Centimeter Level Location Accuracy is unnecessary for Location Based Services

Abstract

Location Based Services are services that exploit knowledge about where an information device user's location. These services make use of different positioning techniques most of which currently give meter level accuracy. Currently, meter level accuracy has been found to be sufficient for most location based services. There is a controversy as to whether we should improve the accuracy of these services to centimeter level or not. We claim that centimeter level accuracy is not needed for such services. The reason for our claim is symbolic location is more important that physical location and current positioning systems are accurate enough to determine the symbolic location of an object. Also, in case of small symbolic locations, direct sensing devices can be used thereby avoiding location calculation. It has been found that high accuracy is needed for tracking applications and it is a matter of debate as to whether tracking applications should be considered as location based services. Privacy might be another reason why accuracy of location based services could be restricted to meter level.

1 Introduction

The use of wireless devices such as mobile phones and PDAs has been on the rise in recent years. [6] In 1994, 16 million Americans were cell phone subscribers. In 2001, it increased to more than 110 million Americans. Experts believe that worldwide subscription would increase to 1.2 billion people in 2006.

Wireless devices enables the user to move about freely from one location to another and still remain connected. This means that the context in which the device is operating is constantly changing. The Computer / Telecommunication Industry saw that there was a opportunity to provide service to the user depending on his or her context. The most important context information is the location of the user. For this reason many services using location information were (are being) created. This include advertising / billing depending on location, providing information suited to the context of the user, tracking of user, emergency assistance such as E911 service, road side assistance etc. These services are categorized as Location Based Services.

Location Based Services are services that exploit knowledge about where an information device user is located. [1] Applications are normally divided into two categories: tracking and positioning. In tracking applications, an object other than the user device is being tracked. In positioning applications, it is the user device which is being tracked. [9] In any case, location of the user needs to be accurately obtained so that service can be correctly provided. Different positioning techniques have been invented for the purpose. A survey of popular techniques is described in [8].

2 The Argument

Most of the techniques mentioned in [8] give meter level accuracy. By meter level accuracy, we mean that the error in position is of the order of meters. It is hard to improve the accuracy of general purpose location systems without considerable costs. For example, a simple GPS (Global Positioning System) uses 3 out of 24 GPS satellites in orbit to position itself. This gives position with error of less than 6 m in the horizontal direction and less than 12 m in the vertical direction. [10] If the accuracy has to improved further, we need to use Differential GPS receivers which are costly. Typical cost of differential GPS receiver to normal GPS receiver is 20:1. (source: http://www.gpsw.co.uk/)

Two techniques mentioned in the paper [8] give centimeter and even millimeter level accuracy, however those techniques are suitable only for finding out the physical location in a localized space (e.g. a room).

Before we decide whether location accuracy of the services be improved we must first ask whether this improvement is necessary. Most of the services are known to use location information at the granularity of a block, a building or a room at the least. This means that meter level accuracy is sufficient for most applications. The controversy therefore is: should research be directed towards improving location systems? Also, if a company decides to launch a location based service, should it design the system for centimeter level accuracy ? Should the infrastructure be such that centimeter level accuracy be obtained? This is an important question since this infrastructure might be used for many years to come and we should avoid the situation where we need centimeter level accuracy and the infrastructure only allows meter level accuracy.

Researchers improving locations systems say that accuracy should be improved. People working in the industry on location based services however considers centimeter level accuracy to be unnecessary. Visionaries are divided on this topic, since they consider different kind of location based services to be implemented in the future. Some applications may need high accuracy while other may not.

We claim that centimeter level accuracy is not necessary for Location Based Services.

3 Counter-Position

There are two arguments in favor of improving accuracy of location systems. The first argument is that higher accuracy is always better. Secondly, if we attain centimeter level accuracy in location systems, we can track small items or find location of objects in a small space. For example, we could detect in which box (of the 1000 boxes present), a particular item is placed.

The reason for the first argument is quite obvious. If we are able to position objects with centimeter level accuracy, we can give better error bounds on the services which use these positions.

The second argument is based on futuristic application of location systems. As [11] suggests, computers will soon be absorbed into the fabric of everyday life. Weiser gives the example of electronic tabs in library catalogs which automatically locates books whether they be lying in their shelves or on tables. Since books are quite small, they should be located with high accuracy. He also gives the example of a self-locating manual and a foreview system helpful for finding parking space. All these applications seem to require highly accurate location.

The first argument can be easily refuted. If we can show that location based services do not really use the current meter level numerical accuracy provided, we can easily prove that higher accuracy is useless. The second argument would require a careful analysis of future applications and how they would be using location information.

