Thesis proposal

Working topic

Indoor local positioning system for smartphones with infrastructure-free integration.

Background and problem statement

Figure 1. Keywords used in patent search

We all use positioning services: maps, navigation apps for cars. Positioning services require positioning technology to work with. The most well-known is a GPS, which can't work inside buildings. For indoor positioning services there exist some products, but there are huge drawbacks. The main problems are the price and complexity of the whole system.

- Two most popular technologies - WiFi and BLE - requires an additional hardware and cost too much for usual application.
- Other technologies (WiFI and magnetic field fingerprinting, image reconstruction and visible light) seems perspective, but complex in development, integration or / and usage.

Several companies and researchers are now developing the infrastructure free approaches. This means that the system works without any additional hardware installed "on-stage". We define our system as infrastructure free, we use fingerprint database.

The problem

There is no classical SLAM algorithm for fingerprints database collection.

Our proposal

Framework for collecting database of fingerprints

State of the art approaches for fingerprints collection use neural networks, Bayesian and Kalman filtering, human step prediction and other complex techniques.

The reasons for the choice of the thesis project topic:

- it is possible to create and deliver a working system in less than one year
- all technologies on the market have a similar level of accuracy >> we focus on improving a system to be more universal and stable

- we see the opportunity to create a startup and deliver services based on this technology

Objectives

We want to create a framework for collecting database of fingerprints (magnetic, WiFi, BLE and others).

Because the approach is SLAM, it may be considered from both sides: as a mapping tool and as a localization product. We have to satisfy criteria for both of them.

Criteria for the system proposed:

- can be implemented locally
- no special hardware for operation
- positioning accuracy enough for operation (1-2m depending on requirements)
- cost, complexity, accuracy, time of development

Hypotheses:

1. Current systems on the market (WiFi, BLE) are not suitable for standalone applications in common use-case.
2. Competitive technology of magnetic field navigation may be implemented and fine-tuned for several common use-cases.

Literature review

Indoor navigation solutions are a wide range of products and services. While "indoor routing" functionality that guides people through the buildings is important, there are lots of services that support it, such as content management system, mobile and web applications, indoor and outdoor localization, social networks, data analytics, and many others.

Indoor positioning systems is a growing industry with hundreds of applications. Different applications from security applications and assets tracking in business and manufacturing to the proximity advertising in retail. From fully protected to broadcast solutions, from cheap high range proximity to high precision solutions in robotics.

Different applications have different technologies behind it. Over 15-20 different working technologies are known. Only 3 of them are widely used now (WiFi, Bluetooth Low Energy, Image-Based).

Table 1. technology comparison

IPS Technology	Type	Accuracy, m	Scalability	Complexity	Cost
Geomagnetic	fingerprinting	2	Low	Low	Very Low
Photo	camera	1-10	Low	High	High
Barcodes	camera	1-10	Medium	Low	Low
Video, AR	camera	1-10	Low	High	High

IPS Technology	Type	Accuracy, m	Scalability	Complexity	Cost
Bluetooth Low Energy (BLE)	Radio	1-3	High	Medium	Medium
RFID, Active	Radio	1-10	Medium	Medium	Medium
RFID, Passive	Radio	1-10	Medium	Medium	Medium
Wi-Fi	Radio	5-10	High	Medium	Low
Ultra Wide Band (UWB)	Radio	0.15-0.5	Low	Medium	Medium to Low
Zigbee	Radio	3-5	Low	Low	Low
FM		2-4	Low	Low	Low
Lighting-Based – Infrared LED	Lighting	0.15-3	Low	Low	Low
Lighting-Based – Visible LED	Lighting	0.3-3	Low	Low	Low
Audible	sonic	0.5	Low	Low	Low
Ultrasound	sonic	0.05-0.25	Low	Medium	Low to Medium
Inertial	supplementary		Low	Low	
Pressure	supplementary				
GPS	supplementary	6-10	Low	High	

Relevant publications:

- RinQ Fingerprinting: Recurrence-Informed Quantile Networks for Magnetic Resonance Fingerprinting https://link.springer.com/chapter/10.1007/978-3-030-32248-9_11
- Scene-LSTM: A Model for Human Trajectory Prediction https://arxiv.org/pdf/1808.04018.pdf
- Magnetic Resonance Fingerprinting using Recurrent Neural Networks https://paperswithcode.com/paper/magnetic-resonance-fingerprinting-using
- Multicompartment Magnetic Resonance Fingerprinting https://arxiv.org/pdf/1802.10492.pdf
- Magnetic resonance fingerprinting https://mriquestions.com/uploads/3/4/5/7/34572113/mr_fingerprinting_nature11971.pdf

Methodology / theoretical framework

Preparation landscape research

First, we define the current state of the art, we build the model for existing technologies, analyze products on the market, list key players and IP owners, create Pareto frontier. This part is intended to make a visible and understandable landscape of this technology segment.

