NOPPA

NAVIGATION AND GUIDANCE SYSTEM FOR THE BLIND

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1. Introduction

The presented information server concept, developed at VTT, is a user-centred and task oriented client-server approach for solving informational needs of special user groups. This paper describes application of the concept for producing an unbroken trip chain for the visually impaired. The goal of the study was to build a navigational aid for the visually impaired using commercial passenger information and personal navigation services without laborious and expensive changes in the current infrastructure.

Generic travelling difficulties for the visually impaired are localisation and environment perception, selecting and maintaining correct heading, and detecting obstacles above waist and unexpected road works.

There have been numerous research projects about creating electronic travel aids (ETA) for visually impaired persons. These projects usually have concentrated on solving one specific problem. The result has been usually technically simple device, which may be difficult to use. Because the visually impaired have several problems, they would have to acquire a wheelbarrow to take with all these devices to carry off everyday life.

Development of travelling aids based on positioning 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 [1], Drishti [2] and Brunel Navigation System for The Blind [3], and commercial products like Sendero Groups BrailleNote GPS [4] and VisuAide's Trekker [5] addressing GPS based ETA for the visually impaired. Navigation systems have usually worked well in small-scale implementations, but a large-scale implementation will be extremely expensive (especially with beacon based navigation systems). Percentage of visually impaired persons of the whole population is less than 1.5 % in developed countries; therefore large investments to the infrastructure are not reasonable. Still, visually impaired persons have equal rights to achieve the same services as all other citizens. Despite intensive research and development, electronic travelling aids for the visually impaired have not yet become common. This indicates that the problems at hand are not easy to solve.

The most important guidance aids for the visually impaired are still the **white cane** and **guide dog**. Electronic travelling aids should be considered as supplementary equipment. What we need is a travelling aid that produces a small amount of navigational information and does not disturb other information perceived from the environment. Further, the evaluation of the device should be based on the benefits it produces not the amount of information it generates.

2. NOPPA architecture

VTT's Information server concept aims to utilise commercial services and devices for improving public transport accessibility with creating access to passenger information with a personal mobile device rather than building physical infrastructure.

Research and development of the concept was done in a research project NOPPA (Navigation and guidance for the visually impaired) [6], which started at June 2002 and ends of the year 2004. Project pilots a personal navigation system for the visually impaired, which produces a unbroken trip chain for the visually impaired.

The most important building blocks of the system are mobile Internet, mobile phones and personal navigation systems and services. For unbroken trip chain for the visually impaired there are requirements for continuous, general use positioning techniques, continuous (Internet) access to passenger information and availability of map data accurate enough for users' needs. For example there aren't generally maps available, which would include pavement information or information about large public premises either. Door-to-door guidance would require map data including entrances and continuous guidance would even require indoor maps and indoor positioning, which are generally unavailable.

Design goals of the NOPPA -guidance system were:

- Easy and fast to use
- Flexibility
- Affordable to the user
- Access to public transportation and passenger information systems

