User tracking as an alternative positioning technique for LBS

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Abstract

Different approaches are used for positioning of mobile users and all of them have advantages and disadvantages. The Global Positioning System (GPS) offers the easiest and most accurate 3D positioning of the user but it is not operational indoors. The positioning within mobile networks (using only the information related to the base network transmitter) could be made available everywhere but it is rather inaccurate. Still, there are many situations when the position of the mobile client cannot be detected with the needed accuracy and within an acceptable waiting time.

This paper investigates a user tracking (more specifically optical tracking) as an alternative approach for establishing locations. The tracking system utilised within the outdoor AR reality system (i.e. UbiCom project) is discussed and new ideas for users tracking for LBS are presented. The ideas are motivated by and linked to the OpenGIS Consortium (OGC) specifications for Location Services and related OGC specifications for Web Services.

1 Introduction

Many systems already exist that offer Location Based Services (LBS) with a variety of services (from only visualisation and navigation to update of information) for different applications. All of them however rely on GPS positioning. Currently OGC is developing OpenGIS Location Services (OpenLS) specifications (in stage of collecting comments).

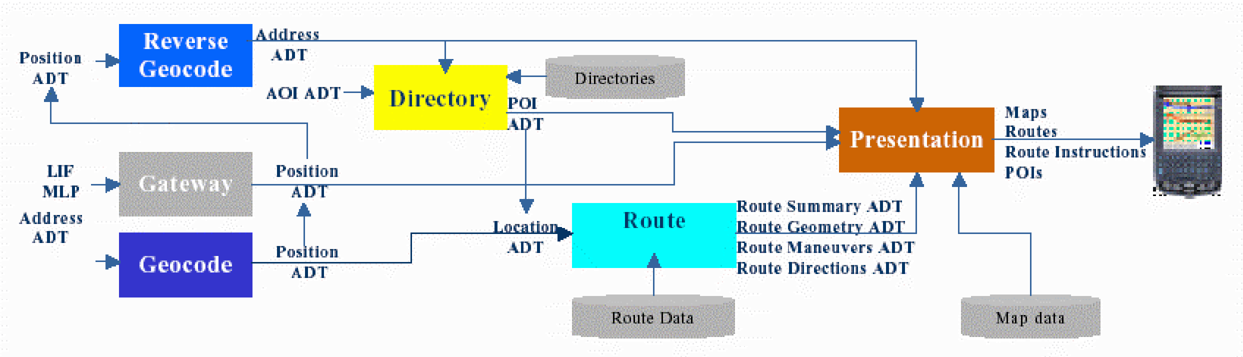

Figure 1: Services and data types supported by GeoMobility server (OpenLS)

OpenLS specifications (OpenGIS Specifications, 2003) aim at defining the mechanism a mobile user is served by a GeoMobility Server. To date OpenLS has six core services, i.e. Gateway (access to servers to get position), Directory (access to information related to restaurants, cinemas, and other Points of Interest), Geocode (conversion from address to co-ordinates), Reverse Geocode, Route (commutation of route) and Presentation (in case of maps the service should provide images) (Figure 1). The services are intended for all classes of mobile devices. The request should contain the type of the user device (according to a list with well-known devices) and a number of parameters specifying the range and type of requested information.

As it can be realised, the possibilities for introducing a position are *automatically* (using mobile networks via the Gateway Service) and *manually*, by providing address/co-ordinates. A sensible question is whether such a mechanism is sufficient. Unfortunately all approaches have drawbacks.

Mobile networks (GSM, GPRS, UTMS) are available everywhere but the positioning accuracy is rather low (100m and more). It may even occur that a mobile phone (e.g. on last floors of a high building) is connected to a transmitter in a cell different from the cell the mobile unit is located (thus the accuracy may go down to kilometres). Some solutions to increase the accuracy of mobile networks already exist (e.g. *Cell Global Identity* and *Time Advance Positioning Method (CGI-TA)*). The mobile client is located within a network cell with the help of supplementary information (e.g. postal code information, street, town names). The accuracy is further improved by using the time taken by the signal to reach the mobile device. Still, due to lack of directional information, the user could be located anywhere in a circular band (or a section of a circular band) around the base station. Thus, the uncertainty remains.

