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ROUTE4ALL: a novel approach to pedestrian navigation for people with special needs

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ABSTRACT

Within ROUTE4ALL project we created an extended data model of geographical information database suitable for navigation of people with special needs as well as of general population. Moreover, we provide a methodology for its interpretation and a guide for its implementation into navigation devices. The results of the project could be used by navigation device developers for creating a fully-fledged navigation for people with special needs. First, we describe the requirements for the extended data model, which rise from the research we conducted with people with special needs and from the survey of existing solutions. Second, we introduce a catalogue of geographic elements, their attributes and relationships. Finally, we discuss its benefits over the traditional approaches.

KEYWORDS: geographic information database, landmark-based navigation, routing algorithms, disabilities

1. Introduction

Mobility and ability to travel independently is one of the key requirements for satisfactory level of quality of life. The limited possibility to travel freely can often lead to social exclusion and all of its negative impacts such as loss of work, friends, and hobbies and eventually to worsening psychical condition of a person.

This applies specifically to people with limited orientation and mobility abilities, e.g. visually impaired [1] and mobility impaired persons (e.g. wheelchair users). Their limitation affects the efficiency of the wayfinding process, which consists of ability to avoid obstacles and hazards in their vicinity and of finding a route to a remote destination [2]. There are already a number of navigation aids and systems focused on people with special needs. They range from "human" assisted systems and tools (i.e. tele-assisted navigation centers for visually impaired SONS, http://navigace.sons.cz) to individual navigation tools (e.g. BlindSquare, Navigon), with the tendency towards individual unassisted navigation. Unassisted navigation systems often require hardware allowing the localization of the user and the software for route planning and navigation instructions. The backbone of such systems is a geographical information database. However, even navigation systems for people with special needs usually uses geographical information databases primarily designed for car navigation. These databases uses street network for route planning and presentation of the navigation instruction, which are the weakest part of today's navigational aids.

The project ROUTE4ALL – "The extended data model for the disable people and the methodology of its interpretation in the navigation" aims to eliminate this problem by means of enhancing geographical information database with sidewalk network. This is in line with conclusions of the meeting Galileo User Forum in

2013[1], that basically states that common models used in pedestrian navigation still use street network, which is not acceptable and that if there are special pedestrian databases they are scattered all around the world and not unified, which poses a problem for wide scale implementation.

One of the main goals of the project is to bring together expectations of pedestrians and people with special needs and experience with creation of car navigation maps in order to create easy to maintain map data model with all the required features in sufficient level of detail.

2. Related Work

Currently, there are a number of projects and applications focused on navigation of pedestrians with special needs. The main aspects negatively affecting the wide-spread usage of these systems are: positioning accuracy, usability of user interface (both software and hardware) and navigation functionality – route planning and navigation instructions.

The positioning accuracy is affected by the precision of satellite positioning systems (up to 24.5 meter mean error in buildup areas [3]). Therefore, it has not yet been possible to develop a navigation system precise enough to recognize the precise location of the user in the urban environment. The accuracy problems are caused by distortion of the navigation signal on the way from the satellite to the receiver. Most of these errors can be eliminated using a combination of several existing satellite navigation systems (e.g., GPS[2], GLONASS, COMPASS and Galileo together with satellite correction systems, e.g., EGNOSS[3]). The combination of different satellite navigation systems and built-in sensors of a navigation device (e.g., accelerometers) can significantly improve the positioning accuracy. However, the final accuracy error is caused by multipath signal distortion present mainly in the urban environment. These errors cannot be mitigated easily and developers of navigation aids have to focus also on other possibilities than just satellite based navigation.

The software and hardware development has resulted in significant advances allowing comfortable use of navigation devices by people with special needs. Majority of modern smartphones is equipped with text-to-speech and speech-to-text technologies and they are already used as a primary navigation device). Even though modern navigation devices are often equipped with touch screens, which are highly impractical for people with special needs, there has been an extensive research focused on improvement of usability. Approaches such as dividing screen of the device into a several virtual keys with different functions assigned or tactile stickers overlaid over the virtual keys have been explored [4].

