Abstract

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

It 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

1. Introduction

This 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 subject of study. 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 Groups 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.

1.1 Design principles of Electronic Travelling Aids (ETA)

The most important travelling aid for the 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 to 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 of acquiring information of 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 ETA's 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). 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.

2. 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 - 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 1). This requires that system must be context aware to recognise transition points and change automatically its mode of operation accordingly.

![Figure 1. Unbroken trip chain and different operation modes of operation.](image)

3. 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 is based on commercial information services, mobile Internet and high end mobile devices with capabilities for speech user interface and satellite positioning.

Design goals of the system were:

- Easy and fast to use
- 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.
The Information Server (figure 1) is an interpreter between the user and Internet information systems. It collects, filters and integrates information from different sources and delivers results to the user.

The server handles speech recognition (e.g. from 13200 street and destination names) and functions requiring either heavy calculations or data transfer. The data transfer between the server and the client is minimized. The user terminal holds speech synthesis and most of route guidance.

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
Voice watch,
Voice 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 with location based voice comments, basic GPS functions
Search of current address
POI (Point of Interest) and AOI (Area of Interest) databases
Voice descriptions of some public transport terminals

Figure 3. 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.

4. 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 and XML, for distributing public transport passenger and real time information for third party purposes, is gaining more importance. 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

For the visually impaired, real time information is useful when waiting a bus: it would be a lot easier to select the correct bus at a busy stop when the arrival of the bus is known accurately, instead of usually 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 audio announcements, which are often seen as disturbing by other passengers and therefore have even been turned off.

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

- **Cheap.** There is no point paying 2 € for information concerning 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
In view of a service provider:

- In standardised or at least stable format
- Security issues have to be thought of (public or secure information, intranet security).

The problem with real time information interfaces is that starting costs are possibly higher than projected income, so the projects need governmental support.

5. 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 far away from the visually impaired person and never sees him.

The required data for the task are:

1. Route plan (made 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 to bus entrance in the case that the bus is located too 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, standing direction).

This approach requires that the data transfer delays from a bus to a user terminal are not too long. An indication of arrival should rather be received before the bus leaves the stop.

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

![Figure 4. Real time information flow.](image)
6. 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 (see figure 5).

![Diagram: Guidance information and navigation modes inside a bus.]

7. Conclusions

Our prototype fulfills 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 expensive investments in the infrastructure.

Currently the mobile terminals with programming, speech user interface and positioning capabilities are a little bit too expensive (around 1100 euro) for general public, and only the very newest GPS prototypes fill the functional needs of personal navigation. However, the concept and prototype presented are near product phase.

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 fault
situation information in a way that it can be made accessible by a third party to basically all user groups.

Development of public transport route planners should be focused on pedestrian use, because the 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 2 meters, routing via pavements, crosswalks and traffic lights. For financial reasons this kind of accuracy will become possible only in city centres and similar areas and will require additions to current standards and changes to work methods. This development work may in the future include building site and indoor maps.

Concept of accessing bus real time information was presented. The best results can be achieved, when both vehicle coordinates and arrival time estimate are available. Utilising realtime systems, expensive investments for infrastructure can be avoided.

In successful operation also the data transfer delays play a big role. If the delays don't hinder the system, it's possible to even 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 it's time to leave the vehicle.

The real time concept seems applicable to at least buses, trains and trams in the same format. With flights the flight and gate status can be followed.

8. References: