American Journal of Information Science and Computer Engineering
Vol. 6, No. 3, 2020, pp. 15-18
http://www.aiscience.org/journal/ajisce
ISSN: 2381-7488 (Print); ISSN: 2381-7496 (Online)

Cooperative Localization Based on WiFi and Geomagnetic Signals

Jiacheng Ni[1], Wenmin Xia[1], Litong Sun[1], Chaogang Xu[1], Yuqi Yang[1], Hao Yang[1, 2, *]

[1]School of Information Engineering, Yancheng Teachers University, Yancheng, China
[2]Jiangsu Provincial Key Constructive Laboratory for Big Data of Psychology and Cognitive Science, Yancheng Teachers University, Yancheng, China

Abstract

The WiFi fingerprint location method is greatly affected by spatial ambiguity and temporal instability. Due to the practicability of WiFi facilities and the widespread layout in various indoor scenes, indoor positioning based on WiFi fingerprint has become the most attractive technical means. This paper combines WiFi signal and geomagnetic signals to achieve effective collaborative positioning method and track tracking. In details, the main work of this paper is to design an effective location and trajectory tracking method by cooperating with WiFi and geomagnetism. Firstly, we propose a robust localization algorithm for RSS signal level; secondly, we propose a real-time trajectory matching algorithm for geomagnetic signals; finally, we design a particle filter to realize the user's trajectory collaborative tracking. The ultimate goal is to achieve a high-precision and robust positioning algorithm based on WiFi signal and geomagnetic signal, so that it can not only achieve high-precision single point static positioning using WiFi, but also realize real-time trajectory tracking combined with IMU reading. This method can not only realize high-precision single point static positioning with WiFi, but also realize real-time trajectory tracking combined with IMU reading. Therefor, our approach provides a new idea to cooperatively employ WiFi and geomagnetic signals for future indoor positioning research.

Keywords

Cooperative Localization, WiFi, Geomagnetic Signals

Received: September 30, 2020 / Accepted: November 15, 2020 / Published online: December 11, 2020

1. Introduction

With the rapid development of Internet of things technology and a variety of indoor location-based applications, the demand for high-precision and real-time indoor positioning services has become increasingly strong. In the past decade, many indoor positioning technologies based on WiFi, RFID, sound signal, magnetic signal and inertial sensor have developed. Among all the above technologies, due to the practicability of WiFi facilities and the widespread layout in various indoor scenes, indoor positioning based on WiFi fingerprint has become the most attractive technical means. Many big companies, including apple, Cisco, Huawei and Baidu, have developed WiFi Based indoor positioning related products. These methods use the signal strength of WiFi signal as the fingerprint of the current location, and use smart phones as the client, so that no additional infrastructure and special hardware are needed, and large-scale deployment can be realized.

In addition, the positioning based on geomagnetic signal is becoming more and more prominent. The advantage of ubiquitous geomagnetic signals lies in the fact that there is no

* Corresponding author
E-mail address: hobbyc@163.com (Hao Yang)

need to deploy any facilities and the signal itself is stable and anti-jamming. The reading of geomagnetic signal in the same place but at different time or in different surrounding environment is basically stable. At the same time, the geomagnetic signal intensity curves collected by users under different paths have obvious differentiation, which makes the geomagnetic signals very suitable for the matching of user trajectories.

Although there are many methods for indoor positioning using WiFi and IMU data, these methods still face the following problems:

(1) Fingerprint spatial ambiguity

Due to the complexity of indoor environment and multi-path effect, the RSS fingerprints of WiFi signals at two remote locations may be very similar, which leads to fingerprint mismatching in the localization algorithm, resulting in large error.

(2) Fingerprint time instability

Because the layout of indoor environment may change, and even the widely deployed commercial AP will automatically adjust the channel parameters according to the number of connections, channel status and other external factors, these reasons make the fingerprint collected at the same location at different times will be significantly different, which brings a lot of errors to positioning.

2. Method

The main work of this paper is to design an effective location and trajectory tracking method by cooperating with WiFi and geomagnetism. Firstly, we propose a robust localization algorithm for RSS signal level; secondly, we propose a real-time trajectory matching algorithm for geomagnetic signals; finally, we design a particle filter to realize the user's trajectory collaborative tracking.

(1) Robust localization algorithm for RSS signal hierarchy

In order to solve the spatial ambiguity and temporal instability of RSS signal fingerprints, we proposed the concept of signal spatial hierarchy based on the traditional WiFi fingerprint, and designed an efficient and accurate signal spatial hierarchy construction algorithm and matching algorithm, which provided a new idea for the existing single fingerprint location. At the same time, we used a number of mobile devices and carried out a large number of experiments in the laboratory, office building and classroom. The total number of fingerprints tested was up to 100000.