The route planning algorithms and navigation instructions and their presentation need to be adapted for specific needs of users with special needs. For example aspects of length and speed of a route are may be less important than a requirement of the route with fewer barriers. Moreover, the route planning algorithms have to combine more criteria than standard car navigations, which are nevertheless still used for pedestrian navigation despite the lack sidewalk information (important landmarks, staircases, barriers, etc.). It is apparent that standard turn-by-turn car navigation instructions and route planning are insufficient for navigation of people with special needs, particularly visually and mobility impaired.

There is an intensive need for extended data model of sidewalks suitable for navigation instructions based on sidewalks and landmarks and optimized route planning. Moreover, experimental navigation systems with instructions enhanced with landmarks (corners of buildings, slopes of pavements, or even photos of buildings) proved to have higher acceptability by users and improved their comfort during the travel [5].

Even though navigation systems still use the standard “street only” geographical information databases, research is focused on experiments with “sidewalk level” navigation. Results from this area bring new knowledge and concepts of geographical information databases as well as new drawbacks. However, only small test areas have been covered by these experimental geographic information databases so far. Further, different approaches of different research groups are leading to incompatible data models. In most cases experimental geographic information databases cover university campuses [6], and therefore cannot be used as a suitable exemplar for the creation of geographical information databases covering large scale areas such as centers of capital cities.

The lack of focused research and development in the field of geographical information databases based on sidewalk networks tailored to the needs of navigation of people with disabilities hinders the mass use of navigation devices in the community.

2.1. Navigation systems for people with disabilities

The research of navigation problems related to people special needs also focuses on utilizing existing products and services. As an example, we mention several projects and applications that help people with special needs when navigating in the urban environment.

Projects:

- Project Sidewalk – a project focused on crowdsourcing of curb information for navigation of wheelchair users. http://sidewalk.umiacs.umd.edu/
- HaptiMap – a project focused on user requirements and design guidelines for map applications used in navigation http://www.haptimap.org
- Inclusion – a navigation system for mobility impaired users moving on the electric wheelchair with route planning based on the type of disability. http://www.gsa.europa.eu/innovative-lbs-socialpublic-dimension
- WAYS4me – a project aiming at barrier-free navigation on mobile devices. Emphasis on additional information for the blind, for entire route including public transport and trains. http://www.ways4all.at
- Rollstuhlrouting – a project for wheelchair users from Germany, which allows calculation of the route to the destination point, taking into consideration parameters selected by the user from

[1] Use of GNSS services for persons with reduced mobility or orientation

[2] http://www.space.com/19794-navstar.html

[3] http://www.egnos-portal.eu

the list. Uses OpenStreetMap for navigation http://www.rollstuhlrouting.de
- ACCESS – a project aiming at navigating blind people or older people, with lot of available documents. http://www.fp-access.de
- BIS project – a project aimed at creating a routing web applications tailored to the needs of wheelchair users for the city of Vienna. The data model is formed on the basis of findings from consultations with the "wheelchair" community (http://wege-finden.at)
- Atlas of accessibility of Prague by the Organization of Wheelchair – a printed map covering the accessibility of buildings within the city of Prague, parks and monuments. It includes accessibility information and classification for selected objects. The publication is a practical and useful guide also for people with strollers and other groups for which can be stairs or other barriers in public spaces unpleasant obstacle http://www.presbariery.cz/publikacni-cinnost/publikace-pov.html

Routing

- Loadstone GPS application – a mobile application. Blind person has the possibility to determine its location and to find out information about nearby objects, or to get routed to the specified destination. Maps used by the application are from freely available sources, particularly from OpenStreetMap http://www.loadstone-gps.com
- Naviterier – application for navigating visually impaired people in the buildings using a mobile phone. Uses landmark based navigation and itinerary approach http://www.naviterier.cz/
- Navigation service center SONS CR – provides navigation over the phone (by an assistant). Use special tracking unit. In the center the user position is visualized on the aerial map http://navigace.sons.cz
- Easy Walk service – application for mobile phones that enables blind people to get a voice information about his position and eventually to get an assistance from call center – similar to the navigation center SONS http://easywalk.ilvillage.it/en/index.jsp
- BlindSquare – a mobile application listing points of interest in the vicinity of visually impaired user http://www.blindsquare.com

