Facilitating Utilization of Public Transportation for Disabled Persons by an Open Location-Based Travel Information System for Mobile Devices (VIATOR)

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Abstract — **In this paper, we present an open and extensible platform for mobile devices that guides disabled (i.e., blind or physically impaired) persons on their journeys using public transportation. The main objectives of this platform are to (1) provide up-to-date intermodal travel information (i.e., connecting vehicles, schedules, and delays) across different transportation companies, (2) automatically, without manual interaction, reroute to alternative transportation options, if required, (3) visualize physical obstacles and offer hints for each particular target group (e.g., stairs vs. elevators for wheelchair users), and (4) provide an open interface for leaving and consuming self-created location-bound hints (e.g., blind people guide blind people). The platform is called VIATOR (lat.: "the traveler") and has been developed in cooperation with three transportation companies and three research institutes in Austria. This paper presents the technical architecture, shows first results of a prototypical implementation and gives user experiences from blind and mobility impaired people.**

Keywords-VIATOR; Public Transportation; Disabled People; Mobile, Location-Based Servce Platform.

I. INTRODUCTION

People with disabilities are disadvantaged when using public means of transportation. Wheelchair users, for instance, are severely limited by stairs and raised vehicle entrances, whereas blind or visually impaired people are reliant on tactile lines or proper path descriptions in order to be able to maneuver on their own at public transportation nodes. Commercially available travel information- and navigation systems for public transportation inform their users about departure times, platforms, and type of vehicles. However, they lack instructions for handicapped persons on the way to and from public vehicles particularly at larger transportation nodes. Ponderous and inflexible content management mechanisms at the backend of such systems exacerbate maintenance for this task. Moreover, many of the systems use proprietary protocols and are unable to exchange data with or connect to competing transportation companies for a closed information chain throughout a journey.

In the course of the research project ways2go [1], within the framework of the strategic initiative IV2Splus funded by the Austrian government (FFG), a prototype for an open and extensible location-based travel information system for disabled persons has been developed guiding each target group through stations regarding their needs. It consolidates diverse travel information systems and provides navigation instructions from arbitrary sources, even from the users themselves (self-organizing content management) using a mobile client prototype with accessible User Interface (UI) elements.

The technical basis for the implementation of this research topic was a mobile location-based and context-sensitive information-, communication-, and collaboration system (Digital Graffiti, see [2], [3] and [4]) developed by the University of Linz, in association with Siemens Corporate Technology in Munich, and the Ars Electronica Futurelab also in Linz, which enables its users to place and consume information at arbitrary locations using state-of-the-art mobile tracking-enabled cell phones. Travel information (including up-to-date actual data of delays, cancellations or detours, etc.) was provided, classified and made generic for shared networking by the project partners Austrian Federal Railways Company (ÖBB), Upper Austrian Transport Association (OÖVG) and Linz AG (a Local Traffic Line Service Provider in Linz). In cooperation with the Department Integriert Studieren at the University of Linz and the Central European Institute of Technology in Vienna (CEIT Alanova) new paradigms for barrier-free interaction have been created, not only guiding users, but also offering them an instrument to provide self-created content for other users. Blind people shall be able to annotate their way for other blind people regarding their special needs.

The paper is structured as follows: Section 2 deals with selected points of state-of-the-art methods and technology. Section 3 gives an insight into the proposed system architecture for VIATOR. Section 4 illustrates the prototype and finally, Section 5 concludes the paper, assesses the preliminary results critically and prospects future work.

II. RELATED WORK

The FH Joanneum in Austria focuses on unaided free movement for people with disabilities using public transportation in a project called NAVCOM [5]. Blind persons are required to find the right vehicle or to signal their wish to enter or leave a vehicle. The authors propose a WLAN-based system communicating between public transportation vehicles and smartphones, an extension to navigation systems for pedestrians, the functionality of which ends at the entrance door of the vehicles. In general, this project group investigates the potentials of technical support for navigating handicapped people in public spaces. Within the project ways4all (funded by the Austrian government), they explore indoor navigation for visually impaired using Radio Frequency Identification (RFID) and navigation instructions with relative coordinates [6][7].

