Tracker: Indoor Positioning for the LOK8 Project

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Abstract

Spatial awareness is identified as a key feature of today’s mobile devices. While outdoor navigation has been accessible and broadly used for some time already with the help of GPS, indoor positioning has not yet made it into mainstream life. GPS and other GNSS systems offer accuracy of a scale different to that required for efficient indoor navigation. This research aims to investigate how a number of sensors such as a Digital Compass, Bluetooth and Accelerometer may be combined to calculate device position and orientation to perform directional querying in a spatial database. These three technologies were chosen because they appear in some mobile devices available today and are likely to become even more widespread in the nearest future.

Keywords: indoor positioning, directional querying, location based services

1 LOK8 Project Overview

The LOK8 (locate) project is funded by Strand III and its goal is to create a new and innovative approach to human-computer interactions. With LOK8 a person will be able to engage in meaningful interaction with a computer interface in a much more natural and intuitive way than we are used to. A virtual character (Avatar) will be displayed in numerous locations depending on the user’s position and context. Users will be able to communicate with this virtual character through speech and gestural input/output, which will be processed and controlled by the dialog management component. This will allow “face-to-face” interactions with the LOK8 system. The LOK8 system will deliver content to the user in a variety of context-specific ways with the aim of tailoring content to suit the user’s needs. In addition to screens and projectors displaying the avatar, the user’s mobile device, as well as speakers within the environment, will be used to deliver focus-independent content. Ultimately the goal is to replace a human-computer interface with a human-“virtual human” interface.

2 Tracker Overview

Tracker module is one of the key components in the LOK8 system. It lets the rest of the system have access both to information about the current user’s position and his surroundings. Together these make the system spatially aware. Tracker consists of 3 components. Positioning component attempts to track the user’s location throughout the program’s runtime using hardware both on the phone and other parts of the LOK8 system. Environment Model stores information about the shape and size of the rooms as well as the locations and properties of objects in them. Finally Spatial Querying combines the two and allows the user to point his phone at any registered object and the premises and find out what it is. This poster for the 9th IT&T conference summarizes the work presented at 6th International Symposium on LBS & TeleCartography [1].
3 Related Work

There are a number of locationing services that operate on a larger (outdoor) scale. First of all there is GPS and GLONASS, which make use of trilaterating signals transmitted from satellites. These don’t work indoors very well and the average accuracy is found to be in the neighbourhood of 15 meters in urban environments [2]. Then there’s Assisted GPS (A-GPS) which improves the startup “fix” time and accuracy in urban environments by accessing some rough positioning of visible satellite information (ephemeris data) through GPRS. Cell tower triangulation is also an emerging service. Its reported accuracy however is between 50 and 300 meters depending on atmospheric conditions and tower dispersion geometry [3].

Another approach is to read MAC addresses and associated signal strengths of all currently accessible WiFi access points and calculate position through trilateration. This service is currently offered commercially by Navizon and Skyhook bundled with cell tower triangulation and optionally GPS [3,4]. Their services are designed to either replace GPS, for example on mobile devices without GPS receivers, or enhance its accuracy in urban environments. However the resulting accuracy is still roughly in the 10-20 meter range.

Among locationing systems currently published, there are some that achieve a much higher level of accuracy using specialised client-side hardware. The Bat and The Cricket both use ultrasound, for example, to measure distance to receivers placed on the ceiling in a grid, but do so in different ways [5,6]. In case of the Bat transmitter, the device transmits a short ultrasound pulse, the time-of-flight from the transmitter to receivers mounted at known positions is measured. Because the speed of sound in the air is known, distance to each of these transmitters can be calculated and then used to calculate the exact position of the transmitting device using trilateration.

4 Positioning

To allow Spatial Querying the system has to be aware both of the location of the phone and it’s orientation.

It is possible to determine which direction a mobile phone is pointing if the following angular/spatial variables are gathered in real time: pitch angle, yaw angle and x,y,z coordinates. Pitch is an angle of rotation in the vertical plane (i.e. an angle in the up and down direction) and can be measured either from the Zenith (up) position downwards or from the Nadir (down) position upwards. (Figure 1)

Two of the three variables can be registered by accelerometers, which are becoming ever more present in modern mobile devices. Unfortunately accelerometers can’t determine yaw – rotation in the horizontal plane (i.e. an angle in left and right direction) usually measured as a compass bearing or the azimuth from North. However, yaw angle can be read from a digital compass.

The device's position in space will be determined through trilateration. A lot of care has to be taken into account for any unwanted interference (e.g. walls, electrical interference, reflection, etc.) that can significantly degrade the original signal strength properties [7]. A Bluetooth beacon will be placed at the top corner of every room in the testbed environment. Other beacons will be placed in the corridors. It is proposed to implement this module as follows. (Figure 2)

1. First we determine in which room the mobile phone is right now. The easiest way to do that is to assume the user is in the same room as the closest beacon.
2. Signal strength and Bit Error rate are recorded for the other beacons in the same room. Signals from beacons that are in other rooms are easily identified and ignored as they are greatly influenced by walls.
3. A trilateration procedure is used to calculate device position relative to the known positions of fixed beacons.
4. The local position in the room is then converted to the relative position in the premises.
5. Parallel to Bluetooth positioning, accelerometers will work in both movement and rotation modes to track a user’s movements. If successful this technique will be similar to dead reckoning, and can be used in a number of ways.

5 Environment Model

There will be a central spatial database accessible through Bluetooth. There will be an entry in the database for each beacon’s ID, xyz position, and distance to other beacons in the same room, along with the room ID. At some point, attributes of objects (e.g. desks, posters, paintings) will be added to the dataset as well. These various objects will carry position, dimensions and description attributes (e.g. whose desk it is, what poster is it, whose office is it).

6 Spatial Querying

After an accurate position and orientation have been determined, it is possible to find out which object, if any, the phone is pointing at. This will only be done when the user presses a button associated with querying. We will assume that the phone in this case is used in the same way as a television remote control – e.g., the top end of the phone points in the direction of the object of interest. Once the query parameters have been captured and the query processed, the phone will beep to let the user know a query result has been returned to the screen. If no object was identified a doublebeep will sound.

Identifying an object in the room could be done through ray-box collision detection in 3D space. This can be achieved either externally using existing ray-box collision detection algorithms or inside the spatial database itself, if it supports such ray intersection queries in 3D [8].

7 Current Work

Currently all four LOK8 modules are collaborating on setting up the “Wizard of Oz” test environment. This should let us simulate the surface functions of the system and then record and analyze user’s interaction with it. The results of analysis will be used to improve the interface and see how the setup makes the user experience different, or what improvements/drawbacks it presents. In respect to the Tracker module it will be useful to see what level of accuracy the user expects or can tolerate, as well as how exactly the user makes queries or does other interactions using the phone. A detailed description of the setup can be found in [9].

8 Conclusions

The focus of our upcoming work therefore involves experimenting with the Bluetooth, magnetometer, and accelerometer sensors on the phone. Sensor fusion research into finding the most responsive and
efficient combination of these three different sources of information about a device’s movement will be made, followed by creating a reliable locationing framework on which to build our Lok8 spatial query system. One idea is to use beacons in a different way by limiting their transmitting area with a form of Faraday cage. If beacons are positioned in such a way that their areas overlap, this will prove to be a reliable source of information as certain beacons can only be detected within certain areas of the room. Combining this with information gathered by the accelerometers, it may then be possible to achieve the higher locational accuracy we require for accurate indoor cellphone positioning for targeted 3D directional querying.

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References


Figure 2: Bluetooth beacon layout for the LOK8 environment.