Future Directions for Indoor Information Systems: A Panel Discussion

Demetrios Zeinalipour-Yazti
Department of Computer Science, University of Cyprus, 1678 Nicosia, Cyprus
Email: dzeina@cs.ucy.ac.cy

***Abstract*—Geographic Information Systems (GIS) have enabled a vast range of applications in outdoor spaces, but these systems are bound to accurate localization technologies that are not available inside buildings where people carry 90% of their activities. Additionally, GIS don't address the unique characteristics of complex indoor environments off-the-shelf. At the same time, we witness the uptake of a new class of *Indoor Information Systems (IIS)*, which store indoor spatial models along with sensor signals (e.g., wireless, light and magnetic) used to localize users. Such IIS might be considered as specialized GIS applications that are tailored to the unique challenges pertinent to indoor spaces, namely new indoor data management operators, new indexes, new data privacy schemes, built-in data-driven localization algorithms, models to crowdsource IIS data and these might even use NoSQL architectures. This panel will explore how the academia and industry are tackling the future challenges that rise in the scope of IIS. It will also identify and debate the key challenges and opportunities, in terms of applications, queries, architectures, to which the mobile data management and mobile data mining communities should contribute to.**

Keywords*—*Indoor Information Systems, Data Management, Analytics, Smartphones, Query Processing.

I. Introduction

People in modern societies do 90% of their activities, business, commerce, entertainment and socializing indoors. As all of these are increasingly aided by online services and as indoor spaces are becoming bigger and more complex, there is a growing need for cost-effective indoor localization, mapping, navigation and information services. People are nowadays equipped with omni-present mobile computing devices, which creates new opportunities for a variety of compelling applications in indoor spaces, such as, in-building guidance and navigation, inventory management and logistics, marketing and elderly support through ambient and assisted living, eHealth scenarios, management of humanoids in indoor spaces (e.g., Sophia), tracking hazards indoors, etc. Additionally, there is a growing interest by retailers to enhance the shopping experience by offering on-the-spot coupons and by analyzing shopping behavior. Finally, the entertainment industry aims to design new games that exploit the actual indoor environment of players as the playground (i.e., from augmented and virtual reality to mixed/immersive reality) and all of these require the management of moving objects indoors.

Geographic Information Systems (GIS) have successfully enabled the management of moving objects outdoors, since the 1970, in a vast range of applications, namely: real estate, public health, crime mapping, national defense, sustainable development, natural resources, climatology, landscape architecture, archeology, regional and community planning, transportation and logistics. Unfortunately, such systems typically operate on the presumption of accurate localization technologies that do not work inside buildings, e.g., GPS, GLONASS, Galileo, Beidou and other regional *Global Navigation Satellite System (GNSS)*, due to the blockage of satellite signals by building structures. Additionally, indoor spaces are characterized by complex topologies and are composed of entities that are unique to indoor settings, such as multiple floors, rooms and hallways connected by doors, walls, stairs, escalators, and elevators. To make things worse, doors may be one-directional (e.g., in security control in airports), while temporal variations may occur (e.g., a room may be temporarily available due to its opening hours, or conference hall might be partitioned into several smaller rooms to accommodate different events). It is clear that the traditional *Geometric* (i.e., Euclidean) modeling approach is not appropriate. For instance, a location may not be directly accessible from another nearby location, even though their Euclidean distance is small because of a wall or floor.

The above factors along with the advances of Internet-of-Things (IoT) technology in recent years, has gradually lead to the uptake of a new class of *Indoor Information Systems (IIS)*, which rely on scalable geolocation databases that store spatial models along with wireless, light and magnetic signals used to localize users. Such IIS might be founded, among other, on typical GIS software, but address new challenges pertinent to indoor spaces, namely new indoor data management operators, new indexes, new data privacy schemes, data-driven localization algorithms, models to crowd-source IIS data and NoSQL architectures. Examples of such IIS include both commercial systems, e.g., Google Indoor, Mazemap.com, Micello.com (merged to Here Maps), deep-map.com and academic/open-source systems, e.g., Anyplace, OSIRIS, KAILOS and i-locate.eu.

The goal of this panel is to convey an advanced understanding of the unique characteristics, challenges and opportunities of IIS to its audience. The panel is targeted to scientists with a basic understanding of mobile data management, but no knowledge of IIS in particular should be expected. Through the short positioning statements of panelists and the active engagement of the audience, the goal will be to derive the future directions in the emerging domain of IIS. Our panelists are expected to bring a wealth of experience from the GIS and Information Systems sector, the mobile data management and the indoor industry. The intent is not to overview individual products and or solutions, nor to provide a background on specific indoor information solutions. The panelists will attempt to clarify where the challenges of IIS are expected to take place in the future, the kind of architectures necessary, potential applications and killer queries, privacy and ethical aspects as well as commercial uptake possibilities.

