Personalized Public-Transport Guidance Using Mobile End Devices

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Abstract. Mobility is a vital part of human life. Mobility needs can be met in a variety of ways: motorized and non-motorized individual traffic, local public transport using buses and trains, or mixed systems like taxis and park and ride systems. Individual traffic in particular causes major environment problems and problems of traffic congestion. Strengthening public transport is often favored, but this preference is not reflected in the number of local transport users. This phenomenon can be explained by the fact that a central problem involved in local public transport usage is its complexity. The article presented here develops demands on a personalized local public transport guidance system, analyzes existing systems and presents a solution for a personalized support system for users of local public transport systems. The software Hermes was developed for this purpose. It accompanies the travelers through all steps of public traffic usage - from checking time tables to purchasing tickets to a navigation system for pedestrians guiding the user to a street address destination.

1 Introduction

Without noticing most people put distances behind them every day that add up to several kilometers. We drive to work, to the supermarket, to the post office; we visit friends and go to the cinema. Mobility, understood as the opportunity to move around, is an important part of our lives. Opaschowski, a sociologist, even sees mobility as a "vital principle for individual and society" [1]. There are multiple ways of satisfying mobility needs [2]. Although transport is important for society, it always

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involves undesired side effects, too. The negative effects of individual motorized transport on the environment and the traffic situation in the cities are a steadily recurring issue in politics and society. There is a general agreement that local public transport needs to be strengthened and motorized individual traffic should be cut back.

The complexity of local public transport is its central drawback. Time schedules need to be found and understood, connections must be combined and adequate tickets purchased. This is usually not a problem for planned movements like the routine trip to work, but unplanned movements usually pose problems as otherwise used planning tools may not be available in such situations. Very often the difficulties involved in using public transport systems lead to using individual means of transport if spontaneous needs for movement are involved.

Mobile end devices, e.g. PDAs, smart phones or mobile telephones are especially suitable to support travelers because these devices can be used any time without booting. As the diffusion rate of mobile telephones is high in industrialized countries (e.g. Italy 123%, Germany 102%, Japan 80%, USA 77% [3]), a rising number of people are accustomed to using them. Many mobile telephones support the installation of additional software providing access to the local data of the user and the ability to access further data via the mobile network [4]. If the present geographical position of the device can be located too, its application as a personal assistant to support the user in his or her travel planning, and especially to facilitate spontaneous movements, becomes achievable. In this sense, transportation companies could give mobile applications for local transport guidance to their customers to increase usage of their transportation system. Other functions, like purchasing tickets or recommending restaurants or entertainment facilities, are also thinkable. The limitations of end devices must be taken into account if such systems are to become really useful. These shortcomings include small screens, low data processing capacities, uncomfortable navigation and data input [5,6,7];. A possible way of coping with these shortcomings is to take account of the present context of the user and his or her personal preferences and adapt the application automatically [8].

The present article aims at developing demands towards such an application for individualized local public traffic guidance, comparing it to existing solutions and presenting a solution in the form of the prototype implementation of a system called *Hermes*: Hermes (Greek Ἑρμῆς, a pile of marking stones) in Greek mythology was the messenger of the Gods as well as the protector of ways, traffic and ramblers [9].

2 Application Situations and Motivations

Computer-based, personalized public transport guidance systems have a multitude of possible application situations. The following description of six possible situations is supposed to provide an overview.

Situation 1: unplanned movement occasion: Due to a spontaneously arranged meeting, a café has to be reached. The application finds out the best public transport connection, guides the user to the nearest station or bus-stop, provides information on the station of exit and guides him or her from there to the final destination. Personal preferences and characteristics of the user are taken account of when establishing the connection. Should he or she be a member of a car-sharing company, for example, the usage of this service would be one of the possible options offered by the application.

Situation 2: change of means of transport in a planned movement: Due to very bad weather or a defective vehicle, the daily trip to work cannot be done by car or bicycle. The planned movement has to be done by public transport. The application guides the user to his or her workplace and purchases one or several adequate tickets which are presented to the ticket collector as bar codes. If the user is eligible for fare reductions or has a season ticket, this will be taken account of when purchasing the tickets.

Situation 3: support in planned movement situations: During breakfast the application checks the planned route. The evaluation of the information shows that the scheduled bus will be seven minutes late due to roadworks and there is still time for another cup of Sencha.

