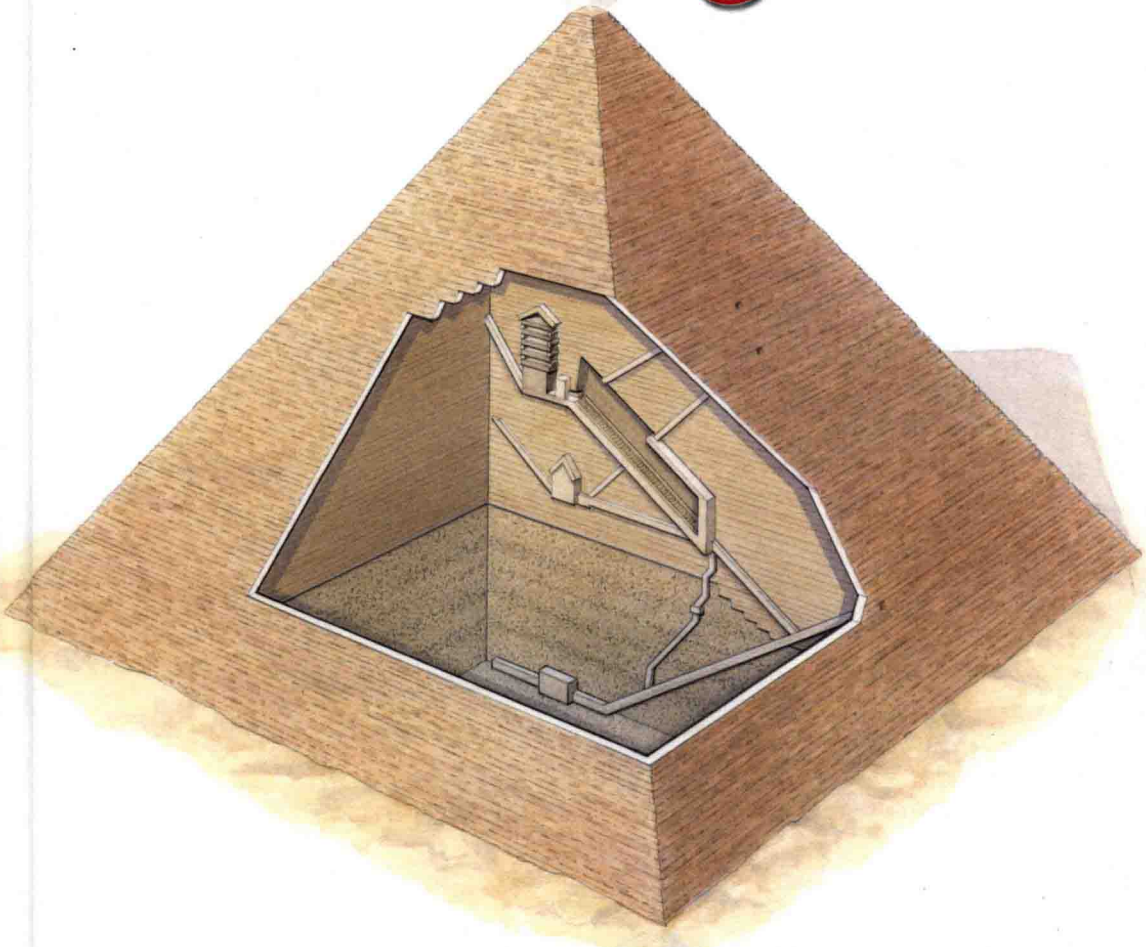
Indoor Wayfinding and Navigation



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Preface

In papers, reports, or websites related to navigation and transportation, the terms *wayfinding* and *navigation* are often used interchangeably. Although these terms overlap semantically, there is an important but subtle difference between them, namely, that wayfinding involves finding routes between pairs of locations whereas navigation involves traveling and receiving continuous real-time guidance while on a chosen route. Another way to observe the difference between these two terms is through common technologies used for wayfinding and navigation. Geographic information system (GIS) technology is commonly used for wayfinding, and an integration of GPS and GIS technologies (as well as others) is used for navigation. There are also differences between "wayfinding and navigation systems" and "wayfinding and navigation *services*." The former is a reference to specialized devices that provide wayfinding and navigation solutions without the need for communication links or connection to other systems and without third-party providers. The latter is a reference to services (more recently through smartphones) that provide wayfinding and navigation solutions only through wired-wireless communication links to remote systems supported by third-party providers. From a computing perspective, wayfinding and navigation systems are centralized platforms, and wayfinding and navigation services are decentralized (distributed) platforms, distributed over clients (on smartphones) and servers (maintained by providers).