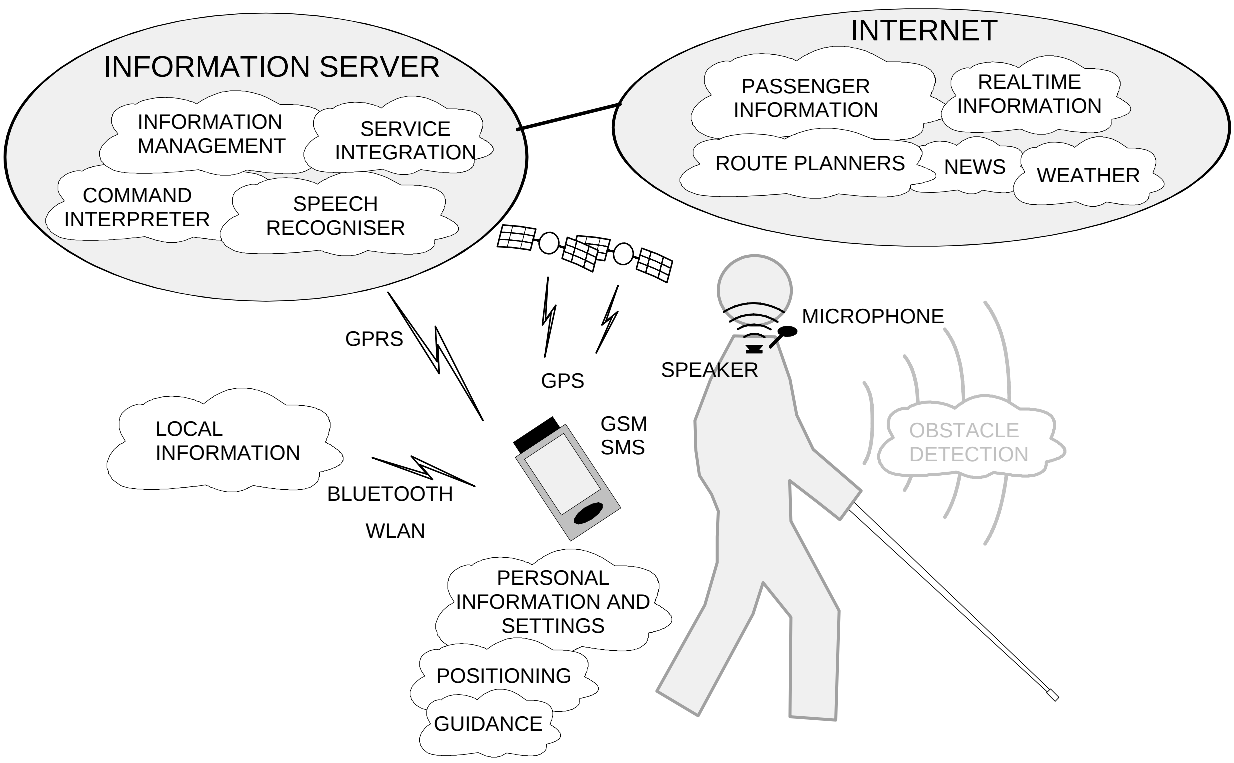

Figure 1. Architecture of the NOPPA guidance system.

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

To fulfil these requirements, we created an architecture presented in Figure 1. Because of low processing capacity of the mobile terminal and a low bandwidth wireless data connection, most of the work is done in the Information server. Data flow between mobile client and Information server is minimized, which keeps the communication costs low and shortens response time.

2.1 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 only the results to the user. For the visually impaired speech user interface is a natural choice. If the users are deaf, user interface based on text and visual information is used instead.

The server constructs a route plan, which is transferred to the terminal. Terminal is responsible for route following and guidance functions. It however reports its coordinates periodically to the server which could follow the progress of the journey and possible changes and disturbances concerning the rest of the journey. Real time information plays an important role through the unbroken trip chain.

Route following and guidance is done in the terminal, because these are time critical functions and because of unreliable wireless connection. Although GPRS connection is often considered continuous, in practise it is not. Implementation of guidance in the terminal makes it available even when the connection to the server is temporarily off.

2.2 The Prototype

The prototype of the terminal is built on a commercial mobile phone. The system carries out following characteristics

- Speech user interface (Finnish)
- Route planner (commuter and intercity traffic both bus and train)
- Access to bus and train real time information
- Guidance and route following during a trip
- Personal stop announcements in-vehicle
- Roadwork information
- Airport departures (domestic flights), real time information
- News, watch, local weather, memo
- GSM phone and SMS services
- GPS, GSM positioning, pedometer, compass
- Bluetooth, GPRS (WLAN) connectivity
- Indoor navigation system based on Bluetooth or WLAN positioning
- Own recorded walking routes with location based comments

User evaluation tests are planned for autumn 2004. In the tests the value of the information provided is under evaluation not usability of the device.

Figure 2. A visually impaired NOPPA navigation system [1] user entering a bus.

Figure 3. Noppa prototype terminal.

3. Visually impaired persons and unbroken trip chain

If we examine problems a visually impaired person meets when using public transport, we recognize the following list (depends slightly of the transportation mean):

trip planning, finding a stop/station, finding an entrance to the station, navigating inside the station, finding the right platform and waiting place, knowing when the right vehicle arrives, finding a vehicle entrance, payment, finding a seat, depart on right stop, navigating inside the station, finding the exit of the station and finding the destination.

Most of these tasks are trivial for the sighted, but very difficult for the visually impaired. There are cases when a blind person has spent several hours on the bus stop, because he couldn't recognise arrival of the right vehicle.

