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How to cite

ISSOM, David-Zacharie et al. Challenges and issues of geolocation in clinical environment. In: Studies in health technology and informatics, 2012, vol. 180, p. 447–451. doi: 10.3233/978-1-61499-101-4-447

This publication URL: https://archive-ouverte.unige.ch/unige:31473

Publication DOI: 10.3233/978-1-61499-101-4-447

Quality of Life through Quality of Information
J. Mantas et al. (Eds.)
IOS Press, 2012

doi:10.3233/978-1-61499-101-4-447

Challenges and Issues of Geolocation in Clinical Environment

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Abstract. Reaching a good indoor geolocation without deploying extensive and expensive infrastructure is a challenge, because satellite positioning system is not available indoors. Geolocation could be of major use in healthcare facilities; to help care providers, visitors and patients to navigate, to improve movements and flows efficiency or to implement location-awareness systems. A system able to provide the location of a person in a hospital requires precision, multi-floors and obstacles management and should also perform in basements and outdoors. Such system needs also to be insensitive to environmental variations occurring in a hospital. These changes may be various kinds of obstacles. These can be the displacement of metallic objects, metallic machines, strong magnetic fields or simply human displacement. A system conforming to the above requirements can also answer various security questions, operational workflow management but also assist movement of people.

Keywords. Geolocation, ubiquitous computing, indoor positioning, mobility, service continuity, localization, wireless, assistance, smartphones

Introduction

Geolocation is a major challenge with useful purposes. Overcoming this challenge can lead to important changes, such as indoor personal navigation support to find locations but also for flows and movements optimizations, workflows management, to provide pro-active decision-supports with location awareness, intelligent people finders, security purposes, etc.

In buildings, GPS satellite signals are not available. Thus, other technologies must be used. Some of them, such as Radio-Frequency identification (RFID) and EM readers are usually dedicated to identification and localization, mostly around logistics and patients. Another approach is to use existing signals, thus without having to deploy any dedicated infrastructure. This approach concentrates on telephony signals, Wi-Fi, etc.

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1. Background

The University Hospitals of Geneva (HUG) is the major care providing consortium of public and teaching hospitals in Switzerland. It covers primary, secondary, tertiary and ambulatory care. It has about 9'000 FTE's all of them with an RFID identity badge. HUG handles about 1 million outpatients' visits and 50'000 inpatients a year. HUG uses an in-house developed clinical information system. This system integrates tightly commercial systems covering all clinics and care. HUG is made of 8 hospitals in 4 different campuses in the Canton of Geneva. There are about 10'000 rooms, well described in the facility management. Most important doors are equipped with RFID readers.

2. Localization technologies

According three criteria, different localization techniques have been evaluated: the need for additional structures, the proposed level of accuracy and the sensitivity to the environment.

RFID: These systems can be used to track a patient in real-time [1]. They can also be used to track inventories of pharmaceutical materials or identify and track medical equipment. The use of such systems for buildings access or parking access is interesting. It is possible to use this system to set perimeter alarms or count of I/O in an area. But also to keep tracks of a patient and identifies him and equally well to correlate care and patients. RFID systems work by using active or passive sensors [2]. These sensors can be embedded in bracelets or can be various wearable objects. RFID chips can also be pasted somewhere.

The passive system works with an emitter and a reader. This system is rather tracking-oriented and the self-location accuracy is limited. It is therefore suitable for monitoring and verification. By showing the RFID tag to an RFID reader, the terminal returns the desired information for the detected tag. With this solution, it is possible to know which objects or person have been detected, where and when.

There are also active RFID tags. These tags emit a signal over longer distances. This technology needs using a different and heavier infrastructure. These tags allow refining geolocation. Because of inherent cost, additional infrastructural and technological (active RFID tags) constraints, this choice does not meet the desired constraints.

Global System for Mobile Communication: Geolocation for Global System for Mobile communication (GSM) is a positioning technique based on terminals and antennas information (identifiers and signal strengths). The accuracy depends on the environment where they are (city, rural). The precision and can be from 200m to several kilometers.

This depends on the network coverage and the number of available antennas. In cities, these relays are relatively numerous and an accuracy of about 100m can be expected. Some studies show an accuracy reaching 5m [3]. In clinical environments, 100m of accuracy allows to know the building in which the terminal is located, or at least, the nearest building. The lack of network coverage (Wi-Fi, GSM, and GPS) in basements and in some isolated rooms is a problem. In addition, the GSM solution doesn't required any additional costs, unless relays inside buildings must be added. It must be emphasized that these GSM signal repeaters only relay the information of a specific antenna and don't possess specific information for their own position. With such signal repeaters, it is possible to improve network coverage, but it does not improve geolocation accuracy.

Wi-Fi: The most common techniques for indoor positioning use Wi-Fi. These systems work the same way as the GSM geolocation. Only the density of Wi-Fi access points is different. Similarly to GSM geolocation, Wi-Fi geolocation can use methods based on hotspots identifiers. Several techniques exist, such as *trilateration* or *fingerprinting* algorithms [4, 5]. At this time, the most simple, passive and precise technique is the Fingerprinting technique. A device records passively the surroundings Wi-Fi networks and it computes probability calculations [6]. This technique is compatible with the increase of Wi-Fi networks and has many rooms of improvement. Wi-Fi geolocation systems don't require additional hardware or infrastructure. At least, in a hospital providing a full Wi-Fi coverage but also a dense enough signal reception. This technique provides an accuracy level up to 5m but Wi-Fi Signals are sensitive to environment changes and obstacles [7]. Some Wi-Fi Access Points operate at variable energy for power saving purposes and this is also an additional constraint. In this case, signal strengths vary and it is more difficult to calculate accurate positions [8].