Section 4 describes typical categories of applications and the normal accuracy required for each one of them. We also discuss whether some applications which are traditionally considered to be Location based services should not actually be considered Location Based Services by definition. Section 5 describes what type of location information is needed by location based services. Section 6 explains how location context can be derived without actually knowing the position. Section 7 deals with privacy issues involved in giving high location accuracy. All these sections would clarify why we consider centimeter level accuracy as unnecessary.

4 Typical Location Based Services and their Accuracy Requirements

[4] describes the following application classes.

1. Information Services
   (a) B2C (Business to Consumer) service: Business "pushes" information to the consumer. eg:- advertising
   (b) C2B (Consumer to Business) service: Consumer "pulls" information from the Business. eg:- resource location, weather, traffic
   (c) C2C (Consumer to Consumer) service: Consumer wishes to locate or talk with another consumer. eg:- best meeting spot, instant messaging
2. Emergency Services
   E911 calls (firefighters, medical teams), roadside assistance for drivers
3. Tracking Services
   Fleet tracking, human tracking, etc

The paper states that cell-id, OTDOA (Observed Time Difference of Arrival), AGPS are positioning technologies in use for these applications (in the mobile phone world). Cell-Id provides accuracy between 300 m and 10 km. OTDOA would give accuracy of around 30 m, while AGPS gives accuracy of around 5 m.

Information services need location information at the level provided by cell-id or cell-id++. Traffic, navigation and assistance require better location accuracy hence they use OTDOA or AGPS. This means that positioning type applications (information services) require lower accuracy than tracking applications (traffic, navigation and assistance).

Navigation is considered to be tracking application inspite of the fact that it is the user who is being tracked (positioning). This is because the user directly uses the position information as if he is tracking some object.

At the moment, tracking requires only meter level accuracy. Sooner or later, as wireless devices become ubiquitous, we would like to track small objects. This would probably need centimeter level accuracy. However the real question is whether tracking applications can be considered as location based services.

Location Based Services are services that exploit knowledge about where an information device user is located. [1] According to this definition, we cannot consider tracking applications to be a 'strict' location based service. This is because in tracking objects, we want the position of the object rather than the position of the user.

Inspite of the definition, we find that tracking has become a valid location based service (by use). We cannot just discard it. We can however show that physical location (in case of positioning or tracking application) is of little importance.

5 Symbolic Location

Most location systems give the position of various devices in absolute or relative cartesian coordinate system. Such a system would allow location to be expressed in terms of (x, y, z) coordinates. There is another system in which locations can be expressed, it is known as symbolic location system. [8] Symbolic location involves semantic knowledge of the surroundings. For example, we might want to know whether a user is near a printer, is in a room, in the building, etc. We can clearly see that cartesian coordinates are not useful for this purpose. The cartesian coordinates must be converted to symbolic locations.

Symbolic locations are more important than physical locations since the human user can easily understand them. Also, symbolic locations give a better idea of the context in which the user is operating than physical location. For example, the fact that user is at (40.4N, -74.5E) will not be useful until it is converted into the fact that the user is in Rutgers University.

[7] explains in his paper that space is of less importance than place. The behavior of humans is intimately tied to the concept of place. A human will not behave the same manner at home as he does in the office. A human has different behavior at a funeral as compared to a marriage party. If place determines behavior, it is reasonable to expect that humans will expect location based services to based on places rather than unqualified space. A symbolic location is a computer representation of a place while a physical location is the computer representation of space. Therefore, location based services should be based on symbolic location rather than physical location

Processing on symbolic location is easier than cartesian coordinates. This is because containment, correlations, etc can be easily deduced without much processing. [2] discusses how symbolic locations can be used to predict user movement patterns using learning algorithms.

[3] discusses a schema for representing symbolic information of objects. The space is tagged with friendly names using the table as shown in table 1. Type gives description of the space. A space can be divided up into subspaces as shown in table 2. Every device is considered as an atom. Presence of atom in a space is given by table 3.

Space-id	Friendly-name	Type

Table 1: Space scheme

Space-id of superspace	Space-id of subspace

Table 2: Containment schema

Space-id	atom-id

Table 3: Atom Presence schema

Position of objects can be easily found by finding out associated atoms and the space they occupy. We can therefore see a hierarchy of spaces being created. Similar concepts are discussed in [9]. The paper discusses an architecture for location based services. The architecture is as shown in the figure 1.

The reception layer removes sensor id information from physical location and associated physical location with objects instead. The abstraction layer converts physical location into symbolic locations. The fusion layer combines different readings for the same object to improve accuracy and to develop a multiresolution view of the object's space.

These papers clearly demonstrate how physical location can be converted to symbolic location.

