Location-based navigation and services

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***Abstract*—Location-based services are used in many fields. These services use different technological solutions. This paper is a systematic mapping study with the aim of giving an overview of what kind of location-based services exist and in what fields and domains they are mostly used, as well as what technologies and devices enable these services to function and what potential other technologies could be implemented instead or as an improvement to existing ones.**

Keywords—navigation, service, location-based, technology, device, systematic mapping study

I. Introduction

Location-based navigation and services are increasingly popular and have become an important part of smart systems in security, healthcare, entertainment, building automation and others [1]. These services use location-tracking technologies and devices. There are many research topics in the field of location-based technology and services, but this paper is mainly focused on Internet of Things (IoT), asset tracking, object detection and indoor navigation. In addition to exploring different services enabled and provided by the use of location-based systems, this paper reviews different technologies and devices that allow location-tracking of people and objects, fields and domains that benefit from the location-based technology and possible future improvements and implementations in the location-tracking sphere.

II. Methodology

The given paper is a systematic mapping study and is done using the following five steps: (1) research questions are posited, (2) data is researched, (3) studies of appropriate quality are selected, (4) data is extracted, and (5) results are gathered.

A) Research Questions

This systematic mapping study protocol aims to find relevant papers on the subject of location-based navigation and services. The goal is to gain an overview of location-tracking technologies used, of services and of alternatives proposed. For this objective, four research questions (RQs) were put forward:

- RQ1: For what kind of services is location-based technology used?
- RQ2: Which fields and domains have applications of location-based navigation and other services?
- RQ3: What are the different location-tracking technologies and devices?
- RQ4: What are the proposed potential location-tracking technologies or solutions that have not yet been widely implemented?

B) Data Search

The database IEEE Xplore Digital Library was selected for this study, as it has one of the largest amounts of computer science and engineering articles available on the internet. For searching this data source, a search string was formulated:

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location AND tracking AND technology AND
(sensor OR device) AND (Internet of Things OR
asset tracking OR object detection OR indoor
navigation)
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Fig. 1. The search string

To exclude various other location-tracking research fields, the query included Internet of Things, asset tracking, object detection and indoor navigation keywords. To include hardware related results, sensor and device keywords were also added. The search string was triggered against the document titles of the available publications. The query returned 72 results with no additional filtering.

C) Study Selection and Quality Assessment

Searching using the search string yielded a large collection of papers, but not all of them answer the research questions of this study. Thus, further filtering was needed in the form of exclusion and inclusion criteria. The following exclusion criteria was created in order to filter out unwanted publications:

- EC1: Papers that are not conference materials or academic journals (69 remaining)
- EC2: Papers published before 2016 (28 remaining)

A set of inclusion criteria was created:

- IC1: Journals discussing services that use location-based technology
- IC2: Journals mentioning fields and domains that have applications of location-based navigation and other services
- IC3: Journals reviewing different location-based technologies and devices
- IC4: Journals proposing potential location-tracking technologies or solutions that have not yet been widely implemented

To the original collection of 72 papers, EC1 was applied, leaving 69 results. To exclude papers not published during the previous five years, EC2 was applied, which resulted in 28 papers. As a result of utilising the exclusion criteria, 28 papers remained.

After applying exclusion criteria, each of the 26 papers' abstracts were read through manually. The inclusion criteria were applied by analysing the abstracts. Consequently, 17 papers total were included to be used in this study.

Additional quality criteria were added during manual overview to better filter out suitable papers:

- QC1: Is the title and abstract clear in their aim and their connection to the current paper?
- QC2: Is the full text of the paper written in correct English?

After applying the quality criteria, one paper was excluded. As a result of study selection, 16 papers were chosen.

D) Data Extraction

For data extraction, a data extraction table was used, which consists of several data items (Table 1). The data items were the article link and title, author name(s), services, fields and domains, technologies and devices, and future solutions. The 16 papers collected during this study were read through and analysed to gather what data items they contained: whether they mentioned any location-based services, any fields or domains where these services are in use, if they contained information about location-tracking hardware or discussed possible new technologies to implement.