3. Extended Data Model Requirements

The projects and applications mentioned in Related Work section are each focused on a specific community of people with special needs. However, the specific needs of visually impaired and people with mobility impairment with regard to the identification of barriers in urban environments largely overlap. For example stairs are a barrier for wheelchair user, however, a significant landmark for visually impaired person. Therefore, there is a potential for creating a common data model of navigation maps.

3.2. General requirements

Based on the related work, we have identified that there is a general lack of an appropriate geographic information database model usable by more groups of users with special needs. Regardless the individual navigation techniques of the groups of users, the extended data model has to build on several fixed rules and requirements:

- Compliance with existing standards and rules of a barrier free accessibility i.e. determining and deriving of attributes and their limit values.
- Maximum possible compliance with the GDF standard, used for navigation model description, i.e. if possible, use existing nomenclature.
- Maximum ease of administration and updating data given by the model, i.e. if possible the simpler and more forward solution is better than a complex one.
- Extensibility of used dictionaries and enumerations by new values when the need arises, and its implementation into data model.
- Incorporation of different user perspectives on map attributes (physical landmarks), e.g. lamp post, a restriction for a wheelchair passage due to narrowing of the sidewalk, is a good information landmark for visually impaired, the important attributes has to be not only remaining width of the sidewalk but also lateral and longitudinal post position relative to sidewalk.
- Possibility of a crowdsourcing (community supported update off the map data). Data model is created so that it is possible to store information about current phenomena (barrier, obstacle) or degraded surface conditions without the necessity to change an underlying geometry. For example by indicating the beginning and end of the phenomenon relative to the geometry.
- To respect the „multi-phase" data collection, for example, orientation points for visually impaired can be collected at a later stage, if it turns out that it is a busy route for a blind people.
- Possibility to import (use) geometry or attribute information from other existing databases. Vectorization should be based on a technical map, which is a ground truth for other elements.
- Ensuring direct linkage / interconnectivity to navigational road databases (i.e. StreetNet), where some sections are for both vehicles and pedestrians and their representation already exists in a road database (e.g. Pedestrian zone). To ensure navigation even for unimpaired pedestrians in areas that are not yet covered by "pedestrian" data update it is required to have geometrical continuity between the already existing routable road database(s).

3.2. Requirements from methodologies for navigation of people with special needs

Several methodologies are used for classification of on-route objects according to dimensions and obtrusiveness for the impaired and existing accessibility mappings. These methodologies are cornerstone for creation of a data model for a navigation map. Moreover, the methodologies were created by organizations uniting visually impaired people and mobility impaired people and are used to manually describe their regular routes (e.g. route to work, nearest bus stop, etc.). Methodologies are as follows:

- Methodology for mapping the accessibility of objects from the perspective of persons with reduced mobility www.presbariery.cz
- Methodology of marking routes for of wheelchair routes KCT http://www.kct.cz/cms/turistika-pro-vsechny
- Methodology for labeling the accessibility of routes and roads http://www.presbariery.cz/konference-a-jednani/jednani-trasy-2014.html
- Methodology of accessibility www.vozejkmap.cz
- OSM methodology of University of Heidelberg http://wiki.openstreetmap.org/wiki/Wheelchair_routing
- Ordinance of the Ministry for Regional Development of the Czech Republic no. 398/2009 about general technical requirements ensuring barrier-free use of buildings.

By mapping of accessibility we understand a collection of specific information about a particular segment of pedestrian segment in a real world. Evaluation of the information from different user perspectives leads to assessment of overall passability of the segment. Each user group has different passability criteria. The data model is designed to take into account the criteria of all user groups.

