LaureaPOP Indoor Navigation Service for the Visually Impaired in a WLAN Environment

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Abstract: - Many navigation systems for visually impaired people have been developed, but few can provide dynamic interactions and adaptability to changes. The aim of this working life project is to create an innovative navigation service solution that will improve the quality of life of the visually impaired. For example, a university campus might be such a large and rambling place that visually impaired people can not always find the services or rooms they want to. Therefore, we are devising new service solutions that exploit the technical features of modern WLAN systems in an innovative way. This paper describes the LaureaPOP system that focuses on the indoor navigation service design in a wireless local area network environment.

Key-Words: - Indoor positioning, indoor navigation, blind navigation, WLAN positioning, WiFi positioning, VoIP over WLAN

1 Introduction

According to The Finnish Federation of the Visually Impaired, there are about 80 000 visually impaired people in Finland; roughly 10 000 of them are blind. An estimated 80 % of the visually impaired are elderly people whose number is growing at a high rate. About 10 000 visually impaired people are in their working-age and about 6 % (1500) are under 18 years of age. One third of the registered visually impaired also have some other disability or a long-term illness. The most common reason for visual impairment is age-related macular degeneration. Other common reasons among pensioners are glaucoma and diabetes. Among children visual impairment is mostly caused by congenital anomalies of the eye and disorders of visual pathways. Within working-age groups the most common reasons are diabetes, glaucoma, neurological diseases and hereditary eye diseases that often appear during young adulthood. Accidents concerning eyes have diminished significantly since the use of diverse protection has increased. Blindness related to premature birth is falling down although it is still the fourth most common reason for visual impairment among children. The development of the medicines has also decreased infections as a cause for visual impairment. [1]

Many visually impaired people have difficulty knowing where they are or where they are going, frequently feeling disorientated or even isolated, therefore supplemental positioning and guidance services are very important to them. The positioning and guidance service involves updating one's position and orientation while he or she is traveling an intended route, and in the event he or she becomes lost, reorienting and reestablishing a route to the destination. Guiding people is about augmenting them with contextual information, which usually includes obstacle prompting and optimal routing.

In this paper, the personal navigation and information system for users of public transport outdoor navigation system for blind pedestrians [2-4] is extended to include indoor navigation. The outdoor navigation system uses Global Positioning System (GPS) to locate the user on campus or downtown areas, answers the user's various requests and gives information about routing and rerouting dynamically according to changes in the environment. In an indoor environment, traveling is made more difficult by relatively small spaces and narrow hallways, stairs, doors and pieces of furniture. As such, in closed spaces visually impaired people may encounter more and closer obstacles. If they are new to the environment, it can be dangerous for them to walk alone. The system conveys the layout of the indoor facility to its user orally, giving him or her a broad picture of what the environment is like. The user may also get distance and navigation information between destinations. As the user moves inside the facilities, the system guarantees traveling safety by employing timely obstacle prompting. The system can also communicate with the user and answer different contextual awareness questions on demand.

Because GPS is not available indoors, and because the requirements of measurement error change in closed spaces, the LaureaPOP system switches on the fly to a different location tracking technology when the user moves in to a building: WLAN (or WiFi) positioning service, which provides a high precision measurement scale, for indoor use and prompts the user with the indoor room layout.

The LaureaPOP system is designed to enhance the user's real world navigation experience by augmenting their reality through vocal interfaces with contextual information about their surrounding environment. Advances in wearable computing, voice recognition, wireless communication (e.g. VoIP over WLAN), and WLAN positioning devices have made our goal possible. In the remainder of this paper we will give a brief review of related work (section 2), discuss the problem domain (section 3) and present the system architecture and expose important implementation issues, tradeoffs and lessons learnt (section 4). We present future work in section 5 and give conclusions in section 6.

2 Related work

2.1 Personal navigation and information system for users of public transport [2-4]

The three year pilot for the research project NOPPA (personal navigation and information system for users of public transport) started in 2002 and ended in 2004. The project was part of Ministry of Transport and Communications Finland's Passenger Information Programme (HEILI). The financial size of the project was half a million euros. The NOPPA project participated also in Personal navigation - research and development programme (NAVI). Nowadays the project is being developed within the PUMS (new methods and implementation of voice processing) project. State Technical Research Centre (VTT) is currently negotiating piloting NOPPA outside Finland and making it a product. NOPPA was the first guidance system for pedestrians including real time public transport information. The system has gained considerable publicity, mostly due to its speech user interface. The project has been presented in over 300 media.

