Navigation System for the Visually Impaired Based on an Information Server Concept

Sami Koskinen, Ari Virtanen
VTT Industrial Systems
P.O.Box 1302
FI-33101 Tampere, Finland
email: sami.koskinen@vtt.fi
email: ari.virtanen@vtt.fi

***Abstract* - NOPPA navigation and guidance system is designed to offer public transport passenger and route information for the visually impaired. It provides an unbroken trip chain for a pedestrian using buses, commuter trains and trams in three neighbour cities' area.**

The system is based on an information server concept, which has user-centred and task oriented approach for solving informational needs of special user groups. Information server with speech user interface acts as an interpreter between the user and different information databases.

Use of commercial information databases and web services ensures that the visually impaired persons get the same up-to-date information than other citizens.

This paper also presents concepts and experiences of using public transport real time information in personal navigation systems. The case presented is about using bus real time information to help the visually impaired to get in and leave a bus at the right stop.

Keywords: *visually impaired, unbroken trip chain, navigation, guidance*

I. Introduction

The presented work has been done in NOPPA project [1], which is a three-year (2002-2004) project piloting a personal navigation system for the visually impaired. NOPPA is part of Ministry of Transport and Communications Finland's HEILI Passenger information program [2], which aims to improve the accessibility of public transport information.

Electronic travelling aids (ETA) for the visually impaired have been an active theme for research. Global Positioning System (GPS) was introduced in late 80's and since then there have been many research projects like Mobic [3], Drishti [4] and Brunel Navigation System for The Blind [5], and commercial products like Sendero Group's BrailleNote GPS [6] and VisuAide's Trekker [7] addressing GPS based ETA for the visually impaired.

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.

II. Design Principles of Electronic Travelling Aids

The most important travelling aid for a visually impaired person is still **the white cane**. It is after all an excellent example of a good travelling aid: multifunctional, cheap and reliable. It also tells others that the person is visually impaired. Another irreplaceable travelling aid is **a guide dog.** Among other things the dog is also a friend and a companion.

In studies about visually impaired person navigation it has been noted that even a small amount of extra information about the environment makes a remarkable increase in performance [8]. Also it seems that a good travelling aid should produce only *small amounts of meaningful information* and the ETA should not block hearing or other senses so that the visually impaired can still use their traditional methods to acquire information about the environment. If the user needs to concentrate heavily on using the ETA, he or she has no capacity left for normal environment perception.

Therefore, instead of trying to develop ETAs to replace primary travelling aids, one should develop ***complementary*** systems.

Navigation systems have usually worked well in small-scale implementations, but a large-scale implementation may be extremely expensive (especially with beacon based navigation systems). The amount of visually impaired persons of the population is small (~ 1,6 %) and therefore large investments to special infrastructure are not sensible.

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 and 10 000 buses, a similar system would cost at least 10 M€ just for the bus transmitters.

Other methods need to be found to ensure that the visually impaired persons have equal possibilities to access same services than all the other citizens.

III. Visually Impaired Persons and Public Transport

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

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

- planning a trip
- finding a stop or 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
- receiving passenger information during the trip
- depart on the right stop
- finding the destination.

Most of these tasks are trivial for the sighted persons, but very difficult for the visually impaired. For example there have been cases when a blind has spent several hours at a bus stop, because he couldn't recognise the arrival of the right vehicle.

For true door-to-door navigation for a visually impaired there are requirements for continuous positioning, continuous (Internet) access to real time public transport information and availability of accurate map data together with roadwork information.

Electronic maps are designed for car navigation and not suitable for pedestrian route planning purposes. Information about pavements and pedestrian crossings is collected separately and not included in typical map data. Door-to-door guidance requires map data pointing entrances to houses and continuous guidance would require indoor maps and indoor positioning. These are generally unavailable today.

Nevertheless, in our studies we did not find many specific information needs for the visually impaired group alone. The information needed and sought for is in most cases useful for all passengers or already accessible to some user groups. Only the means for a visually impaired to access the information would be different. Therefore it is very important to offer additional interface, when new passenger information services are designed.