We must now discuss whether symbolic location can be deduced from meter level accuracy. Let us consider positioning and tracking applications. In positioning application, it is the user (mostly human) who is being tracked. Symbolic locations of importance to humans are mostly of huge

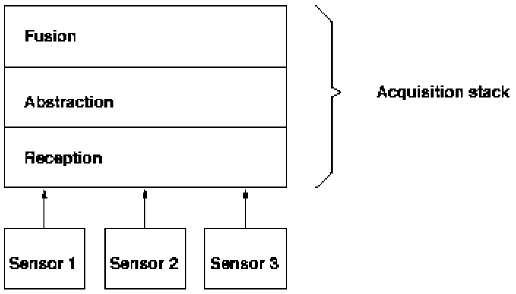

Figure 1: Processing Layers of a typical Location Based System

dimensions. Examples being rooms, buildings, blocks, etc. In tracking application, the device being tracked may be small or large. Also, the symbolic location relevant to the device may be minute or large.

For example, we might want to find in which box (meter dimensions) a particular item is located. Also, in certain cases, we might want to position the user with greater accuracy. (like in front of the computer monitor, on the sofa, etc). In such cases, we might need better positioning accuracy. The next section however shows that claim to be false.

6 Location Context without Positioning

The symbolic location of an object can be found by obtaining latitude and longitude of the object location and converting it into symbolic location using a symbolic location database. Such a database contains information about static objects and their locations. So if a room is located with (0,0,0), (0,5,5) and (5,5,5) as its corners and this information is stored in the database, we can conclude that an object located at (3,3,3) is in that room. We have given a simple example, but the operations perfomed can get complex and it would get increasing difficult to do this for a large number of devices.

Let us go back to the example of a book locator given in section 3. [11] There could be millions of books in a library. If the catalog (online / offline) has to locate all these books using an accurate location system, there may be a serious scalability issue involved. There could be too many transmissions and too many conversions from cartesian to symbolic locations. On certain busy days (e.g. just before the exam), the library could be a busy place and this system would just fail. The main problem here is that we are trying to locate the cartesian coordinates of the book. If we could use sensors to give the symbolic location directly we will avoid this information explosion.

A good solution to this problem can be found in [5]. The paper says that resources can be discovered through direct sensing (infra read beacons). In this case no positioning is being done; infrared transmission just tells that the transmitter and receiver are close together. In addition if transmitter sends its id through infrared transmission, the receiver can know which device is nearby.

In case of the library, the shelves and the tables could be equiped with receivers which could locate the books by “seeing” infrared transmissions from the book. We thus have no location processing to do. Observation of the infrared transmission gives the symbolic location of the book.

Normally if high location accuracy is needed, it is because we need to determine whether some object is present in some small space. We could then set up proximity sensors in the way mentioned above to localize the object in the small space. The small space that we mention could be of the order of meters. If we wanted to calculate the physical (GPS) location and find out whether the object is in that space, we would need centimeter level accuracy. However using proximity sensors we do away with location calculation, so effectively we do not need centimeter level accuracy.

Thus, the only case where we need high accuracy is if we want to find out if some object is present in a small space (meter dimensions) and no proximity sensor is available, then some positioning technique is needed. We could not find any application which needed such information. Such high accuracy positioning seems unnecessary because in a large space, high accuracy seems useless. For example, in the context of a country, it is considered good accuracy to locate a user in a particular city. In the context of a city, it is considered good accuracy to locate the user in a particular locality and so on. The point is that accuracy should be proportional to the size of the space being searched. If the space is large, high accuracy is useless.

As a side issue, we discuss whether mobile users would like themselves to be tracked at a very high accuracy.

7 Privacy of users

It may not be a good idea to give centimeter level accuracy of user location since it may involve privacy issues. As an example, consider two person wearing mobile trackable devices entering a restaurant. If we are able to track their location upto centimeter level accuracy and found that they spent quite some time close to each other, we could probably infer that they met. Those two people might wish that others do not know about the meeting. Using tracking systems, the whole world can find out they met. One way of avoiding this problem is to provide low location accuracy.

Other ways of avoiding this problem is to restrict access of this information through the use of cryptography and data distribution on a need to know basis. However, considering the conspiracy theoretic arguments that have sprung up around simple issues, we could have a situation where in the people may not trust the government and the industry on this issue leading to laws preventing high accuracy in location based services.

8 Conclusion

As we have shown in the paper, centimeter level accuracy is unnecessary for location based services. This has far reaching consequences on the design of location based services. Differential GPS devices will be not needed for any location based service thus cutting down on cost.

In addition, we propose that any location based service should keep track of symbolic locations rather than physical location. This would mean that physical locations would have to be converted to symbolic locations or the symbolic location would have to be obtained directly from the sensors. Techniques mentioned in [8] giving centimeter level accuracy for local positioning are thus not needed.

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