Situation 4: occurrence of an exceptional situation during planned movement: On his way to work, the public transport user misses a connection. The application at once establishes alternative connections as well as a footpath that could be used; additionally, it offers to call a taxi automatically. The taxi can be paid using the integrated pay function. The application can also calculate the new time of arrival and communicate it, for example by SMS, to a target person.

Situation 5: planned movement on unknown territory: On a business trip to a big city the user feels insecure because the town is unknown to him or her and the variety of means of transport is great. He or she is guided through the unknown system of traffic lines, tariff systems and stations, including guidance when changing at big traffic junctions or changing from one means of transport to another.

Situation 6: change of time schedule: While on the public transport, the next appointment is postponed or cancelled. The application provides a changed travel route and opportunities for entertainment or activities adapted to the user at the present location or at the destination.

In addition to usage situations, motivations for the usage of such an application have to be taken into account. The most important motivation is the user's wish to change his or her geographic location successfully, i.e. to reach a destination. However, there are also additional demands, e.g. the user wants to reach his or her destination on time, using as little time and money as possible; comfort and safety of the means of transport also play an important role [10]. Choosing the optimal mode of transport also depends on the user's needs, aversions and preferences.

Users can be sure that the application will definitely take them to their destination and provide support in bridging waiting times, if necessary. While users of motorized individual means of transport have full control over their times of departure and routes, public transport users depend on routing and means of transport controlled by third parties. Subjectively as well as objectively the user gains sovereignty through the high availability of information, the objective-centered processing of information and the uninterrupted support provided.

Last but not least, the application is able to reduce stress, understood as a reaction of the human body to adapt to its surroundings [11]. Distress, the disruptive form of stress, is generally seen as a negative emotion. It emerges especially when somebody needs to handle manifold information, is forced to decide unter time pressure and reach his destination unconditionally [12]. In local public transport this is definitely the case. As the application takes over information handling and partially decisions from the end user, stress can be reduced. On the other hand, the mobile end device usage as a new source of stress has to be considered.

3 Demands Towards a Mobile Personalized Public Transport Guidance System

Based on the application situations and motivations for usage described above, there are certain requirements towards a mobile application for a personalized local transport guidance system. Such an application must be aimed at a door-to-door guidance of the user. Based on the user's personal preferences and characteristics, it must process information, prepare activities and carry them out. The application must not just support single activities, but must be process-oriented. It has to support all required activities of public transport guidance.

The target group consists of all public transport users owning a mobile computer. The application must be available and operational at any time in order to facilitate also unplanned movements and to guarantee reliable public transport guidance. It has to be able to retrieve data from data networks; however, it also has to be able to cope with short-term losses of connectivity (e.g. in a tunnel).

Taking account of the users' profile, the application has to combine means of public transport, purchase tickets and pay for them, order means of transport (e.g. taxis) and guide the user via footpaths. It has to inform the user about the means of transport selected and about his or her present location to provide support in finding and using means of transport. The system has to indicate forthcoming bus stops and calculate when the user must get off the bus. It must be possible to change travel plans any time, whether caused by the user or by delays of public transport vehicles. This includes support to the user to bridge waiting time, e.g. by indicating a suitable café or restaurant or informing waiting persons (e.g. with text messages).

There are also a number of non-functional requirements. To keep user inputs low and to make the application easy to use, it should be adaptable to the user's context [13]. Most important are adaptations to preferences and characteristics, personalization and location, i.e. adaptation to the present geographic location. The usage of resources should be optimized, causing as little costs as possible. The most important cost factor in mobile applications is usually the network connection, and that is why data transfer should be minimized. As battery life time is another limitation, this resource must also be taken into account. The application should be able to run on a maximum number of different devices in order to distribute it as widely as possible [14].

The limitations of mobile end devices have to be taken account of, too. These are to be found especially in the input and output facilities and in the processing and storage of data. Context adaptation should help to make a great deal of user input unnecessary, as for example the local position is recognized automatically. The user profile should be edited on a normal PC and then transferred to the device. Mobile end devices often have functions that are useful for local transport guidance. The address of destination could, for example, be retrieved from the address book of a mobile telephone. It would also be possible to use the inbuilt calendar or text-messaging services (like SMS) as a means of communication. The application must be easy to use in order to find acceptance. Therefore it has to be adequate for the task, capable of self-description, conducive to learning, steerable, conform to expectations, error-tolerant and individually adjustable (ISO 9241 Standard). Data security and security on the level of device, transfer, transport and application also have to be assured as the application deals with sensitive data due to the processing of the present geographical position, the geographical destination and personal characteristics and preferences of the user. Otherwise privacy issues could be a central drawback for the usage of *Hermes*.

