Towards a Spatial Position Information Management System for Interactive Building Environments

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Abstract. Indoor localisation systems enable a variety of assistance services in commercial buildings and home environments. Applications in this area cover guidance, asset tracking, behaviour monitoring for smart assistance and alert systems, intelligent remote control, to name a few of them. It is desirable to employ a position information management system which collects, manages, offers and distributes such information. This paper focuses on how to design such a middleware which gathers position information from one or more localisation systems and provides this data to interested and authorised applications.

1 Introduction

Today there exists a variety of indoor localisation systems. Many of them allow the determination of spatial positions of persons or things, with system-dependent accuracy in the range of a few centimeters to some meters. The systems considered in this paper typically comprise objects whose positions shall be determined, and a fixed positioning infrastructure deployed in the indoor environment. The position of an object is typically calculated by determining ranges between the object and reference points given by the infrastructure, and/or determining angles between the object and reference points. For fundamental examples see [1,2,3,4,5,6,7,8,9]. In applications like goods tracking, robot control, navigation and logistics such systems are already marketed by several companies (references: [10,11,12,13]). Applications in the building and home automation sector are currently evolving. An obvious application is guidance in hospitals. Here patients receive a display device, for example a PDA. This device may visually and, if desired, also acoustically, guide a patient to destinations within the hospital and back to his room. Such systems may also be used in large scale office buildings. Also in this area lie the commonly used phone-like devices employed in museums or exhibitions, which provide location based explanation of exhibits.

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Another example are universal remote controls, which may be dedicated physical devices or which may be implemented in software on a mobile device of the user. Such devices allow access to control functionality based on the position of the device. A popular example is the control of equipment in a presentation room. Here the blinds, lightning, sound volume and the beamer may be controlled by a presenter (see for example [14] and references therein).

In private homes such systems are yet quite uncommon. A typical resident may actually not have a need for such a system, especially if it costs money. Today one application focus of localisation systems for private homes and retirement- or nursing homes is the sector of assistance systems, in particular the topic “AAL” (Ambient Assisted Living). Main applications are fall detection, object localisation and data provisioning for behavioural monitoring systems. Such systems increase the subjective and objective security sentiment since the system can alert someone if the inhabitant is in a situation where he/she needs help but is not able to actually perform the alert.

In a future scenario, where such systems are installed at numerous locations, it is predictable that further, not yet thought-off applications will be demanded. A monolithic application which includes a localisation system, data analysis and some reaction and/or presentation mechanisms will not easily allow use cases like inclusion of new types of sensors or integration of new applications. In this paper we discuss a structure for a position related information management system for interactive building environments. We do not focus on the localisation system itself since this is not part of the management system. We assume that the underlying localisation system(s) provides spatial positions of subjects/objects. Systems which deliver relative positions or other information which is not directly convertible to absolute spatial coordinates (with respect to a local reference frame) are not considered at this stage of the project.

A proof of concept implementation is presented: The demonstrator comprises a generic position information management system, which collects position information from underlying indoor localisation systems and offers services to clients which implement the actual applications. The system also manages static spatial information like floor maps and interaction points to allow the applications to identify position dependent services available at the current spatial context. On the application side, 2d- and 3d visualisation and interaction points are demonstrated.

2 Requirements

For an integrated position information management system for buildings, be it in the residential or in the commercial sector, we assume that at least the following data should be managed:

- Reference grid and building map: This includes information which can be used by clients for visualization of rooms and routes, and to relate positions of goods and persons for example to a room context given by area identifiers.

– Static objects. The static objects can be on one hand used for visualisation purposes, and on the other hand as tracking points, for example to enable applications like "alert if someone crosses line".
– Interactive objects - The interactive objects are static objects which are enriched with a so called "interaction point" functionality. An application may sense for interaction points in the vicinity of a person and then provide a position-related "action menu" to a user. For example, a user who uses a client on his mobile phone, may be presented a menu to switch the light on, call an elevator, or open a door, according to the spatial context of the user.
– Dynamic subjects/objects, whose position shall be observed. The position of these items will be tracked by underlying localisation systems. Dynamic subjects represent people who use a guidance application or which are tracked for security reasons. Dynamic objects are typically goods which are tracked for finding them or for which an alert shall be generated if they leave a specific region.