Nevertheless, in our studies we couldn't find any specific information needs for the visually impaired. Information needed is either available for the sighted, existing but not accessible, or would be useful for all passengers. However, the means for a visually impaired person to reach the information is different. This is an important factor to take into account when new passenger information services are designed.

To produce unbroken trip chain for visually impaired, we have to switch seamlessly between different modes of operation during the trip (see Figure 4). This requires that system must be context aware to recognise transition points and change automatically its mode of operation accordingly.

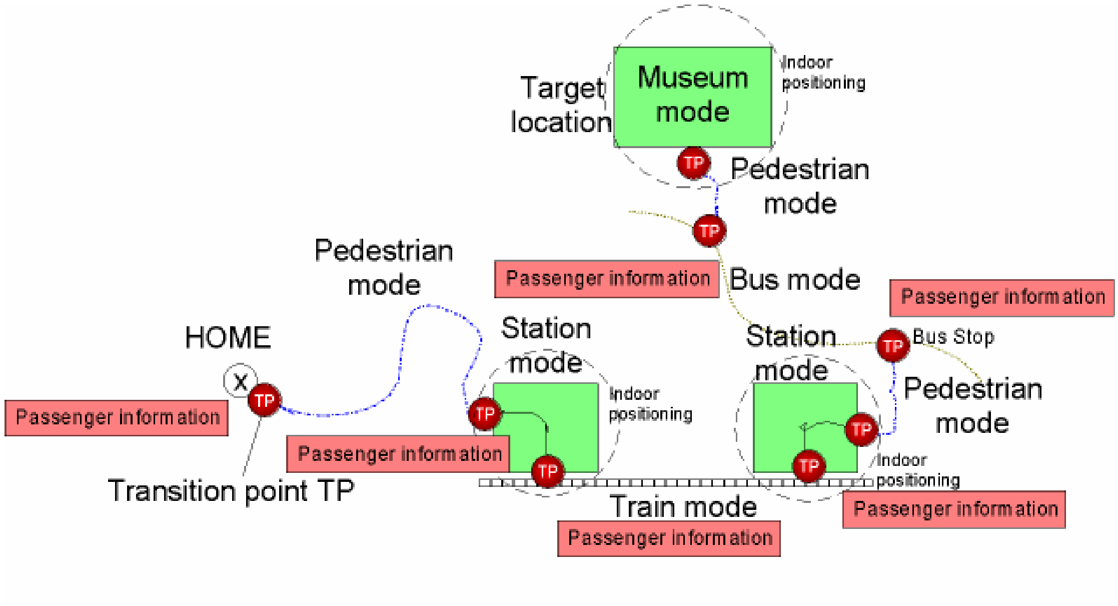

Figure 4. Unbroken trip chain and different operation modes.

3.1 Trip planning

All planning is based on commercial journey planners. Helsinki metropolitan area (Helsinki, Vantaa, Espoo and Kauniainen) is covered by one planner [7], which covers local bus, tram, metro and local train traffic. A speech user interface for the journey planner was constructed in the server. Speech recognition software is speaker independent and requires street names from these cities to accomplish recognition. List of 10 000 street names is acquired from the journey planner and automatically compiled to recogniser grammar.

Positioning makes route planning easier, because the current address can be searched with reverse geocoding. Often used target addresses can be saved to a list, but if the start or target address is unknown, terminal asks for an address. Voice response is recorded and transferred to the server for recognition. Recognition result is then transferred back to the terminal for certifying. All personal parameters like walking speed are also transferred to the server. When we have all the information needed for route planning, the server generates a route request and sends it to the journey planner.

Route plan is based on journey planner's response. It is augmented with road work information, Point of interest (POI) -information and Area of interest (AOI) -information. Road works on the route are gathered from WINKKI-database from Helsinki Public Works Department. User listens the route plan and if he/she considers it acceptable, the next step is to start route guidance.