A scientific consortium consisting of four universities in Japan has developed a different approach supporting blind travelers in their navigation. A device with a haptic interface (they call it the Future Body-Finger [8]) enables blind persons to perceive their environment, measuring distances to obstacles using infrared sensors.

MoViH [9] is an approach that goes a step beyond. It tries to identify both mobility and hindering factors for persons with visual or hearing impairments. The outcome of the findings is a catalogue of effective and efficient measures to be depicted in recommendations and standards supporting public transport companies in planning environments considering special needs of blind or acoustically disabled persons. BIS – Barrier Information System [10] especially focuses on the requirements of wheelchair users. The project aims at developing a barrier-free interactive routing system in close coordination with the target group, technology experts and administrative and political stakeholders throughout the research process in order to calculate and visualize the most suitable ways to go for wheelchair users.

Target-oriented automatic delivery of information to the traveler (e.g., for indicating a transfer or delay) is the next field of investigation. First approaches try to inform travelers about entry and exit maneuvers, as an assistive application from the Polytechnic Institute of Leiria, Portugal does [11]. Most systems, though, do not inform their users about changes in the time schedule, once the trip has been calculated. Travel information has to be requested from scratch at every transition point or is difficult to handle due to a complex system of rules across transportation providers. Until today, to the authors' knowledge, there is no automatic mobile travel information system that continuously guides the passenger during his journey and context-sensitively keeps him up-to-date considering transfers or delays.

As a summary, we already recognize a series of isolated research subjects dealing with navigation aspects for disabled persons or closed information chains. The novelty in the VIATOR project is the approach for constructing traffic support systems, i.e., it utilizes a smart location-based information system and a simple processing procedure for triggering specific actions due to regional closeness of its users to selected locations, in contrast to complex rule systems discovered in related projects.

III. SYSTEM ARCHITECTURE

The name of this location-based information system is Digital Graffiti [2][3][4], a framework that stores 3D spatial information elements (e.g., text, images, sound, videos, links, or even executable code) in a central database. Every stored data tuple (i.e., a geo-position and an attached information element – we call it a Digital Graffito) is additionally characterized by a visibility space and a set of recipients. It is transferred when any of the recipients steps into its visibility space. For related developments, see, for example, [12].

As a special feature, the platform offers automatic control of electronic actions (e.g., opening a gate, starting or stopping a machine, triggering a measurement or transaction) without any additional manual action, when a given device is in the vicinity of a Digital Graffito containing executable code (see [13]), presuming adequate access privileges of a person, a device, or a software system.

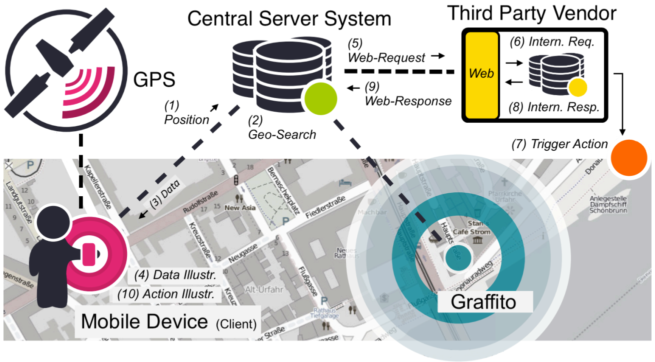


Figure 1. System Architecture for Proximity-Triggered Code Execution

Figure 1 illustrates the common principles of the software architecture enabling proximity-triggered code execution: A central server system stores geographically linked information in appropriate fast traversable geo-data structures (e.g., r-trees). Clients repetitively transmit their own (commonly by GPS-based) position to this server (1) which evaluates the geo-data considering visibility radiuses and access constraints (2) and transmits the corresponding results back to the clients (3). Generally, when the transmitted information contains conventional text or pictures, it is immediately displayed on the output device of the client (4). The basic idea for executing code is to store program fragments inside these information elements instead of text or binary picture data. Therefore, we propose a web-service-based mechanism, which is both effective and simple to extend: The information elements contain URL or XML-based web-requests to a remote web-service, which is the actual component to execute the code. When a client receives information containing a URL or web-request, it is resolved (5), handled internally (6) and finally triggers the desired action at the third-party vendor (7). A response back to the client (8, 9) can additionally be illustrated as a visual confirmation whether the action was executed successfully or not (10).