TABLE I. DATA EXTRACTION FORM

Data Item	Value	RQ
Article link	IEEEXplore link to article	
Article title	Name of the article	
Author name(s)	Set of Names of the authors	
Services	Services that use location-based technology	RQ1
Fields and domains	Fields and domains where location-based services are used	RQ2
Technologies and devices	Location-tracking technologies and devices	RQ3
Future solutions	Not widely implemented proposed technologies or solutions for location-tracking	RQ4

III. RESULTS

Answers from the papers were collected into tables representing each research question. The category labels were formulated based on the information gathered. All tables except for Table 5 (future solutions) are ordered by frequency and similar entries from the data extraction table have been summated to represent the same label.

A) RQ1: For what kind of services is location-based technology used?

TABLE II. OTHER SERVICES

Service	Source
Indoor localisation	[5], [7], [8], [9], [10], [11], [13], [14], [15]
Indoor location tracking	[2], [3], [4], [5], [6], [7], [14], [16]
Asset tracking	[3], [7], [8], [9], [12], [16], [17]
Path generation	[6],[14],[16]
Vehicle tracking	[2],[7]
Outdoor location tracking	[7], [15]

All references in the 16 papers to services, where location-based technology is used, are shown in Table 2. Any tracking that does not include humans (e.g. animals, objects) were grouped under asset tracking.

B) RQ2: Which fields and domains have applications of location-based navigation and other services?

TABLE III. FIELDS AND DOMAINS

Field or domain	Source
Asset management	[3], [7], [8], [9], [12], [16], [17]
Healthcare	[2], [5], [7], [10], [11]
Care facilities	[4], [10], [11]
Wearables	[5], [10], [11]
Navigation	[6], [14], [15]
Marketing	[14], [15], [16]
Law enforcement	[2], [15]
Smart home	[10], [11]
Smart city	[10], [16]
Social networking	[16]
Activity monitoring	[16]

All references in the 16 papers to any fields and domains, where location-based technology is applied, are shown in Table 3. Nursing homes and child care facilities were grouped under care facilities.

C) RQ3: What are the different location-tracking technologies and devices?

TABLE IV. TECHNOLOGIES AND DEVICES

Technologies or devices	Source
Wi-Fi	[3], [4], [5], [6], [9], [12], [13], [15], [16]
Radio Frequency Identification Device (RFID)	[3], [4], [5], [6], [9], [12], [13], [15], [16]
Bluetooth Low Energy beacons (BLE)	[2], [5], [6], [9], [10], [11], [16]
Global Positioning System (GPS)	[2], [5], [7], [9], [12], [15], [16]
Visual image processing	[13], [15], [17]
Ultra-Wideband (UWB)	[3], [17]
Infrared	[3], [15]
Ultrasound	[3], [4]
Inertial sensors	[11], [13]
GLONASS	[5]
GALILEO	[5]

Technologies or devices	Source
Zigbee	[9]

All references in the 16 papers to any technologies or devices, which are used to implement location-tracking, are shown in Table 4.

D) RQ4: What are the proposed potential location-tracking technologies or solutions that have not yet been widely implemented?

TABLE V. FUTURE SOLUTIONS

Future solution	Source
Time difference of arrivals of ultrasonic reflections	[4]
Magnetic field identification	[6]
Device-free passive indoor system (DfP)	[8]
Kalman-LULU in signal processing stage	[9]
Amazon Echo voice interface with ultrasonic sensors	[10]
Action recognition system with BLE	[11]
RSG matrix for enhanced Wi-Fi fingerprints	[13]
Deanonymisation of Wi-Fi traces for efficient tracking	[14]
Auxiliary observation nodes determining signal strengths	[16]
Correcting error tracking by image tracker and UWB device	[17]

All references in the 16 papers to any not widely used technologies or solutions, which could be used to implement or improve location-tracking, are shown in Table 5.

IV. DISCUSSION

A) RQ1: For what kind of services is location-based technology used?