The above identified items shall be made available to interested and authorized applications by the management system. The list has been defined by analysis of the data needed for the functionalities given in the following list:

– Guidance
– Behavioural observation based alert applications
– Object finding
– Fall detection
– Position based control / remote control
– General location based services

These functionalities may be provided by dedicated client applications. According to the description given so far, the principal tasks of a spatial position information management system shall include at least:

– Sensor input for a variety of modalities. Some examples are: position information from localisation systems, position information from proximity-based detectors like movement detectors, pressure-sensor equipped floors and light barriers. The sensor input must be processed by an underlying localisation system to generate spatial coordinates of objects, which are collected by the actual management system.
– Data management: This includes recording, storing, retrieving and deletion of position data of dynamic subjects/objects, map-related spatial information, the map itself and static objects as well as data and bindings for action points.
– Application interfaces: There shall be interfaces which provide the above mentioned data to applications. The interface shall provide static data and shall allow subscription for the client to receive information on dynamic subjects/objects.
– Interaction interface: The system shall forward services provided by action points to the clients registered at the system. Note: Besides keeping an identification and a binding to a service interface, it is not a task of the system

to itself provide high level services. In the case of action points, the system shall act as a broker rather than interpret the communication between an application and the services behind an action point.

- The system shall manage authentication and privileges at the service interface.

3 Related Work

Intelligent building and home automation systems are highly relevant research topics, and numerous groups perform research on integrated systems. We will here focus only on some particular projects which have reasonable overlap with our particular requirements. The "Mundo" [15] Project goal is to provide universal models, concepts, architectures, and frameworks for a ubiquitous computing world. The Mundo Vertical Architecture classifies the devices according to their primary function and shows their relationships. It is centred around a users personal device, called Minimal Entity (ME). Mundo comprises the "Indoor Scout - Local Positioning System (IRIS-LPS)" [4] which is an optical infrared local positioning system. The tracked objects carry active tags that emit infrared signals which are received by stationary mounted stereo-cameras.

Fraunhofer "Booth Staff Tracker" is an example of the Fraunhofer localisation systems portfolio [5], targeted to applications like Inventory Systems, Facility Management, Asset Management, Tracking of emergency responders or Anti-theft systems.

Some "early" indoor localisation systems were the Bat, Active Bat, Cricket, and Calamari projects [3,1,2]. Besides the comprehensive Mundo project, all of the above focus on the localisation technology. For most of them, the mentioned applications have been implemented. To our knowledge the applications were closely related to the particular localisation system, and technology independent position data management was not a main goal of the systems.

4 Experimental Implementation

4.1 System Overview

Fig. 1 explains the scope of the position information management system (PIMS) within a position based application infrastructure. The PIMS forms the center of the infrastructure. It receives position data, accesses a database and supports applications with position data. It also keeps binding information by which applications may access controllers by their spatial context.

Fig. 2 sketches an overview of the experimental Java implementation intended as a proof of concept. In the figure, the main components and interfaces are depicted. The core of the system is formed by the PIMS. A localisation system is connected via the LSI interface. This interface is actually implemented using Web Services. No UDDI Server is currently deployed. Instead connecting to a real world localisation system, the position data is generated by so-called