This mechanism is fairly simple and handles standardized HTTP-requests supported by a majority of currently utilized mobile platforms. Important for third-party vendors: Their internal data representations, servers and control units are hidden from the publically accessible location-based service, guaranteeing a maximum of data security for the vendors. The architecture provides the basis for a high degree of extensibility to third-party systems, for the number and variety of electronic connections is unforeseeable and simultaneously enriches the potentials of such a service.

We have conducted experiments on this innovative interaction paradigm: We have put a proximity-triggered code element in front of an electronically controllable gate at the

University Campus. An authorized person approaching the element automatically triggers the execution of the contained code, which causes the gate to open. Admittedly, this use-case is more of a proof of concept than a practical application, for GPS-data are not accurate enough to differentiate between two cars in a row, however, it demonstrates the potentials of the service enabling its users to initiate any electronically controllable actions just by their physical presence.

Applying this service as the technological basis for a mobile public transportation guide means utilizing the location-based action control mechanism for up-to-date calculations regarding transportation schedules. The transportation companies have to provide standardized interfaces for requesting their schedules, enabling their users to site-specifically and automatically perceive appropriate departure information when they arrive at a station or stop (similar to the big screens showing the departing trains). The user is consequently able to pick the desired destination by a single click and, thus, to anonymously specify a route.

Concerning intermodal travel routes, the system does not invent routing algorithms and scheduling procedures from scratch. Instead, it utilizes existing services and triggers them on demand in the same way as the time schedule example given above. So, the system continuously (and, in particular, location-sensitively) re-initiates calculations regarding the selected route by the location-based action control mechanism at neuralgic maneuver points during the journey, i.e., at train stations, bus or tram stops, etc. In general, neuralgic points are particular locations along the route where users may enter or leave means of public transportations. This means that a user automatically triggers the route planning service of the appropriate vendor at spatial proximity to his next stop and is informed about his schedule and connecting means of transportation, giving the passenger a continuous information chain during his journey.

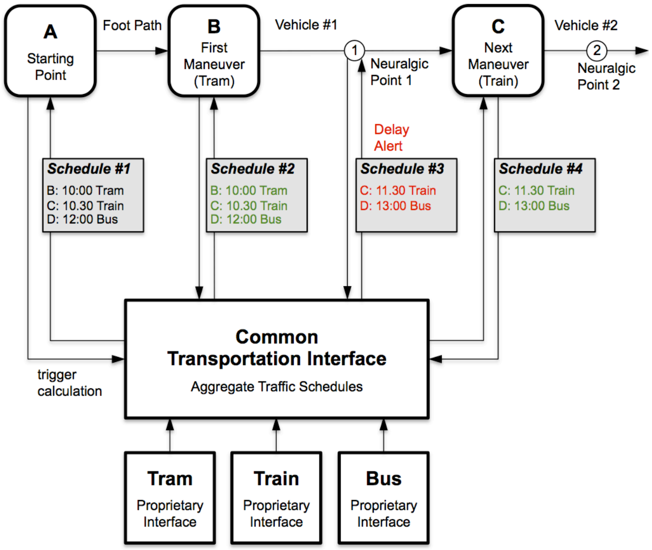


Figure 2. Intermodal Route Recalculations at Neuralgic Points

Figure 2 gives an impression on the procedure with a fictive example: A user starts his journey at an arbitrary location (point A), walks by foot to a tram station (point B), takes the tram to the main railway station (point C), uses the train, and finishes his journey with a bus (point D, not depicted in the figure, anymore). At point A, he initiates the calculation procedures (the only manual interaction by specifying the desired destination), i.e., the system collects all available data concerning the given route from different transportation providers (via a Common Transportation Interface) and offers a sequence and a schedule of the involved vehicles. Along the route, the system places active Digital Graffiti at neuralgic locations, which automatically trigger recalculations when the user arrives there.