(2) Real time trajectory matching algorithm for geomagnetic signals

In order to achieve the high accuracy and robustness of fingerprint location, we design a high-precision geomagnetic signal curve matching algorithm, which can help WiFi signal track the user trajectory. The geomagnetic signal can maintain stability and anti-interference, but it is greatly affected by the orientation and diversity of the acquisition hardware. In order to take advantage of the advantages of the geomagnetic signal and overcome the disadvantages of the geomagnetic signal, we combine the dynamic time warping algorithm and the derivative dynamic time warping algorithm to match the two magnetic induction intensity curves, which not only considers the absolute signal strength of the curve, but also considers the absolute signal strength of the curve The shape of the curve is taken into account. At the same time, in order to reduce the time cost of matching, we propose a real-time dynamic time warping algorithm, which reduces the time complexity of the algorithm from 2) to, ensuring the real-time performance of the algorithm.

(3) Collaborative tracking algorithm for user trajectory

In order to realize the user's trajectory tracking, WiFi signal and geomagnetic signal are processed together. So we can effectively combine the advantages of the two methods in the design of a single magnetic fingerprint filter to match the signal effectively. Particle filter method is a process of finding a group of random samples propagating in the state space to approximate the probability density function and replacing the integral operation with the sample mean value to obtain the minimum variance distribution of the state. In the scene of this project, particles are randomly generated in space. Each particle is given a weight by calculating the signal space level distance and trajectory matching distance between the signal in the database and the measured signal. The user's real position will be in the position with the most dense particle weight, and each step of the user's movement will bring particles In this way, the process can be carried out and the track tracking is realized.

3. Technical Route

The technical route is divided into three parts:

(1) At the database side, we construct WiFi fingerprint database and geomagnetic database by crowdsourcing or pre sampling. According to WiFi fingerprint database, we generate signal space hierarchical matrix database. In addition, we can consider the limitation of map to provide more accurate calibration for the later positioning system.

(2) At the user end, users will continuously collect WiFi fingerprint, geomagnetic signal strength, accelerometer and gyroscope data when walking or stationary, and use the data of accelerometer and gyroscope to realize the user's

motion state recognition. WiFi fingerprint and geomagnetic signal strength are matched with the data in the database respectively, and the user's position is calculated.

(3) In the cloud server, according to the data collected by the user, the user's motion state identification and user's rough position (using WiFi Positioning results and moving geomagnetic positioning results respectively) are completed, and all the data are input into the particle filter. The output results of the particle filter can be used to develop location-based applications or services.

4. Experiments

4.1. Comparison of Different Environments

Our positioning errors in small office area, medium-sized laboratory and large teaching building are 1.74m, 2.30m and 3.04m. The results of experiments are in Table 1. The environment, people walking, WiFi environment and other factors of these three places are very different, but the actual positioning accuracy of hierarchical distribution positioning algorithm is not very different, which can reflect the universality of our algorithm in different environments to a large extent.

Table 1. Effect in different environments.

Locations	average error (m)	Median error (m)	Maximum error (m)	≤2m
office area	1.74	1.61	3.7	90%
laboratory	2.30	1.98	4.2	85%
teaching building	3.04	2.54	6.0	78%

4.2. Comparison of Different Localization Algorithms

In order to demonstrate the superiority of our WiFi localization algorithm, we selected three classic RSS fingerprint localization algorithms to compare with our signal hierarchical distribution localization algorithm. Their brief introductions are as follows;

1) Radar: it includes offline training and online position estimation. In the offline training part, the main task is to complete the fingerprint database construction and model training. Radar collects the RSS spatial fingerprint information of all WiFi access points (AP) in each observation point, and stores all RSS fingerprint information into a multi-dimensional matrix into the database to build a signal strength location database.

2) Horus: there are also two stages, offline training and online position assessment. In the offline phase, the first step is to establish a sampling map and RSS fingerprint collection. Firstly, the corresponding sampling map is designed in the room, and the sampling points are evenly distributed. The RSS signals of all AP are collected at each collection point to form fingerprint map. However, unlike radar, Horus uses a probabilistic method to determine the signal strength characteristics of each AP at a specific location.

Table 2. Effect of different localization algorithms.

Locations	average error (m)	Median error (m)	Maximum error (m)	≤2m
Our method	1.52	0.98	3.7	2.84
RADAR	5.16	4.78	8.68	8.43
Horus	3.97	3.5	6.88	5.62

5. Conclusion

This paper focuses on the study and solution of the above problems. The ultimate goal is to achieve a high-precision and robust positioning algorithm based on WiFi signal and geomagnetic signal, so that it can not only achieve high-precision single point static positioning using WiFi, but also realize real-time trajectory tracking combined with IMU reading. To break the limitations of WiFi positioning, and then provide new ideas for the future indoor positioning research.