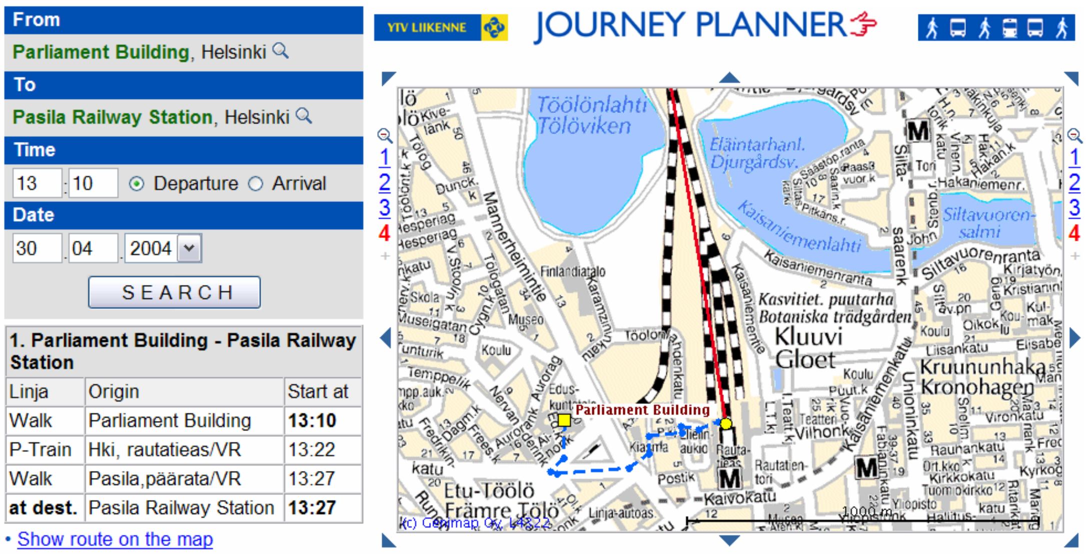

Figure 5. Example route planned by Helsinki metropolitan area journey planner [7].

3.2 Pedestrian navigation

In pedestrian mode we have to navigate using mostly the same map data than in car navigation. Map data used in navigation systems today is collected for car navigation purposes. The map usually includes only street centre line, street name and class, no pavement information. Example of this can be seen in Figure 5, where walking route is marked (on) with blue dashed line. This is not adequate for pedestrians, because pedestrians use pavements, zebra crossings and footpaths. Required accuracy of the maps would be about 2-5 meters and routing should include pavements, zebra crossings and traffic lights. Result information should include coordinates and form points of the route.

Map quality is an important factor in navigation, because navigation systems can't recognize map errors without environment perception sensors. Correct route is more essential for the blind persons, because they can't see if the route proposed by the navigator is dangerous or unusable.

Positioning errors are easier, because for example GPS receiver delivers error estimate. Therefore, although we can't correct the error, we can warn the user of the operation defect. Navigation systems must always take into account that the maps are not accurate and have errors and positioning accuracy varies sporadically.

Guidance methods change according to possible inaccuracies in positioning. If the positioning accuracy is 1 m, you can give guidance to a target, which is for example 10 meters away, but not if the positioning accuracy is 100 m. Guidance in the case of low positioning accuracy is telling the big picture of the route and resembles asking for another person for guidance.

3.3 Public transport terminals

Stations and terminals are usually indoor environments, where satellite positioning is unavailable. There are several possible technologies available for indoor positioning, but none of these methods has the same standard position than GPS has for outdoors. Moreover we must be able to utilize the positioning with our terminal device. The most promising candidates for indoor positioning are wireless LAN and Bluetooth based systems [8], but positioning methods are still at early stages and not commonly accepted. Both of them need also infrastructure investments, but these investments concern all passengers. Cell phone based positioning is too coarse for navigation purposes. Cell ID based systems give usually coordinates that are not inside building's area but the coordinates of closest GSM antenna.

Besides of no feasible indoor positioning, lack of standardized indoor maps or data models is the second barrier for indoor navigation. Often there already exists a suitable guide map of the area or building. This is the case with museums, fairgrounds and airports for example. These maps need to be modified into navigational form, where it is possible to plan simple routes and search location based data.

For public transport terminals and similar areas we use Area of Interest (AOI) information. These are detailed descriptions of target locations. Proximity of the AOI is detected from position coordinates. In NOPPA project, orientation and mobility specialists made speech descriptions of two railway stations for the visually impaired. Visually impaired listen the description and produce a mental map of the terminal.

Terminals have acoustic announcement systems. Information is not available for example deaf persons. Usually announcements are generated by automatic systems, where information is already in text form. Also this information should be made available through suitable public interface. Then it would be possible to serve for example minor language groups as well as disabled persons.

3.4 Personal announcements

Personal announcements are possible to produce trough a navigation system in a station and in a vehicle. There are cases where for unknown reasons, that acoustic announcement system is turned off in a station or in a vehicle. Also there are some user groups that cannot hear or understand acoustic announcements at all.

