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Elcano: Multimodal Indoor Navigation Infrastructure for Disabled People

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Abstract-- **Lately, indoor navigation systems has been a hot topic for the research community with many different proposals to positioning people and keeping track of their movements. In this paper we go a step beyond designing an object-oriented distributed architecture for highly scalable indoor navigation systems. The idea behind this architecture is to provide assistance for people with different needs while they stay in large spaces or buildings such as public administration buildings, transport facilities, hospitals and so on, helping them in the tasks to be performed in such environments.**

I. INTRODUCTION

Assistance for disabled people in large buildings or public spaces shows many different issues that can be subject of multidisciplinary research activities. Some of the current works focus on specific localization techniques that offer information suitable for a particular disability [1], Our work proposes a more general architecture aimed at using in a flexible and cooperative manner the positioning techniques available in the environment, being able at the same time to dynamically adapt itself to the specific user needs. In this sense, a context-aware information system has been designed able to provide the user with all the information she needs (positioning, location of architectural barriers, points of interests, potential movement paths, available activities in the building…) to perform in an autonomous way different tasks related with her stay in the building. The information is provided in a neutral way but according to the user disabilities.

II. KEY COMPONENTS

The architecture consists of the following components (Fig. 1):

- *Building Repository*: It stores all building-dependent information such as maps, available paths, wireless footprint characterization (for positioning purposes), location of cameras and other interaction devices (information points), etc.
- *User Manager*: This component is used for user profile management. It is also environment-dependent.
- *Task Manager*: This module is responsible for elaborating a set of steps/indications to guide the user through the environment (according with the activity to be performed and the user needs).
- *Explorer*: Embedded in the user’s device (e.g. the mobile phone), it is used to exchange information with the rest of the components. Due to confidentiality and privacy reasons, it controls which information is shared with the environment.
- *Multimodal Location Service*: This module is an indoor location service which uses different technologies for user’s positioning. It will be described in depth in the next section.
- *Path Search Module*: It has the responsibility of finding movement paths according to the specific user’s disabilities and the task the users wants to perform in the environment.

All the modules are designed using the distributed object-oriented paradigm. Fault-tolerance and scalability issues have driven the design.

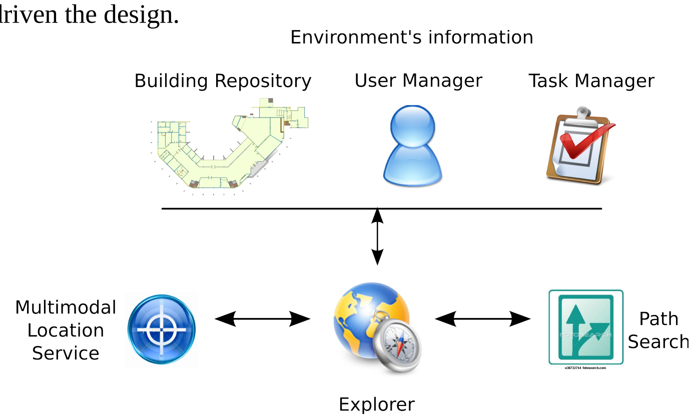

Fig. 1. Elcano general architecture.

A normal interaction starts when the *Explorer* asks to the *Multimodal Location Service* about its position (user’s device). Then it sends to the *User Manager* the user location together with other user-related information (the needs related to specific disabilities and tasks to be performed). The *User Manager* interacts with the *Building Repository* and the *Task Manager* to provide the user with the place (or places, or sequence of places) to perform such tasks together with other related information of interest (e.g. procedures, points of special attention). With this information, the *Explorer* asks to the *Path Search Module* the more convenient path to those locations. The *User Manager* keeps track of the user movements to identify possible deviations from the elaborated plan. It is worth noting that the *Explorer* interacts with the user directly at any moment, so the whole process can be managed adequately if needed. In any case, the interaction between the *Explorer* and the user is done according to the specific user disabilities (e.g. by voice for visual impaired people).

