Chapter 7
Machine Learning Techniques for IoT-Based Indoor Tracking and Localization

Pelin Yildirim Taser
https://orcid.org/0000-0002-5767-2700
Izmir Bakircay University, Turkey

Vahid Khalilpour Akram
Ege University, Turkey

ABSTRACT

The GPS signals are not available inside the buildings; hence, indoor localization systems rely on indoor technologies such as Bluetooth, WiFi, and RFID. These signals are used for estimating the distance between a target and available reference points. By combining the estimated distances, the location of the target nodes is determined. The wide spreading of the internet and the exponential increase in small hardware diversity allow the creation of the internet of things (IoT)-based indoor localization systems. This chapter reviews the traditional and machine learning-based methods for IoT-based positioning systems. The traditional methods include various distance estimation and localization approaches; however, these approaches have some limitations. Because of the high prediction performance, machine learning algorithms are used for indoor localization problems in recent years. The chapter focuses on presenting an overview of the application of machine learning algorithms in indoor localization problems where the traditional methods remain incapable.

INTRODUCTION

The popularity of the Internet, smartphones, and different kinds of wireless devices has enabled the provision of new services such as indoor localization and tracking systems. Indoor localization is the process of detecting the real-time location of wireless devices in an indoor environment with a bounded error rate. Indoor localization and tracking of mobile objects have extensive and increasing applications in dif-

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ferent fields such as healthcare, advertisements, marketing, monitoring, security, building management, surveillance, and warehousing (Karimpour, 2019)(Khelifi, 2019). For example, in a hospital, tracking the assets, patients, and medical staff can increase the service quality and lead to efficient resource planning. As another example, the indoor localization of customers in a big shopping center can help send more efficient advertisements and analyze customers' behavior and shopping interests. Finally, the indoor localization of assets in a big warehouse can help to find the assets or free spaces faster and simpler.

The GPS signals are not available inside the buildings; hence the indoor tracking and localization systems try to use other signals such as Bluetooth Low Energy (BLE), WiFi, RFID, Wireless Sensor Networks (WSN), and Ultra-Wide Band signals (UWB). Receiving the signals from different sources allows the localization systems to merge the information and estimate the location of target assets. Recent advances in wireless communication modules, low energy BLE modules, sensors, memory chips, and processors have emerged a new generation of small and powerful devices that can store and run programs, measure the signal's strength and communicate over radio channels. The wide spreading of the Internet and the exponential increase in the diversity of small hardware allow us to create a network of devices that communicate over the Internet and form an Internet of Things (IoT). The IoT-based tracking systems allow the real-time positioning and monitoring of different assets. The precision of available localization systems generally depends on the underlying hardware and localization method. This chapter reviews the traditional and machine learning-based methods for IoT-based positioning systems and discusses their challenges and limitations.

An ideal indoor localization system should determine the exact location of the desired number of mobile targets inside a large building with minimal energy consumption, small mobile devices, and low cost. The main properties of an ideal indoor localization system are as follow:

1. **Accuracy:** Accuracy is the most important property of an indoor localization system. An ideal localization system detects the exact and real-time coordinates of the mobile targets using the available anchor points. Developing accurate indoor localization systems is a hard challenge because wireless signals are affected by different obstacles in the environment, which leads to incorrect distance estimation. Different methods are available to increase the accuracy of indoor localization systems; however each approach has some limitations and disadvantages. For example, increasing the number of anchor points may help increase the accuracy but also increase the cost and energy consumption of the system.
2. **Cost:** Generally, a localization system consists of many anchors and mobile nodes that communicate over radio channels. The anchor nodes are distributed in the environment in predefined (known) locations, and the mobile nodes are attached to the mobile target assets. The recent advances in hardware and IoT devices have led to the production of small, low-cost, and energy-efficient devices useful in indoor localization systems.
3. **Energy Efficiency:** Generally, indoor localization systems are expected to work for a long time. In some approaches, the nodes are battery-powered, and the batteries should be replaced periodically. Different approaches have different battery-replacing periods. In some approaches, the nodes can work with a battery for many years, while in some other approaches, the batteries should be recharged every day. Therefore, energy efficiency is an important factor of a localization system that directly affects the quality of provided services.
4. **Size:** To track and locate the mobile assets in the environment, a device should be attached to the assets. Such a device should be able to send or receive the radio signals and may have some pro-

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