The main idea of the personal announcements is to pick up only those announcements that have meaning for the passenger.

In a vehicle it is possible to produce personal stop announcements. From the route plan we know names, passing times and coordinates of the start and end stops and all stops between them. GPS positioning is usually available in a bus and our tests show that method works quite nicely. Another way to produce personal announcements is to request the vehicles position from an operator's real time tracking system, if available.

3.5 Public Transport Real Time Information

Currently there are several public transport real time information systems in use and in development in Finland [9], [10]. However, in most cases, the information is used only inside the operator's system, such as in fleet management or passenger terminal screens. The information is typically not available via Internet for other purposes.

Development of public interfaces, such as XML queries via WWW, for distributing public transport passenger and real time information for third party purposes, is gaining more importance. Mobile phones with advanced graphics are coming to the market and they could be used as mobile real time passenger information displays.

Recently there have been investments in real time displays on bus and tram stops. In many cases, different operators' vehicles use the same stop and preferably all available real time information should be displayed on the screen. However, the operators may be unable to share real time information between their systems. Also third party service providers are unable to combine real time information from several sources. CEN TC 278 [11 [4] has standardization plans based on results from TRIDENT and TRANSMODEL, to solve the issue with interfaces. Standards will be published after a few years.

Public transport real time information has use in personal navigation: In guidance mode, the system would check if there is need to inform the passenger or calculate a new route, for example if a bus is several minutes late. Disturbances (trains delayed, traffic jams, accidents) might require calculating an alternate route. It is also a common requirement to be able to quickly change the goal or route parameters, or pause the route guidance to stop by in a coffee shop for example. To successfully manage public transport routes with short waiting times for the user requires accurate timetable information.

For the visually impaired, real time information might be useful for example when waiting at a bus stop: it would be easier to select the correct bus at a busy stop when the arrival time of the bus is known accurately, instead of often 5-10 minute error compared to static timetable. Real time information would also help to tell when to leave the bus. It would enable personal stop announcements instead of continuous audio announcements, which are often seen as disturbing by many passengers and therefore have even been turned off. Possibly in the future, a personal navigation system could also communicate with the vehicle systems (via GPRS or Bluetooth) to "press STOP" when it's time to do so, or when waiting at a bus stop, indicate the driver that a visually impaired person is waiting to get on (GPRS or other wireless Internet connection).

A sighted person could set alarms in his mobile phone to tell when it's time to start running to the bus stop - he could follow the bus he's always taking to go to work. Or he could sit down in a lobby waiting for a train or flight to leave, not having to go check the screens every now and then, but receiving an alarm instead when it's time to leave for the gate or track.

The public transport operators would benefit from a real time information interface in the web by not having to create separate interfaces TV channels (teletext) and other media requesting the timetables and updates. An operator could create one channel actually resulting in multi-channel.

Public transport route planners could use information from several operators (also static timetables) to help customers plan better routes and that way improve the use of public transport.

The operators and society would benefit from real time information services by having a cost-effective choice for building physical infrastructure to improve the accessibility and use of public transport: some of the information needs expensive to fulfill with traditional methods can be solved with personal navigation systems.

As an example, there have often been suggestions about equipping buses with radio transmitters to help the visually impaired to know when the bus is coming. The visually impaired would in turn carry a radio receiver. In Prague there is a pilot system in operation. However, for example in Finland, where we have about 80 000 visually impaired (most of them are over age 65) and 10 000 buses, a similar system would cost at least 10 million euros just for the bus transmitters. Investment this large does not seem reasonable for just one user group. All beacon based systems generally suffer from same dilemma. Also, as the visually impaired have many problems, every problem can't be solved with a separate device.

Real time information has to be, in view of a user:

- Cheap. There is no point paying 2 € for information regarding a 2 € bus trip
- Easy and fast to get. The number and format of SMS services are hard to remember. Usually ease of use requires a personal navigation software
- Correct and up-to-date.

And in view of service providers:

- In standardized or at least constant format
- Security issues have to be thought of (is the information public or classified, intranet security).

The problem with real time information interfaces and services is that starting costs are possibly higher than projected income, so the projects probably need governmental support. However, real time information would also increase the use of public transport.

