Preface

Geolocation systems have been present during decades thank to Global Navigation Satellite System (GNSS), of which the best known is the GPS. However, the eruption of mobile technologies and the availability of geographical data have driven to an eclosion of geolocation services and its popularization. Nowadays, most of people daily use services that deal with geographical information. These services, known as Location-Based Services (LBS), include navigation systems that guide users by car, foot, or bicycle; help to evacuation systems; social network services, among others.

Nevertheless, despite its popularization, these services can be considered useless in most of the situations, since they are based mostly on GNSS and people spend 80%-90% of their time in places where GNSS do not work: indoor environments. These environments include offices, undergrounds, shopping malls, airports, etc. The main reasons for GNSS not working in indoor environments are two: satellite signal cannot reach with enough intensity in indoor spaces; and in the case signal would be strong enough, maps of the buildings are not available in the same way that nowadays are outdoors maps, that is, the maps should have to be available and they should have to be in a digital format that LBS could understand and interpret. Thus, indoor positioning has two challenges: location, to know the coordinates of an object within a building; and position, for which development and creation of indoor maps is needed. Therefore, new solutions should be taken into account.

Another relevant issue when dealing with indoor positioning is the creation and access of indoor maps. Although several solutions have been proposed, like *IndoorGML*, *IndoorOSM, Indoor Here Maps*, there is not a unique way to access and to create maps. If indoor positioning and navigation should be used as democratically as outdoors, new specifications to define maps in a unified semantics should be provided. In addition, the publication of indoor maps arise new serious issues that should be taken into account carefully: (1) privacy, that is, which maps should be available and for whom?; and (2) security, that is, which techniques are need to enforce the detected privacy constraints?

It is important to note that several solutions and techniques are already available to get positioning in indoor environments with acceptable accuracy, such as Bluetooth, radio frequency, infrared, ultra-wide-band, etc. But all these solutions need the deployment of dedicated sensors within the building. Therefore, although they are efficient, they may not be economically scalable and should need maintenance. Furthermore, most of them do not provide continuity outdoor-indoor, some of them do not even work in smartphones, and also they only work properly in the single environment for which they have been designed.

There are other techniques that are able to work in current indoor environments without adding new infrastructure: they just use the signals already present in the environment, named *opportunity signals*, like WLAN, magnetic field, or even GPS. To get location with these signals, one of the most popular techniques nowadays is fingerprinting. Fingerprinting is a data-centric approach based on two phases: a training phase, when fingerprints are taken for further reference; and a location phase, when the location of an object (or user) is estimated by using the map of fingerprints generated in the previous phase. The training phase is very tedious and consists in gathering a great amount of signal lectures of different locations within buildings. To simplify the process of gathering data, some collaboration mechanisms have been proposed that take advantage of crowds in order to gather the required information with low cost. But once the data are collected, typical problems of big data arises, due to the amount of data gathered and its heterogeneity. The location phase uses machine-learning techniques to forecast the location of objects according to the data gathered in the previous phase. Although this is an apparent affordable technique, it has some drawbacks: accuracy is usually lower than sensor-based techniques; obtaining the fingerprints is very costly and not scalable; the system is not robust against changes in the infrastructure (like changes in the WiFi access points), that can be done without notice; environment conditions, like the number of people in the room or the mobile used, affect the results. Another challenge in fingerprinting is to find out what signals should be taken into account for locating objects. Nowadays, there is multitude of signals available in, and for each signal there is a huge amount of data that can be gathered, cleaned, integrated, and analyzed.

Thus, fingerprinting is a very promising technique, whose applications provide location services in indoor environments without extra infrastructure. However, some challenges should be taken into account in order to facilitate the creation of fingerprints; to infer more accurate positioning; to define sustainable and scalable environments; to deal efficiently with the big deal of data required for fingerprinting; and to define specifications in order to take into account indoor maps in positioning and navigation.

This book addresses the challenge of developing positioning and navigation systems within indoor environments by using fingerprinting techniques, but also of working in indoor and outdoor locations seamlessly. It covers scientific, technical and practical perspectives that will contribute to advance of the state of the art, to provide better understanding of the different problems and challenges when dealing with indoor environments and to facilitate the design and implementation of indoor positioning and navigation systems to practitioners. It is important to note that, although the main technique with which the book deals is fingerprinting, it offers also introductions to other techniques.

The book is composed by 18 chapters organized in 8 sections:

1. *Challenges of fingerprinting in indoor positioning and navigation.* This section introduces the main topics and concepts related to indoor positioning and navigation, summarizes the current state of the art in indoor positioning and navigation, and presents the current challenges faced.

2. *Privacy and security aspects of indoor positioning and navigation*. This section reviews some of the issues that indoor positioning faces regarding security and privacy, since, for example, making indoor maps available in the same way that outdoor maps are and what privacy issues should be taken into account, since revealing the map of a floor in a building can reveal the fundamentals of the other floors in the same building.
3. *Creating radiomaps for fingerprinting*. This section shows the main issues found when creating a radiomap. It is a very challenging work and it is important to be very effective in order to maximize the outputs of the process. Thus, this section gives instructions and recommendations on how to create radiomaps.
4. *Fingerprinting positioning*. This section explains in detail the fingerprinting positioning process. It focuses in the use of WiFi and magnetic field signals, since they allow to position users either when they are in movement or when they are static. Nevertheless, the fundamentals of fingerprinting are the same whatever the signals are.
5. *Mapping indoor environments*. This section deals with the base map of indoor spaces. It explains how to create vector maps useful for the systems in order to facilitate the positioning and navigation. The map can also be a piece that can help to improve positioning.
6. *Infrastructures to support fingerprinting services and data*. This section reviews the technologies related with indoor positioning using fingerprinting. It presents also the platform: indoorlocplatform.uji.es, which allows to compare the quality of different solutions of indoor positioning; and makes also a review of the competitions that have taken place last years in Indoor Positioning and Indoor Navigation (IPIN) international conference.
7. *Navigating necessities, solutions, and success cases in indoor positioning*. This section shows some issues related to navigation in real environments and provides successful examples of indoor positioning deployments pointing out the problems faced, the approaches followed and the lessons learnt.
8. *Other technologies to position and navigate in indoor environments*. This section introduces other technologies to indoor positioning, different for fingerprinting. This can help to know the range of validity of fingerprinting, as well as to choose the best of option for every indoor positioning problem. In particular, the techniques explained allow to deal with indoor positioning using ultrasound, optical and inertial signals.