Standard *GPS positioning* provides the highest accuracy (1-10m). In addition, GPS receivers are getting rapidly portable (GPS chips are implemented in handheld devices), cheaper and convenient for general use. However three general problems can be distinguished:

- Disturbed satellite availability due urban canyons in cities or in forest areas. It is expected that it will be significantly improved after the European System for global positioning Galileo becomes operational. More information and several interesting examples can be found in (Verbree et al, 2004).
- Non-operability indoors.
- User authorisation is required for sending automatically the co-ordinates to the GeoMobility Server.

Hybrid solutions attempt to overcome individual problems of GPS and mobile networks by providing satellite data (e.g. the almanac) and thus speeding up the initialisation.

The *address specification* is theoretically very attractive (suppose clear indications of street names and street numbers are available), but practically it might be very inaccurate. Two major factors play a role:

- The accuracy (scale) of the base map used for implementation of the Geocode service.
- The approximation used to link street numbers and corresponding co-ordinates. The geo-coding is usually linked to the street. Very often (especially in central areas) one street number corresponds to a complex of buildings (with different shapes). The user might be inside the complex, but he/she will be located as being on the street.

Apparently, global positioning approaches are still not at a level to locate the user always, everywhere with an acceptable accuracy. In this paper we concentrate on a relative positioning of the user. We believe user tracking can be seen as a supplementary to global positioning techniques, which will provide data about the movement of the user when global approaches fail. Motivation we find in fast developments mobile technology toward minimisation, standardisation, improved speed and resolution.

2 Relative positioning

Relative positioning can be defined as process of evaluating the location and orientation (direction of movement) by integrating information provided by diverse sensors. The integration starts in a certain moment at an initial position and is continuously updated, i.e. the movement of the user is continuously tracked. An advantage of such a relative localisation is that tracking can be done relative to some object the application is interested in, for instance the location where GPS positioning fails.

Relative tracking has been initiated indoors with the goal to provide high accuracy tracking of human body (e.g. head, hand, full-body) basically for Augmented Reality (AR) systems. A plenty of research (Hit Lab, 1997) employing a variety of sensing technologies (*mechanical*, *magnetic*, *acoustic*, *optical, radio*) deals with motion tracking and registration as each technology has strengths and weaknesses. Existing systems can be grouped into two categories: *active-target*, and *passive-target*. Active-target systems incorporate signal emitters, sensors, and/or landmarks placed in prepared and calibrated environments. Passive-target systems are completely self-contained, registering naturally occurring signals or physical phenomena. Examples include compasses sensing the Earth's magnetic field, inertial sensors measuring linear acceleration and angular motion, and vision systems sensing natural scene features. Most of the outdoor tracking is based on a sort of passive-target systems utilising vision (Azuma, 1997). Vision methods can estimate camera position (thus user position) directly from the same imagery observed by the user. But vision systems suffer from a lack of robustness and high computational expense.

Unfortunately, all tracking sensors used in passive-target systems have limitations. For example, poor lighting disturbs vision systems, close distance to ferrous material distorts magnetic measurements, inertial sensors have noise and calibration error, resulting in a position and orientation drift. Hybrid systems attempt to compensate for the shortcomings of a single technology by using multiple sensor types. Among all other approaches, the most common is passive-target magnetic combined with a vision system because:

- Inertial gyroscope data can increase the computing efficiency of a vision system by providing a relative frame-to-frame estimate of camera orientation.
- A vision system can correct for the accumulated drift of an inertial system.

2 UbiCom tracking system

The general idea of the UbiCom project was developing of AR system helping urban planning and maintenance by visualising newly designed objects (buildings, statues, etc) and/or providing information about objects (pipe lines, electrical cables, cadastral boundaries), which are not visible in real world. The tracking system used for the AR project UbiCom (UbiCom, 2003) is a typical example of a hybrid magnetic-inertial-vision system. One of the main goals for the UbiCom position tracking system was a centimetre range accuracy and 2ms latency. The initial investigations on inertial tracking and GPS positioning have shown rather large drift violating the required accuracy. The main job of the additional vision system was to resolve this drift problem.