3.5.1 Concept Example: Waiting at a Bus Stop

In order for a visually impaired person to get on a bus, he has to know the right bus has arrived and the relative place of the entrance. Traditionally the visually impaired hold up a sign showing bus number indicating they wish to get on the bus. However, it may happen on a busy stop that the bus driver has to stop behind other buses, far away from the visually impaired person and easily misses him.

The required data for the task:

- Route plan (by a public transport route planner) indicating the line number, estimated time of departure, stop number and stop coordinates

- Real time data from bus operator ("Bus 23 arrives in 3 minutes", "Bus 23 at stop" and/or bus coordinates).

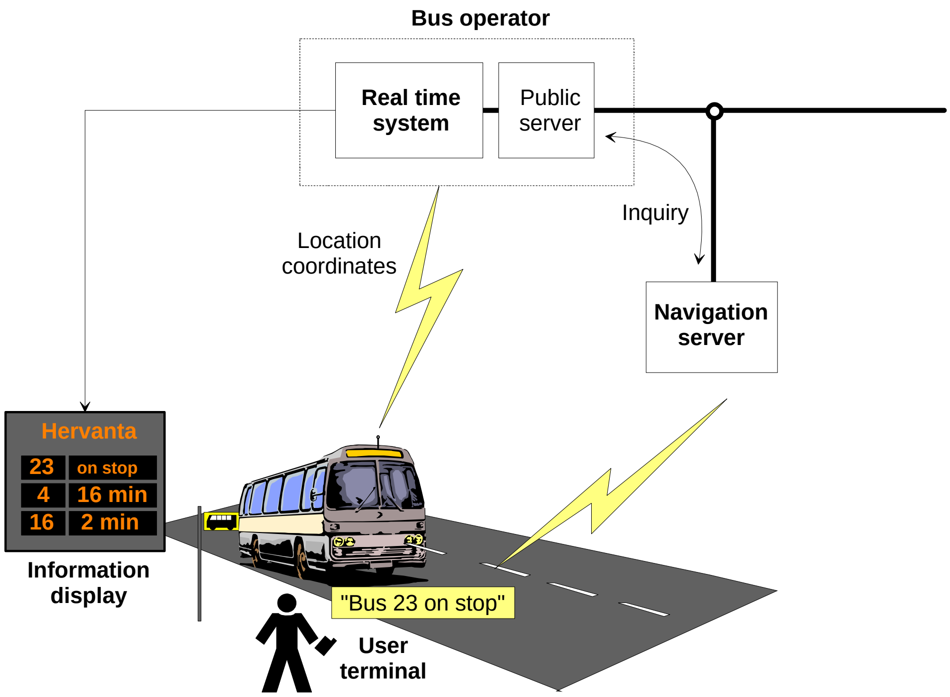

Figure 6. Real time information flow.

If real time data includes bus coordinates, it is possible to guide the visually impaired person closer to bus entrance in the case that the bus is located far from him. This requires a GPS positioning device. Positioning also indicates to the personal navigation software that the user is standing at the stop (coordinates, speed and heading). After the bus has stopped its coordinates are forwarded to the personal navigator to calculate the relative distance.

From line number and timetable we get the exact bus number to follow. The arrival at the stop can be detected from bus coordinates and speed, if exact arrival is not triggered. This method requires that the data transfer delays from a bus to a user terminal are not too long. An indication of arrival needs to be received in good time before the bus leaves the stop. The information flow is presented in figure 2.

VTT is currently building a test setup to measure delays from bus to the operator's system and then to a personal navigator, and positioning inaccuracies.

The best results can be achieved, when both the vehicle coordinates and arrival time estimate are available. In successful operation the data transfer delays play a big role. If the delays don't hinder the system, it's possible to guide a visually impaired close to a vehicle door. At least a person can be alarmed when the right vehicle is about to arrive or when it's time to leave the vehicle.

3.5.2 Concept Example: Guidance Inside a Bus

During a bus trip the personal navigator follows a route plan and gives out stop and street names. When the GPS receiver functions well inside the vehicle, the stop announcements can be generated from the route plan and coordinates directly. In case the GPS is not available, the location and stop information need to be requested over GPRS from bus operator.

The navigator can calculate the time to the target and alert the user to press STOP early enough (figure 3).

