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Real-Time Indoor Geolocation Tracking for Assisted Healthcare Facilities

Kinjal Gala, San Diego State University, San Diego, USA
Paul David Bryden, University of Strathclyde, Glasgow, Scotland
Christopher Paolini, San Diego State University, San Diego, USA
https://orcid.org/0000-0001-6563-917X
Matthew Wang, University of California, Los Angeles, USA
Albena Dimitrova Mihovska, Aarhus University, Aarhus, Denmark
Mahasweta Sarkar, San Diego State University, San Diego, USA

ABSTRACT

A leading cause of physical injury sustained by elderly persons is the event of unintentionally falling. A delay between the time of fall and the time of medical attention can exacerbate injury if the fall resulted in a concussion, traumatic brain injury, or bone fracture. The authors present a solution capable of finding and tracking, in real-time, the location of an elderly person within an indoor facility, using only existing Wi-Fi infrastructure. This paper discusses the development of an open source software framework capable of finding the location of an individual within 3m accuracy using 802.11 Wi-Fi in good coverage areas. This framework is comprised of an embedded software layer, a Web Services layer, and a mobile application for monitoring the location of individuals, calculated using trilateration, with Kalman filtering employed to reduce the effect of multipath interference. The solution provides a real-time, low cost, extendible solution to the problem of indoor geolocation to mitigate potential harm to elderly persons who have fallen and require immediate medical help.

KEYWORDS

Assisted Healthcare Technology, Indoor Geolocation, Indoor Location System, Indoor Positioning System, Kalman Filtering, Location Tracking, Trilateration, Wireless Sensor Networks

INTRODUCTION

As reported by the World Health Organization's Global Report on Falls Prevention in Older Age, based on research conducted by Blake et al. (Blake et al., 1988), (*WHO Global Report on Falls Prevention in Older Age*, 2007), 35% of population 65 years and over experience at least one unintentional fall per year, due to tripping, dizziness, and blackouts. Elderly people are more likely to fall due to loss of handgrip strength used for control and stabilization when using walking aids such as walkers and canes. Arthritis, dizziness, neuromuscular, cognitive, and foot impairments also contribute to an increased prevalence of falling by older people when using stairs and steps, or while turning around or reaching for objects. Research by Tinetti found that 61% of elderly nursing home residents fell at some point during their first year of residence (Tinetti, 1987), a greater proportion than elderly people who live in residential communities. Those assigned to live in assisted living facilities may fall more frequently due to greater weakness in their lower extremities, a potential contributing factor for their

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decision to live in such a facility since facility staff can assist with mobility. Many algorithms and embedded technologies have been in research and development for the past several years, which aim to work towards the basic goal of detecting a fall and reporting the location of the fallen individual to a respective authority.

Indoor geolocation tracking is an evolving technology which aims to calculate the location of an individual within an indoor environment. One of the promising classes of this emerging technology is to take advantage of existing infrastructure to determine the location of a user (Pahlavan, Xinrong, & Makela, 2002). Much work has been carried out to use GPS for indoor location tracking (Álvarez, de Cos, Lorenzo, & Las-Heras, 2010; Kjærgaard et al., 2010); however, GPS only has an accuracy of 5-50m in an indoor environment (Liu, Darabi, Banerjee, & Liu, 2007).

This paper presents the development of an open source software platform capable of tracking the movements of individuals using existing 802.11 Wi-Fi infrastructure. The modularity of the software framework developed and its strong use of C++11 design principles enables the framework to be easily adapted to a variety of hardware platforms and radio technologies, such as Bluetooth or LoraWAN. In addition, this solution provides flexibility of monitoring multiple people using a mobile app.

BACKGROUND

The ability to identify the geographic location of an individual residing outside of a building by latitude, longitude, and altitude is easily accomplished using a relatively inexpensive GPS receiver. Typical commercially available receivers for under $100 can provide coordinates within a sampling time of 30 seconds to an accuracy of 3m. For example, the Copernicus II 12-channel GPS module from Trimble is under $70 and can provide updated coordinates with a period of 3s. GPS receivers typically use a carrier wave in the L1 band at 1575.42 MHz on which navigation messages are modulated. Unfortunately, such microwave signals are significantly attenuated by building roofs and walls, rendering GPS unusable in indoor setups.

Indoor position measurements can be accomplished using different mechanisms such as radio signals, magnetic fields, and sound waves. Newer, emerging technologies employ computer vision to identify objects in a camera field of a view. A vision system can measure distances in between recognized objects, and between a user and recognized objects. These measurements provide a system with depth perception and can identify how far a user is away from a surface or other rigid body in a field of view.

The well-established Cricket indoor location system developed at MIT uses a combination of RF and ultrasound to provide location information via wall- and ceiling-mounted beacons placed throughout a building (Priyantha, Chakraborty, & Balakrishnan, 2000), (Priyantha, Miu, Balakrishnan, & Teller, 2001), (Teller, Chen, & Balakrishnan, 2003). Cricket uses *time difference of arrival* between RF and ultrasonic signals, which can accurately identify the indoor location of a static object but was shown to present difficulties tracking the location of an object in motion.

The indoor location of an object or person using received signal strength was investigated by (Álvarez et al., 2010), with the goal of improving the characterization of EM to provide a precise indoor location. Álvarez proposed a full wave-based method measurement setup and tested this idea in different scenarios. A practical implementation was carried out using a ZigBee-based sensor network and was able to achieve a desired accuracy requirement of less than 5% for location error.

Issues faced by estimating indoor location from received signal strength, time of arrival (TOA), or time difference of arrival was investigated by (Chitte & Dasgupta, 2008) who found the mean square error (MSE) of location measurement increases exponentially with noise power.

Topological discovery with boundary recognition and hole discovery in a wireless sensor network can be accomplished using methods based on the Poincare-Perelman Theorem (Wei, Yang, Shen, & Zhou, 2012).