3.3. Physical phenomena (elements) suitable for data collection

The selection of phenomena important for route planning and navigation instructions is based on the specific requirements of people with special needs and the results of extensive user research conducted in 2016 [7].

Table 1. Possible elements and attributes of a navigational model for 2 user types [own study]

Movement impaired	Visually impaired[4]
Problematic parameters:	
• lateral slope • longitudinal slope • horizontal gap • vertical gap • grate with gaps in the walking direction • walking areas surface • the coefficient of friction • passage width	• open areas (max 8 m without guideline) • objects that cannot be discovered by white cane (e.g. in height from the knees up), waste-bins, side payphones, of stopping shelters • doorway height • passage width • temporary obstacles – e.g. Excavation
Longitudinal elements in the data model (segments) "pedestrian road" (crossings, sidewalks, pedestrian paths, places for road crossing, passages, overpasses, underpasses, pedestrian zone, shoulder, ramp)	
• Section length • passable width • magnitude and direction of lateral slope • magnitude and direction of longitudinal slope • surface type • crossings type (controlled or uncontrolled) • coefficient of friction • railings	• Section length • passable width • magnitude and direction of lateral slope • magnitude and direction of longitudinal slope • surface type • crossings type (controlled or uncontrolled) • railings • land use around the sidewalk (building, greenery, road, etc.) • longitudinal projection of special features (scent, noise)
Point elements	
Local barrier on a given segment of a maximum length of 3 meters or stairs up to three. • ramps to sidewalks – length, width, magnitude and direction of lateral and longitudinal slope • ramps to public stops – length, width, magnitude and direction of lateral and longitudinal slope • elevators – door width, "cage" width and depth, lift capacity, on-line information about the functionality of the lift, travel (lifting) time, comprehensive assessment of accessibility (availability of controls / buttons, door opening system, availability of controls / buttons inside the cabin – height, offset from the corner) • platform – entry width, platform width and depth, load (capacity), on-line information about the platform functionality, travel (riding) time, platform type (vertical, slanted, on a closed track, open, locked) • horizontal gaps (rails, rain drainage ...) – gap width, distance of two horizontal gaps • Vertical gaps (steps) – directionality (entry or exit), distance between two vertical gaps.	Orientation points mainly. • Guidance voice beacons • information boards with voice output • natural guidelines (minimum length of individual parts 1500 mm) – house walls, retaining walls, fences, greenery edges (with curbs > 6 cm, or without), railings with a stop for a white cane or other compact elements of the minimum width. 400 mm height min. 300 mm • artificial guide line – signal strip, warning strip, guide road crossing strip, palpable strip, warning strip on dedicated lane (metro), guide line with warning stripe function, sinusoid or trapezoid grooves • entrances to buildings • Places / objects with a strong sensory potential (sound/noise/scent) • passages • types of building corners (round, square, polygon …) • public stop posts and other landmarks • pitfalls (without a stop for a cane) – billboards, trash cans, phone booth, bus stop shelters, information stands • information stands with voice output

[4] People with serious visual impairments, the blind, practically blind

4. Implementation of Geographical Information Database

All possible elements of the extended data model and general principles for their selection are discussed above and in more detail in the project ROUTE4ALL internal memos. This chapter constitutes of a description of basic procedures and elements that were selected for the creation of geographical information database.

4.1. Data collection

Basic criteria for the selection of attributes / features of an extended data model were:

By identifying users and their requirements for passage of the route, select the real world phenomena that will be collected and define the way of collecting them (either by field work or by deriving data from existing sources). Define the way how the elements will be fitted into the model, for "obstacle type" elements define the criteria which make them a barrier, use this criteria for as a precision guidance when collecting these elements.

The navigation model is designated for route planning and guidance along the way. Users, especially in the urban environment, cannot estimate their position with high precision (meters), due to incapability of positional systems such as GPS in urban environments given by especially reflections from buildings.

