Survey of Location Sensing Techniques

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ABSTRACT

Location-based services (LBS) have wide applicability in areas like navigation, tracking, emergency services, gaming, persuasive applications etc. The core element of any LBS is its positioning technology. This paper reviews taxonomy of location sensing techniques. Then several location sensing techniques like Global positioning system, Visible light positioning, Cell-Id, Received signal strength, Image recognition and IP based geolocation is surveyed, summarized and classified. Finally, this paper identifies the similarity and differences in location sensing techniques, current research trends and also area for future study.

Introduction

The ability of mobile devices to be aware of it s location has opened door to multitude of applications. Most popular computer and mobile applications including Facebook, Twitter, Google map, Pokemon Go and Tinder are using location based service. However, location sensing techniques used in those applications are not same and vary based on methods, accuracy, environment of the usage etc.

Location sensing or position techniques are undoubtedly core element of any location based service. Location sensing can be considered as hybrid technology comprising of both the positioning, system which computes its own position and the tracking system which monitor tracked object without involving tracked object in computation [4]. Wide varieties of location sensing techniques are available and are continuously evolving. For the systematic study of these sensing technology different attempts has been mad e [3][14].

This survey paper aims to provide an overview of the most important sensing technique. This paper also aims to review different taxonomy attempts and compare them. The author hopes that this paper will highlight the existing knowledge in location sensing and also identify the limitations and research gap. The paper wil help researchers to select an appropriate sensing technique for their application or develop suitable sensing technique.

This paper is different from existing taxonomy and summary paper [12, 13, 14] because it intends to review some sensing techniques which were not classified before. Moreover, this paper also aims to assess existing approaches for taxonomy and identify their limitations.

In the rest of the paper, first existing classification approaches made for Location sensing are reviewed. Then we summarize some important papers related to location sensing techniques and also classify them. Finally, we conclude the paper with significant findings of the survey.

Taxonomy of location sensing Techniques

Various studies have been conducted to systematically classify location sensing methods. Location sensing techniques are classified based on how the location data are expressed, into Absolute, Relative, Anonymous or Symbolic data [3]. Absolute data is the absolute coordinate of adevice in terms of longitude and latitude. Relative data refers to a location relative to other device but does not have absolute coordinates. Motion sensors also identify presence of object however it does not ascertain the identity of the object. Such data are anonymous data. In this data you know something is present at any specific location but you don't know the id of that object. Further anonymous data can also be obtained in privacy preserving Location based services. Symbolic data does not have a geographic location in itself. However, it can be converted into geolocation in the subsequent step. IP address is an example of symbolic data.

Another paper which was published after a year categorized positioning technique into self-positioning and remote positioning based on whether the object to be positioned knows its location or not [14].

In self-positioning approach, receiver receives signal (electromagnetic wave) transmitted by terrestrial or satellite antenna and calculates its own positions. So the receiver is the object to be positioned and knows its own position. The examples of such approach as mentioned in the above paper are GPS and Assisted GPS (A-GPS), Indoor Global Positioning System (Indoor GPS) and Mobile Terminal Positioning over Satellite UMTS (S-UMTS). A-GPS uses data from mobile network to assist faster location. Indoor GPS uses pseudo satellites to generate GPS like signals in indoor environment. S-UMTS is also form of GPS which uses only two satellites so there is no need of dedicated satellites.

In the remote positioning approach the object to be positioned either reflects signals transmitted by the set of receivers or emits the signals which are then received by the set of receivers. The signal measurements are then used to compute the location of the object. So the object to be positioned does not know its location. Its examples as described in the paper are Cell Identification (Cell-ID), Direction or Angle of Arrival (AOA) and Time delay positioning.

Location Sensing Techniques

This section briefly summarizes some important location sensing techniques. Finally, table presented at the end of this section classifies the location sensing technique reviewed during the survey.

Global Positioning System (GPS)

GPS is the most commonly used outdoor sensing technology [13].It is a satellite-based navigational technology which uses radio signal broadcasted by a group of satellites which are orbiting around the earth. These signals are received by receiver and distance of satellite to the receiver is computed based on the transit time of signal. The distance from at least three satellites is used to compute the position of receiver based on the principle of trilateration.

GPS give precise position and are cost efficient because of the availability of inexpensive receivers and GPS antenna are already installed and there is no cost for the user. Therefore it is most appropriate technology for outdoor sensing.

However, near dense trees and tall buildings signals are obstructed and do not give good fix. Nevertheless due to the availability of a large number of satellites than required this problem can be resolved. Another issue with GPS based positioning is it consumes a large amount of battery.

The energy consumption can be reduced up to 90% by optimizing algorithm in such a way that only positioning method with least energy consumption get activated [1].

Visible Light Positioning (VLP)

Though GPS is precise, cost efficient and flexible positioning technique, it is unsuitable for indoor positioning and the places where signals are blocked by trees or buildings.