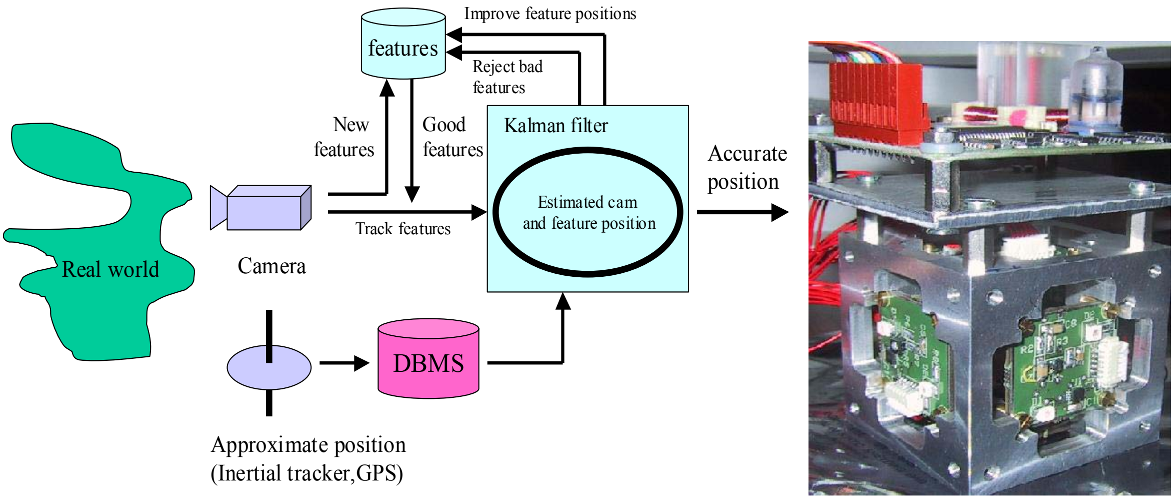

Figure 2: Set-up of the UbiCom tracking system and the inertial cube (in-house development)

Figure 2 shows a very general schema of our AR tracking system. It consists of a GPS receiver (to determine initial location), an inertial cube (to determine orientation and acceleration) and a camera (for the vision system) (Persa and Jonker 1999). This equipment is a part of the mobile unit. On a backbone, a 3D model of the test area was available and organised in DBMS. We concentrated on DBMS organisation to simulate maximally real-world situations, where geo-information is stored in GIS/DBMS software. The system operates as follows:

- An initial position and orientation are provided by the GPS receiver and the inertial cube
- The data (x,y,z, direction of view, Field of View) is sent to the database containing a 3D model of the area.
- 3D subset of the model (within the Field of View) is extracted and send to the processing unit (on a backbone).
- Simultaneously images from the video camera are also provided to the processing unit.
- Matching database data with video data is performed, which results in computing шге accurate position of the userл
- The measurements of the inertial system are used to compute positions for a certain period of time (determined on the basis of drift evaluation).
- On the basis of a current position and a direction of movement, a new set of 3D data is extracted and matched with features on images from the video camera.

The core of our tracking system is matching features extracted from the video camera with features extracted from the 3D model. In our case we have used line matching, i.e. 2D match of lines (edges) detected on the image and lines stored in the database. The lines in the database are organised in a model, specially designed for the purpose, consisting of outlines of real-world objects and loose lines on facades of buildings. To be able to distinguish between large amount of loose lines, they are grouped according to a criterion ‘belonging to a particular façade’. Prior retrieving lines, invisible facades are excluded from the set, which means the corresponding lines are also not considered. Thus the number of lines to be selected is significantly reduced and corresponds in certain degree to the lines that might appear in the video images.

The approach looks promising, but we have encountered a lot of problems, basically due to the high requirements for AR systems. Among all, the matching procedure is most interesting for the scope of this paper.

