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Safe radiation training using wireless signals devices

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1. Introduction

All personnel who are working with sources of ionizing radiation are required to be instructed in the basic principles of radiation protection and the potential risks of ionizing radiation. As part of the training in radiation protection is necessary to use real radiation sources, since detecting illicit trafficking of radioactive substances is a task for which some personnel need to be trained for. This requires a considerable amount of paperwork to move sources, even very small ones, from secure areas to exercise areas. This paper describes the development of radiation simulation and positioning in indoor environments using wireless signals, as Bluetooth Low Energy (BLE), Wi-Fi and radio, based on RSSI, a Radio Frequency (RF) term that stands for Received Signal Strength Indicator. Wireless source simulators can replicate the ionizing radiation field from radioactive sources, including shielding and approximation to the inverse square law; this is not possible to achieve with a real source scenario without undue exposure to the personnel. These allow students to search for small sources or experience a radiation field anywhere, without the use of sources like in traditional methods for radiation detection training.

2. Methodology

Simulation is becoming increasingly important in many types of training. For example, simulation for training is highly effective in weapons training, aircraft pilot training, and even medical operations [1], thus the idea is well established. We have many reasons for the use of simulation: to reduce cost; technological difficulty in providing training without a simulator; to reduce strain on the trainee. A more specific reason in the case of radiation protection training, where ionizing radiation sources are necessary: the environment of the trainee is fundamentally hazardous and international regulations forbid any unnecessary exposure of staff even during training [2]. A further difficulty in detection training with real radiation sources is the amount of bureaucracy required to move sources to field exercise areas. Fig. 1 depicts a prototype of simulation for the usage of radiation monitors.

Through the radio frequency communication between a device, simulating a radioactive source, and another device, simulating a radiation monitor, it is possible to demonstrate the situation of search and approach of radioactive sources. The idea is to use the system also in demonstrations of fairs and exhibitions, especially to the younger audience, showing that all electromagnetic waves, such as radiofrequency and gamma radiation, have an inverse proportional relationship between the power received and the distance.

Figure 1: Devices developed to simulate a source and a radiation monitor.

The system works as follows: a low-intensity radio signal, in the range of 27MHz, is emitted by the transmitter located in the radioactive source simulator. The signal is then picked up by the receiver located on the radiation monitor simulator. The intensity of this signal is then measured and displayed through a led scale and a digital display. A buzzer also simulates the approach of the radioactive source, increasing the frequency of the sound, as it occurs in a real radiation monitoring equipment.

Wireless signal devices can also be utilized to identify the location of training employees in an area, allowing the training supervisor to observe their position remotely. The development pace of research associated with location tracking is highly associated with the breakthrough of wireless sensor networks and wireless technologies, being explored in several different areas. A classic example is the Global Positioning System (GPS), in which satellites are used to send signals to receivers on Earth, which, in turn, use these signals to compute navigation information. In order to address the growing interest in the research for position tracking in indoor environments, it is necessary to rely on wireless devices based on Bluetooth Low Energy technology or Wi-Fi (IEEE 802.11). Fig. 2 shows the development of an applications using Wi-Fi devices (ESP8266) for the estimation of positioning in indoor environments.

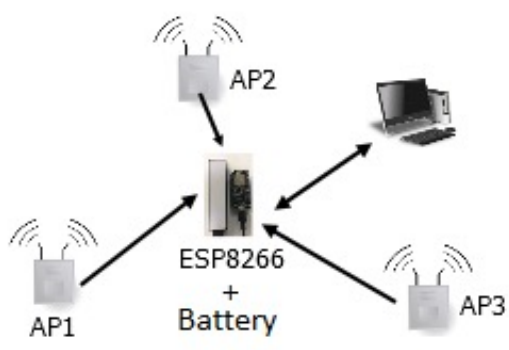

Figure 2: Developed system to positioning in indoor environments.

The ESP8266 microcontroller has a firmware called NodeMCU. The program, developed using the LUA language, gathers the values of the signal strength of the transmit power between the ESP8266 and multiple wireless Access Points (AP) in the environment, also sending these data via wireless to a PC that is present on the network (Fig. 1). The ESP8266 device can work portably with a battery.

Since this study proposes to use the RF signal of Wi-Fi devices, the choice of the method of lateration, in this case setting up a trilateration, is the most recommended. In order to use lateration techniques [4], at least three reference nodes are needed, hence defining a trilateration. In trilateration, the distances between the reference position and an unknown position can be regarded as a circle radius with a center in each reference position, as showed in Fig. 3. Therefore, the unknown location is the intersection of the three circles.

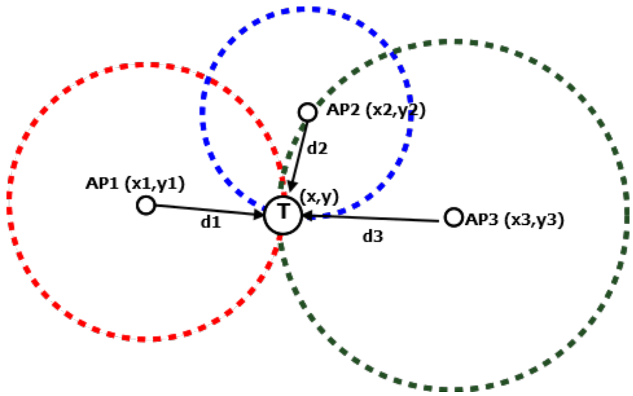

Figure 3: Trilateration technique.