So, while staying at point A the system continuously (i.e., with a time-controlled delay) recalculates the same route over and over again, offering the user the chance to specify his journey in advance without considering time schedules. The system always has the most up-to-date travel information for its users.

When leaving point A, the next neuralgic point along the route (i.e., point B in our example) initiates recalculations. As this point is also a maneuver point (i.e., where the user must enter or leave a vehicle due to his schedule) the system not only provides an up-to-date route but also informs the user on the departure time by an alert. In our example, the first recalculations (schedule #2) produce the same data as the initial calculations, indicating that there is no delay or change in the schedule.

While travelling with the tram, the same mechanism is repetitively applied at every neuralgic point (exemplarily shown by point #1). The corresponding schedule reveals a delay for the subsequent train (i.e., the new schedule deviates from the last one) and automatically postpones the trip with the connecting means of transportation after the newly calculated arrival time of the train. When schedules differ, the system automatically notifies its users by an alert. Alerts are also fired when the user is requested to get off at his last stop before changing means of transportations. The signal to leave is triggered by location and is therefore independent from any delays in the time schedules.

Principally, this procedure with repetitive recalculations (done by external schedule calculation services) as shown in Figure 2 is the main idea and a new approach for implementing an automatic mobile location-based travel information service. A “Common Transportation Interface” consolidates proprietary interfaces from different transportation providers and delivers up-to-date schedules every time a user approaches his next neuralgic point along his route.

In terms of barrier-free routing the same mechanism is applied: A handicapped person entering a station or stop automatically triggers navigation calculations due to his/her user profile (i.e., due to the type of disability), selected route and schedule. Users may either receive navigation instructions along tactile lines or get the quickest route to the next elevators. These calculations are externally sourced out to special route computing services with centralized data collections to be updated either via Content Management System (CMS) operators or by the users of the system themselves, who are able to edit these instructions due to their experiences on-site via the inherited mechanism of the basic system for editing Digital Graffiti information elements.

Figure 3 illustrates the principle: Every neuralgic point stores a set of additional active information elements addressed to specific profile groups, e.g., blind people, wheelchair users, etc., which automatically trigger profile-related footpath calculations for the way to the next vehicle. Please note that not every point necessarily stores information for each profile group. However, every user is capable of adding or updating information. Also, note that, for simplicity and scalability reasons, these information elements are directly linked to neuralgic points; they do not have their own position, e.g., in between two bus stops.

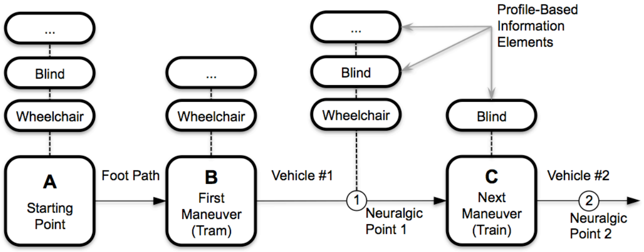


Figure 3. Profile-Based Navigation Instructions at Neuralgic Points

As a summary, the basic mechanism for barrier-free intermodal navigation providing up-to-date travel information and offering an active notification- and feedback instrument for direct interaction and self-organization of the information content is based on location-based action control, a function available from the basic platform Digital Graffiti. So, the VIATOR system does not contain complicated new algorithms for managing complex collaboration of different information providers. Instead, it utilizes a simple mechanism applied for all tasks, which makes the entire system easy to understand, maintain and extend.