Table 2 gives an overview of different services that use location-based technology. Among them the three most common services mentioned were indoor localisation, indoor location tracking and asset tracking. In addition to them some papers discussed path generation that enables navigation services, vehicle tracking that was connected to law enforcement and outdoor location tracking that was usually implemented via GPS technology. Different fields and domains where there are applications of the aforementioned services are discussed in the following paragraph.

Due to the focus of this paper being on Internet of Things, asset tracking, object detection and indoor navigation, the results were mostly expected.

B) RQ2: Which fields and domains have applications of location-based navigation and other services?

According to results presented in Table 3 the two fields where the use of location-based services has been the most common in the past five years are asset management and healthcare. The asset management category contains all the fields that deal with tracking the location and movement of objects of interest, for example tracking valuables in a warehouse. The healthcare field mostly used the indoor localisation and location tracking services to monitor patients' location who may be in need of critical care.

Among other frequently mentioned fields and domains were care facilities, wearables, navigation and marketing. Care facilities like nursing homes and child-care facilities often used tracking the location of their residents for similar reasons as in the healthcare field. However, nursing homes often use location tracking and inertial sensor technology to track patients' location and well-being from the patients' homes, to give quick and effective assistance in case of an emergency.

Wearable devices are often used as sensors or receivers of signals to enable tracking of people. Such wearable devices are for example wristbands that are used in hospitals to track the location of patients.

The navigation field uses indoor and outdoor localization of two different entities to allow for generation of optimal paths between them. For outdoor navigation the most common technology is GPS.

There were also some mentions of fields that use location-based services like law enforcement, smart home and city, social networking and activity monitoring but these were not as common.

C) RQ3: What are the different location-tracking technologies and devices?

Table 3 shows all the technologies and devices that were mentioned in the 16 reviewed papers that enable location-based services. The amount of different technologies is notable even for such a small range of research topics that were chosen for this study. The three most popular technologies that were used for indoor services were Wi-Fi, Radio Frequency Identification Devices and Bluetooth Low Energy beacons. For outdoor location tracking the most common technology was GPS, which unfortunately didn't have many alternatives.

For indoor location detection there were also mentions of technologies like Visual Image Processing, Ultra-Wideband, Infrared, Ultrasound, inertial sensors and Zigbee (digital radios). For outdoor localization the alternatives for GPS were GLONASS and GALILEO, both of which are satellite navigation systems like GPS.

D) RQ4: What are the proposed potential location-tracking technologies or solutions that have not yet been widely implemented?

Several papers proposed new and interesting approaches or optimizations to improve the capabilities of location-based services. Among them were the use of ultrasonic reflections in addition to direct waves for more accurate calculations of time difference of arrivals, the use of magnetic fields (identifying the naturally occurring magnetic fields inside concrete buildings), use of Amazon Echo in addition to ultrasonic sensors to identify location of people, applying a Received Signal Strength Spatial Gradient matrix for enhanced Wi-Fi fingerprints and others.

V. Conclusion

For this paper, a systematic mapping study was carried out. Research questions were put forward, data selected, researched and analysed. By filling out a data extraction table, valuable information was found to answer the four research questions about location-based navigation and services.

The study focused mainly on Internet of Things, asset tracking, object detection and indoor navigation and consequently, most of the found data covered these fields. Many papers discussed services (RQ1) like indoor localisation and location tracking, as well as asset tracking. The services (RQ2) in these papers were used in fields such as asset management and healthcare, but also law enforcement, wearables, navigation and others. Most commonly, Wi-Fi, BLE, RFID and GPS were brought out as technological solutions (RQ3). Interesting proposals for alternative technologies were discussed, like magnetic field identification and ultrasonic reflections (RQ4).

Improvements could have been made in the selection of the study subject. Initially the search string was very generic, but also yielded around a thousand articles with exclusion and inclusion criteria applied. Focusing on Internet of Things, asset tracking, object detection and indoor navigation helped limit the amount of articles found, but also restricted the amount of interesting topics that could have been encountered.

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