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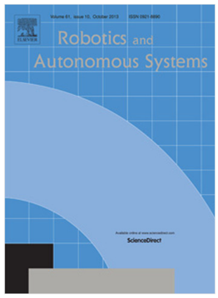

Robot-assisted smartphone localization for human indoor tracking

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Robot-Assisted Smartphone Localization for Human Indoor Tracking

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Abstract

Smartphone-based human indoor localization was previously implemented using wireless sensor networks at the cost of sensing infrastructure deployment. Motivated by increasing research attention on location-aware human-robot interaction, we propose a robot-assisted human indoor localization scheme utilizing acoustic ranging between a self-localized mobile robot and smartphones. Data from the low-cost Kinect vision sensor are fused with smartphone-based acoustic ranging, and an extended Kalman filter based localization algorithm is developed for real-time dynamic position estimation and tracking. Real robot-smartphone experiments are performed, and performances are evaluated in various indoor environments under different environmental noises and with different human walking speed. Comparing to existing indoor smartphone localization methods, the proposed system does not rely on wireless sensing infrastructure, and has comparable localization accuracy with increased flexibility and scalability due to the mobility of the robot.

Keywords:
Human indoor localization, robot-assistance, acoustic ranging, extended Kalman filter

1. Introduction

Human indoor localization and tracking have recently received increasing research attention due to many real-world applications such as location detection of medical personnel or firemen, pattern of passenger flow in airports or shopping malls [1, 2]. More recently, as intelligent mobile service robots are introduced into the human's life, location-aware human-robot interaction becomes popular [3, 4]. Although the global positioning system (GPS) has been dominating the realm of outdoor localization applications, GPS signal transmission is prone to be blocked and distorted by buildings, which severely deteriorates its indoor performance. Accurate, robust localization technologies in indoor and other GPS-denied environments are in great demand by the bloom of indoor location-aware services and applications. In this paper, we propose a novel indoor localization method utilizing robot-smartphone cooperation. Low-cost sensors such as the Kinect sensor on robots are used together with acoustic communication techniques. A new dynamic Kalman filter based indoor human localization and tracking algorithm is developed and validated in indoor experiments.

Smartphone localization has been extensively studied utilizing prevalent WiFi-based techniques, which offer solutions for indoor positioning and localization either leveraging existing wireless access points or with a modification of infrastructure, see Section 2 for a more detailed literature review. The biggest issue of existing WiFi-signature-map based localization without expensive infrastructure deployment is in the localization accuracy of position estimates. It has been reported that significant errors in the magnitude of $6-8$m always exist for WiFi localization [5, 6]. Even with recent improved statistical processing of radio signal strength [7] and advanced algorithms utilizing acoustic ranging [6], the limit of WiFi based localization by smartphones is reported to be around $1-2$m [1]. The focus of this paper is to develop accurate smartphone localization with the assistance of a mobile robot, and the goal is to achieve higher localization accuracy without the cost of intensive deployment of sensing infrastructure.

Meanwhile, localization is a classic topic studied in navigation of autonomous mobile robots. Kalman filter based localization [8, 9], grid-based Markov localization [10] and Monte Carlo localization [11, 12] provide solutions for either local position tracking or global position estimation. A more challenging problem of simultaneous localization and mapping (SLAM) arises when the robot has no prior knowledge of the environment map [13]. Recent attention has been drawn to the cases that only relative range to the landmark can be detected. In [14], the range-only SLAM using extended Kalman filter was investigated where prior knowledge of landmark location is partially known. Experiments on SLAM of mobile robots in indoor environments were presented in [15], where a wireless sensor network was deployed for either robot-to-beacon or beacon-to-beacon range measurement. The estimation error of the robot and landmark positions was reported less than 0.2m and

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