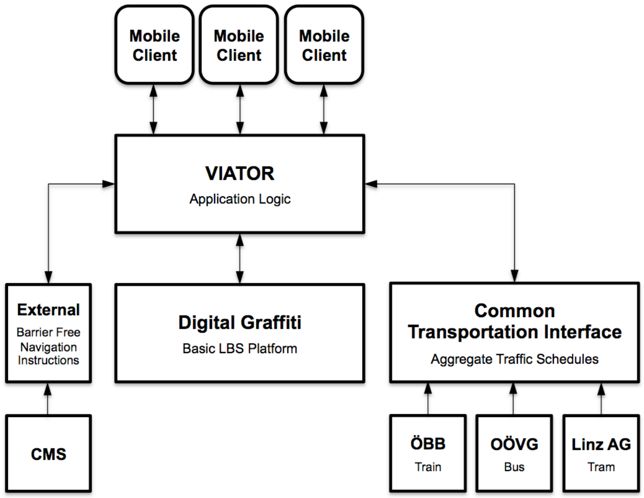


Figure 4. VIATOR system architecture (simplified excerpt)

Figure 4 gives an impression on the collaboration of involved components, omitting details due to space limitations: The application logic is encapsulated within the main VIATOR server component, communicating to its basic platform Digital Graffiti, which remains completely unchanged in its elementary behavior and is executed as a separate process. The mobile clients connect to the main VIATOR server component, which delegates all Digital Graffiti-related functions to its underlying platform, enabling the clients to create and consume location-based information elements. The system is extended by two separate processes consolidating travel information from different transportation providers on the one hand (Common Transportation Interface) and providing barrier-free navigation instructions on the other (left side). The latter can either be managed through CMS or via the VIATOR application logic indirectly by the clients.

IV. PROTOTYPE AND EXPERIMENTS

VIATOR has been prototypically implemented using JBoss AS7 Java Enterprise Application for the server components and Android for the clients. We have conducted several tests in the city of Linz arbitrarily using different means of transportation from the involved transportation companies. Figure 5 gives an impression on a typical test run:

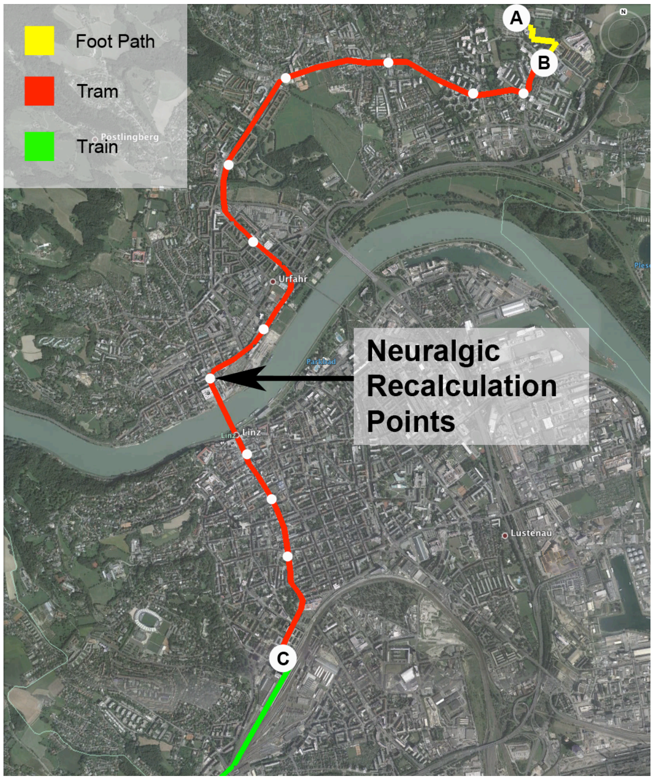
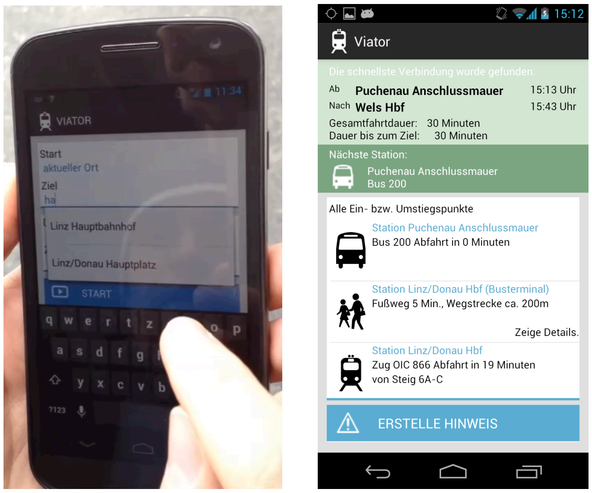


