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Hybrid Indoor Positioning and Directional Querying on a Ubiquitous Mobile Device

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Introduction

Spatial awareness is identified as a key feature of today's mobile devices. While outdoor navigation has been available and widely 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. Due to this and poor signal quality in urban environments, a lot of effort has been put into developing dedicated indoor locationing systems. However, many such systems use specialized hardware to calculate accurate device position, as readily available wireless protocols have so far not delivered accuracy close to what is desired. This research aims to investigate how a number of sensors such as a Digital Compass, Bluetooth, WiFi, and Accelerometer may be combined to calculate device position and orientation to perform directional querying in a spatial database. These four 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, spatial database

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.

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.

Positioning

Orientation

To allow Spatial Querying the system has to be aware both of the location of the phone and it's orientation. Accelerometers and the compass are primarily used for the latter.

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)

Gyroscopes or accelerometers can register and present this variable. Although gyroscopes are known to be better at this task [1], they are not normally found in devices such as mobile phones and currently there is no trend that suggests that they will. Accelerometers, however, are becoming ever more popular, being used for example to automatically switch between portrait and landscape screen views on some devices currently

available today (e.g. HTC Diamond, iPhone, GPhone).

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 (magnetometer). Magnetometer sensors are not yet as widely available in most modern mobile phones as are accelerometers, although it is becoming more popular of late.

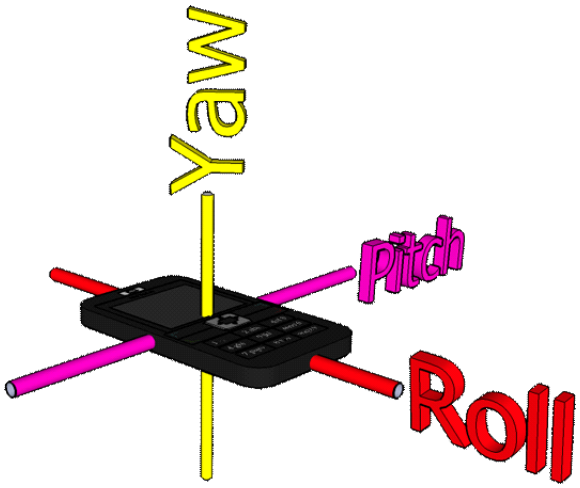

Figure 1: Roll, Yaw and Pitch axis.

Position

Finally there are the device positional coordinates in 3D space. These three variables show where the device is located relative to a particular origin point inside the building along the x, y and z axis. These measurements can only be taken indirectly by processing Bluetooth or WiFi properties such as signal strength in some sort of trilateration adjustment. Therefore, 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 [2]. Using specialized hardware could help significantly in this case, however that would seriously impede LOK8's scalability and ease of setup.

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. It may also be useful to take differences between ceiling height and a device's position into account.
4. The local position in the room is then converted to the relative position in the premises and may be further converted to absolute coordinates in real-world space if required for seamless indoor/outdoor navigation and wayfinding.
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. First of all the program can generate a path the user has walked so far. When a user enters a room, the path can be checked against the layout of known obstacles stored in the database and help correct the user's current position. Also it can be used to determine which of the signals is blocked by the user and accordingly apply appropriate weights in the trilateration procedure. [3]

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).

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. [4]

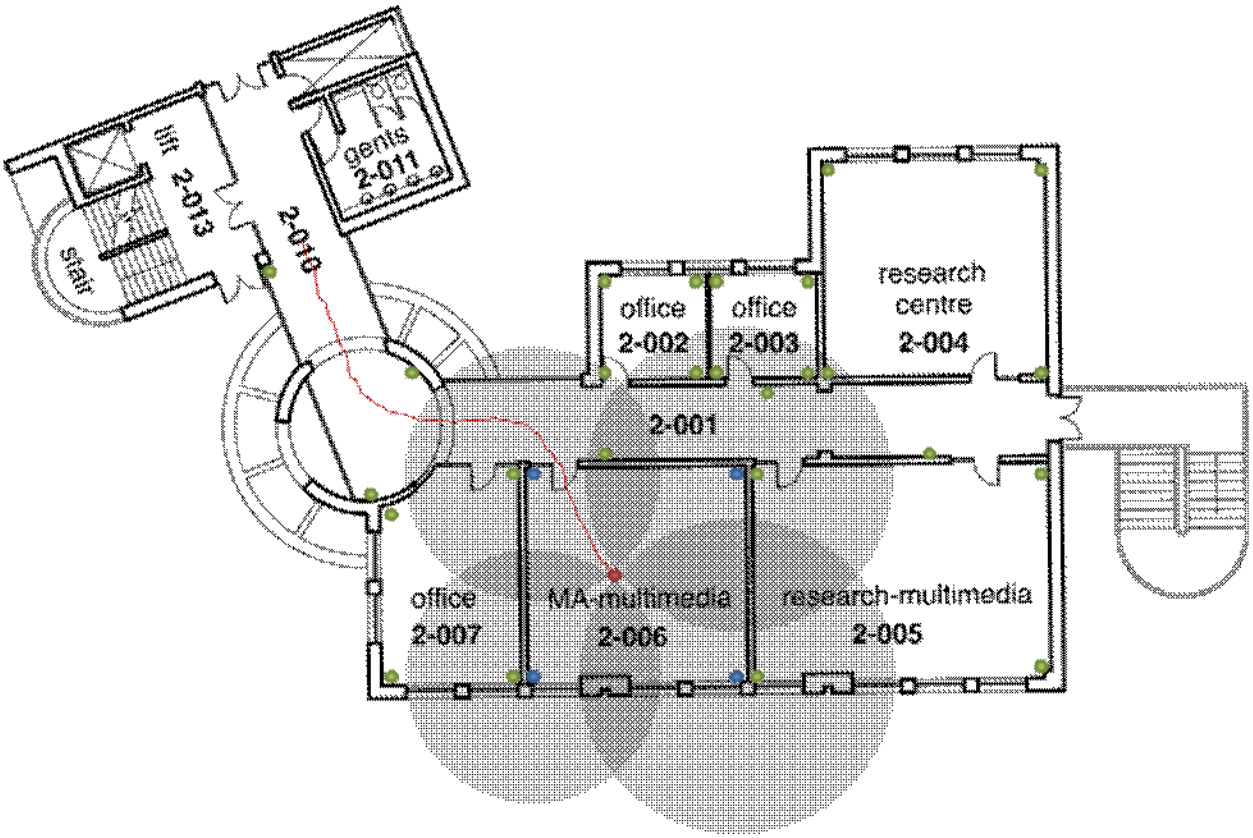

Figure 2: The red dot is user's location. Blue dots are beacons that are currently used for positioning. Green dots are other beacons. Red line is user's route as traced by the system.

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