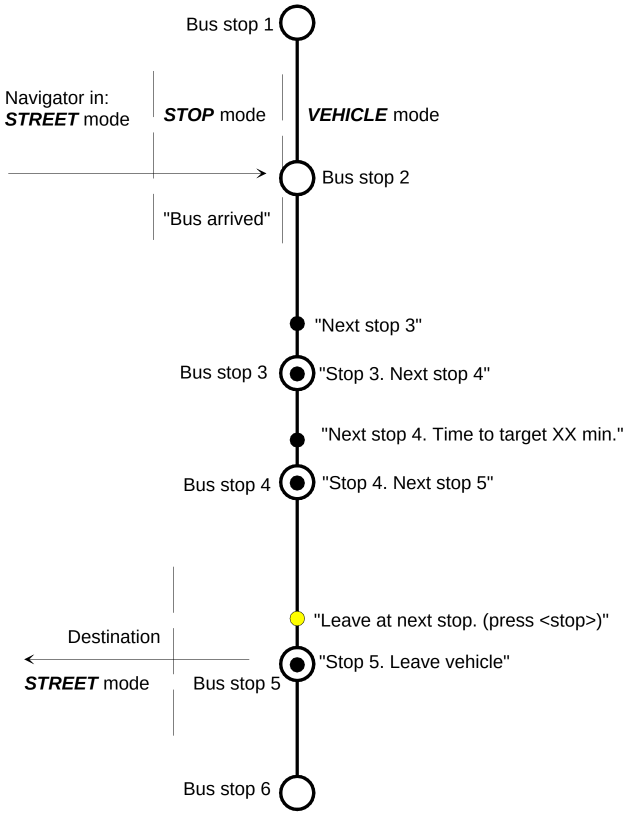

Figure 7. Guidance information and navigation modes inside a bus.

VTT has implemented GPS-based route guidance and personal announcements functionality in NOPPA personal navigator. In user tests the stop announcements from the navigation software have been found to be quite exact. When the map doesn't have large errors (> 30 meters) and GPS signal is not close to disappearing, it is possible to tell with an error of typically max two seconds, when a moving car or a bus passes a stop.

Project's real time tests are due to autumn 2004 when Helsinki City Transport's real time information interface becomes available in the Internet.

3.5.3 Concept Example: Trains

To board a train, at least some information about time, platform, train configuration and seat is required. In long distance trains, most of the information reads in the ticket. In commuter trains seat and time are not as important. Also some knowledge of the station is required to find to the platform.

Currently in Finland all train timetables are available via Internet, also for 3rd party route planning purposes. Real time information is coming into test use this year (2004) by Finnish

Railroad Administration. At the first phase information about the train's platform may however not be available via Internet, only from the train station's information display.

Station maps are available from the largest stations, but as there are no standard for indoor maps and models, the plain images are not very usable in navigation applications. Especially there is no way to automatically produce information about indoor premises for the visually impaired.

At European level a ERTMS/ETCS (European Rail Traffic Management System / European Train Control System) traffic management system is becoming into use. It is expected to provide a basis also for real time information systems and route planning.

Currently there is no sufficient digital information to guide a visually impaired board a train with a navigation system. In principle the logic is as follows:

The train's destination, time and/or id has to be entered to the navigation system, if an intercity route is not planned, in which case the user would have to enter only his seat number. Based on the train and seat numbers the navigation system can search for the train configuration and the right car.

When the train stops, if we get the position of the trains engine (or other GPS origin) from real time information system, it would be possible to tell the places of the passenger car doors and guide a person close to the right door. The idea is presented in figure 4.