Figure 5. Test Run for Route Recalculations at Neuralgic Points

We started our journey at the University (A), walked by foot to the next tram and bus station (B) and continued either by tram or by bus (both options are possible for this route) to the main rail station (C), where we stopped our journey (for convenience and time reasons). However, this abbreviated trip is enough for evaluating the mechanism when more than one vehicle is involved. The picture also gives an idea of the position of neuralgic points along our test route. Please note that the points are closer along the tram line than along the train line. This is due to the distance of stops and stations for the different means of transportation.

At point A, the user enters the desired destination (see Figure 6a). The user can either type (and auto-complete) a destination or select from a list (considering the transportation options due to the user's current location). After clicking the START button, a summary of the input, the next station and all subsequent maneuvers are listed (b).

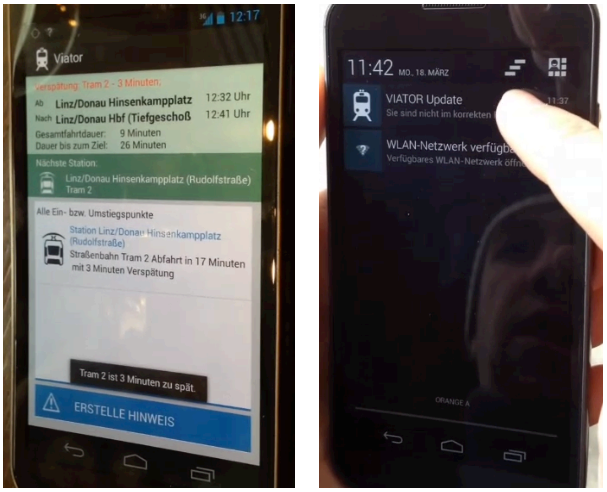


Die schnellste Verbindung wurde gefunden.
Ab Puchenau Anschlussmauer 15:13 Uhr
Nach Wels Hbf 15:43 Uhr
Gesamtfahrtdauer: 30 Minuten
Dauer bis zum Ziel: 30 Minuten
Nächste Station:
Puchenau Anschlussmauer
Bus 200
Alle Ein- bzw. Umstiegspunkte
Station Puchenau Anschlussmauer
Bus 200 Abfahrt in 0 Minuten
Station Linz/Donau Hbf (Busterminal)
Fußweg 5 Min., Wegstrecke ca. 200m
Zeige Details.
Station Linz/Donau Hbf
Zug OIC 866 Abfahrt in 19 Minuten
von Steig 6A-C

Figure 6. VIATOR UI: (a) Enter Destination, (b) Display Route

As the user interface in all figures is kept in German, here is a brief translation: The upper input field in Figure 6a contains the current location ("aktueller Ort") determined by the location sensors of the smartphone. The user inputs two letters for the destination ("Ziel") and is offered a list of options. The light green section in Figure 6b always displays a summary of the specified route. Departure ("Ab") and destination ("Nach") are listed in combination with departure and arrival times and a summary of the total travel time ("Gesamtfahrtdauer") and the remaining time ("Dauer bis zum Ziel"). The dark green section always shows the next maneuver task for the traveler (in this case, the user has to take a bus with number 200 at the given bus stop). Finally, the remaining white section lists all subsequent maneuver tasks including footways.

So far, VIATOR looks similar to existing travel information systems. The first difference is noticeable, though, when unforeseen events occur and the route changes (i.e., either means of transportation or the schedule). In these cases, VIATOR actively reacts, informs the traveler about the change and calculates new options without manual intervention. Figure 7a gives an example of a delay immediately announced via an acoustic signal and a red marquee text on the top. When the app is in foreground, the user is directly confronted with the change.

