"Exploring the Systems and Tools of Indoor Navigation"

Mohammed Elsaeh[1], Abdurahman Al Furjani[2], Zouhir Younsi[3]

Abusaif Abdulalli[4], And Ahmed Imjabber [5]

1 University of Sebha, Libya, Email: moha.elsaeh@sebhau.edu.ly
2University of Lille, Lille, France, Email:abdurahman.alfurjani.etu@univ-lille.fr
3 École Hautes Études d'Ingénieur, Lille,France : zohir.younsi@yncrea.fr
4 Bright Star University, EL-Brega, Libya, Email: Abusaif.Abdulalli@bsu.edu.ly
5 University of Sebha, Sebha, Libya, Email: ahmad.imjabber@gmail.com

Abstract

The indoor navigation is a crucial research topic. Positioning and accurate localization are essential for indoor mapping and navigation; a combination of different tools and techniques is deployed to overcome the lack and limitation of Global Positioning System GPS for indoor comparing to the outdoor navigation. Various types of three-dimensional, Geo-Information, and spatial data sets are needed to process and model the indoor navigation system. Many methods and solutions could be applied, such as Fingerprint-based, Radio Signal Strength RSS, radio map, GSM base Stations, Computer vision, Augmented Reality AR and many other methods. This paper will explore and highlight the different protocols, techniques, and tools of the most used indoor navigation systems.

Keywords: Localization, indoor mapping, Computer Vision, AR, Positioning.

1. Introduction

Various methods and solutions have conducted and applied in the last 15 years in order to overcome the limitation of indoor navigations, especially for huge buildings. The social and economic principles of various communities have played the vital elements of the sharp rise of the Indoor Location-Based Service (ILBS), with a critical market value prediction of 10 billion$ by 2020 [1]. Indoor environments usually are characterizing as Non-Lone-of-Sight (NLoS) of signal fluctuation, obstacles, reference objects, etc. this uncertain configuration makes those indoor environments complex and multifaceted. One of the significant methods of measurements in these criteria is still the high accuracy of localization within meter ranges.

Global Positioning System (GPS) cannot permeate well in indoor environments. Therefore, several other signals have been validating and investigating some particular objectives like localization. For example, signals include FM radio [2, 3], radio frequency identification (RFID) [4,… 7], Bluetooth [8, 9], Wi-Fi [10], ultrasound or sound [11], [12], light [13], [14], magnetic field [15], [16], etc. By the time the use of the Wi-Fi signal has dramatically increased over the other signals. This usability can be seen clearly in both fields academic [17, 18] and industrial [19, 20] due to the wide distribution of the wireless (LANs and WANs) and the ability to use Wi-Fi for mobiles.

However, computer vision and Augmented Reality (AR) are other technology fields, which contain a unique sequence of generated computer virtual images in-witch we put them over real worlds. Virtual images are allying with real-world objects in specific mechanisms that can be seeing and interacting in real-time. In this technology, the computer generates 2D or 3D objects; those objects could be graphics, audio, text, Point-Of-Interest (POI), or video that interact the physical, real-world objects with the virtual objects in order to provide users with meaning-full and useful information. This configuration enables users to interact with the application quickly and comfortably. An increasing number of people, in both academics and industries, are using augmented reality.

The indoor navigation is a crucial research topic. According to the study that was done in order to investigate the use of the navigation maps by smartphone users, they found that 95% of the selected group of people uses the mapping application at least once [21]. Nowadays, around 85% of users utilize mapping more than ten times on their phones compared with the survey period, which illustrates the significant rise of the use of mapping by the time. However, there are still several limitations on the currently available technologies for navigation, such as low cost and universal mobile navigation systems. These limitations are due to the require installation or the dedicated infrastructure [22].

An overview and comparison between different methods and solutions that were developed for indoor navigation have been conducted. Various related papers to the indoor topic have been divided based on the type of the method itself. We first performed an overview of the available novel technologies in the field; then, make the comparison. We determined that our target readers would focus on the following aspects: Fingerprint-based and augmented reality methods, as they are the most used techniques in the indoor navigation field. Therefore, this paper is organized as follows: Fingerprint-based method augmented reality method and a case study that will give the readers a clear insight into the used technologies.