II. Potential Questions

During the panel, the panelists will be asked to provide perspectives on the following indicative list of questions:

Is the vision of stand-alone IIS credible or will IIS remain an application of GIS?
In the scope of existing IIS there is already a growing interest towards more GIS integration, where *OGC's IndoorGM standard*, GeoJson.org or any other standard that may appear in the future becomes fully inter-operable. The European project i-locate.eu aims to bridge IndoorGML and Open Street Maps (OSM) by building upon the lessons learned from the deprecated IndoorOSM tagging schema and extensions. The open-source Anyplace project merges indoor signal layers and indoor models on popular web mapping services, such as Google Maps. Having the right modeling primitives will give rise to a variety of data management and query processing challenges in the future, such as effective in-building search and exploration. The question here is whether IIS will evolve into independent system software, or whether IIS will continue to be an application of traditional GIS?

What are the right architectures for IIS?
GIS has been founded since their advent on RDBMS (e.g., PostGIS on Postgres, ArcGIS on any DBMS) or even common file system folders. Yet, IIS are emerging in an era where the data management landscape has shifted towards big data architectures that are highly parallel and distributed, in order to cope with the inherent I/O and CPU limitations (e.g., Hadoop/Hive data warehouses for purely analytic scenarios but also Apache Storm/Spark for streaming and micro-batching scenarios). Such systems nowadays typically perform on mid-scale internal/private clouds, offering higher privacy, to large-scale public clouds, both exposing operational and analytic functionality stand-alone or as-a-Service. The question here is whether IIS will reside on traditional GIS/RDBMS architectures or whether it will shift to counterpart big-data distributed architectures for spatial (e.g., Geospark, SparkGIS, SpatialHadoop), spatio-temporal/timeseries data processing (e.g., DITA) or even document-oriented data processing (e.g., Couchbase) appropriate for Web 2.0 scenarios?

How does the type of indoor environment change operational requirements of IIS?
Indoor refers to some environment that is situated within doors. These environments are obviously very diverse, from conventional building structures (e.g., house, shopping mall, airport, library, hospital), to moving objects (e.g., ships, airplanes, buses), to underground environments (e.g, underground mines). One can claim that different types of indoor environments will change the operational requirements of IIS in the future. How reusable will IIS become to different application scenarios in the future? Will the trend of application-specific IIS remain the norm (e.g., for navigation, for inventory tracking, etc.)?

How are different localization technologies complicating the task of managing indoor data?
The indoor localization literature is more than 15 years old and very broad and diverse, as it exploits several technologies, including: Infrared, Bluetooth, visual or acoustic analysis, RFID, Inertial Measurement Units, Ultra-Wide-Band, Sensor Networks, Wireless LANs, etc.; including their combinations into hybrid systems. Most of these technologies deliver a high level of positioning accuracy, comparable to GNSS that does not operate indoors, however they require the deployment and calibration of expensive equipment, such as custom transmitters, antennas or beacons, which are dedicated to positioning. This is time consuming and implies high installation costs. At the same time, it complicates data management tasks and queries, as solutions might be targeted to a specific set of technologies in particular. The question is whether sensor data can be abstracted to enable meaningful handling of data diversity inside IIS (e.g., same index for both BLE and Wi-Fi)?

What is the role of next generation interactive media technologies to IIS?
New technology interfaces make it into the daily life of the mobile workforce in an ongoing manner. Nowadays it is very typical to expect turn-by-turn *voice navigation* and/or *augmented reality* (e.g., head-up displays in cars, smart glasses or conventional mobile applications), as these enable custodians to follow the instructions without requiring them to look away from their usual viewpoints. In the future it is expected that users will have Augmented Reality (AR) and Virtual Reality (VR) immerse into Mixed Reality (MR) scenarios, enabling, according to Intel, custodians to interact with and manipulate both physical and virtual items and environments, using next-generation sensing and imaging technologies. How is this explosion of peripheral user interfaces affecting the design of next generation IIS?

What are the most prominent Privacy and Ethical aspects you see with IIS?
Location privacy refers to the the ability of an individual to move in public space with the reasonable expectation that their location will not be systematically and secretly recorded for later use. A fundamental drawback of IIS, is that these involve different types of location tracking technologies (e.g., beacons, bluetooth, Wi-Fi) that can enable a service to track custodians even if these never engaged in a given service (e.g., by downloading an app on their smartphone). IIS can even become attractive targets for hackers, aiming to steal location data and carry out illegal acts. Location tracking by IIS services poses a serious imminent threat, which will have a much greater impact than other existing forms of location tracking, as it can occur at a very fine granularity in indoor spaces. The panelists are expected to expand on whether those aspects present a legal barrier to the uptake of IIS, under the prism of stricter global regulation on data privacy (e.g., GDPR in Europe).

What are the killer (top) queries to answer in mobile indoor data analytics?
A few examples include: Spatio-Temporal Analytics, Anomaly detection, Association Rule Learning, Clustering, Classification, Privacy Issues. The panelists are expected to expand on specific projects they have worked on in the past, which are related to this theme and that can trigger discussions on what is important to be tackled in the future.

Are IIS expected to have a commercial/real impact in the near future?
What are specific industries where IIS will play a crucial role in the future (e.g., Manufacturing, Navigation, Marketing and Shopping Analytics, Healthcare, Museums, IoT)? The panelists are expected to expand on the business domains they expect this paradigm to have the earliest commercial/practical impact.