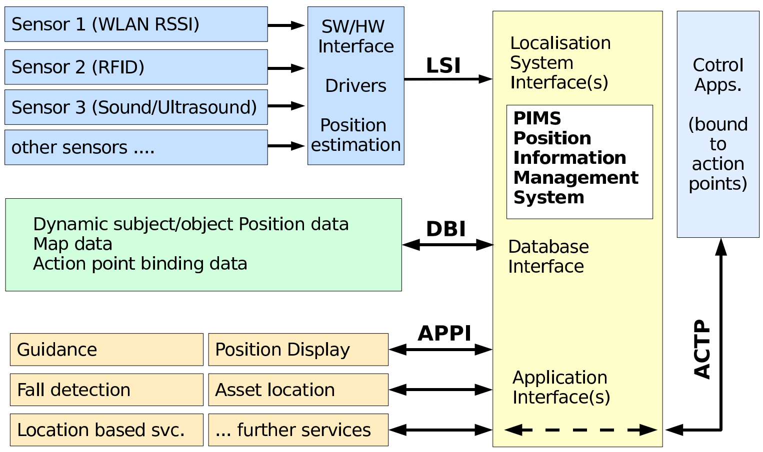

Fig. 1. Scope of the position information management system within a position based application infrastructure

PG (Position data generator) instances. The position data generator simulates objects which can be moved by user commands via CLI (Command line interface) or a GUI. Position data comprises the Cartesian coordinates of an object and the heading, which is an angle in the (x, y) plane and can either be interpreted as "direction of view" of the object or as movement direction. Position data is pushed to the server. The server stores this data and pushes it to registered applications. The applications subscribe to online position information on a per

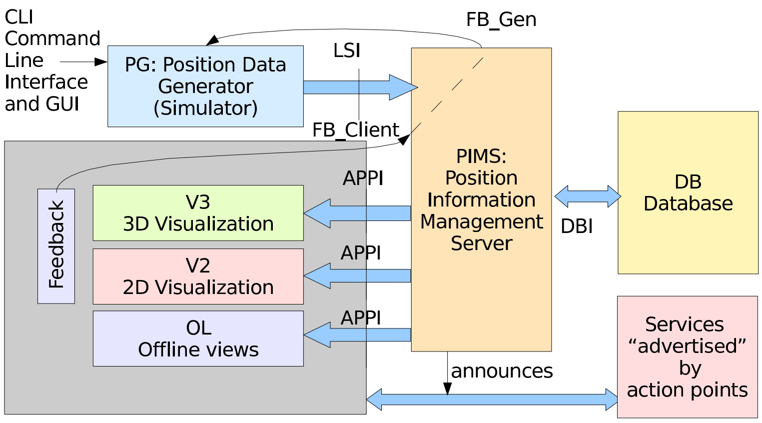

Fig. 2. Set up overview. The main blocks are: PG - Position data generator, PIMS - Position information server, DB - Database. The clients are grouped within the grey box. Arrows indicate flow of information. The feedback interfaces for simulation control are indicated by "FB...".

subject/object base. Additionally, applications may request map information, information on static objects and information on action points.

The usage of a "virtual positioning system", i.e. simulated position data, does not principally influence the validity of the implementation and results, since the localisation system itself is not part of the management system. Any localisation system can be connected via the LSI interface. Therefore typically a small tool needs to be created, which mediates between the given positioning system and the LSI interface of the management system (i.e. data format and interface modality conversion).

Currently implemented applications include 2d online visualisation, 3d online visualisation and offline visualisation, The latter requests previously recorded position data from the database via the PIMS.

4.2 PIMS: Position Information Management Server

The PIMS resembles the core of the system. It comprises 3 main interfaces. The LSI interface and the APPI interface are implemented using SOA. A "MySql" database (DBI interface) is accessed via ODBC/JDBC (Java "hibernate"). Fig. 3 lists the current database layout. For initial database setup and database maintenance like deletion of records a simple separate application has been created. The static information for the maps, the static objects and the action points is currently stored in an XML file. Its data structure is tailored to the needs of a building information system and contains among others information on boundaries like walls which are not traversable by subjects/objects, about visual objects like windows, tables, chairs, shelves, etc. These elements allow an