1. Fingerprint-based

One of the major advantages of the Wi-Fi fingerprint positioning systems is the low cost, as they do not require any further infrastructure investment. In other words, Wi-Fi fingerprint positioning systems can be adapted and used directly with various building structures and complexity. Triangulation and trilateration are essential and always require traditional out-door localization and navigation [23, 24]; this configuration requires Line-of-Sight (LoS) measurement. These schemas cannot be used for indoor navigations as they have complex setups such as obstacles, rooms and walls. By ignoring Line-of-Sight measurement, signal collection and association in indoor locations knowing as Wi-Fi finger-print method can be considered as a promising method [25, 26]. However, detected signal patterns like a vector of Received Signal Strength Indicators RSSIs are responsible in order to characterize each position in indoor navigations' schemas [27]. Therefore, there is no need for the precise Access Point AP locations; because finger-print does not require the distance information nor the angle measurement. Based on that evidence, the finger-print method can be considered as one of the most appropriate methods for indoor navigation.

There are two main phases in Wi-Fi finger-print method; those phases are named Offline and Online. The Offline phase is responsible for gathering all related data and information of the concerned location. Whereas, the Online phase is responsible for querying the related positions in order to know the exact location and the potential direction in order to reach the destination, as can be seen in Fig. 1. This figure demonstrates the necessary operations for the finger-print navigation systems.

In the Offline phase, inspection or survey needs to be done in order to collect the related vectors of RSSI of all Wi-Fi signals that have been detected from various possible Access Points APs at several Reference Points RPs of the determined locations. Then, a finger-print will represent each reference point. Finally, all finger-prints will be stored in the database to be used later on for the Online queries.

In the Online phase, a user or target will measure a RSSI vector at their particular position and store it in the server. By using some related algorithms, the server verifies the entered user or target vector with the finger-prints that have already been registered in the database. The next position to be reached by the user is predicted based on the nearest neighbor of registered vectors.

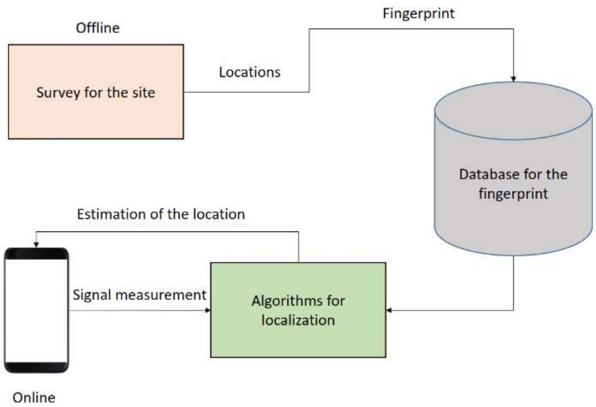

Figure [1]: Site map of basic system flow

Several studies were conducted and reviewed for indoor navigations [28, 29, 30]. Although these studies give a promising potential for the indoor navigations, finger-print positioning systems still need to be investigating and adapted to be more suitable for the already existing complex buildings. These investigations need different conceder categories such as collaborative localization, reducing site surveys and motion assisted localization.

For the collaborative localization, some mobile phone sensors might need to be used, such as sounds [31] in order to get the most appropriate location of the available neighbor users. This may reduce the localization error between the users of the same building or block of buildings.

For the reducing site surveys, in order to achieve the survey for the site, various collection of data and maintenance need to be performed. These collections require an expensive time to store area. Due to the potential change within the inside infrastructure of a building, another process of collection and maintenance needs to be performed in order to keep the database up to date that makes these processes even more difficult. Therefore, consideration needs to be done to avoid these spend times and efforts.

For the motion assisted localization, it concerns on the inertial sensors of the smartphone in order to measure the trajectory of the user. It collects the walking direction of the user to be integrated with the Wi-Fi signals in order to determine the best trajectory among the possible available trajectories. This schema can improve the accuracy of the calculated trajectory based on the collected data from the sensors [32, 33].

2. Augmented Reality-Based

In this study, an overview of augmented reality solutions that were developed for indoor navigation has also been conducted. Various related papers to the indoor topic have been divided based on the type of the method itself. However, in augmented reality maps, the smartphones show the related virtual points of the interesting trajectory over the real map. Therefore, users can determine their trajectories by following the virtual points while using the real building structure.

The main objective in this part of the study is to provide a clear scope of the used methods that have been developed for the indoor positioning navigation systems through the imaging processing and without using wireless technologies. Also, it aims to investigate the impact of using interactive indoor navigation methods on complex buildings. However, augmented reality is used to mount direction signs on the real view of the interior environment in a three-dimensional shape. Various tools could be used with augmented reality, such as voice guidance, 3D graphs, and lighting. All of these tools come as outputs of the system in order to assist smartphone users in following the right directions to their destinations.