The line matching procedure contributed poorly to the positioning, because features detected on the video images were rather different from the lines stored in the database:

- The images used for both data sets were different in terms of resolution and time of the day (year). The images used to extract 3D lines and populate the database were taken once, at the beginning of the project.
- The line extraction algorithms were different. The 3D lines stored in the database were extracted from a sequence of high-resolution images applying several filters to reduce amount of features not part of facades (threes, cars, shadows). The edge detection algorithm was based on line-growing algorithm (Zlatanova and Heuvel, 2002). The edge detection algorithm used on the video images was based on Hough transform of the image, because the performance of the line-growing algorithm was unsatisfactory.

3 Tracking systems for LBS

The requirements for LBS are very similar but (in most of the cases) not as strict as for an AR system. Similarly to an outdoor AR system, a LBS tracking system will be based on passive-target approaches (since in general case prepared environments do not exist) and LBS will need access to geo-data. However, the LBS tracking system should not necessarily provide an accuracy of few centimetres and the response time can be several seconds (instead of ms).

The system architecture aimed at the UbiCom project can be applied for LBS in three variants (depending on the hardware) as a hybrid system (using inertial tracker and accelerator), as a pure vision system or using only a tracker.

Figure 3: HP PhotoSmart camera 1.3Mb and Xsense motion inertial tracker

3.1 Hybrid system

The components needed for a hybrid tracking system will be a telephone cell, camera, inertial tracker and GPS receiver. Nowadays different combinations of mobile devices can be used, e.g. a telephone with integrated camera, PDA with a camera, PDA with GPS, etc. Numerous add-on devices are also available. For example, HP PhotoSmart camera has resolution 1.3MP, Xsense (inertial trackers) has developed a 3D motion input device for PocketPC (P3C) (Figure 3).

The proposed user tracking can be summarised as follows:

- 'Lost satellite reception' is used as a trigger to initiate tracking. The direction of the user and the speed are being registered and the position is computed for a certain period of time.

- The user is connected to a Gateway and the last available co-ordinates (and/or the direction) are sent to the database to extract a portion of the 3D model.
- The user is prompted to take an image from the direction of movement.
- The image is sent to the processing unit to perform matching and compute a refinement of the current position.
- The position is send back to the mobile unit.
- Depending on the drift of the inertial system, the above two steps are repeated regularly until necessary.

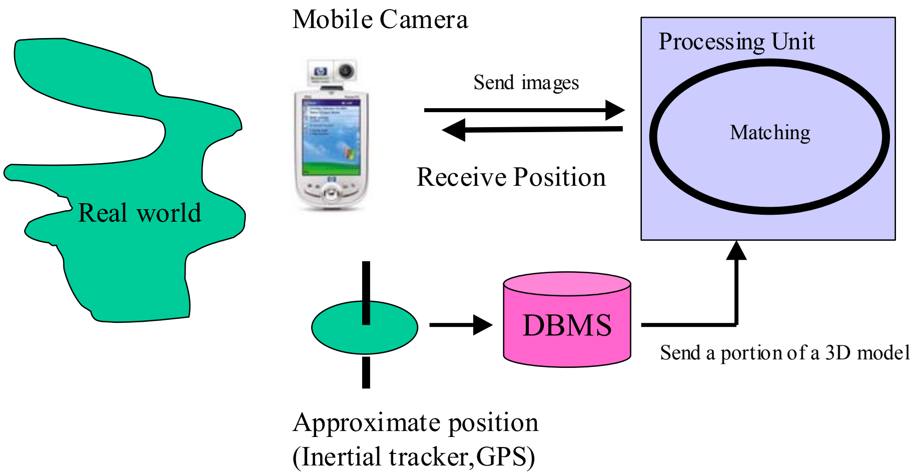

Figure 4: LBS hybrid tracking system: inertial tracker + vision system

In this set-up the most important aspect is matching reality with a predefined model. We expect better performance in this set-up compare to the one in the AR system, because the two major obstacles mentioned above can be avoided. The image resolution sent by the user can be better than the resolution of video camera. Furthermore, if the match fails the user can be prompted to take a new image. If line matching is applied, one line extraction algorithm can be applied for both images coming from the mobile user, and images used to create the 3D model. In case of 3D textured models, it is possible to compare images, e.g. a colour image obtained from the camera 3D perspective image from the model (created with WTS, see Section 4). This approach is expected to accelerate the matching procedure although different lighting and weather condition may introduce uncertainties (see Section 3.2).