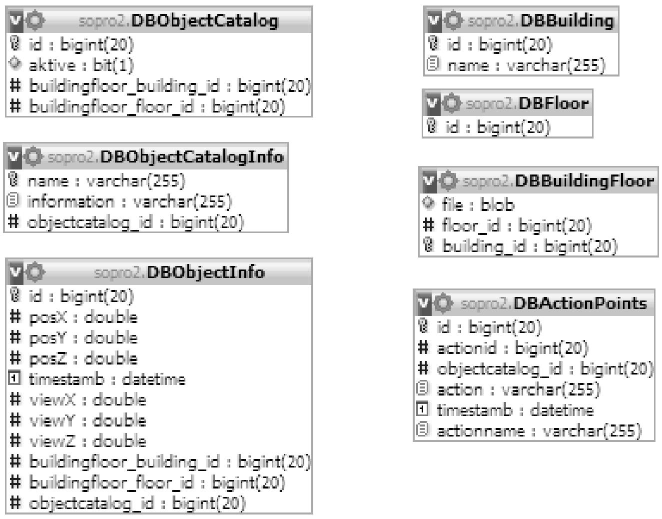

Fig. 3. Database structure.

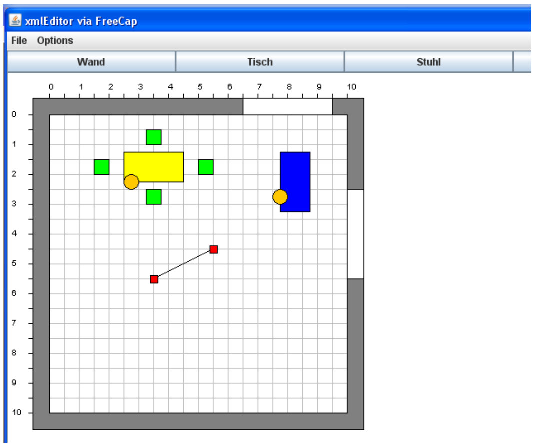

Fig. 4. Screenshot of the map tool. Rooms are easily created and edited by placing predefined objects on a canvas representing a particular area like one or some rooms or even a whole floor. Several such areas are related to each other by absolute coordinates with respect to a reference point in the building.

abstract visualisation of the area. It is not the aim of the map to give an optical exact representation of the room where the actual deployed interior is visible. Rather, since the system shall be easily deployable without having to render the real interior of a room, the map can be easily created and edited by a map creation tool using predefined visual components. An impression of the creation tool is shown in Fig. 4. The map data is actually not processed by the PIMS, but the PIMS provides this data to interested applications which themselves use the information for example for visualization or route planning. The application interface APPI is also implemented via SOA. Offered services are parsing the dynamic objects list, subscribing for position data of dynamic objects, delivery of this position data, retrieving of recorded data, retrieving of map and static data, and retrieving of action point locations as well as simple interfacing with applications bound to these action points.

To increase reliability of the system, it is possible to run several PIMS instances for a given region. All running PIMS receive the position information via the LSI interface in parallel. An application shall use services from only one of the PIMS instances at the same time. The database may be replicated, but the behaviour when recording position data to the database needs to be specified. Possible policies are to write it only to the currently accessed database and replicate it later by a regularly scheduled synchronisation service, or to perform the write operations to the databases simultaneously.

Given the above description, the main functionality of the PIMS is to act as an abstraction level between the position data sources and the applications, and to act as a central building data information system. No particular data processing is associated with the PIMS.