Most of the solutions for indoor positioning are using wireless technologies like Bluetooth. Those solutions are not easy to use and require pre-build technology in concerned buildings [34]. In other words, systems for indoor positioning, which based on wireless technologies, are built to use internet connections in the concerned buildings.

The principle idea of augmented reality is to build and use a mixture scenario; this new scenario contains the real world's components mixed with the virtual points and sounds for guiding the users. However, augmented reality technology was created in 1950; it has been used for various fields such as collaboration, education, entertainment, gaming, industrial, interaction, medicine, perception, tourism, exploration, and finally navigation [35]. It has rapidly explored due to the potential use in various scientific aspects such as the effects of visual feedback on the users during the use of this technology in those fields. Therefore, the interactive 3D image is superimposed on the real scene may improve the efficiency in training based applications such as assisting users in navigation demonstration especially for smart cities.

Open Source Augmented Reality Software that named ARtoolkit is responsible for displaying the virtual objects for guiding. These virtual objects, which typically used in 3D format, are placed on the detected markers, as can be seen in Fig. 2. This configuration helps the users to find their trajectories toward their destinations based on the registered paths for the optimal direction within the indoor plans.

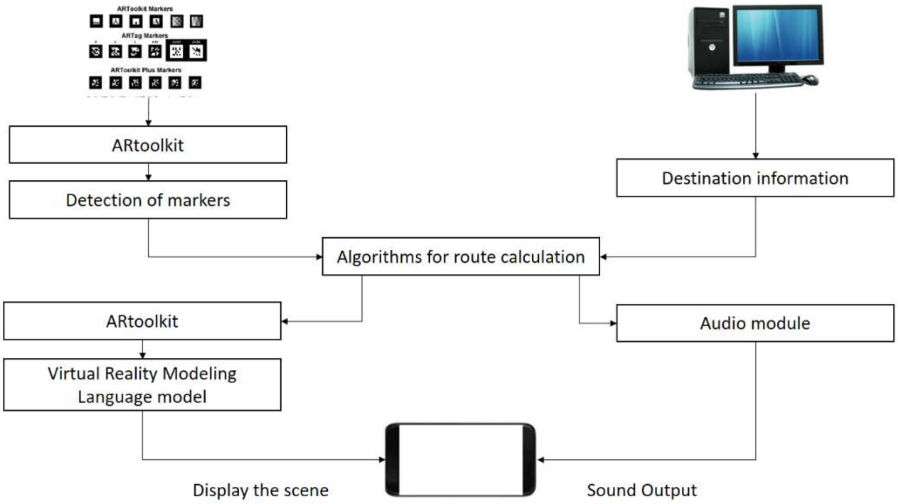

Figure 2: augmented reality-based indoor positioning navigation

The open-source software library named ARtoolkit is responsible for facilitating the development of augmented reality applications. Dr. Hirokazu Kato has invented the ARtoolkit, and then, it has been supported by the laboratory of human interface technology at the University of Washington [36]. The main objective of using ARtoolkit is to overlay the virtual 3D images on the detected markers. Furthermore, the main advantage of ARtoolkit is that it enables real-time tracking with critical precision. This high precision comes from the ability of the ARtoolkit to track the viewpoint of the user by calculating the position of the camera and its orientation, and then find its relative to the marker orientation. Therefore, the virtual images that render over the real world and markers appear always tied with the related markers. This rendering enables smooth simulation of virtual images over the real world. Firstly, a frame of the video stream is captured from the webcam. The image will be converted to a binary image (black and white) based on the threshold value, which is the binary coding technology [37]. Secondly, the program will search for square areas using the image tagging technique where those connected components and the size that almost accommodates a fiduciary mark will be extracted. The square area can take any orientation, so it has to be oriented to its initial position when the markers were placed. Finally, when a marker is detected, the viewpoint will be computed and appeared to the users based on the related virtual image to that marker. The ability to detect markers is the crucial element to judge the performance of an ARtoolkit. Also, lighting conditions affect the accuracy of the used ARtoolkit.

OpenAL is a 3D audio that used distributes related sounds of each point in the platform application. It allows the users to experience the various related details of the virtual environment that have been organized by the developers. Each audio effect is responsible for a unique location, and it will be applied when the user reaches that virtual point.