The expressions for the calculation of the coordinates can be obtained using the Pythagorean Theorem. By solving the equations (1) for x and y, the coordinates of the unknown position T can be calculated.

$$\begin{aligned} d_1^2 &= (x_1 - x)^2 + (y_1 - y)^2 \\ d_2^2 &= (x_2 - x)^2 + (y_2 - y)^2 \\ d_2^2 &= (x_2 - x)^2 + (y_2 - y)^2 \end{aligned} \quad (1)$$

The location using a trilateration is deeply useful, since the distances (d1, d2, d3) can be obtained from the Received Signal Strength Indicator (RSSI), and the coordinates for the location of all the reference nodes are known and stored beforehand.

3. Results and Discussion

The program's screen intended to display the position is shown in Figure 4. The consecutive locations computed on a one-minute interval are represented by the red dots. The deviation was 1.2 meters away from the true position, which was highlighted in a green dot. A more accurate characterization of the environment, taking into account adjustments in function of furniture and curtain walls, may help increase the accuracy. However, when compared to other solutions, such as RFID (radio frequency identification), which is currently utilized in some applications, the usage of the ESP8266 chip is extremely advantageous.

4. Conclusions

Training simulations are good opportunities for closing knowledge gaps and helping employees improve their skills. They are interactive and immersive and mimic real situations, helping trainees effectively learn much faster. Radiation simulation instruments could be used for training workers in nuclear facilities, homeland security, defense and emergency services. Simulation use safe, transferable and invisible radiation using wireless technology to demonstrate the concept of time, distance, activity and shielding in radioprotection. Radiological protection training can be enhanced by simulating radioactive sources and integrating them with indoor positioning.

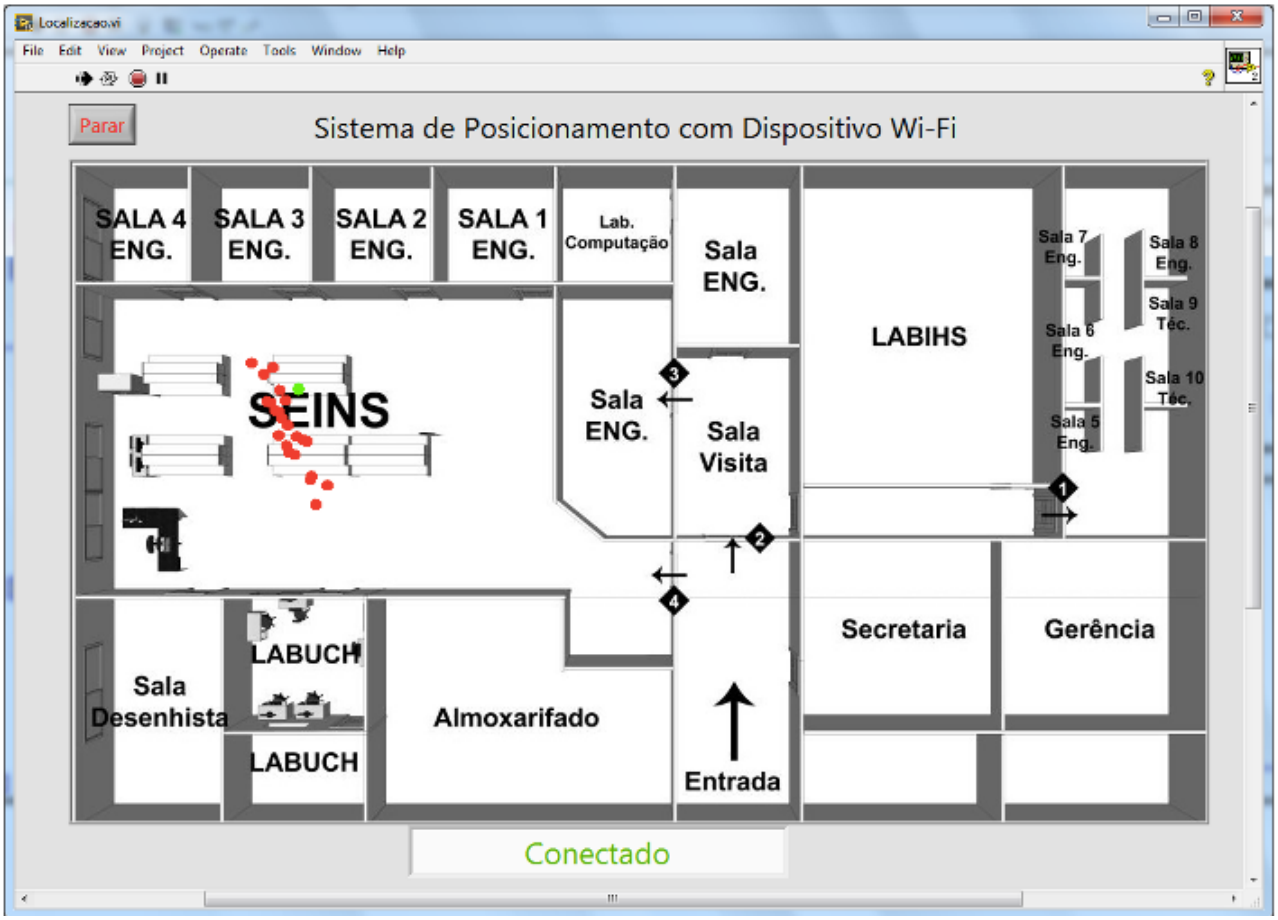

Figure 3: Screen to positioning the device.

Acknowledgements

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