A special thought about that approach could be taking images of well-known features like brand names and other commercial expressions. If the user specifies enough information on what he or she is looking at, the processing unit should be able to limit the possible locations of the user. A picture of an ATM indicates the user is very close to that feature. This idea could also be applied when image matching is too complicated to establish. One can think of an application at the handheld that tries to identify the location of the user by requesting clear identifications of what the user looks at in the real world.

3.2 Vision System

A second approach can be realised without using an inertial system. The inertial system can be substituted with tracking features on the images obtained from the mobile camera. The feature tracking can introduce certain drift as well, and most probably after a given period of time a request for a 3D model still will be necessary.

- On 'lost satellite reception', tracking is initiated by sending the last available co-ordinates to the database to extract a portion of the 3D model.
- The user is prompted to take an image. The image is sent to the processing unit to perform matching. In this case, besides the position of the user, appropriate features from the images (which are going to be used for tracking) have to be coordinated.
- On regular basis, a sequence of images is taken, features are tracked and the position is computed.
- The above two steps are repeated until necessary.

The disadvantage of this approach is that the user has to be asked to take images more often than in the previous case. Too many images will increase power consumption and may reduce the real operable time of the mobile unit.

The major issue in this approach is the type of features that can be tracked. Supposed a fast algorithm is selected, feature tracking can be performed on the mobile unit. Several different features can be used (Pasman et al, 2001 for more details) namely *templates*, *point*, *lines*, *corners*, *colour* and combinations of them. *Template tracking* is tracking a position based on a piece of real-world scenery. Templates are small image patches that can be followed over a range of camera positions. Reliable templates can be extracted automatically and their position can also be estimated automatically. Template tracking has shown accuracy better than 1 cm if nearby (1 m) features are visible (Davidson 1999). Such systems can work even when less than three features are in view. *Corners* (e.g. crossings of lines, or gradient and curvature measurements) are considered very appropriate features for fast detection and processing (You et al 1999). *Colour* might be a powerful means to enhance tracking robustness. Colour tracking is still not very well explored, perhaps due to the fact that colours are highly invariant when lighting conditions change.

3.3 Tracking without vision system

Having in mind fast technology developments, developers might be able to remove completely the drift of inertial systems and accelerometers in a very short time. Vendors already report devices without drift (e.g. inertial system of Xsense). More extensive market study may reveal existence of devices that can be easily combined in a working driftless solution. This practically will allow tracking without need for a drift correction and therefore matching with a 3D model will be either redundant or very occasional.

4 Realisation of user tracking for LBS

Last but not least is how tracking process will be integrated with the concepts of OGC and some other initiatives for interoperability. In the view of harmonisation and documenting of available datasets and providing common access to spatial data (e.g. INSPIRE, 2003), LBS also have to make use of existing data (as they are organised in different software and located on different servers). Technically, a user tracking as it is described above can be realised with the help of OGC Web services. Figure 5 shows a *Tracking server* that consists of Tracking portal, Data processing unit and Data discovery unit.

The Tracking portal has to ensure the communication between a mobile device and the Data processing unit. A Data discovery service has to be able to locate appropriate data and fetch portions of a 3D model. Currently, Web Feature Service (WFS) and Web Terrain Service (WTS) are the two OGC web services (OpenGIS Specifications, 2003) that can be utilised to get the data over the Web. Implementations of these services are already on the market (e.g. IONIC, 2003).

WFS is a ‘geometry service’, i.e. it returns geometries described in GML. The Web Feature Server supports GetCapabilities (what kind of services are available), DescripeFeatureType (data schema), GetFeature (selection of geometries) Transaction (edit, delete, add feature) and LockFeature (locking feature when changing) operations. This service can be used to request objects in the area of interest in case of matching geometries (lines, points, corners). GML does not have limitations on dimension, thus 3D data can be exported.