Acknowledgements

This work is supported by National Natural Science Foundation of China under Grant No. 61772448, 61402394, Natural Science Foundation of Jiangsu Province under Grant No. BK20191481, China Postdoctoral Science Foundation funded project under Grant No. 2019M660132, Natural Science Major Project of the Higher Education Institutions of Jiangsu Province of China under Grant No. 17KJA520006, Postdoctoral Research Subsidy Program of Jiangsu Province under Grant No. 2019K123, the Fifth “333 high-level personnel training project” Scientific Research Subsidy of Jiangsu Province under Grant No. BRA2019288, the Open Foundation of Jiangsu Provincial Key Constructive Laboratory for Big Data of Psychology under Grant No. 72591962002G, Six talent peaks project in Jiangsu Province under Grant No. JY-072, 333 high level talent training project in Jiangsu Province, Innovation and entrepreneurship training program for College Students of Jiangsu Province (202010324011Z, 202010324070Y).

References

[1] A. F. G. Ferreira, D. M. A. Fernandes, A. P. Catarino, and J. L. Monteiro, "Localization and positioning systems for emergency responders: A survey," IEEE Commun. Surveys Tuts., vol. 19, no. 4, pp. 2836–2870, 4th Quart., 2017.

[2] J. Xiao, K. Wu, Y. Yi, L. Wang, and L. M. Ni, "Fimd: Fine-grained device-free motion detection." in Proceedings of IEEE ICPADS, 2012, pp. 229–235.

[3] Walters C. Characterization of Smart Phone Received Signal Strength Indication for WLAN Indoor Position Accuracy Improvement [J]. Journal of Networks, 2014, 9 (2): 1061-1065.

[4] Kim S Y, Choi J Y, Lee M H. Indoor Positioning System using Incident Angle Detection of Infrared sensor [J]. Journal of Institute of Control, 2010, 16 (10): 991-996.

[5] E. Asimakopoulou and N. Bessis, "Buildings and crowds: Forming smart cities for more effective disaster management," in Proc. IEEE 5th Int. Conf. Innov. Mobile Internet Services Ubiquitous Comput. (IMIS), 2011, pp. 229–234.

[6] M. Centenaro, L. Vangelista, A. Zanella, and M. Zorzi, "Long-range communications in unlicensed bands: The rising stars in the IoT and smart city scenarios," IEEE Wireless Commun., vol. 23, no. 5, pp. 60–67, Oct. 2016.

[7] Bemri. Visible Light Communication (VLC/Li-Fi) Systems. Accessed: Apr. 12, 2019. [Online]. Available: http://bemri.org/visible-lightcommunication.html

[8] X. Wang, L. Gao, S. Mao, and S. Pandey, "CSI-based fingerprinting for indoor localization: A deep learning approach," IEEE Trans. Veh. Technol., vol. 66, no. 1, pp. 763–776, Jan. 2017.

[9] Zhong Z, Ling C, Huan X, et al. XJTLUIndoorLoc: A New Fingerprinting Database for Indoor Localization and Trajectory Estimation Based on Wi-Fi RSS and Geomagnetic Field[C]// 2018 Sixth International Symposium on Computing and Networking Workshops (CANDARW). IEEE Computer Society, 2018.

[10] Han, Wei, Li, et al. A Novel Cooperative Localization Method Based on IMU and UWB [J]. Sensors, 2020, 20(2):467

[11] Wang Y, Wu Y, Shen Y. Performance Limits of Cooperative Localization using Signals of Opporunity in Aray Networks[C]// ICC 2019 - 2019 IEEE International Conference on Communications (ICC). IEEE, 2019.

[12] Zhang, Cao. Cooperative Localization Approach for Multi-Robot Systems Based on State Estimation Error Compensation [J]. Sensors, 2019, 19(18):3842.

[13] Jin D, Yin F, Fritsche C, et al. Bayesian Cooperative Localization Using Received Signal Strength With Unknown Path Loss Exponent: Message Passing Approaches [J]. 2019.

[14] MarínLeonardo, Sorianongel, VallésMarina, et al. Event based distributed kalman filter for limited resource multirobot cooperative localization [J]. Asian Journal of Control, 2019.

[15] Chen S, Zhang J, Xu C. Robust Distributed Cooperative Localization with NLOS Mitigation Based on Multiplicative Convex Model [J]. IEEE Access, 2019, PP(99):1-3.