IV. NOPPA Architecture and Prototype

Our approach is to improve public transport accessibility by creating access to passenger information with a personal mobile device rather than building physical infrastructure. NOPPA architecture (figure 1) is based on public and/or commercial information services and databases available via

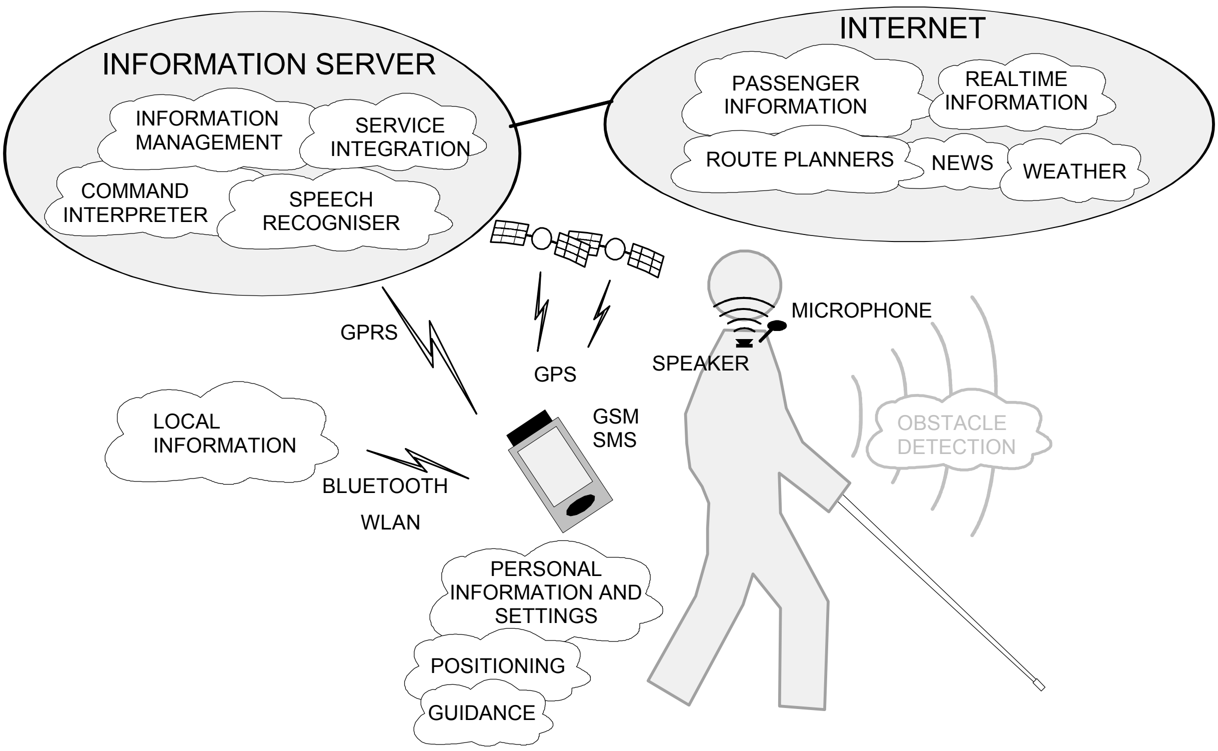

Fig 1. Architecture of the NOPPA system.

the Internet, a client-server approach with near continuous TCP/IP connection (GPRS for practical reasons) and programmable mobile devices with capabilities for speech user interface (mainly speech synthesis) and satellite positioning.

The terminal devices in NOPPA user tests have by far been various PDAs with Microsoft's Pocket PC / Pocket PC Phone Edition operating system and there is also an early version for mobile phones with Symbian Series 60 operating system.

Design goals for NOPPA were:

- Easy and fast to use (preferably faster than any traditional method)
- Affordable to the user
- Access to public transportation and passenger information systems
- Applicable both indoors and outdoors
- Integration of products and services for personal navigation
- Modular, easy to update, easy to add functions
- Speech user interface
- Easy to customize for various user groups and purposes.

The Information Server is an interpreter between the user and Internet information systems. It collects, filters and integrates information from different sources and delivers the results to the user.

The server handles speech recognition (e.g. from 13200 street and destination names) and functions requiring either heavy calculations or large data transfer from the Internet. The data transfer between the server and the client is kept in minimum. The client terminal (figure 2) holds speech synthesis, user interface, positioning and most of route guidance. The user interface is menu-based and selections are done with hardware buttons and speech input.

As the mobile devices gain more memory and faster processors some of the speech recognition work can be done in the user terminal which will further reduce the need for data transfer between the client and the server. It will also enable menu selections with speech user interface when there is no server connection. Nevertheless, the speech recognition requires a very large vocabulary (street names) which also has to be updated from time to time, so it may be unpractical to completely do the processing in the terminal.

NOPPA terminal software with speech synthesis needs to be installed on the device, completely replacing the underlaying operating system's user interface. If the operating system supports a screen reader for example, more functions (such as phone calls, SMS and MMS) can be left to original software.