Augmented reality for the indoor positioning systems aims to extend the user awareness in perceiving the information transmitted from the map and facilitate it to the users by determining the path that leads to the destination.

3. Case study

The primary purpose of this case study is to establish an augmented reality indoor navigation system as a solution for positioning navigation in indoor environments that is the most recent technology in the field. The system is designed to be used by smartphone users, as most people nowadays are using these devices. The main reason for augmented reality navigation systems is to use the non-wireless environmental tracking tools to assist the users in discovering and navigating the indoor buildings based on the augmented reality instructions.

The proposed handled device for the system is the android phone that will be suitable for augmented reality applications as they have the needed components such as a magnetometer, accelerometer, and proximity sensors. These components ensure the tracking abilities as well as the essential orientation that is needed to enable virtual images to overlay the real environment components.

Unity 3D application is used in this case study because it has the Vuforia SDK that can be used with android SDK to enable the aggregation between the smartphone and the unity 3D' application and to make the development of the system possible. Some steps need to be done before starting the development of the system. For example, the indoor environment needs to be scanning in 3D format and then stored in the database as images. Vuforia and Mapbox SDK is used in order to develop the application in Unity 3D. The visual features that have been scanned need to storing as targets; those targets need to be displayed in the application to represent the real environment. Virtual 3D images need to placed on top of the targets in the creation of the application in order to enable the calculation of the best route between two points in the real environment. Once one of the stored targets is detected, the related virtual images are also detected and overlaid on the real environment components displayed by the camera as can be seen in Fig. 3.

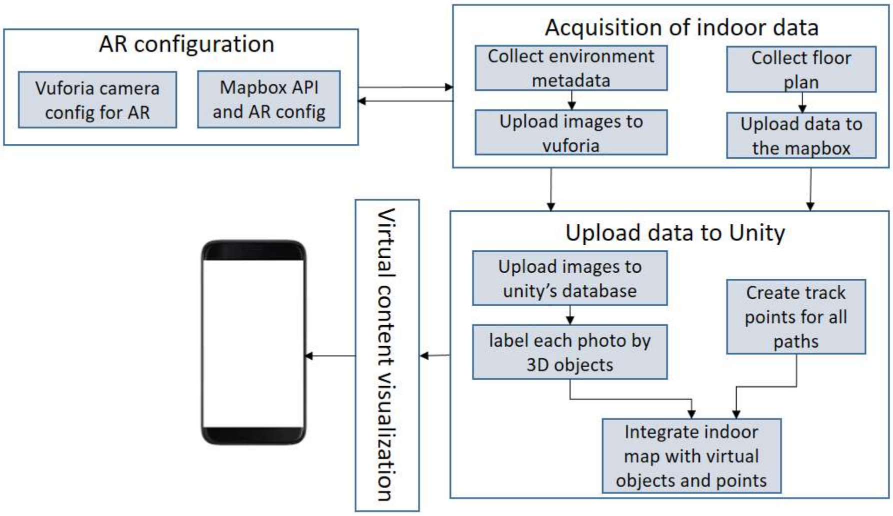

Figure 3: the system architecture

Each location in the real environment needs to be captured and stored in the database along with the floor plan to enable the integration of the virtual images that will provide the users with the trajectory plan to the destination.

The external plugins for android phones need to be configured in Unity 3D before the implementation of the system. Now, all related data have been imported to Unity 3D; from Vuforia, we can upload all needed images of the environment to the Vuforia developer portal that is used as an image target. As can be seen in Fig. 4. The images need to download from the database as Unity 3D package as well as the floor plan of the building. Point-Of-Interest (POI) will be added by determining virtual data points on the floor plan for each destination to enable the tracking from the start point to the endpoint. The data points will be taken as synchronization points to the destination point. Once the data acquisition is done, the virtual guide images will be added to each image target from the database in order to direct the users to the destination from any point within the floor map.

The method of tracking

The data points have to be plotted in the various possible destinations or rooms of the building in the floor plan. This will facilitate the navigation process from any point to the destination in the indoor environment.

4. Conclusion

Meanwhile, the majority of the huge buildings do not have indoor positioning and navigation systems available for the people who might visit them. The users need to process and gather the dispersed and uncomfortable facilities information. Although various technologies and solutions for indoor positioning and navigation have recently been developed and introduced, they still unknown for lots of potential users. People are still losing time and effort in order to locate their destination especially in huge buildings. In this paper, we have presented the most recent and usable methods and solutions in the field. Although there is still some limitations to use those systems, the potential benefits such as time reducing and less-effort as well as supporting smart cities make it mandatory to continue developing and enhancing those technologies to be available for people.