Wayfinding and navigation systems and services for cars driving outdoors have been around for a long time and have become indispensable in people's mobility, in particular in unfamiliar environments. The popularity and the high demand for car wayfinding and navigation systems and services can mainly be attributed to GPS technology, which has become compact, affordable, and ubiquitous. A similar trend but a different technology (i.e., smartphones) has been the impetus for building pedestrian wayfinding and navigation systems and services. Since pedestrians seamlessly walk between different environments (outdoor to indoor and vice versa), and different data and technologies are required for indoor wayfinding and navigation, the interest in building wayfinding and navigation systems and services indoors has significantly increased, though they are still in their infancy.

While, conceptually, wayfinding and navigation in outdoor and indoor environments involve similar activities, from the physical space and functionality perspectives, there are differences between them. For example, the physical space (or environment) for pedestrian wayfinding and navigation outdoors generally involves sidewalk networks consisting of sidewalk segments and intersections, regardless of the city or the neighborhood in which wayfinding and navigation activities are needed. This is different from the

physical space (or environment) for wayfinding and navigation indoors, where building structures are not uniform (e.g., different floor plans for different floors of a building and single-story vs. multistory buildings). Another difference with respect to the physical space is that while it is possible for wayfinding and navigation systems and services outdoors to provide solutions using only 2D map data, in buildings they must contain 3D (or 2.5) map data to allow travel between floors. An example of difference with respect to functionality is that unlike wayfinding and navigation systems and services outdoors, which are predominantly based on GPS as the sole positioning sensor, there is no single positioning sensor suitable for navigation in all buildings. In short, wayfinding and navigation differences indoors pose unique challenges that are not present in wayfinding and navigation outdoors.

The purpose of this book is to provide the breadth and depth of knowledge needed for understanding the issues and challenges in building wayfinding and navigation systems and services for indoors and the current approaches, techniques, and technologies considered for addressing them. This book is unique because the cognitive, positioning, mapping, and application perspectives of indoor wayfinding and navigation are discussed in one collection. This mix of different perspectives in this book helps readers better understand the issues and challenges for building indoor wayfinding and navigation systems and services, how these systems and services are different from those used outdoors, and how they can be used efficiently and effectively in challenging applications. Nonetheless, despite these unique features, to be consistent with the general perception about the terminology, as reflected in the literature, the chapters of this book sometimes reference *wayfinding* and *navigation* as they were defined previously; in other times they are used interchangeably.

The cognitive aspects of wayfinding and navigation are the subjects of the first two chapters, whereas several possible sensors for indoor positioning and a unique positioning sensor for indoor environments are discussed in chapters 3 and 4. Chapter 5 provides an example of a unique environment, while chapter 6 discusses map-aided indoor navigation. Chapters 7 through 10 focus on wayfinding and navigation issues related to the blind/visually impaired (B/VI) and discuss current approaches, techniques, and technologies for them. The last chapter addresses the privacy concerns in indoor wayfinding and navigation. The following paragraph provides the details in each chapter.

Chapter 1 discusses navigation of complex environments from the cognitive perspective. This is important in that wayfinding and navigation systems and services, like systems and services for other applications, can provide desired and reliable solutions if they are designed based on cognitive principles related to wayfinding and navigation. In chapter 2 an experiment related to indoor spatial knowledge is described. Considering that there is no sole positioning sensor that can provide acceptable positional accuracy for navigation indoors, like GPS, which has become ubiquitous for

outdoor navigation, several possible positioning sensors suitable for indoor positioning are described in chapter 3. To provide a rather unique example of a positioning sensor, chapter 4 presents indoor positioning through magnetic technology and techniques. Similarly, to provide a rather unique example of the indoor environment, localization techniques and technologies in underground tunnels are presented in chapter 5. Considering that maps are a core component of wayfinding and navigation systems and services in any environment, chapter 6 discusses map-aided indoor navigation. While building indoor wayfinding and navigation systems and services poses challenges that are different from those for outdoors, there are different and unique challenges for adequately addressing the wayfinding and navigation requirements of people with disabilities. The next four chapters are devoted to the discussion and analysis of wayfinding and navigation requirements for B/VI individuals and possible approaches, techniques, and technologies for addressing them. Chapter 7 provides the challenges of indoor wayfinding and navigation for B/VI individuals. Chapter 8 discusses various suitable technologies that can be used to aid B/VI people for indoor wayfinding and navigation. Chapter 9 discusses the NavPal suite of tools that can be used to assist B/VI travelers in wayfinding and navigation in indoor environments. Chapter 10 discusses future directions in indoor wayfinding and navigation technology for B/VI travelers. Issues of privacy in indoor wayfinding and navigation systems and services are discussed in chapter 11.