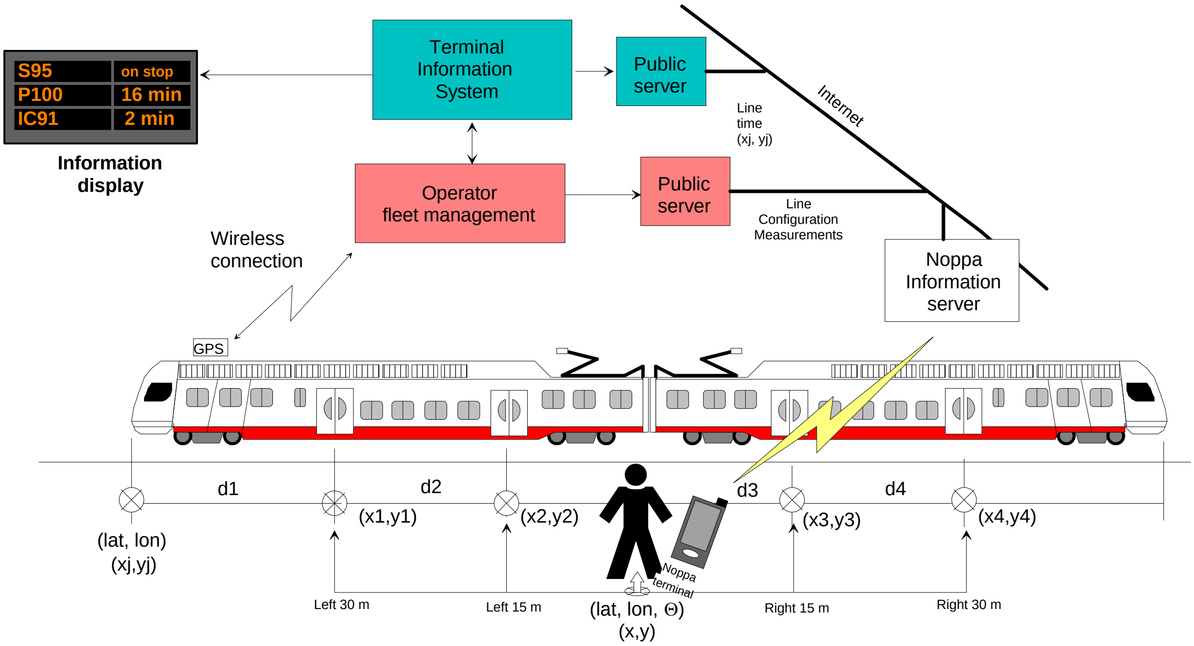

Figure 8. Guiding a passenger to car door.

At a train station it may not be wise to tell exact distances and directions, as with GPS they are always estimates with about 10 meter error, to avoid guiding the user straight to empty rails. Rough estimates with e.g. left/right directions should be sufficient. The waiting places are usually near rails and the directions could be told according to the direction of rails and train.

At a commuter train the guidance will be to the nearest car with ticket reader.

Inside a train the current GPS receivers don't usually work, so the information about the train's location or next stops has to be requested over GPRS. Time based route following is also possible when there aren't long delays. Counting stops is also possible, but the train may also stop between stations and the stops have to be compared also to timetable.

3.5.4 Concept Example: Air TRAVEL

The difference or air travel to other public transport forms are mainly that airports can be very large and complicated areas with check-in, boarding and safety controls, operation at gates and with baggage. There are also a variety of services available while the passenger is waiting for a flight.

Mobile phone navigation may be useful in requesting information about a certain flight (a personal information display) and automatically following the flight's status, receiving only the status changes. Personal announcements are also a way to ensure that the user gets the information, when audio announcements may go unheard. The user could get the information of the terminal and gate for example while traveling in a taxi, to tell the driver. Or the taxi driver could have such an information system installed which could tell the next departuring flights, their terminal and check-in desks.

In the future, electronic tickets and electronic payment may enable the ticket information to be entered directly to the mobile phone and navigation software, so the user doesn't have to enter a lot of data.

Guiding the visually impaired at an airport with navigation software could be done with text (synthesized to speech) descriptions of the area. The wireless LAN networks which are coming into use in airports could be used to some degree in positioning. Some guidance can be given even without positioning.

After boarding a plane the navigation system and mobile phones have to be turned off.

4. Conclusions

Our prototype fulfils the requirements we set at the beginning of the project. The main goal was to show that a guidance system for the visually impaired person is possible to build without laborious and expensive changes in the current infrastructure. This is possible with utilising common Internet services for passenger information and personal navigation. It seems applicable to at least buses, trains and trams in the same format. With flights the flight and gate status can be followed.

Passenger information systems should be equipped with a standard Internet interface (XML). Through this interface it would be possible to deliver static information (timetables), real time information and disturbance information in such way that it is accessible to the special user groups. These interfaces are needed for example when developing mobile applications for all passengers. Utilising real time information systems, it is possible to guide visually impaired persons to right vehicle without costly investments to the beacon systems

Development of public transport route planners should be focused on pedestrian use, because pedestrians use public transport. Required accuracy of the maps would be about 2-5 meters and routing should include pavements, crosswalks and traffic lights. Result information should include coordinates and form points of the route..

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