References

[1] "Indoor location in retail: Where is the money?" ABI Research: Location Technologies Market Research, May 2015, https://www. abiresearch.com/market-research/service/location technologies/.

[2] Y. Chen, D. Lymberopoulos, J. Liu, and B. Priyantha, "FM-based indoor localization," in **Proc. ACM MobiSys**, Jun. 2012, pp. 169–182.

[3] S. Yoon, K. Lee, and I. Rhee, "FM-based indoor localization via automatic fingerprint DB construction and matching," in **Proc. ACM MobiSys**, 2013, pp. 207–220.

[4] L. Ni, Y. Liu, Y. C. Lau, and A. Patil, "LANDMARC: Indoor location sensing using active RFID," in **Proc. IEEE PerCom**, Mar. 2003, pp. 407–415.

[5] J. Wang and D. Katabi, "Dude, where's my card? RFID positioning that works with multipath and non-line of sight," in **Proc. ACM SIGCOMM**, 2013, pp. 51–62.

[6] L. Yang, Y. Chen, X.-Y. Li, C. Xiao, M. Li, and Y. Liu, "Tagoram: Real-time tracking of mobile RFID tags to high precision using COTS devices," in **Proc. ACM MobiCom**, 2014, pp. 237–248.

[7] W. Zhuo, B. Zhang, S. Chan, and E. Chang, "Error modeling and estimation fusion for indoor localization," in **Proc. IEEE ICME**, Jul 2012, pp. 741–746.

[8] S. Liu, Y. Jiang, and A. Striegel, "Face-to-face proximity estimation using Bluetooth on smartphones," **IEEE Trans. Mobile Computing**, vol. 13, no. 4, pp. 811–823, Apr. 2014.

[9] X. Zhao, Z. Xiao, A. Markham, N. Trigoni, and Y. Ren, "Does BTLE measure up against WiFi? A comparison of indoor location performance," in **Proc. European Wireless Conference**, May 2014, pp. 1–6.

[10] P. Bahl and V. N. Padmanabhan, "RADAR: An in-building RF-based user location and tracking system," in **Proc. IEEE INFOCOM**, 2000, pp. 775–784.

[11] Z. Sun, A. Purohit, K. Chen, S. Pan, T. Pering, and P. Zhang, "PANDAA: Physical arrangement detection of networked devices through ambient-sound awareness," in **Proc. ACM UbiComp**, 2011, pp. 425– 434.

[12] W. Huang, Y. Xiong, X.-Y. Li, H. Lin, X. Mao, P. Yang, and Y. Liu, "Shake and walk: Acoustic direction finding and fine-grained indoor localization using smartphones," in **Proc. IEEE INFOCOM**, Apr. 2014, pp. 370–378.

[13] Y.-S. Kuo, P. Pannuto, K.-J. Hsiao, and P. Dutta, "Luxapose: Indoor positioning with mobile phones and visible light," in **Proc. ACM MobiCom**, 2014, pp. 447–458.

[14] Z. Yang, Z. Wang, J. Zhang, C. Huang, and Q. Zhang, "Wearables can afford: Light-weight indoor positioning with visible light," in **Proc. ACM MobiSys**, 2015, pp. 317–330.

[15] J. Chung, M. Donahoe, C. Schmandt, I.-J. Kim, P. Razavai, and M. Wiseman, "Indoor location sensing using geo-magnetism," in **Proc. ACM MobiSys**, New York, NY, USA, 2011, pp. 141–154.

[16] H. Xie, T. Gu, X. Tao, H. Ye, and J. Lv, "MaLoc: A practical magnetic fingerprinting approach to indoor localization using smartphones," in **Proc. ACM UbiComp**, 2014, pp. 243 253.

[17] C. Wu, Z. Yang, Y. Liu, and W. Xi, "WILL: Wireless indoor localization without site survey," **IEEE Trans. Parallel and Distributed Systems**, vol. 24, no. 4, pp. 839–848, 2013.

[18] S. Yang, P. Dessai, M. Verma, and M. Gerla, "FreeLoc: Calibration-free crowdsourced indoor localization," in **Proc. IEEE INFOCOM**, 2013, pp. 2481–2489.