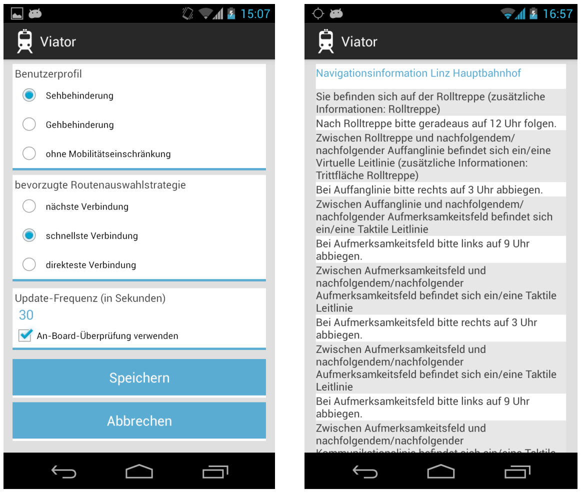


Verspätung: Tram 2 - 3 Minuten;
Ab Linz/Donau Hinsenkampplatz 12:32 Uhr
Nach Linz/Donau Hbf (Tiefgeschoß 12:41 Uhr
Gesamtfahrtdauer: 9 Minuten
Dauer bis zum Ziel: 26 Minuten
Nächste Station:
Linz/Donau Hinsenkampplatz (Rudolfstraße)
Tram 2
Alle Ein- bzw. Umstiegspunkte
Station Linz/Donau Hinsenkampplatz (Rudolfstraße)
Straßenbahn Tram 2 Abfahrt in 17 Minuten mit 3 Minuten Verspätung
Tram 2 ist 3 Minuten zu spät.

VIATOR Update 11:37
Sie sind nicht im korrekten
WLAN-Netzwerk verfügb
Verfügbares WLAN-Netzwerk öffn

Figure 7. Alerts: (a) Detour Info, (c) Notification Bar Alert

In Figure 7a, the user is informed in the black bottom bar that the alternative vehicle chosen is also 3 minutes late. When the app is in background mode, VIATOR utilizes the Android notification bar for alerts and enables the user to get back to the app via a single tap (Figure 7b).



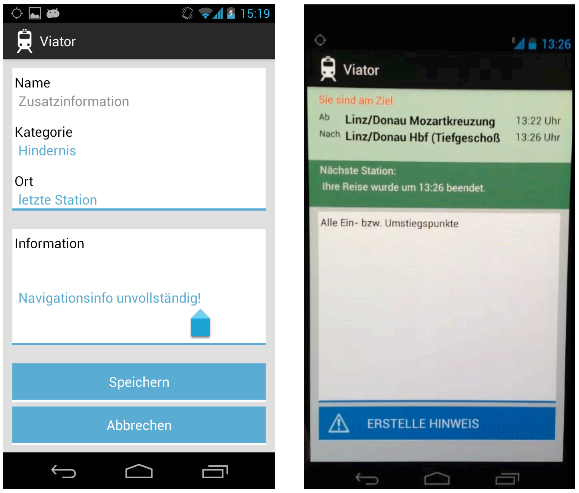
Benutzerprofil
● Sehbehinderung
○ Gehbehinderung
○ ohne Mobilitätseinschränkung
bevorzugte Routenauswahlstrategie
○ nächste Verbindung
● schnellste Verbindung
○ direkteste Verbindung
Update-Frequenz (in Sekunden)
30
☑ An-Board-Überprüfung verwenden

