the rooms in the building, the placement of base stations, and the location of the mobile user which all have an effect on the received signal. Specifically in Figures 6, 7, 8 and 9 the signal strength value obtained by the mobile device is different

dependent on the user's orientation in location 1. For example, the signal strength value of AP2 is the highest during user orientation: 270° (see Figure 9) compared with the signal strength obtained in 0° (see Figure 6). Meanwhile in location 2, we can see the signal strength value obtained by the mobile device in Figures 10, 11, 12 and 13. This also shows that the signal strength depends on the user's orientation although the distance between the mobile device receiver and AP is close. In this case, the signal strength value of AP3 is the highest during the user's orientation: 270° (see Figure 13) compared with the signal strength obtained in 0° (in Figure 10). The reason behind this is that the orientation of the user may contribute towards blockage; and thus the signal strength that is obtained by the mobile device will be reduced. This reason can also be applied with other values in the graph.

7. Conclusions and Future Directions

This paper has discussed problem solving regarding how to develop an indoor positioning system in terms of its mobility and robustness. In order to do this, the positioning method integration on mobile sensing platform is needed. Thus, the indoor positioning system by utilising the WLAN and FM Radio function inside a mobile phone has been proposed, since the mobile phone is a personal device which is used by most people. The positioning method was switched based on type of environment in order to ensure the robustness of the indoor positioning system. The preliminary result showed that the majority of the signal strength decreased if the distance increased. It is also showed that, the signal strength depended on the user's orientation since their body contributed as blockage between the mobile device and the WLAN access point. As future work, we will continue our experiment by using this result and simulate FM radio positioning in order to obtain more valuable findings.

Acknowledgements

These should be brief and placed at the end of the text before the references. This paper was inspired from my Ph.D proposal which is related to beacon selection method in FM-radio positioning system. The author would also like to thank our supervisor Dr. Mohd Murtadha Mohamad for their insightful comments on earlier drafts of this paper.

References

- [1] Y. He, R. Martin and A. Bilgic, "Scalable low-complexity GPS and DGPS positioning using approximate QR decomposition", *Signal Process*, vol. 94, (2014), pp. 445-455.
- [2] Y. Lou, W. Zhang, C. Shi and J. Liu, "High-rate (1-Hz and 50-Hz) GPS seismology: Application to the 2013 Mw 6.6 Lushan earthquake", *Asian Earth Sci.*, vol. 79, (2014), pp. 426-431.
- [3] E. Wang, T. Pang, M. Cai and Z. Zhang, "Fault Detection and Isolation for GPS RAIM Based on Genetic Resampling Particle Filter Approach", *TelKOMNIKA Indones. J. Electr. Eng.*, vol. 12, no. 5, (2014).
- [4] P.-J. Lin, S.-C. Chen, Y.-H. Li, M.-S. Wu and S.-Y. Chen, "An Implementation of Augmented Reality and Location Awareness Services in Mobile Devices", *Mobile, Ubiquitous, and Intelligent Computing*, Springer, (2014), pp. 509-514.
- [5] W. M. Y. W. Bejuri, M. M. Mohamad, M. Sapri and M. A. Rosly, "Ubiquitous WLAN/Camera Positioning using Inverse Intensity Chromaticity Space-based Feature Detection and Matching: A Preliminary Result", *ArXiv12042294 Cs*, (2012) April.
- [6] W. M. Y. W. Bejuri, W. M. N. W. M. Saidin, M. M. B. Mohamad, M. Sapri and K. S. Lim, "Ubiquitous Positioning: Integrated GPS/Wireless LAN Positioning for Wheelchair Navigation System", *Intelligent Information and Database Systems*, A. Selamat, N. T. Nguyen, and H. Haron, Eds. Springer Berlin Heidelberg, (2013), pp. 394-403.
- [7] W. M. Y. W. Bejuri, M. M. Mohamad and M. Sapri, "Ubiquitous Positioning: A Taxonomy for Location Determination on Mobile Navigation System", *Signal Image Process. Int. J.*, vol. 2, no. 1, (2011) March, pp. 24-34.