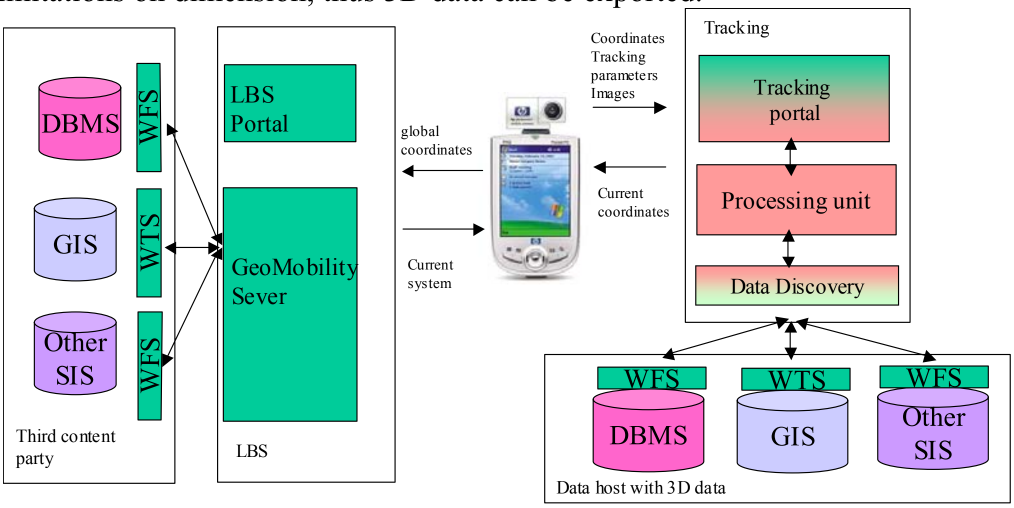

Figure 5: User tracking with respect to OpenGL and OGC Web Services

WTS is an ‘image service’, i.e. WTS specification (in status ’Request for comment’) defines a standard interface for requesting three-dimensional scenes. This service has to be used in case of matching images (template, colour). The WT Server is expected to support two operations GetCapabilities and GetView. The view or a ‘3D scene’ is defined as a 2D projection of three-dimensional features into a viewing plane. To be able to create this view, the server has to receive a list of parameters such as Point of Interest (x,y,z of user focus), Distance between the user and the POI, angle of View, etc.

Once the co-ordinates are obtained from the tracking module, they are forwarded to the mobile device for further use with the GeoMobility server. In this respect, the services of the GeoMobility server (as they are designed at the moment) do not require modifications. The GeoMobility server will obtain the global co-ordinates from the mobile unit.

5 Conclusions

In this paper we have presented our concept on tracking mobile users as an alternative positioning technique for LBS. We presented three passive-target approaches with and without a vision system. We consider relative tracking a very interesting and promising approach for locating mobile users in case of:

- Dense urban areas, where GPS positioning fails.
- 3D indoor navigation.
- Close spaces, such as tunnels, undergrounds, etc.

A very important requirement for tracking using a vision system is the existence of a 3D model. However, the model can bear much more simplifications compared to the model required for AR systems. For outdoor areas, the level of resolution used to create 3D city models is expected to be sufficient. This theoretically means, that there is no need to create a specialised 3D model. 3D indoor models can be obtained from construction companies. Topological structuring is not of particular interest since small discrepancies are not of importance, which means CAD models have to provide sufficient detail. Though, it should not be forgotten that 3D topology is desirable for 3D routing (Zlatanova and Verbree, 2003).

Tracking of the user will not require changes of the OpenLS specifications, i.e. tracking will be organised as a separate module complementary to the GeoMobility Server. Furthermore, the data required for user tracking can be obtained from different data hosts using OpenGIS Web services that will ensure flexibility and interoperability.

The concepts presented in this paper are still to be investigated. As mentioned before, could be that a user tracking system needs only an appropriate assembling of components. To be able to develop and implement an optical tracking system still many issues have to be addressed:

- Mobile GUI for requesting and sending images.
- Testing and selecting appropriate matching procedures.
- Investigating suitability of 3D CAD models of interiors for feature matching.
- 3D visualisation on mobile devices using OpenGIS Web Standards.

The possibility to track a mobile user indoors and outdoors will definitely increase the functionality and operability of LBS and can be a starting point for 3D LBS. The most challenging topics in 3D LBS are mechanisms for 3D geocoding and 3D routing (and the corresponding browser for 3D visualisation and navigation on the handheld).

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