4 Existing Solutions for Public Transport Guidance Systems

Existing solutions include conventional as well as newer systems in the form of web-based or mobile applications. The public transport guidance systems are divided within the three kinds of software mentioned above according to their purpose, as shown in Figure 1.

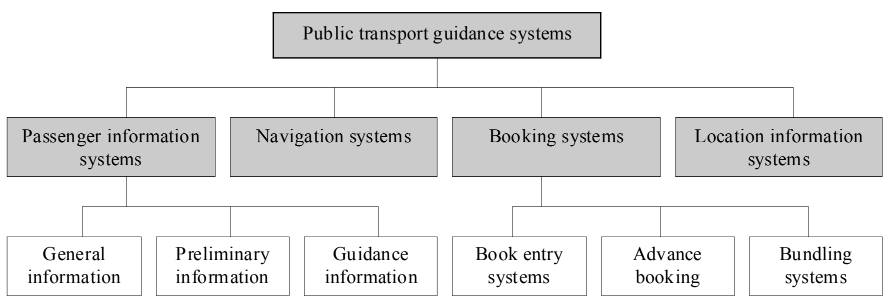

Fig. 1. Classification of public transport guidance systems

Conventional approaches: Public transport companies use printed time schedules for the general and preliminary information of passengers. These include general overviews as well as handy schedules for single routes. These are also displayed at the stations. Electronic information systems are also to be found there; they are either simple ticket issuing machines or kiosk systems with detailed information and advice functions. The information thus available is usually static; it can only show the intended state of the traffic system. Guidance information is provided through signboards and signposts at crucial traffic junctions or stops. In addition there are voice announcement, and increasingly also optical systems like digital sign boards. These systems are called "dynamic passenger information systems" [15]. Information about the next stop is increasingly announced automatically and displayed on a signboard inside the means of transport.

Web-based approaches: General information is often provided on the web sites of public transport companies. Web-based applications facilitate door-to-door guidance, providing search functions for train stations or stops, addresses and interesting sights. Certain context information, like the number of fellow travelers, reduced ticket prices on offer or preferences may be included. The application often calculates connections using multiple modes of transport, offers printouts of connections and ticket order and place reservation where applicable. Navigation is done by route planners which calculate routes using addresses and points of interest. These programs generate instructions which can be printed together with a map. Meanwhile, there are also some booking systems available from the Internet. Taxis and hailed shared taxis can be booked online in many cities, costs for car rental and car-sharing can also be calculated and vehicles booked. The bundling of traffic can be done by applications like agencies for arranged lifts; this is where users can search for appropriate lifts or offer them to others. Similar arrangements could be made for the sharing of train tickets. Local information systems facilitate the search for companies and the display of their locations on road maps or satellite images.

Mobile applications: Meanwhile there are some mobile applications in the area of public transport guidance systems. They differ in their tasks but also in the mode of implementation. Mobile travel information applications can check out connections from station to station, enter the connection into the calendar of the mobile phone and perform a simple kind of travel guidance: they list all stations to be passed through using the planned times of arrival and departure. A selection of means of transport once chosen can be used several times. More recent applications provide additional service in the form of maps of the surroundings, site plans and local information.

There are also route planners and local information systems that are mostly additions to web-based applications. Traditional navigation systems and local information systems using maps and satellite images which are able to search for companies are also available. Applications for electronic-onboard-ticketing have recently become available; they facilitate the payment of tickets via mobile phones [16]. At least in Europe, these systems are not yet very wide-spread.

Assessment of existing solutions: Conventional approaches support public transport guidance, but they are oriented towards single activities and do not cover all the needs. Web-based applications are widely available, but not applicable for mobile use. Existing travel information systems for PDA, smart phones and mobile phones can be used on the move, but they fail in classic public transport situations, e.g. underground routes or areas not covered by mobile networks. Only mobile application with intermediate data storage facilities which remain active in situations where there is no mobile network are eligible for a reliable public transport guidance system.

All existing systems are not process-oriented and have functional gaps (ticketing, payment, footpath guidance, support in finding and using means of transport, support in emergencies). Furthermore, they have a low degree of context adaptability (personalization of preferred means of transport, software localization through language adaptation).