The proliferation of white LEDs provides an alternative for indoor location sensing system. Visible light transmitted by the LED can be used to determine the position of an object within a room [7].

The visible light positioning sensor uses the received signal to determine distance and or direction to the number of LED transmitter. These measurements are used to compute the position of the receiver either using triangulation or trilateration [8]. Though it is not possible now to envisage all the use of LED based positioning, It will surely have a multitude of applications in future for indoor positioning.

Luxapose is an example of VLP which uses unmodified camera present in a commercial smartphone as receiver and slightly modified LEDs to allow rapid blinking as signal. Smartphone receives transmissions using its camera and determine its location and orientation using an angle-of-arrival localization algorithm. It not only computes the position but also provide the orientation of the receiver [6].

Vision Based Positioning

One of the uses of Image matching technique is location sensing. Vision based positioning using Augmented reality [5] recognizes location from image taken in indoor environment by comparing it with previously made database and location model of indoor environment. The average recognition rate in this system was found to be 89%.

IP Address based Positioning

IP address of a computer is widely being used to compute location of the user. Based on the location we are getting tailored advertisement, search results, web content and security warnings in different websites.

Each IP address is mapped to a location and ip of the user is compared to that database. There are several databases that provide IP geolocation but their reliability can be questioned [10]. There are not many studies that access the reliability and accuracy of IP geolocation. This study published on 2011 claims to be first study which uses ground truth to access the reliability of IP geolocation. Based on this study there is bias in mapping location of few popular cities. Thus IP geolocation can be claimed to be accurate to the country level only but not city level.

Received Signal Strength (RSS) based Positioning

Radio-frequency identification uses the electromagnetic field to detect tag present in the vicinity. This technology has been used for tracking goods in warehouses, tracking livestock and in industries to track progress in assembly lines.

SpotOn [3] is a pioneer work where an active tag is used for location sensing through analysis of the strength of radio signal . The principle of SpotOn is that multiple base stations provide signal strength data to an active tag whose approximate distance is known. The server then aggregates all the measurement and compute precise location based on the principle of triangulation. This system prov ided accuracy of about 3 meters. The accuracy might not be sufficient for positioning within a room. Still, it provides theoretical basis for future research.

Later signal strength based positioning research focused on fingerprinting technique which performed better than triangulation based computation. In fingerprinting technique first training database is built then this database is used for positioning. RSS positioning was basically developed for the indoor system but fingerprinting also perform ed well in the outdoor environment [11]. In the above study Wifi signal and fingerprinting was used to find the location in the outdoor environment. The study was conducted in CBD area of Sydney and result in an accuracy of 35 meters on an average.

Location Sensing Technique	Environment	Technology	Data Expression	Position Fixing	Position Awareness
Fingerprinting	Indoor/ Outdoor	Wi-Fi	Relative/Absolute	Fingerprinting	Self-Positioning
Spoton	Indoor	RFID(Radio Frequency)/wifi	Relative/Absolute	Trilateration	Remote Positioning
Luxapose	Indoor	Visible Light	Relative	Triangulation	Self-Positioning
IP Based	N/A	Database driven	Absolute/ Symbolic	Database Mapping	N/A
GPS	Outdoor	Radio Wave	Absolute	Trilateration	Self-Positioning
Cell ID	N/A	Radio Wave	Relative/Absolute	Proximity Sensing	Remote Positioning
Vision based position	Indoor	Object recognition	Symbolic	Image matching	Remote Positioning

Table 1 Classification of Location Sensing Methods

Cellular Network based Positioning

The cellular tower has a zone of radio frequency around it which is known as a cell. When a cell phone enters to that zone cellular tower recognize it. Thus the approximate position of the device can be known based on the cell tower that device is using. The accuracy of this method is low ranging from 200 meters to kilometers [2]. Nevertheless, the accuracy can be increased by increasing number of cells

Conclusion

In this paper, we surveyed major location sensing techniques. Different approaches of taxonomy of the location sensing techniques were also reviewed in this paper. Furthermore, we also classified the surveyed location sensing techniques into different categories.

From this study we identified GPS is most popular outdoor positioning technique. We also identified the research in indoor sensing is rapidly increasing in recent years. Regarding outdoor positioning, developing energy efficient algorithm is new research trend. This survey also suggests that the VLP has huge potential in indoor navigation. Though IP based Geolocation is becoming popular, study claims that the current location mapping database can be used with certainty only at country level [10].

It can also be inferred that existing positioning techniques compute location from either solving triangle (using range measurement or angle measurement) or some kind of database mapping.

Based on the survey we also identified few research gaps in location sensing technique that should be addressed in future. The accuracy requirement for different location based system is different and the application might not work in desired way when accuracy requirement is not meet. So location based application should be aware of the accuracy also. Existing study is lacking to address this issue.

Also there is limited research about IP based Geolocation and its accuracy. Furthermore we observed that most of the studies that we considered do not address temporal dimension of geospatial data. So study is needed to define temporal extent, temporal accuracy and time sequence of spatial data.

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