Bluetooth When a device detects the Bluetooth relay, an information exchange happens and a location can be provided. A Fingerprinting-like technique could be used too [9]. This technology achieve the same level of precision that Wi-Fi geolocation. On the other side, it requires the installation of additional Bluetooth AP and needs compatible terminals. Therefore, Bluetooth positioning would only work in locations where customized Bluetooth hardware has been deployed [10]. In addition, the mesh needs to be important, as the range of Bluetooth emitters rarely exceeds 5-20m.

GPS: Geolocation by satellite allows, with the help of signals from a satellite constellation, to calculate the current location. This calculation, performed by a terminal equipped with a compatible receiver chip, provides a raw position. This position is then translated in terms of latitude, longitude and altitude.

GPS provides an outdoor positioning accuracy ranging from 10 to 100 meters. GPS signals can't be received indoor. However, it is possible to use signal repeaters to relay satellite signals inside buildings. These technologies relay GPS and Galileo signals [11, 12,13]. The idea is to install small boxes which re-emit the GPS signal inside. This solution provides more precision and there is no cutoff between indoor and outdoor [14]. It requires an additional costly infrastructure. To overcome costs disadvantages, a way to obtain a satisfactory precision and function in different situations is to combine Wi-Fi techniques, but also others techniques. For example, using first the GSM signals to obtain a first approximate position, then GPS signals and Wi-Fi techniques to refine accuracy. The accuracy level, with a combination of Wi-Fi signals can be better than 1 meter.

Table 1. Comparison of the five principal existing techniques

	Additional Structures	Accuracy	Sensibility
RFID	Yes	<1m-10m	Low
GSM	No	5-1000m	Medium
Wi-Fi	No	2-10m	High
Bluetooth	Yes	2-10m	Medium
Indoor GPS	Yes	<1m	Low

3. Challenges

Indoor geolocation addresses multiples issues and many applications. Whereas the Wi-Fi geolocation is not precise enough and is sensitive to environmental variations, others existing techniques are largely dependent of the establishment of additional structures. One challenge is to be able to overcome the size and complexity of hospital buildings, another is to consider the specificity of each building, each database and knowing all possible movements or obstacles and one last is to use existing infrastructure in order to lower costs.

Several questions can be asked: 1) How to do it without GPS. 2) How to relay with low-cost GPS repeaters. 3) How to get sufficient accuracy at a room level. 4) How to deal with obstacles, floors and barriers.

There are also many signal variations to consider: 1) Remoteness of Aps. 2) Human movements, positioning and orientation. 3) Physical obstacles (reflection and refraction). 4) Wi-Fi Access Points with automatic variable power. 5) Handheld of devices.

4. Issues

Geolocation in clinical environments can meet several needs and issues:

An information and guidance service for patients and visitors: 1) Reduce the workload of receptions. 2) Help visitors unfamiliar with the hospital to move easily in building. 3) Help visitors to easily find a patient in his room. 3) Help patients to find consultation or examining room.

A service for the security of patients: 1) Allow assistance and calls systems deployment. 2)Give patients more autonomy, enable them to orient themselves more easily and be found quickly.

Track people and maintain equipment. Perimeter crossing alerts. 1) Useful to give a limited autonomy to a patient. 2) Prevent patients from endangering. 3) Tracking of mobile devices (Computer carts or others mobile devices).

Other issues such as monitoring security teams, tracking medicals orders, medical interventions or monitoring of flow movements.

4.1 Improving precision

There are several ways to improve accuracy of geolocation techniques. For example, what can be done is to consider all elements affecting the signal, such as emissions and obstacles, and model them on a probabilistic network of localizations. Such a model is difficult to build, but preliminary results are encouraging. A refinement of the model can be obtained with the addition of manually mappings. Some other research areas may be:

1) Use a 3D model of the clinical environment and its obstacles standing. 2) Use a model of possible movements. 3) Use a model of possible locations. 4) Use a 3D map for the various locations. 5) Use models to anticipate movements. 6)Use all the various available signals (GSM, Indoor GPS, Bluetooth and WiFi). 7) Be helped by other people or devices that they know their position. 8) Have a self-adapting system (variations). 9) Have a self-correcting system (variations of signals and topology).

5. Result and discussion

Geolocation in care facilities will lead to important new possibilities for care, logistics and patients or visitors. Existing technologies already allow being located accurately in a hospital and, under some conditions, the precision could be reached without additional infrastructures such as RFID [15, 16]. Among all existing solutions of geolocation in indoors environment without dedicated infrastructure, one of the most attractive is Wi-Fi geolocation. One important advantage of this technique is that it can be used on smartphone, and thus provide patients and visitors new features without specific tools. However, this technique is insufficient alone. It is therefore clear that only the combination and coupling of different techniques is viable solution. The combination of different existing technologies coupled with better processing of the information, such as pre-mapped probabilistic models, can improve the accuracy. Given the various infrastructure found in care facilities, there is no generic solution. The example of power savings Wi-Fi antenna illustrates this problem. Indoor positioning can be more or less difficult according to infrastructures differences. The barriers are significant but the intelligent adaptation and consideration of environment, obstacles, different usable techniques and models will meet the challenges and issues of geolocation in clinical environment [17]. Certainly in a short time, the geolocation in the clinical environment will no longer be a problem.

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