The first prototype system has the following characteristics:

- Speech recognition and synthesis
- 6 simultaneous users per single server computer (a 2 GHz PC) for speech processing time limits
- Access to three route planners (commuter and intercity traffic both bus and train, also a possibility to calculate car navigation type of routes)
- Guidance and route following during a trip
- Personal in-vehicle stop announcements
- Roadwork information (connection to a city's database)
- Access to some bus, tram and train real time information systems (only early development)
- Flight departure information at the largest airport in Finland, real time
- Several news services, local weather
- Watch
- Memo
- GSM phone and SMS services (basic implementation)
- Bluetooth and GPRS connectivity (also WLAN possible)
- GPS and GSM positioning, optional pedometer and compass unit
- Indoor navigation features based on Bluetooth, WLAN positioning or compass/pedometer
- Own recorded walking routes, basic GPS functions
- Search of current address
- POI (Point of Interest) and AOI (Area of Interst) databases

Fig 2. NOPPA Pocket PC terminal and a Bluetooth GPS receiver.

The prototype is now at user evaluation phase. Usability, reliability and recovery after an error are known to be important issues. For example a continuous GPRS server connection is not possible when moving in a train, elevator or basement. The system must be designed to handle connection failures so that they don't break guidance or prevent using other functions (phone call, SMS, memo etc).

Commercial sensitive GPS receivers are able to operate inside a bus and a tram, but still greatly benefit from antenna placement near window. Also GPS receivers' slow time to first fix (TTFF, typically 30-60 seconds) can be a problem when turning a GPS first on or leaving a building after being a long time inside with no update to receiver satellite data.

The speech output in guidance and in describing a route must be carefully planned to avoid misunderstandings and to help create a mental image of the route. The program should not try to give more accurate guidance than it safely can. For example when standing near a bus stop, if the program would advice that "the bus stop is 10 meters forwards", the user might very well end up standing on a driveway. Combined inaccuracy of GPS positioning and map data is very often over 10 meters and the program should not really try to guide that short a distance (at least not require the user to move), even though there would seem to be a clear difference between GPS and target coordinates.

The difficulty is to tell the user without misunderstandings, that the calculated target is maybe 20 meters forwards, but the user has to find the exact location himself and it may not be even safe to move the full 20 meters. Often there is some information even in the short distances, so the user might want to hear the target distance and direction after all, instead of just hearing "the target is near".

In practise, one must take into account that map data can have outdated information or inaccuracies, positioning can be unavailable or inaccurate, or wireless data transmission is not always available. Therefore a lot of responsibility is left for the user and guidance is complementary.

V. Real Time Information Systems

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 WWW/XML, for distributing public transport passenger and real time information for third party purposes, is gaining more importance. Even different operators may be currently unable to share information between their systems.

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

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

Mobile phones with advanced graphics could be used as mobile real time passenger information displays. The operators and society would benefit from real time information services by having a cost-effective choice for building physical infrastructure.

Personal navigation systems should be able to provide the user with real time information regarding the route: trains delayed, traffic jams, accidents etc. The system could also check if there is need to calculate a new route.

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.

For the visually impaired, real time information might be useful for example when waiting at a bus stop: it would be easier to pick the correct bus at a busy stop when the arrival time of the bus is known accurately, instead of often 5-10 minute error to static timetable.

Real time information would also help to tell when to leave a 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.

A. Concept Example: Waiting on 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 "<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:

1. Route plan (by a public transport route planner) indicating the line number, stop number and stop coordinates
2. Real time data from bus operator ("Bus 23 arrives in 3 minutes" or "Bus 23 at stop").

If real time data includes bus coordinates, it is possible to calculate the relative distance and 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, heading).

This approach requires that the data transfer delays from a bus to a user terminal are not too long. An indication of