Finally, due to the highly distributed nature of the architecture, different services are needed for an adequate performance. In particular, a service discovery framework [2] is used to conveniently locate the different modules, avoiding complex configuration procedures.

III. MULTIMODAL LOCATION SERVICE

Due to its crucial role, the indoor location service is a key component of the system. Lately, different technologies have been used to support positioning (RFID, image streaming, WiFi…) more or less accurately [5]. But, in future buildings, there will be a lot of possible technologies previously deployed that may be used to provide positioning information. So, the key requirement of an advanced localization service will be to merge adequately the information coming from different localization techniques in order to offer the user position with a higher accuracy.

- To design a technology independent location service we have followed some considerations about what a client would need from a location service, mainly:
- To get the actual client position (a user ID is provided). This is how the Explorer module uses it.
- To get tracking information in a continuous way of a specific user. The User Manager uses the service in this way to track the user in order to check whether the appropriate path is being followed.
- To get user IDs from a specified region, that is, to know what users are in that area. It can be extended to know dynamically what people traverse the area. This case corresponds to the monitoring of very complex paths in which the only way of following a user is checking whether she walks across intermediate areas.

An important non-functional requirement is the compliance with industry location-related standards. In this way we use the Mobile Location Protocol (MLP) [3] for low-level positioning services, meanwhile the Path Search Module uses OpenLS [4]. A wrapper has been designed so the different components can easily fit into the distributed object-oriented architecture. A simplified version of the interface is shown below:

```
MLP::Shape getArea();
void federate(MLP::Shape area,
          Elcano::LocationService* locationService);
MLP::Position getPosition(string UserId);
void tracking(string UserId,
              MLP::Location* listener);
DevProfileSeq usersIntoArea(MLP::Shape area);
void watchArea(MLP::Shape area,
               MLP::Location* listener);
```

This interface allows to merge different location technologies behind a unique and homogeneous view (Fig. 2).

The first two functions are used for location service federation, a feature that is intended to face scalability issues (the location service is designed for an arbitrary size of the building and number of users). The federation mechanism creates a hierarchical structure of location services working in a cooperative and transparent way.

MLP::Shape represents an area according to the MLP protocol and the string UserId indexes user profiles. A user profile includes also information about the user device (e.g. the device MAC for WiFi-based positioning systems).

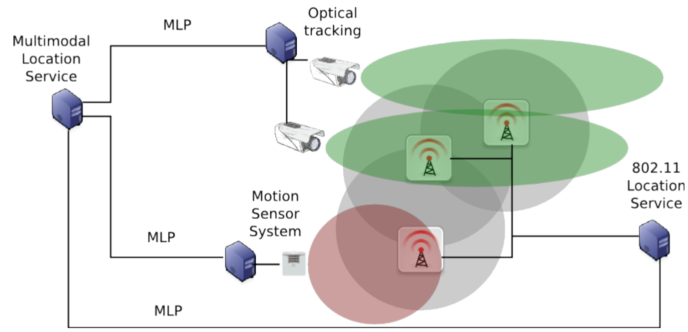

Fig. 2. Multimodal localization service

IV. PROTOTYPE

The Internet Communication Engine (Ice) [6] from ZeroC has been used to implement a prototype of the proposed architecture. Ice is a CORBA-like middleware. The building in which the system has been deployed corresponds to the School of Computer Science of our university (a three-floor building). The location service is based on positioning information gathered from three sources: the WiFi network, the security infrastructure (motion sensors) and a tracking system based on real-time image processing (using a camera on the user device). This last method identifies singular points in the environment to figure out the user location (and even the orientation). The location information merging is done by means of geometric operations with `MLP::Shape` areas. The user device is an Android based mobile phone implementing a version of the *Explorer* module oriented to the interaction with users on a wheelchair or with visual impairments.

V. CONCLUSIONS

In this paper we present an indoor navigation system for disabled people. It has been designed using the distributed object-oriented paradigm. A multimodal location service has been developed, which is able to integrate different positioning technologies in a flexible way and depending of the previously deployed infrastructure (e.g. cameras, sensor networks, etc.).

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