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# Location-based services for elderly and disabled people

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**Abstract**

Many techniques have been developed to perform indoor location. Each strategy has its own advantages and drawbacks, with the application demanding location information the main determinant of the system to be used. In this paper, a system is presented that serves location to innovative services for elderly and disabled people, ranging from alarm and monitoring to support for navigation and leisure. The system uses ZigBee and ultrasound to fulfill the application requirements, differing in this respect from all other existing systems. ZUPS (ZigBee and ultrasound positioning system) provides wide multicell coverage, easy extension, robustness even in crowded scenarios, different levels of precision depending on the user's profile and service requirements (from a few centimeters to meters), limited infrastructure requirements, simple calibration, and cost-effectiveness. The system has been evaluated from the technical, functional, and usability standpoints, with satisfactory results, and its suitability has also been demonstrated in a residence for people with disabilities located in Zaragoza, Spain.


*Keywords:* LBS; Elderly and disabled people; Monitoring; ZigBee; Ultrasound

## 1. Introduction

Location-based services (LBS) are a mainstay of ubiquitous computing and context awareness. Today, LBS are becoming a reality in a wide range of applications, although there are significant differences between indoor and outdoor systems.

Navigation support systems based on geographical positioning systems (GPS) are now used by the general public, and global system for mobile communications (GSM) operators offer valuable services to the subscriber based on his/her location. These services include, not only emergency support as required by the United States and the European Union [1,2], but also commercial services such as locations of the closest restaurants and stores and even navigation. It is possible to offer such services because global localization techniques are highly standardized. However, this is not the case with local positioning, where technologies are closely bound up with the desired services they will support.

The local position measurement (LPM) system from Abatec Electronics AG is a local range-positioning system based on microwaves, which achieves high accuracy and refresh rate, but is suitable only for outdoor use [3,4]. This technology supports an outdoor sports monitoring service. Ultra-wideband (UWB) technology offers similar performance, but is also suitable for indoor scenarios. Ubisense [5,6] offers an indoor positioning system with up to 15-cm 3D accuracy as well as a variety of services for logistics, workplace, and military applications. Another fashionable technology for deploying LBS is WiFi, because location systems can reuse existing network infrastructures. WiFi location systems are usually based on field mapping and achieve a maximum accuracy of about one meter. An example of such a system is that offered by Ekahau [7], which also offers health care, manufacturing, and supply-chain solutions.

However, these technologies usually require complex hardware that sometimes is not feasible. For smart-dust-like

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scenarios, where the sensors are too simple to integrate any specific radiofrequency hardware, the Lighthouse system [8] offers a positioning approach in which three rotating light beams are used to perform 3D localization with no need for complex hardware on the sensor side. LBS for these scenarios are focused on associating sensor information with its location. Another way to avoid the need for hardware on the target side is to use artificial vision, which is widely used in industry for mobile robot positioning.

Many other positioning technologies could be used to provide LBS – radiofrequency, ultrasonic, inertial, infrared, magnetic fields – each one with different drawbacks and advantages [9–14]. In short, on the one hand, use of a particular positioning technology often conditions the services that can be offered, and on the other hand, some services or scenarios also condition the technology needed. To date, there is no positioning technology that could be suitable for every service and scenario.

In this paper, a ZigBee and ultrasound-based positioning system (ZUPS) is described, which can be classified as a local positioning system with high positioning accuracy and low cost. Its implementation is analyzed with reference to a particular case (a residence for disabled people located in Zaragoza, Spain) to support LBS such as alarms, guidance support, and leisure. Section 3 describes the fundamentals of ZUPS. Section 4 focuses on implementation issues such as installation, power consumption, ethical issues, and evaluation. Finally, conclusions are presented.

## 2. Location-based services

The main service developed in this work using ZUPS is intended to warn when an alarm or risky situation occurs, an objective given a high priority by experts in caring for the elderly and people with disabilities. However, ZUPS can also provide support for other services, such as guidance and spatial orientation training inside a large building or a leisure and mobility training system. This particular implementation was carried out in a three-story residence for people with disabilities in Zaragoza, Spain. The ground level includes a yard and common areas (offices, occupational workshops, cafeteria, gymnasium, etc.), and the other two floors are dedicated to private rooms for the residents.

### 2.1. Alarm system

A common strategy nowadays for providing security for people who are considered at risk consists of limiting their mobility by restricting their access or even making them stay in specific areas. The objective of the service described in this paper is to improve security and support users' freedom to move by enlarging their permitted area. The approach combines two ideas. The first involves trying to make people conscious of appropriate behavior in different situations: risk areas or situations where they should not stay (e.g., the kitchen), others where they should be accompanied by a caretaker (e.g., the nursing room), and others where they can move freely. The second idea involves monitoring location to detect abnormal or risky patterns like wandering in the middle of the night. For intensive monitoring, ZUPS, described in the next section, is used to identify users and to monitor when and where each user is going. This type of monitoring is user-dependent, determined by his/her wishes, characteristics, and type of dependency. When the system has determined someone's position, the following situations can be detected:

- Risk due to staying in a room that presents a risk for that person without his/her caretaker (kitchen, medical treatment room, etc.).
- Inappropriate presence or walking patterns (nocturnal presence in the dining room and not in the bed).
- Duration of stay greater than the specified maximum (staying in the bath longer than half an hour may indicate that the person has experienced an accident, is sleeping, or simply has some degree of disorientation).
- Absence or contact loss (the user is leaving or has left the building).
- Conducts that denote anxiety, escapism, or other problems of interest (small-scale repetitive itineraries).
- Lack of movement for too long in an unusual place (no movement for 5 min in the middle of a corridor).

An accelerometer and a button are integrated into the device that the users wear; thus it is possible to detect falls and make emergency calls. Upon the detection of any kind of call or alarm (including information on where it has happened), a warning can be triggered to the most appropriate person to respond to it. The choice of the person to be notified depends on the type of situation detected, the institution's policy, and the user. For example, if fast assistance is required – e.g., because of a fall or an escape attempt – the system will warn the nearest caretaker. In other cases, the person may have a favorite caregiver or, because of his/her characteristics, may need the assistance of more than one person at a time. In the best case, if the user's autonomy is good, the system could simply warn him/her of the situation detected. In all cases, the system analyzes both the situation and the predetermined personal preferences to provide notification of the situation in the best possible way.

### 2.2. Guidance system (navigation training)

The location system will also be used to support and train users to find their way inside buildings. A guiding system (GUIA) [15], intended for people with disabilities, is under development and will be aware of user abilities and building status. The system uses a complete building map together with any special or common landmarks it has available. Common landmarks are those found in any public building that are meant to provide guidance, like signs and directories. Special landmarks are those that are not