- [8] J. Cheng, L. Yang, Y. Li and W. Zhang, "Seamless outdoor/indoor navigation with WIFI/GPS aided low cost Inertial Navigation System", *Phys. Commun.*, (2014).
- [9] W. M. Y. W. Bejuri, M. M. Mohamad, M. Sapri, M. S. M. Rahim and J. A. Chaudry, "Performance Evaluation of Spatial Correlation-based Feature Detection and Matching for Automated Wheelchair Navigation System", *Int. J. Intell. Transp. Syst. Res.*, vol. 12, no. 1, (2014) January, pp. 9-19.
- [10] W. M. Y. W. Bejuri, M. M. Mohamad, M. Sapri and M. A. Rosly, "Performance Evaluation of Mobile U-Navigation based on GPS/WLAN Hybridization", *J. Conver. Inf. Technol.*, vol. 7, no. 12, (2012) October, pp. 235-246.
- [11] W. M. Y. W. Bejuri, M. M. Mohamad, M. Sapri and M. A. Rosly, "Investigation of Color Constancy for Ubiquitous Wireless LAN/Camera Positioning: An Initial Outcome", *Int. J. Adv. Comput. Technol.*, vol. 4, no. 7, (2012) June, pp. 269-280.
- [12] I. C. Paschalidis, K. Li, D. Guo and Y. Lin, "Probabilistic Indoor Tracking of Mobile Wireless Nodes Relative to Landmarks", *The Art of Wireless Sensor Networks*, Springer, (2014), pp. 169-200.
- [13] T. Higuchi, S. Fujii, H. Yamaguchi and T. Higashino, "Mobile Node Localization Focusing on Stop-and-Go Behavior of Indoor Pedestrians", (2014).
- [14] S. H. Yang, E. M. Jeong and S. K. Han, "Indoor positioning based on received optical power difference by angle of arrival", *Electron. Lett.*, vol. 50, no. 1, (2014), pp. 49-51.
- [15] T.-C. Huang, Y.-W. Chou, Y. Shu and T.-C. Yeh, "Activating Natural Science Learning by Augmented Reality and Indoor Positioning Technology", *Advanced Technologies, Embedded and Multimedia for Human-centric Computing*, Springer, (2014), pp. 229-238.
- [16] L. Pei, R. Chen, J. Liu, T. Tenhunen, H. Kuusniemi and Y. Chen, "Inquiry-based bluetooth indoor positioning via rssi probability distributions", *Advances in Satellite and Space Communications (SPACOMM)*, 2010 Second International Conference, (2010), pp. 151-156.
- [17] M. Kourogi, N. Sakata, T. Okuma and T. Kurata, "Indoor/outdoor pedestrian navigation with an embedded GPS/RFID/self-contained sensor system", *Advances in Artificial Reality and Tele-Existence*, Springer, (2006), pp. 1310-1321.
- [18] K. Kyamakya, A. Zapater and Z. Lue, "An indoor Bluetooth-based positioning system: concept, implementation and experimental evaluation", *International*, (2003).
- [19] F. Evennou and F. Marx, "Advanced integration of WiFi and inertial navigation systems for indoor mobile positioning", *Eurasip J. Appl. Signal Process.*, vol. 2006, (2006), pp. 164-164.
- [20] Y. Wu and X. Pan, "Velocity/Position Integration Formula Part I: Application to In-Flight Coarse Alignment", *IEEE Trans. Aerosp. Electron. Syst.*, vol. 49, no. 2, (2013), pp. 1006-1023.
- [21] S. Y. Cho and W.-S. Choi, "Robust positioning technique in low-cost DR/GPS for land navigation", *IEEE Trans. Instrum. Meas.*, vol. 55, no. 4, (2006), pp. 1132-1142.
- [22] A. Bachrach, S. Prentice, R. He and N. Roy, "RANGE-Robust autonomous navigation in GPS-denied environments", *J. Field Robot.*, vol. 28, no. 5, (2011), pp. 644-666.
- [23] S.-H. Fang, C.-H. Wang, S.-M. Chiou and P. Lin, "Calibration-Free Approaches for Robust Wi-Fi Positioning against Device Diversity: A Performance Comparison", *Vehicular Technology Conference (VTC Spring)*, 2012 IEEE 75th, (2012), pp. 1-5.
- [24] M. Soleimanifar, M. Lu, I. Nikolaidis and S. Lee, "A Robust Positioning Architecture for Construction Resources Localization Using Wireless Sensor Networks", *Proceedings of the Winter Simulation Conference*, Phoenix, Arizona, (2011), pp. 3562-3572.
- [25] M. Kessel and M. Werner, "SMARTPOS: Accurate and Precise Indoor Positioning on Mobile Phones", presented at the *MOBILITY 2011, The First International Conference on Mobile Services, Resources and Users*, (2011), pp. 158-163.
- [26] J. C. Ching, C. Domingo, K. Iglesia, C. Ngo and N. Chua, "Mobile Indoor Positioning Using Wi-fi Localization and Image Processing", *Theory and Practice of Computation*, S. Nishizaki, M. Numao, J. Caro, and M. T. Suarez, Eds. Springer Japan, (2013), pp. 242-256.
- [27] M. Werner, M. Kessel and C. Marouane, "Indoor positioning using smartphone camera", *2011 International Conference on Indoor Positioning and Indoor Navigation (IPIN)*, (2011), pp. 1-6.
- [28] J. Fujimoto, S. Hotta, K. Sawada, Y. Hada, K. Hida and S. Mori, "Hybrid positioning system combining spatially continuous and discrete information for indoor location-based service", *Ubiquitous Positioning, Indoor Navigation, and Location Based Service (UPINLBS)*, (2012), pp. 1-6.
- [29] R. Vera, S. F. Ochoa and R. G. Aldunate, "EDIPS: an Easy to Deploy Indoor Positioning System to support loosely coupled mobile work", *Pers. Ubiquitous Comput.*, vol. 15, no. 4, (2011) April, pp. 365-376.
- [30] P. Bahl and V. N. Padmanabhan, "RADAR: An in-building RF-based user location and tracking system", *INFOCOM 2000, Nineteenth Annual Joint Conference of the IEEE Computer and Communications Societies. Proceedings, IEEE*, vol. 2, (2000), pp. 775-784.
- [31] T. Seidl and H.-P. Kriegel, "Optimal multi-step k-nearest neighbor search", *ACM SIGMOD Record*, (1998), vol. 27, pp. 154-165.

- [32] D. Sanchez, J. M. Quinteiro, P. Hernandez-Morera and E. Martel-Jordan, "Using data mining and fingerprinting extension with device orientation information for WLAN efficient indoor location estimation", in 2012 IEEE 8th International Conference on Wireless and Mobile Computing, Networking and Communications (WiMob), (2012), pp. 77-83.
- [33] A. Schwaighofer, M. Grigoras, V. Tresp and C. Hoffmann, "GPPS: A Gaussian Process Positioning System for Cellular Networks," NIPS, (2003).
- [34] K. Kaemarungsi and P. Krishnamurthy, "Properties of indoor received signal strength for WLAN location fingerprinting", The First Annual International Conference on Mobile and Ubiquitous Systems: Networking and Services, 2004. MOBIQUITOUS 2004, (2004), pp. 14-23.

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