NOPPA pilots a personal navigation system for the visually impaired which produces a path on which to travel. NOPPA is designed to provide public transport passenger information and travel guidance for people that use public transport. The system design is based on the visually impaired and their needs but it can also be useful for sighted users. NOPPA includes a speech user interface, a door-to-door guidance system using public transport, the most common GPS functions and several information services. Motorists can use NOPPA to plan routes because it knows the street names and speed limits inside Finland.

NOPPA is based on personal navigation components and services. This enables constant development of the system and helps keep the costs low. Public service databases are used over the Internet to get up-to-date passenger information. A very important part of the project has been to gather data.from different services with the help of created general interfaces

The system architecture is based on using an information server, to which the users mobile phone is connected via the mobile Internet. Data is transferred only when the user makes a request for information or there is real time information to send. The Information Server handles the Internet searches and heavy speech recognition work and passes only the brief results to the user's phone. This saves data transfer costs. The client software includes GPS positioning and guidance, personal settings for security reasons and speech synthesis.

2.2 Other related research projects

There have been many research projects aiming to create electronic travel aids for visually impaired persons. These projects have usually concentrated on solving one specific problem. The result has thus usually been a technically simple device, which might be difficult to use. Visually impaired people can have several disadvantages and to carry all the aids designed to help them would take up a supermarket trolley.

Ram and Sharf [5] designed the "People sensor", which uses pyroelectric and ultrasound sensors to locate and differentiate between human and non-human obstructions in the detection path. Thus, it reduces the possibility of embarrassment by helping the user avoid inadvertent cane contact with other pedestrians. The system also measures the distance between the user and obstacles.

Many technologies have been developed to determine the location and/or orientation and to provide routes to users. The development of traveling aids based on positioning also has a long history. The use of GPS has been researched since the late 80's and since then there have been many research projects like MoBIC [6], Drishti [7-8], Brunel Navigation System for The Blind [9], and the work done by Bruce Thomas, etc [10]. Also commercial products like Sendero Groups BrailleNote GPS [11] and VisuAide's Trekker [12] are available addressing GPS based ETA for the visually impaired. E.g. BrailleNote GPS provides the user with nearby location names and the distance to destination along the journey. Metranaut [13], developed by Smailagic and Martin, label campus information signs with bar codes to provide location-specific information on a hand-held computer equipped with a bar code scanner. Golding and Lesh [14] detect the user's current information by using a set of cheap, wearable sensors that include a 3D accelerometer, a 3D magnetometer, a fluorescent light detector and a temperature sensor, that do not modify the environment at all. Loomis [15] was one of the first to propose the idea of a navigation system for the blind using DGPS with an FM correction data receiver for the stable determination of the location of the traveler. A similar approach is taken by Makino [16] et al.

Computer vision techniques are also used to locate the user. Sequential images are first referenced manually and registered in a database. Then from the registered images the landmark lines are transferred onto an unregistered image by image-to-image matching based on straight-line features to get accurate position and orientation for real world images taken by the camera [17, 18].

Since GPS does not work in indoors, relative positioning systems using sensors such as infrared transceivers, active badges, or accelerometers are exploited [8, 19-21].

Except [8], the major limitation of these systems discussed so far is that they merely deal with navigation service in outdoor or indoor but not in the actual combined traveling environment. A visually impaired person wanting to travel from his or her home to the office or campus, would have to use at least two different guiding systems, in order to move between indoors and outdoors. Thus a visually impaired person's life could be made easier if one single system could guide him all the way to the destination.

3 Design criteria

3.1 Problem domain

While the visually impaired person travels, he or she lacks the many useful inputs that can be registered by the sighted traveler such as orientation and location information, visualization of possible obstacles and signs ahead. Thus he or she would rely very much on repetitive and predefined routes with minimum obstacles. At times these routes may be subject to change: a corridor may be blocked for washing and waxing, a rolled-up carpet or a floor-mounted cord extension set can be dangerous to those who can not see it. A guide dog or long cane may help to detect the problem, but visually impaired need more information to find detours or rearrange routes. In order to augment a visually impaired person's pedestrian experience and help them travel comfortably in known and unknown environments, the navigation and guidance system should provide enough information to give him or her a more complete picture of the environment and deliver the information along the visually impaired person's path in real time through auditory cues.