Therefore exact position of phenomena on the path is not important, i.e. supplying user with exact position in units of meters of a specific object brings no information and possibly creates confusion. Experiments [8] with visually impaired participants showed that navigation instructions in form of precise distance (e.g., „in 31 meters turn left") are less usable than less precise information as the participants were not able to estimate the precise distance.

Furthermore, precise information like exact slope, height or width of an element with an accuracy of centimeters is also unnecessary; only certain limits (from-to) of width, slope, height, are important as they make the route impassable for certain user groups. It is therefore beneficiary to collect them in precision given by those limits.

The above considerations, given by the application of the user perspective, helps to reduce time and work necessary for data collection in contrast to creating a CAD blueprint suitable for construction purposes.

4.2. Data elements of geographical information database

Based on user requirements for movement and orientation in space, mainly introduced above, the model of a navigation map is composed as follows.

Representation of pedestrian segments

The streets in the road model are represented by linear segments that intersect at a point (node). In the case of the intersection on the Figure 1 four line segments connects. In ROUTE4ALL approach a pedestrian network in the same area have eight line segments one for each sidewalk, four line segments one for each crossing and four corner points. In case of changing of sidewalk geometry in real world, that affects pedestrian behavior, the impaired pedestrian should be notified, this is facilitated in the model by dividing such segment to several parts. So, in such case, even more than eight sidewalk segments might be used.

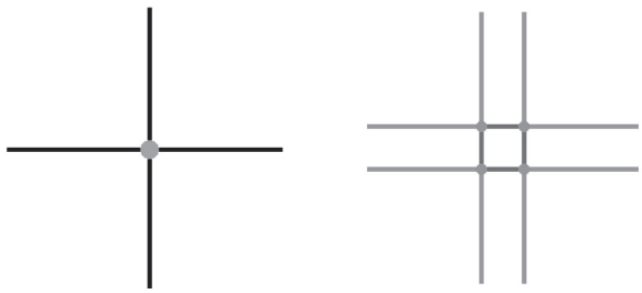

Fig. 1. Topology of a road (left) and pedestrian (right) network [own study]

Definition of types of sections / roads

Movement of people with limited mobility and orientation in an urban area is facilitated mostly on "pedestrian segments", e.g., sidewalks. Those pedestrian segments are mostly reserved for pedestrians only, but also can be shared with other means of transport – cars and bikes. Car movement on such segments is limited – entry only with permit (pedestrian zone) or by speed limit (residential areas) – or is it a dedicated road, which is the only possible approach to the destination.

Table 2. Types of sections in navigation database [own study]

pedestrian only segments	Segments with shared use with other vehicles	cross roads
• sidewalks along the street • sidewalks off the road • trails in parks • public spaces • stairs and ramps in a steep terrain • passages	• cyclists and pedestrians paths • pedestrian zone • residential zone • dedicated road	• level crossings • underpasses • overpasses • stairs and ramps into underpasses or overpasses

Segment characteristics

Each segment has certain characteristics that may affect the travel convenience of users. This may result in lesser speed of users or influence their choice of route. When the characteristics are severe the segment might be impassable for some users. Important characteristics influencing the passability are as follows:

- longitudinal and lateral slope
- width
- the quality and type of surface

Some segments have also important temporal aspect – for example the opening hours of passages, roads in winter, etc.

Not only property of the segment alone, but also the properties of the neighborhood are important for some users. They are mainly used by people with disability to help with their orientation. The most usable are:

- land use and land cover along the segment
- linear phenomena along the segment (railings, etc.)
- sound and olfactory cues

Crossings characteristics and curb ramps

To overcome roads, crossing or dedicated paths are used. Because of the differences in height of road and a sidewalk are crossing entry and exit critical points for citizens with impaired movements (wheelchair). Following features of crossing and curb ramp are important for assessing the possibility of passage:

- the height and the type of curb
- slope of reduced or "angled" curb
- slope of the ramp
- size of landing
- width of ramp (where the sidewalk is in the level of the road)

As the curb ramps eliminate the vertical edge of the curb used by visually impaired pedestrians, it is necessary to have a detectable warnings (acoustic signalization, stripes) to mark the boundary between the sidewalk and street.

