Robot-assisted Fingerprint-based Indoor Localization

Chenhe Li
Department of Software and Computing
McMaster University
Hamilton, ON, Canada
lic54@mcmaster.ca

Cristian Frincu
Department of Software and Computing
McMaster University
Hamilton, ON, Canada
frincuc@mcmaster.ca

Zhe Gong
Department of Software and Computing
McMaster University
Hamilton, ON, Canada
gongz13@mcmaster.ca

Qiang Xu
Department of Software and Computing
McMaster University
Hamilton, ON, Canada
xu22@mcmaster.ca

Rong Zheng
Department of Software and Computing
McMaster University
Hamilton, ON, Canada
rzheng@mcmaster.ca

ABSTRACT

Fingerprint-based indoor localization methods are attractive since there is no need for infrastructure supports. However, their feasibility in practice is greatly hampered by the laborious process of site survey. In this work, we develop an end-to-end robot-assisted indoor localization solution that leverages a rover robot to automate site survey. The fine-grained fingerprints are then used to construct a Gaussian process model for localizing pedestrians from their smartphone sensor measurements.

Keywords

Indoor localization, fingerprint, smartphone, robot, SLAM, pedestrian dead reckoning

1. INTRODUCTION

Despite the fact that people spend majority of their time indoor, indoor positioning systems (IPS) only have limited success due to the lack of pervasive infrastructural support, and the desire to keep user devices as simple as possible. One major category of indoor localization solutions utilize location-dependent fingerprints (e.g. received signal strength (RSS) of WiFi, magnetic, luminous conditions.) to estimate indoor locations [5, 1, 2]. Generally, these methods work in two stages: training and operational stages. In the training stage, comprehensive site survey is conducted to record the fingerprints at targeted locations. In the operational stage, when a user submits a location query with her current fingerprints, a localization server computes and returns the estimated location.

Site survey for fingerprint-based localization is a laborious process and needs to be done repeatedly in case of changes in the environment and infrastructure. To ease the process of site survey, several researchers have proposed to leverage mobile crowdsensing to collect location-dependent fingerprints [3, 5]. While this approach is attractive, it suffers from the problems of noisy data, poor coverage and frauds [4]. In this work, we develop a rover robot based system for automated fingerprint collection and leverage the data collected in a hybrid infrastructure-free indoor localization solution that allows users to be located with commercial-of-the-shelf smart phone devices.

Robot-based solutions to site survey are viable due to the decreasing costs of robotic base and sensors, and the maturity of simultaneous location and mapping (SLAM) techniques in 2D environments. Additionally, using SLAM, the indoor geometric map can be constructed along with fingerprint collection. This makes the technology attractive in places where vector indoor floor plans are not available. However, for the purpose of fingerprint-based localization localization, the robot platform needs to be customized to collect data at heights similar to the positions humans carry their mobile devices and account for obstruction of RF signal due to human body.

In this extended abstract, we first present the overall approach of robot-assisted indoor localization detailing the data collection platform design and the hybrid localization algorithm. Next, the deployment requirements for the competition are discussed.

2. PROPOSED APPROACHES

The overall system can be divided into three parts: offline fingerprint collection, training a regression model and online localization.

Robot platform design. For offline fingerprint collection, a rover robot has been developed that can be programmed with designated waypoints and movement to

collect WiFi and magnetic fingerprints in target areas. The robot can build floor maps automatically and determine its pose (position and heading) on a given map.

Our rover platform (Figure 1) consists of a robotic base, ultrasonic sensors for obstacle detection, 16-channel Velodyne LiDAR sensor for ranging measurements, and a laptop running SLAM and path planning algorithms. The rover is instrumented with a tray at chest height where measurement devices (e.g., phones) can be placed. We are experimenting different materials that can be used to emulate the blockage of RF signals due to human body.

Figure 1: A Robotic Platform for Automated Fingerprint Collection

GP-based regression analysis. Localizing users from fingerprints collected at unknown locations requires training a machine learning model for regression analysis. Due to the stochastic nature of the WiFi and magnetic fingerprints, we adopt Gaussian Process (GP) to model the distribution of the fingerprints over space and time.

Particle filter for localization. During the online phase, pedestrian dead reckoning (PDR) using inertial navigation sensor data is combined with fingerprint measurements in a particle filter (FP) framework to infer the location of the user.

3. DEPLOYMENT REQUIREMENTS

The proposed solution is an infrastructure-less approach and as such poses little constraint on the deployment. However, due to the limit of the battery power on the robotic platform, we would like to know ahead of time, the size of the area and whether it will be single floor or multi-floor.

4. CONCLUSION

In this extended abstract, we present the end-to-end design for a robot-assisted solution to localizing pedestrians carrying mobile phones. The solution is attractive since it is fully automated.

5. REFERENCES

[1] G. B. Prince and T. D. Little. A two phase hybrid RSS/AoA algorithm for indoor device localization using visible light. In *Global Communications Conference (GLOBECOM)*, pages 3347–3352. IEEE, 2012.

[2] Qiang Xu, Rong Zheng, Steve Hranilovic. IDyLL: Indoor localization using inertial and light sensors on smartphones. In *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing*, UbiComp '15, 2015.

[3] A. Rai, K. K. Chintalapudi, V. N. Padmanabhan, and R. Sen. Zee: zero-effort crowdsourcing for indoor localization. In *Proceedings of the 18th annual international conference on Mobile computing and networking*, pages 293–304. ACM, 2012.

[4] Q. Xu and R. Zheng. Mobibee: A mobile treasure hunt game for location-dependent fingerprint collection. In *Proceedings of the 2016 ACM International Joint Conference on Pervasive and Ubiquitous Computing: Adjunct*, UbiComp '16, pages 1472–1477, 2016.

[5] Z. Yang, C. Wu, and Y. Liu. Locating in fingerprint space: wireless indoor localization with little human intervention. In *Proceedings of the 18th annual international conference on Mobile computing and networking*, pages 269–280. ACM, 2012.