3.2 Design goals

Stations and terminals are good examples of indoor environments where satellite positioning is often unavailable. For that reason, the main design goal of the LaureaPOP navigation and guidance system is to extend the NOPPA system to indoor environments. Fig. 1 shows different locations and modes, where NOPPA has interfaces to indoor positioning.

Design goals of the LaureaPOP navigation and guidance system were the same than NOPPA [3] had, with the exception that access to public transportation and passenger information systems was not an essential requirement:

- Easy and fast to use
- Flexibility
- Affordable to the user
- Applicable both indoors and outdoors
- Integration of products and services for personal navigation
- Modular, easy to update, easy to add functions
- Speech user interface.

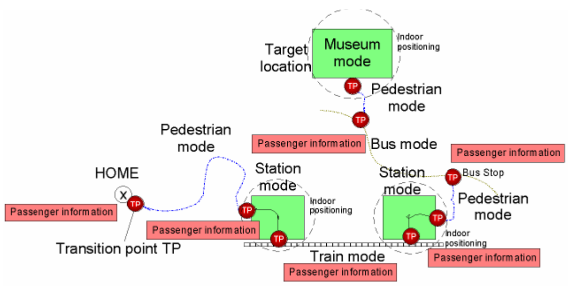

Fig. 1. Unbroken trip chain and different operation modes of NOPPA system [3]

4 LaureaPOP architecture

4.1 Hardware components

The most important building blocks of the system are personal indoor navigation systems and services, an information server, terminals (mobile phones) and the VoIP over WLAN protocol. For an unbroken trip chain for the visually impaired there are requirements for continuous, general use positioning techniques and availability of map data accurate enough for the users' needs. For example, generally there are no maps available that include information about large public premises. Place-to-place guidance would require map data including entrances and continuous guidance would require indoor maps and indoor positioning.

4.1.1 Indoor positioning system

There are several technologies available for indoor positioning, but none of these methods has yet acquired a position as a technological standard comparable to that which GPS has for outdoors. Moreover we must be able to utilize the positioning system with our chosen terminal device. Cell phone based positioning is too coarse for navigation purposes. Cell ID based systems usually give coordinates that point to the closest GSM antenna and not to directly to the mobile phone in use. The most promising candidates for indoor positioning are WLAN and Bluetooth based systems. However out of the two, Bluetooth positioning methods are still at early stages in development and not commonly accepted. On the other hand, the use of WLAN positioning systems also has demands on network infrastructure and thus requires investment. However, depending on the site, the building or upgrading of a WLAN network can be further justified by related other benefits, such as network availability, provided to all users.

The LaureaPOP prototype system takes advantage of the Ekahau Positioning Engine (EPE) version 3.1. EPE is a software based real-time location system. EPE is marketed as being an open and future proof system that can be used on top of any existing WLAN network. EPE’s positioning technology is based on signal strength calibration, which ensures a high granularity. EPE is capable of pinpointing WLAN tags, laptops, PDAs and other WLAN enabled devices, with floor-, room- and door-level accuracy. [22]. In our prototype, we are pinpointing WLAN tags.

Combining WLAN technology with location information enables a variety of asset and people tracking applications for healthcare, manufacturing and other industries. A software based solution ensures fast implementation with affordable cost, the EPE software is also able to utilize existing WLAN infrastructure, making deployment a faster process. EPE 3.1 can be integrated seamlessly with existing systems through a software development kit. Ekahau's positioning technology is a result of over 10 years of extensive research, featuring the most precise real-time location tracking available on the market, for both indoor and outdoor use - wherever there is sufficient WLAN coverage. [22]

4.1.2 Information server

The information server in the architecture is an interpreter between the user and information systems. It collects, filters and integrates information from different sources and delivers the computed results to the user. For the visually impaired, a speech user interface is a natural choice.

The server constructs a route plan, which is then transferred to a terminal device. The server is also responsible for route following and guidance functions utilizing the same information. The indoor positioning system then reports the coordinates of the WLAN tags periodically to the server, that is able to follow the progress of the journey and calculate possible changes and disturbances concerning the rest of the journey. Real time information plays an important role through the unbroken trip chain.