Stairs and ramps

A staircase or even a mere step is problematic for people with limited mobility. Often, there is a possibility to use a ramp along the stairs. In places, where there is a greater height differences an elevator or mobile platform may be used.

Point barriers and landmarks

Information about the elements that are located along or at the sidewalk is important. Those elements might be represented as points (within max. 3 m length) or as linear features in the model.

For a mobility impaired person these elements may represent a barrier – e.g. narrowing the width of walking areas below the width of a wheelchair or a high step. For people with impaired orientation these elements improve orientation thus helping to navigate the route.

Tab. 3. Point barriers and landmarks [own study]

point objects	linear objects	temporary objects
• objects of urban immobiliary (benches, bins, boxes ...) • objects of a technical nature (columns, signs, lamps ...) • gaps, ridges and other obstacles lateral to the walking direction • entrances • corners of buildings	• a fence, wall • handrails, portico • trench / slope	• improperly parked cars • excavations • scaffolding • the front gardens restaurants

4.3. Linking of the model object to a pedestrian segment

Phenomena that are important in terms of route planning and navigation instruction may have one of the following relations to a pedestrian segment:

- phenomenon occurring throughout the pedestrian segment
- phenomenon occurring at specific locations along the pedestrian segment
- phenomenon occurring on the part of the segment
- phenomenon occurring outside the pedestrian segment

The basic pedestrian segment (having geometry) is defined from crossing to crossing. Sometimes the segment are cut even between crossings.

Phenomenon linked to whole pedestrian segment

This is the simplest mode of representation, because it is not necessary to create a new geometric representation of the phenomenon.

Examples of phenomena that can be linked to the entire segment are slope, width and surface quality, described in the model by interval values. For a long segment where some of these phenomena vary outside the interval, it is advisable to split the segment, to two or more homogenous segments.

The assessment of necessity to cut the segment, takes into account the fact that the (wheelchair) user can tolerate for very short stretches certain „worsening" of sidewalk characteristics. So, the section described by the longitudinal slope interval of 4-6 % will have most of the slope in this interval, but on a very short stretch, may have slope of 6-8 %.

Phenomenon linked to a specific location on a pedestrian segment

In this case, a standard approach is to create new geometry – a point described by its coordinates and linkage to the segment to which it belongs. Another possibility is to create just a data item linked to the segment by its relative position from the start.

These "point type" phenomena (shorter than 3 m) can be linked to one segments (typically crossing curb ramp) or more segments (building corner).

Phenomenon linked to a part of a pedestrian segment

Same as above but with extent defining affected part of the segment.

The phenomena has linear representation (extent has to be greater than 3 m). Typical example is railings, landuse, excavations etc. It can also be used as an alternative representation of phenomena that are otherwise related to the whole section, but in terms of data maintenance, it is preferable link it to the segment, e.g. when a part of a section is in desolate condition – after the repair is not necessary to change segment attributes, but only to delete points representing the starting point of the originally desolate part.

Phenomenon outside of a pedestrian segment

In this case, new geometry is created – point described by coordinates and link to segment or by relative position. This is not an own representation of the phenomenon, but only entry point, which links to another object described by its own geometry and attributes. Typically, these represent address points and points of interest. It also serves as representation of public stops – that carries a link to the phenomenon described in an external database of public stops and connections.

4.4. Data collection

Reference base for vectorization of pedestrian segments is a city technical map – segment geometry corresponds to the level of accuracy of the map (see Fig. 2). In nodes (especially in the areas of intersections) the topology has a higher importance than the position accuracy.