This book is suitable for anyone interested in learning about approaches, maps, sensors, techniques, technologies, and applications, among other things, for indoor wayfinding and navigation. Researchers can learn about the latest research developments related to indoor wayfinding and navigation in indoor environments, developers can learn about the issues and challenges in building new indoor wayfinding and navigation systems and services, and students can learn about the fundamentals of indoor wayfinding and navigation.

Editor

Dr. Hassan A. Karimi received his BS and MS in computer science and PhD in geomatics engineering. He is a professor and director of the Geoinformatics Laboratory in the School of Information Sciences at the University of Pittsburgh, Pittsburgh, Pennsylvania. His research is focused on navigation, location-based services, location-aware social networking, geospatial information systems, mobile computing, computational geometry, grid/distributed/parallel computing, and spatial databases and has resulted in more than 150 publications in peer-reviewed journals and conference proceedings, as well as in many workshops and presentations at national and international forums. Dr. Karimi has published the following books: *Advanced Location-Based Technologies and Services* (sole editor), published by Taylor & Francis Group in 2013; *Universal Navigation on Smartphones* (sole author), published by Springer in 2011; *CAD and GIS Integration* (lead editor), published by Taylor & Francis Group in 2010; *Handbook of Research on Geoinformatics* (sole editor), published by IGI in 2009; and *Telegeoinformatics: Location-Based Computing and Services* (lead editor), published by Taylor & Francis Group in 2004.

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Cognition for the Navigation of Complex Indoor Environments

Stephen C. Hirtle
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Abstract: Indoor navigation has proved to be complex to understand and to support with the use of external aids, be it signage, maps, or navigational devices. Research on the spatial cognition of complex indoor environments for the purpose of navigation is reviewed. The result of this analysis is an aggregated view of what makes indoor environments different from outdoor or transitional environments. The goal of this chapter is to coalesce the known cognitive principles to guide further research and tools in indoor wayfinding.

1.1 Introduction

As a catchy subtitle to his recent book *You Are Here*, Colin Ellard (2009) asked, "Why we can find our way to the moon, but get lost in the mall." He went on to describe what is known about spatial cognition from a variety of perspectives, but he discussed relatively little on indoor navigation, despite the title of the book. Navigation has often been studied in outdoor spaces, but the reality is that there is a growing literature on the nature of indoor navigation, starting almost 30 years ago. Given the large body of literature in this area, it is useful to review and categorize the knowledge gained, especially in light of recent advances in the technology for augmenting indoor locational information. The purpose of this chapter is to examine the cognitive aspect of indoor navigation, specifically in complex environments, by taking into account and synthesizing the research that has been carried out in the past three decades. While only a subset of the more than 2,000 articles published on this topic will be reviewed, it is hoped that the review will give a good background to researchers working in this area and support the material found in the rest of this book.

The work discussed falls roughly into three periods, as shown in Table 1.1. There were a number of important, well-cited, foundational studies in the 1980s that were conducted in indoor spaces and established many of the

TABLE 1.1

Methods by Time and Conceptual Areas for the Study of Spatial Cognition of Indoor Spaces

Section	Subareas	Representative Articles
1.2 Early approaches	Spatial knowledge acquisition	Thorndyke and Hayes-Roth (1982); Gärling, Lindberg, and Mäntylä (1983)
	Building complexity	Moeser (1988); O'Neill (1991)
	You-Are-Here maps	Levine (1982)
1.3 Task-oriented studies	Emergency exits	Klippel, Freksa, and Winter (2006)
	Modeling the navigation process	Agarwal (2005); Hirtle, Timpf, and Tenbrink (2011)
	Images and photographs	Ishikawa and Yamazaki (2009); Wang and Yan (2012)
1.4 Cognitive-architectural perspectives		Hölscher, Meilinger, Vrachliotis, Brösamle, and Knauff (2006)
1.5 Analytical methods	Space syntax	Hillier and Hanson (1984); Richter, Winter, and Ruetschi (2009); Turner, Doxa, O'Sullivan, and Penn (2001)
1.6 General principles		Carlson, Hölscher, Shipley, and Dalton (2010); Hölscher, Montello, and Schnitzler (2013); Li and Klippel (2012)