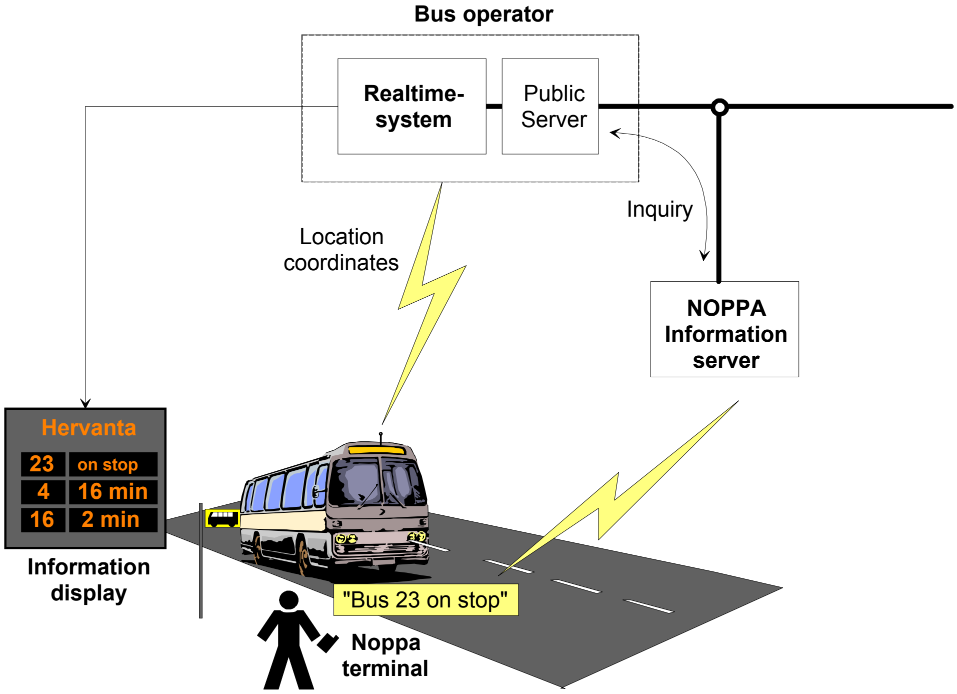

Fig 3. Real time information flow.

arrival needs to be received in good time before the bus leaves the stop. The information flow is presented in figure 3.

Compared to the example given on utilising radio transmitters on bus, the concept presented here does not require any additional investments for the visually impaired.

B. Concept Example: Guidance Inside a Bus

During a bus trip the personal navigator follows a route plan and gives out stop names. In case the GPS functions well inside the vehicle (it usually does in a bus, but not in a train), 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 could 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 4).

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.

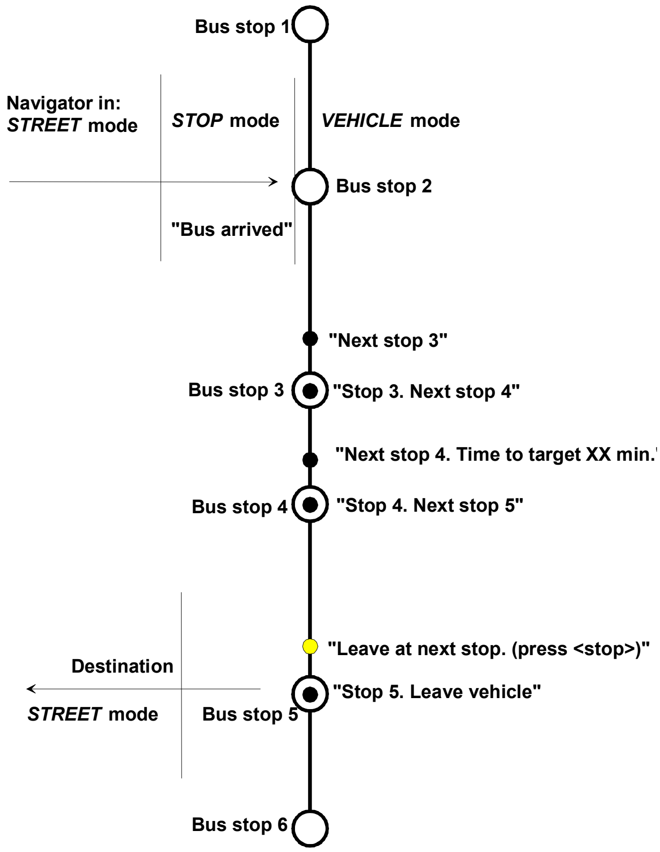

Fig 4. Guidance information and navigation modes inside a bus.

VI. 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 is possible to build without expensive investments in the infrastructure.

Currently mobile terminals with programming, speech user interface and positioning capabilities are slightly too expensive for the general public (a PDA phone and a Bluetooth GPS cost together around 1100 euro), and only the very newest GPS prototypes fill the functional needs of personal navigation in city centres. However, the presented NOPPA concept and prototype are near product phase.

Development of public transport route planners should be focused on pedestrian use, because pedestrians use public transport. Current route planners are based on car navigation maps and principles.

For optimal pedestrian use the accuracy of street maps could be approximately 3 meters, routing via pavements, crosswalks and traffic lights. With current mapping technology this kind of accuracy will become possible only in the city centres and similar areas for financial reasons. The improved quality requires additions to current standards and changes to work methods. This development work may in the future include site and indoor maps.

For efficient use of public transport passenger information in personal navigators the passenger information systems need to be equipped with an XML interface accessible via Internet. Using the interface it is possible to deliver static information (time schedules), real time and disturbance information in a way that it can be made accessible by a third party to basically all user groups.

A concept of accessing bus real time information was presented. The best results can be achieved, when both the vehicle coordinates and arrival time estimate are available.

In successful operation also 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.

The real time concept seems applicable to at least buses, trains and trams in the same format.

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