5 Design of the Application

From the requirements it becomes clear that four main procedures to be executed by the user are indispensable: The user must be able to start using the public transport

without delay, plan the use of public transport, display local information on his or her present location and purchase tickets.
The actual use of public transport is the most complex process and will therefore be described in more detail. It always starts by establishing the optimal combination of modes of transport. If there are several variants to choose from, the user must select one. The guidance will then consist of a combination of footpath guidance, ticketing and passenger information.

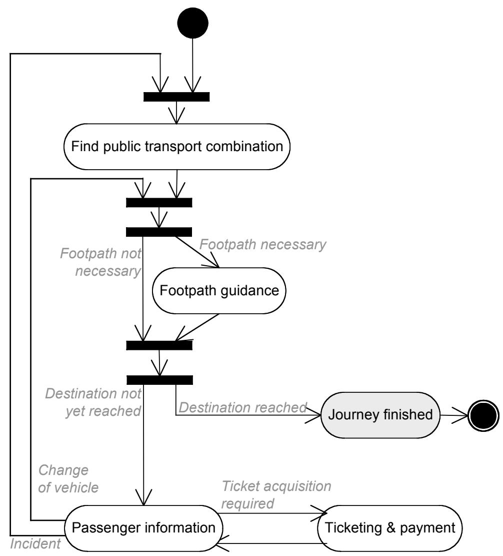

Fig. 2. Concatenation of sub-processes in local public transport guidance

Figure 2 provides an overview of the possible combinations. The user can retrieve additional data on his or her present location any time, e.g. in waiting situations. Maps of the surroundings, information on restaurants, cafés and cultural institutions, including distances, will be provided and the user guided to these locations.

The realization of the context adaptation also needs to be looked into. The application must be personalized, i.e. adapted to the technical, social and physical user context [17]. The technical limits of mobile end devices are the most important factors for the adaptation to the technical context: displays, mobile networks, free memory and energy level are the most important variables. Network connections are characterized by their quality, the amount of data transferable per time unit and usage costs. When the connection is of high quality, cost-efficient and has a high bandwidth (e.g. a WLAN) more data should be transferred than when there is a low-quality, expensive connection with low bandwidth. However, the quantity and quality of the data is to be kept unchanged in the process of adaptation, only the time of transfer should vary. Therefore the software has to anticipate the data to be transferred. If there is, for example, a cost-efficient and effective connection at the start of the journey, all data concerning connecting and destination stations should be transferred in one go - a process called hoarding. If the connection is cost-efficient but slow, the data are transferred successively in small batches; this is called prefetching [18]. However, this process also depends on the available memory. The output of the application should depend on the size of the mobile device's display, its level of activity on the energy level.

Adaptation to the user's context is the most important point in context adaptation as it includes the user's needs, preferences, aversions, competencies and prior knowledge (personalization) as well as the adaptation to the present geographical position (localization). Personalization needs a user profile reflecting the relevant characteristics of the user. It must be possible to edit this profile on the end device because it may change during the journey. The user may, for example, have purchased a season ticket or a discount which need to be entered into the profile. The profile must be easily editable. It must also be possible to edit it on a PC and transfer it to the end device. Saving it on a server system also facilitates the adaptation of information to the preferences of the user before the data are transferred to the mobile end device. All calculations from the selection of the optimal combination of means of transport to the proposal of adequate entertainment opportunities in exceptional situations have to be in tune with the profile.

Localization requires the identification of the present geographic positions and should be done automatically without involving user input. Most appropriately it is done satellite-based by GPS [19] or by triangulation of several UMTS-, GSM- or WLAN-base stations. The geographical coordinate thus received can be used in the further course of the program. Start addresses to be put into input boxes in forms could, for example, be replaced by the coordinates automatically retrieved and used for calculating routes. However, it is not only important to establish the geographical position once, but also to keep track of its change over time. While using public transport, the system must display the next stop, adapt the display automatically and change to textual and graphic aid when changing to another means of transport. Adaptation to the physical context is a complicated form of context adaptation as the physical context is difficult to capture with most mobile end devices. While the time of day is readily available, things like temperature and weather can only be estimated indirectly via globally connected sensor networks; characteristics like noise level and illumination are usually not retrievable. The application should minimize distances to be bridged on foot when the weather is bad and offer route combinations with this option only as a further choice. The same is applicable if the user has entered an aversion to walking on foot during darkness in the user's profile.

The requirements and the technical concepts show that a mobile application for public transport guidance cannot consist of a software component only. It requires the saving and editing of the user profile, which is needed for personalization, on a stationary PC. To minimize data transfer via mobile networks, the data must be adapted to the end device before they are transferred there. Therefore, a client-server-architecture was chosen for *Hermes*.

