Chapter 6

Integration of Bluetooth Technology and Artificial Neural Networks in High Accuracy Indoor Positioning

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ABSTRACT

Nowadays, with the increasing digitalization and widespread use of Internet of Things (IoT) applications, accurate and reliable indoor positioning system applications have become increasingly important. With the increasing need in the areas of use, researchers have proposed various indoor positioning system technologies and methods. In this context, Bluetooth Low Energy (BLE) technology offers a cost-effective, energy-efficient, and easy-to-integrate solution within existing infrastructures. The integration of BLE technology and ANNs for indoor positioning will be the subject of this section, which will cover the theoretical basis and practical applications. A comprehensive review of BLE-based positioning algorithms, performance evaluations, and the design and training of ANN models will be presented. In addition, the limitations of existing systems will be highlighted through the examination of the challenges. The aim of this study is to make a meaningful contribution to the field of indoor positioning and to provide applicable solutions in both academic and industrial environments.

DOI: 10.4018/979-8-3693-7994-3.ch006

1. INTRODUCTION TO INDOOR POSITIONING SYSTEMS (IPS)

This section researches the technologies and methods developed for indoor positioning systems (IPS), particularly emphasizing the use of Bluetooth technology and Artificial Neural Networks (ANN). These technologies are used in basic applications such as positioning individuals or objects in indoor environments where GPS system signals are weak, asset tracking, and smart building management. Also includes large-scale applications, including inventory management, equipment tracking, and product monitoring(Han et al., 2024). At the present time, there is no other system that is as dominant in the field of indoor positioning as GNSS. Deciding on an appropriate indoor positioning system necessitates a compromise between various perspectives. The effectiveness of IPS is determined by the technology used, the algorithms created, and the needs. In this respect, the technologies and methods used offer different levels of accuracy and applicability to the user. Location-based systems are often classified into three categories: (i) interior location systems, (ii) wide-area location systems utilizing cellular networks, and (iii) global location systems. Indoor location technologies are categorized into two groups according to the signal type: (i) radio-based signals and (ii) non-radio-based signals. Radio-based technologies encompass Wi-Fi, RFID, Bluetooth, Zigbee, and UWB, whilst non-radio-based technologies comprise ultrasonic, infrared, and geomagnetic fields (Hailu et al., 2024). The most important technologies include Ultra Wideband (UWB), Wi-Fi Round Trip Time (RTT), Bluetooth Low Energy (BLE), and complementary techniques such as Visible Light Communication (VLC) and Pedestrian Estimation (PDR), as well as AI-supported approaches using Received Signal Strength Indicator (RSSI) and Channel State Information (CSI). When comparing the technologies used for IPS, they have their own strengths and weaknesses in terms of accuracy and reliability. Factors such as the need for sensitivity according to the user's demand, cost constraints and environmental conditions determine which technology will be used to meet the need. However, at this point, the integration of artificial neural networks (ANN) into Bluetooth technology significantly increases the accuracy of indoor positioning systems. An artificial neural network (ANN) for indoor positioning generally has a multi-layer architecture, with the input layer receiving diverse signal properties, hidden layers processing these inputs, and the output layer delivering location predictions. The selection of inputs, quantity of neurons, and activation functions are essential for enhancing the performance of the ANN in indoor settings. RSSI comes signals from various Wi-Fi access points are frequently utilized as inputs. Signal-to-Noise Ratio (SNR) and N values are complementary signal components. They increase the sensitivity of the model by providing more detailed signal features to the developed model (Borenovic & Neskovic, 2011). In some models, Channel Impulse Response (CIR) is used as the input signal. This

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Ibukun Tolulope Afolabi, Opeyemi Samuel Makindeand Olufunke Oyejoke Oladipupo
(2019). *International Journal of Intelligent Information Technologies (pp. 41-56).*