Navigationsinformation Linz Hauptbahnhof
Sie befinden sich auf der Rolltreppe (zusätzliche Informationen: Rolltreppe)
Nach Rolltreppe bitte geradeaus auf 12 Uhr folgen.
Zwischen Rolltreppe und nachfolgendem/nachfolgender Auffanglinie befindet sich ein/eine Virtuelle Leitlinie (zusätzliche Informationen: Trittfläche Rolltreppe)
Bei Auffanglinie bitte rechts auf 3 Uhr abbiegen.
Zwischen Auffanglinie und nachfolgendem/nachfolgender Aufmerksamkeitsfeld befindet sich ein/eine Taktile Leitlinie
Bei Aufmerksamkeitsfeld bitte links auf 9 Uhr abbiegen.
Zwischen Aufmerksamkeitsfeld und nachfolgendem/nachfolgender Aufmerksamkeitsfeld befindet sich ein/eine Taktile Leitlinie
Bei Aufmerksamkeitsfeld bitte rechts auf 3 Uhr abbiegen.
Zwischen Aufmerksamkeitsfeld und nachfolgendem/nachfolgender Aufmerksamkeitsfeld befindet sich ein/eine Taktile Leitlinie
Bei Aufmerksamkeitsfeld bitte links auf 9 Uhr abbiegen.
Zwischen Aufmerksamkeitsfeld und nachfolgendem/nachfolgender

Figure 8. (a) Select Impairment, (b) Maneuver Instructions for Blind

In terms of barrier-free usage, VIATOR offers to select the type of impairment as part of the user profile. The prototype contains three options for blind and disabled persons and for persons without disabilities (see top of Figure 8a). The middle part of Figure 8a offers to select the preferred route calculation method: next, fastest, or direct. At the bottom, the user can select the update frequency – indirectly influencing battery consumption. Figure 8b shows a (pretended unstructured) flow of text representing navigation instructions for blind people. A visual format is unnecessary, though, because this text is meant to be read by screen readers and is only considered for the blind. Exemplary translation: "Nach der Rolltreppe bitte geradeaus auf 12 Uhr folgen" means: "After the escalator go straight ahead, direction 12 o'clock".

Figure 9a gives an impression of an editing tool enabling its users to create or update navigation instructions (self-organization). Users may provide a subject (“Name”), categorize the information (“Kategorie”) and place it to a desired location (“Ort”). Subsequent travelers perceive this information automatically when they arrive at this location. The screenshots show a simple implementation of the principle of self-organization. Of course, voice memos or voice recognition would probably be the preferred technology.



Name
Zusatzinformation

Kategorie
Hindernis

Ort
letzte Station

Information
Navigationsinfo unvollständig!

Sie sind am Ziel.

Ab	Linz/Donau Mozartkreuzung	13:22 Uhr
Nach	Linz/Donau Hbf (Tiefgeschoß	13:26 Uhr

Nächste Station:
Ihre Reise wurde um 13:26 beendet.

Alle Ein- bzw. Umstiegspunkte

Figure 9. VIATOR UI. (a) Editing Tool, (c) “Get Off” Alert

When the traveler arrives at a maneuver point (either for transfer or at the final destination), VIATOR signalizes to get off (“Sie sind am Ziel”, see Figure 9b). This feature distinguishes VIATOR from conventional navigation systems, like Google navigation, location-sensitively (and therefore at the exact maneuver time) telling the traveller what to do next without any manual interaction by its users.

V. CONCLUSION AND FUTURE WORK

The first subjective impressions (no systematic investigations were conducted so far) prove that the general idea of a location-based travel information system for disabled persons is working, however improvements due to experienced weak points are still to be incorporated. VIATOR (1) provides up-to-date intermodal travel information concerning connecting vehicles, schedules, and delays across different transportation companies, (2) automatically, without manual interaction, reroutes to alternative transportation options, (3) guides handicapped people due to their needs (e.g., maneuver instructions along tactile lines for blind people), and (4) provides an open interface for leaving and consuming self-created location-bound hints.

However, the tests have also revealed the first weak points of the system: As an example, the navigation instructions for blind people are in need of improvement (particularly when we consider different types of visual impairment and different walking behavior). We also miss a more accurate method for locating users inside buildings (referring to approaches of indoor navigation done by [5][6][7][8]). In a next step, the consortium focuses on the “bridge” between two connecting public vehicles for handicapped people, their personal preferences regarding navigation instructions (i.e., turn-by-turn vs. “environmental” instructions, etc.), investigating the potentials of categorizing different profiles for the same target group for more adequate support.

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