The server serves as a data storage device for the profile, web server for editing the profile and the download of the client component and as so-called “transcoding-proxy” [20]. The client component requests data from the server, transferring its context when doing so. The server component retrieves the data from its own data stores or from other server system, adapting them to the client and its context before transferring them. External data available for this project is for example the data of the geographical information system (GIS) Microsoft MapPoint®. Alternatively, sources like OpenStreetMap and GeoNames could by used.

6 Implementation of the Application

Client and server components of *Hermes* have been developed in Java. It generates a platform-independent bytecode executed on the end device by a virtual machine (VM [21]). Platform-independency makes Java the optimal programming language for this project. Mobile phones, PDAs and smart phones can be used as hardware on the client side. Java-Edition J2ME ("Micro Edition") will be applied on the end device. It has been specially adapted to the memory size and capacity of mobile end devices [22]. The server component runs on servers, personal computers and notebooks. It requires J2EE - the "Enterprise Edition" of Java and therefore its most complex version. A server application capable of processing Java Server Pages (JSP) and executing Java Servlets is also needed. This could be the Apache Tomcat® Server. Furthermore, a database is needed to save the data on the server and keep them ready.

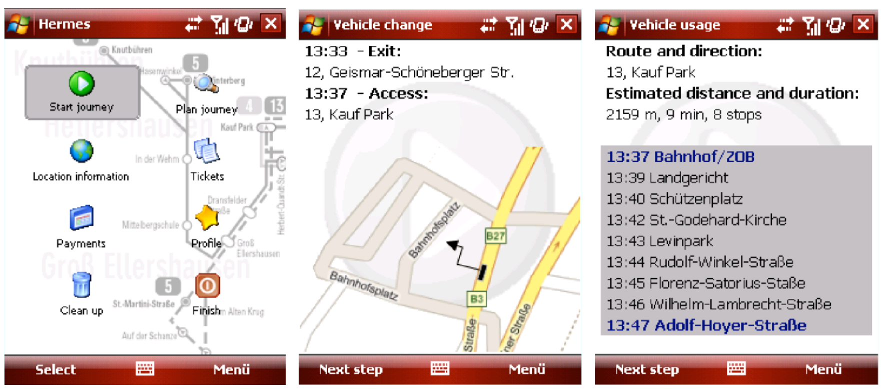

Fig. 3. Screen shot of an exemplary public transport use (main screen, change of vehicle, next stations)

A prototype was developed for the client component showing the process-oriented sequence of the application (cf. Fig. 2). All central functions (local traffic planning and implementation, local information, ticket purchase, payment, profile editing) were implemented prototypically. Figure 3 shows an extract of the sequence of a typical public local transport usage. An Internet page for registration, profile editing and the download of the application to the end device or to a PC was created as server component. It generates output in XHTML which can be displayed by browsers like Internet Explorer®, Firefox®, Safari® or Opera®.

7 Conclusions and Future Work

The ongoing development of mobile end devices and the steadily progressing standardization of platforms and frameworks [23] for the use on mobile end devices create an ever increasing number of applications for mobile use. The easy use of software on mobile end devices is a decisive factor in this context. Attention should not only be paid to the analysis and development of user interfaces and input devices but it should also be borne in mind that it is important to minimize the amount of data to be entered and the number of interactions required between user and application. This can be done through context adaptation and especially through personalization. If the application knows the preferences, characteristics and aversions of the user it can make pre-selections suiting the user or automatically initiate actions.

The implementation of the *Hermes* prototype shows how using public transport can be improved by a mobile application. The application solves central weaknesses of using public transport for the user of mobile end devices: It manages the retrieval of complex combinations of modes of transport and helps in emergencies. Therefore the application raises the attractiveness of public transport use for a growing number of persons. It can help to reduce individual motorized traffic if it becomes widespread. However, the implementation of the prototype also shows its limitations: The user must own a mobile end device and be in a location covered by mobile networks (at least when starting on the public transport journey). If the end device fails or runs out of battery, the user remains without guidance. In addition, the players in the public transport market must provide the complex information required and keep it up to date.

Nevertheless, the mobile application described above also creates new opportunities that remain to be analyzed. The attractiveness of a public transport guidance system could increase if it were not restricted to local public transport but also applicable to long-distance transport. The detailed information collected about routes traveled, regular usage times and records about occasions when public transport was desired but not available opens up totally new avenues in traffic planning.

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