Procedures list

- Collection of magnetic fingerprints database with smartphone sensors: Gyroscope, compass, IMU.
- Implementation of localization model
- Experiments using model, estimation of accuracy
- Implementation of possible techniques, benchmarking
- SLAM model development, re-localization technique, map-merging
- Fine-tuning of SLAM model
- Comparison to other products, interpretation of results

Techniques

There are several enhancements of technology we want to implement:

- Relocalization technique (air imaging approach) >> improve mapping
- Kalman filters for the dead reckoning (extended Kalman filter) >> improve stability
- Bayesian methods of user coordinate prediction >> improve localization
- Smartphone-based magnetic fingerprinting (usual approach) >> infrastructure-free navigation system

We use data of Microsoft competition as a starting reference (D. Lymberopoulos, J. Liu, X. Yang, R. Choudhury, V. Handziski, S. Sen, F. Lemic, J. Buesch, Z. Jiang, H. Zou, H. Jiang, C. Zhang, A. Ashok, C. Xu, P. Lazik, N. Rajagopal, A. Rowe, A. Ghose, N. Ahmed, and P. Hevesi, “A realistic evaluation and comparison of indoor location technologies: Experiences and lessons learned,” 04 2015.).

Timeline

	ACTIVITIES	START	DUE	%
	Procedures:	04/Nov	16/Dec	0%
1	Fingerprints database colle...	04/Nov	16/Dec	0%
	Localization model:	19/Oct	16/Nov	5%
3	RSSI model implementation	19/Oct	03/Nov	0%
4	Experiments using model, e...	04/Nov	16/Nov	0%
5	literature review			100%
	SLAM model:	26/Oct	15/Feb	0%
7	literature review	26/Oct	21/Dec	0%
8	re-localization technique	17/Nov	17/Jan	0%
9	map-merging technique	17/Nov	17/Jan	0%
10	Fine-tuning	18/Jan	15/Feb	0%
	Results presentation:	20/Dec	12/Mar	0%
12	Comparison to other produ...	20/Dec	06/Jan	0%
13	Interpretation of results, ac...	09/Feb	12/Mar	0%
	Product development:			67%
15	market research			100%
16	customer interviews			100%
17	product prototyping			0%

Figure 2. Timeline

https://drive.google.com/file/d/1L3_5NVN5ZbLkKXeJPNRlqRSwNVnguhnO/view?usp=sharing

Innovation impact

The roadmap on the scope of indoor positioning systems is almost finished. With these results, we have a landscape of existing technologies and products and we may design a specific product.

For now, we have the first draft of a business model.

Innovation research

a solution that provides a service to guide users inside of the building. This solution is primarily aimed at social events and commercials, such as exhibitions and expo centers. Also, some of the possible applications are stationary public indoor places, such as museums and Skoltech new campus.

Product and technology development is a key part to complete this project in any variation.

- Roadmap presentation https://docs.google.com/presentation/d/17Y4y7kEfnQPwoDM8SHt8FAUGgpr_LoDErFYHAzCHLqE/edit#slide=id.g8801f1f3c0_0_43
- Roadmap paper https://www.overleaf.com/read/fdjmmbbtwnkn
- Service for indoor navigation on forums and exhibitions, customer discovery: https://docs.google.com/presentation/d/1OGzwogQPFiY9SddoreiYfuIoOX-pSv75EbnpgBfXfGk/

edit?usp=sharing

References

1. S. Walden, “The “indoor generation” and the health risks of spending more time inside,” 05 2018.
2. R. Mautz, “Indoor positioning technologies,” 2012.
3. W. Sakpere, M. A. Oshin, and N. Mlitwa, “A state-of-the-art survey of indoor positioning and navigation systems and technologies,”South African Computer Journal,vol. 29, pp. 145–197, 2017.
4. M. Kjærgaard, “Indoor positioning with radio location fingerprinting,” 04 2010.
5. R. F. Brena, J. P. Garc □ıa-V □azquez, C. E. Galv □an-Tejada,D. Mu □noz-Rodriguez, C. Vargas-Rosales, and J. Fang-meyer, “Evolution of indoor positioning technologies: A survey,”Journal of Sensors, Mar 2017.
6. Infsoft, “Indoor positioning and services white paper,”2019.
7. R. Bernard, “Indoor positioning systems,”Security Industry Association, 2017.
8. IndoorAtlas / Vanson Bourne, “A 2016 global research report on the indoor positioning market,” p. 6, 2016.
9. B. Li, T. Gallagher, C. Rizos, and A. Dempster, “Using geomagnetic field for indoor positioning,”Journal of Applied Geodesy, vol. 7, 11 2013.
10. L. Hou, Y. Li, Y. Zhuang, B. Zhou, G. Tsai, Y. Luo, and N. El-Sheimy, “Orientation-aided stochastic magnetic matching for indoor localization,”IEEE Sensors Journal,vol. 20, no. 2, pp. 1003–1010, 2020.
11. I. Alliance, “ILA system architecture release 1.0,”openmobilealliance.
12. Indoor navigation market review by iBecom, June 4 2015
13. Geofencing market guide, Justin Croxton, Sept 26 2019
14. Thaljaoui, A., Val, T., Nasri, N., & Brulin, D. (2015). BLE localization using RSSI measurements and iRingLA. 2015 IEEE International Conference on Industrial Technology (ICIT). doi:10.1109/icit.2015.7125418
15. Lymberopoulos, Dimitrios & Liu et Al (2015). A Realistic Evaluation and Comparison of Indoor Location Technologies: Experiences and Lessons Learned. 10.1145/2737095.2737726.