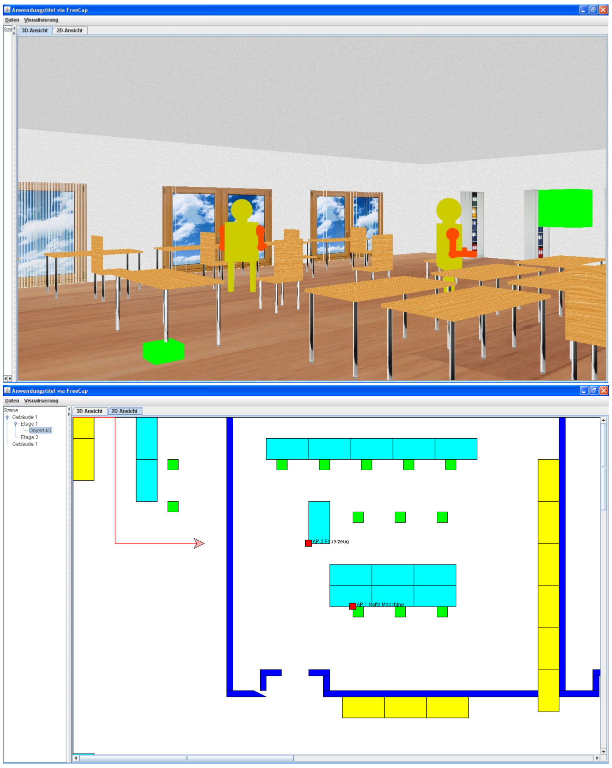

Fig. 5. Visualisation application screenshots. The two coloured squares (top) and rectangles (bottom) indicate interaction points.

4.3 Applications

Currently implemented applications are 2d- and 3d visualisation of dynamic subjects/objects in a 2d/3d building map context. The principal operation is as follows: A visualization client connects to the PIMS via web-services. He requests static data for a region (a floor or a room). Furthermore, the client parses the list of dynamic subjects/objects in the given region and subscribes to some or all of them. The subscription provides the client with regular position data updates. The client puts the received position data of dynamic subjects/objects into a spatial context by displaying a token for the object within a map (2d case) or a rendering (3d case) of the environment. The user can change the context (floor, area), viewport and the camera position interactively. Some screenshots (Fig. 5) give an impression of the visualisation application.

4.4 Position Sensing

The LSI interface provides the mechanism for receiving position information from underlying localisation systems/sensors. Such systems will push information into the PIMS. As mentioned, the current demonstrator does not use a real positioning system but uses object simulators, so called position data generators. These simulators simulate objects by reading trajectories out of a file or provide interactive online position manipulation via a GUI. This interactive manipulation can be performed directly via the visualisation client. A user who views an object, can directly manipulate the object position via keyboard commands, quite like in popular 3d virtual environments or computer games. This allows straightforward testing and evaluation of the system. The visualisation can be set in "objects perspective mode". Here the image screen rendered by the client directly simulates a persons view walking through the building. This enables applications like guidance to be tested on the system even without the need for the actual positioning system. At any stage, the position data generators can be replaced by a real localisation system not inducing any changes in the application.

4.5 Interaction Points

Applications are able to request information on "interaction points". The PIMS provides coordinates and binding data which links an action point with a dedicated control application. An action point may for example represent a light switch. When a person (a dynamic subject) is within a certain range of an action point, the current implementation of the visualisation shows a hint. The user of the visualisation application can then send a string to the action point object. The PIMS routes this information, enriched with the action point id and the object id, to the corresponding application. The application binding is stored in the database. This application is of particular use when run on a mobile device like a PDA (A PDA version is not currently implemented).

5 Conclusion

5.1 Current State

The paper has outlined a possible structure for a spatial position information management system for interactive building environments: The core component is a PIMS implementation, which provides applications with building data like maps and static objects and with position information for dynamic subjects/objects. For interaction, so-called "interaction points" serve as anchors for position-related building services typically in the automation and control domain. Some possible applications are outlined. Such a system can serve as generic platform for services and functionality for example in the sector of ambient assisted living.

A proof of concept of the PIMS and prototype applications have been implemented. Position information was not taken from an indoor localisation system but from so-called position data generators, which simulate dynamic subjects/objects.

A very simple interaction mechanism with building infrastructure has been developed.

5.2 Outlook

The analysis and implementation currently is at a very early stage. Interfaces and map- and object descriptions are very basic. Currently only position data and heading is taken as dynamic subject/object information. For a broader deployment, extension mechanisms should be included which allow for example inclusion of sensor information from acceleration sensors for fall detection, or manual sensor information like keys on a localisation tag for example for manual alerting or remote control. Also authorisation, privileges, safety and security needs to be addressed.

A next step will be to attach the PIMS to a real indoor localisation system like the iLoc [8] system at the iHomeLab, Lucerne [16]. Also more application prototypes shall be developed.

We think that the described approach may serve as anchor point for an open assistance framework for homes and smart homes providing assistance services for residents. We hope that the paper may stimulate fruitful discussions on what data and services such a system might provide.

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