BLE Can See: A Reinforcement Learning Approach for RF-based Indoor Occupancy Detection

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Abstract

The emergence of radio frequency (RF) dependent device-free indoor occupancy detection has seen slow acceptance due to its high fragility. Experimentation shows that an RF-dependent occupancy detector initially performs well in the room to be sensed. However, once the physical arrangement of objects changes in the room, the performance of the classifier degrades significantly. To address this issue, we propose BLECS, a Bluetooth-dependent indoor occupancy detection system which can adapt itself in the dynamic environment. BLECS uses a reinforcement learning approach to predict the occupancy of an indoor environment and updates its decision policy by interacting with existing IoT devices and sensors in the room. We tested this system in five different rooms for 520 hours in total, involving four occupants. Results show that, BLECS achieves 21.4% performance improvement in a dynamic environment compared to the state-of-the-art supervised learning algorithm with an average F1 score of 86.52%. This system can also predict occupancy with a maximum 89.23% F1 score in a completely unknown environment with no initial trained model.

CCS Concepts

• **Computer systems organization → Embedded systems, Sensor networks**.

Keywords

Reinforcement learning, BLE, DQN, Occupancy detection

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1 Introduction

Indoor occupancy detection is a difficult problem, yet a reliable solution can yield a wide range of applications including home automation, energy savings, optimized ventilation, and pet monitoring. Until now, several approaches have been proposed to solve the device-free indoor occupancy detection challenge. The most common and intuitive solution is to use motion sensors. However, motion sensor-dependent systems often exhibit poor performance as they provide false predictions when the occupant is not moving. Another popular approach proposes installing radar at the zone transition point (i.e. doors) where the system counts the number of people entering or exiting the room [13, 14, 16–18, 22]. This scheme often cannot differentiate between a near-door event and a real crossing, also confuses the count when a group of people walks through the door in conjunction. Other alternative solutions use environmental data of a room such as CO_2, humidity, or temperature to infer occupancy [2, 3, 34]. However, environmental data changes slowly with respect to human presence and as such this system fails to make correct prediction instantaneously.

Recent advances in wireless sensing techniques provide a new solution to infer occupancy from the radio signal distortion caused by human presence [5, 12, 23, 27, 29, 31, 32, 36–38]. The intuition behind this technique is that human presence impacts the wireless signal through body reflection which reduces the similarity of the signal pattern between occupied room and unoccupied room. A signal processing algorithm or a machine learning model trained to identify the pattern of an empty room and the occupied room could detect human presence instantaneously.

A common limitation of this approach is that, to identify human presence in all kinds of indoor environment it requires a large database of every occupied scenario in different indoor environments. In practice, this is not possible as human behavior and movements are very random. As such, existing RF-based schemes suffer from high false positive