4.1.3 Terminal

The prototype of the terminal is built on a commercial mobile phone. Our prototype terminal includes a WLAN compatible mobile phone with hands free accessories and a WLAN tag for indoor positioning. As opposed to NOPPA and many other GPS based guidance systems, route following and guidance is not done in the terminal but on the information server. The route plan, route following and guidance information is transferred from the information server to the terminal device.

4.1.4 VoIP over WLAN call manager server

We use the VoIP over WLAN protocol for transferring the guidance information from information server to user. In this content, a VoIP over WLAN call manager server is needed.

4.2 Software components

The guidance method used changes according to inaccuracies in positioning. For example, giving guidance to a target 10 meters away would be impossible for a system that has a positioning accuracy of only the same 10 meters. In the case of a low positioning accuracy, guidance is about forming a big picture of the route and closely resembles asking another person for guidance. Also, the lack of standardized indoor maps or data models is a big barrier for indoor navigation. Often a suitable guide map already exists for the area or building in question. This is the case with museums, fairgrounds and airports for example. These maps need to be modified into a navigational form, where it is possible to plan simple routes and search location based data. Fig. 2 shows EPE software concept.

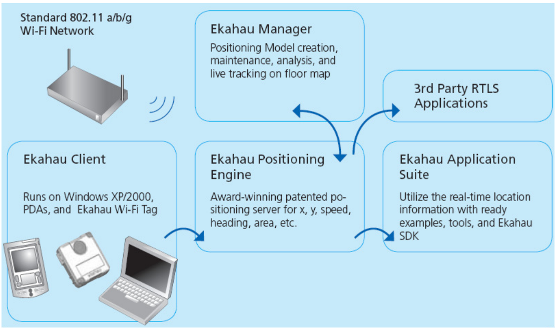

Fig. 2 Ekahau Positioning Engine software concept [22]

4.3 System architecture

To fulfill the requirements shown in Section 3, we created an architecture presented in Fig. 3. Because of the low processing capacity of the mobile terminal, most of the processing work is done in the Information server.

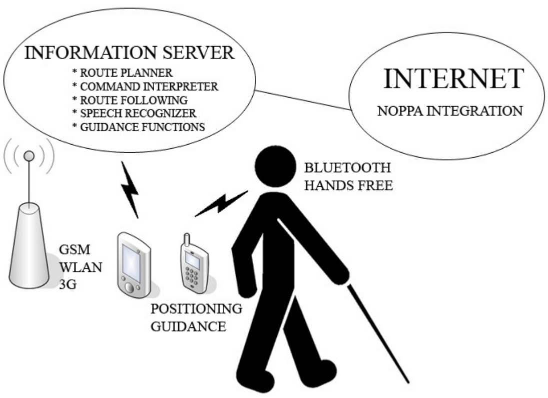

Fig. 3. Architecture of the LaureaPOP navigation and guidance system

5 Summary and future work

We developed an indoor navigation system for the visually impaired, which will in the future be integrated to the NOPPA outdoor navigation system. Our design takes advantage of existing software and hardware and provides a hands-free travel and living convenience to a blind or visually impaired user. Most systems that have been developed so far lack the dynamic interaction, the adaptability to changes and the comprehensive service coverage (both indoor and outdoor). We emphasize the functionality of this navigation system to augment a visually impaired pedestrian's experience with sufficient information to make him or her feel comfortable traveling in both familiar and unfamiliar environments, indoor and outdoor.

The working range of this system depends on the coverage of the WLAN network. The implementation is such that the system is aware when the user is indoors or outdoors based on the available positioning service so that the user does not have to explicitly switch modes.

6 Conclusions

The blind and the visually impaired are at a disadvantage while traveling because of not receiving enough information about their location and orientation in respect to traffic, obstacles and things that can easily be seen by people without visual disabilities. Navigation systems usually consist of three parts to help people travel with a greater degree of psychological comfort and independence: sensing the immediate environment for obstacles and dangers, providing information about location and orientation during travel and optimal routes towards the desired destination.

The most important guidance aids for the visually impaired are still the white cane and a trained guide dog. Electronic navigation systems should be considered as supplementary equipment. An electronic traveling aid that produces a small amount of navigational information and does not disturb other information perceived from the environment should be developed. Further, the evaluation of the device should be based on the benefits it produces, not the amount of information it generates.

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