[19] D. Han, S. Jung, M. Lee, and G. Yoon, "Building a practical Wi-Fibased indoor navigation system," **IEEE Pervasive Computing**, vol. 13, no. 2, pp. 72–79, Apr. 2014.

[20] D. Lymberopoulos, J. Liu, X. Yang, R. R. Choudhury, S. Sen, and V. Handziski, "Microsoft indoor localization competition: Experiences and lessons learned," **SIGMOBILE Mobile Computing Communication Review**, vol. 18, no. 4, pp. 24–31, Jan. 2015.

[21] Do, T. M. T., Blom, J., & Gatica-Perez, D. (2011).Smartphone usage in the wild: a large-scale analysis of applications and context. In *Proceedings of ICMI* (pp.353-360). Doi: 10. 1145/2070481. 2070550

[22] Kasprzak, S., Komninos, A., & Barrie, P. (2013). Feature-based indoor navigation using augmented reality. In *Proceedings of 9th International Conference on Intelligent Environments*, Athens, Greece (pp. 100–107).

[23] Y. Liu, Z. Yang, X. Wang, and L. Jian, “Location, localization, and localizability,” **Journal of Computer Science and Technology**, vol. 25, no. 2, pp. 274–297, 2010.

[24] N. Alsindi, R. Raulefs, and C. Teolis, **Geolocation Techniques: Principles and Applications**. Springer, 2012.

[25] H. Liu, Y. Gan, J. Yang, S. Sidhom, Y. Wang, Y. Chen, and F. Ye, “Push the limit of WiFi based localization for smartphones,” in **Proc. ACM MobiCom**, Sep. 2012, pp. 305–316.

[26] Z. Xiao, H. Wen, A. Markham, N. Trigoni, P. Blunsom, and J. Frolik, “Non-line-of-sight identification and mitigation using received signal strength,” **IEEE Trans. Wireless Communications,** vol. 14, no. 3, pp. 1689–1702, March 2015.

[27] A. Farshad, J. Li, M. K. Marina, and F. J. Garcia, “A microscopic look at WiFi fingerprinting for indoor mobile phone localization in diverse environments,” in **Proc. IPIN**, 2013, pp. 1–10.

[28] H. Liu, H. Darabi, P. Banerjee, and J. Liu, “Survey of wireless indoor positioning techniques and systems,” **IEEE Trans. Systems, Man, and Cybernetics**, vol. 37, no. 6, pp. 1067–1080, Nov. 2007.

[29] F. Seco, A. Jimenez, C. Prieto, J. Roa, and K. Koutsou, “A survey of mathematical methods for indoor localization,” **Intelligent Signal Processing**, pp. 9–14, 2009.

[30] G. Sun, J. Chen, W. Guo, and K. Liu, “Signal processing techniques in network-aided positioning: A survey of state-of-the-art positioning designs,” **IEEE Signal Processing Magazine**, vol. 22, no. 4, pp. 12–23, Jul. 2005.

[31] C. Peng, G. Shen, Y. Zhang, Y. Li, and K. Tan, “Beepbeep: a high accuracy acoustic ranging system using cots mobile devices,” in **Proc. ACM SenSys**, Nov. 2007, pp. 1–14.

[32] Z. Yang, C. Wu, Z. Xinglin, X. Wang, and Y. Liu, “Mobility increases localizability: A survey on wireless indoor localization using inertial sensors,” **ACM Computing Surveys**, vol. 47, no. 3, pp. 54:1–54:34, Apr. 2015.

[33] H. Wen, Z. Xiao, N. Trigoni, and P. Blunsom, “On assessing the accuracy of positioning systems in indoor environments,” in **Wireless Sensor Networks (Proc. EWSN)**, ser. Lecture Notes in Computer Science, vol. 7772, 2013.

[34] L. D. Chou, C.Y. Chang, "A Hierarchical Architecture for Indoor Positioning Services," Department of Computer Science and Information Engineering National Central University, Taiwan.

[35] Dey, A., Billinghurst, M., Lindeman, R. W., & Swan, J. (2018). A systematic review of 10 years of augmented reality usability studies: 2005 to 2014. Frontiers in Robotics and AI, 5, 37.

[36] Kato, HIT Lab of University of Washington, HIT Lab NZ of University of Canterbury, New Zealand, ARtoolkit Website.

[37] Dr. Peter Scott, Animate Vision Principles for 3D Image Sequences, http://www.cse.buffalo.edu/faculty/peter/cse668.