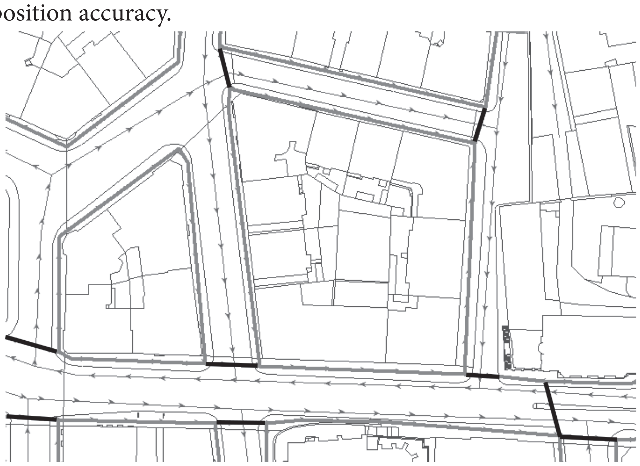

Fig. 2. Representation of sidewalks along the streets (grey) and crossings (black) in the model [own study]

Additionally, aerial photographs, street network geographical information database, specific paper maps created mobility impaired, street view and or even on-site reconnaissance can be used for higher precision of the vectorization.

4.5. From an extended data model to routable geographical information database

The extended data model consists of information usable by all groups of users with special needs. However their preferences in finding the route are different, therefore mappings from the extended model to its routable interpretation has been defined:

- ROUTE4ALL model defines a structure for storing all phenomena – i.e. events important for all pedestrians and people with limited mobility and orientation.
- ROUTE4WHEEL model defines a subset of ROUTE4ALL model for the mobility impaired users, and it is built as a specific interpretation of the ROUTE4ALL model.
- ROUTE4BLIND defines a subset of ROUTE4ALL model for the visually impaired and it is built as a specific interpretation of the ROUTE4ALL model.

All specific geographical information databases have to employ multi criteria route planning with regard to all selected routable features. During the project the segment and feature attribute values (width, slope, etc.) were reclassified into 4 categories with different effect on the segment "passability" following figure. In finding a suitable route, each segment used on a route adds up its passability value (acquired by classification) to the overall impedance of the route. The passability value of a segment is not given by the length but by its characteristics impeding user movement and is classified into values 1, 2, and 3. The segments with lower (better) passability value may have small part belonging to more difficult category.

An example of the phenomena (with different passability impact) is the height of the curb, which is particularly important for wheelchair user group. Limit of height value for full passability is 2 cm, height 5 cm may be acceptable for some users (e.g. a wheelchair user with accompaniment), higher curbs already constitutes a barrier to movement for all wheelchair users. From the perspective of a blind person the important height is 8 cm; lower curb height requires existence of a warning strip. Data model therefore has to take into account the requirements of all user groups – from which it derives the classification requirements of individual phenomena.

			w_width	
	WIDTH	*length*	9+ m	3-9 m
1	0-59 cm		9	9
2	60-69 cm		9	9
3	70-79 cm		9	9
4	80-99 cm		9	3
5	100-119 cm		3	2
6	120-149 cm		2	1
7	150-199 cm		1	1
8	200-299 cm		1	1
9	300+ cm		1	1

Fig. 3. Reclassification of interval attribute width to 4 classes for wheelchair user of different ability (classification: 1 = "novice", 2 = "apprentice", 3 = "master", 9 = "unpassable") [own study]

Based on user selection the route could be composed of segments classified with value 1, 2 or 3. Classification values relate to:

- 1: full barrier-free accessibility to the entire user group,
- 2-3: partial barrier-free accessibility, passability only for some users,
- 9: no barrier-free accessibility for the entire user group, i.e. unpassable.

Total impedance of a route is used for the selection of optimal route.

4.6. Evaluation with people with special needs

The extended data model was evaluated in several user studies with visually impaired participants and in one study with wheelchair users. The results showed efficiency of the itineraries based on the model. The studies confirmed that the proposed extended data model and its interpretation improved the feelings of safety and efficiency of the participants during the travel [7].

5. Conclusion

In this paper we have shown that there have been quite a number of project focused on navigating specifically impaired pedestrians and on creation of a map for such purposes. The project ROUTE4ALL we are describing in this paper focused on convergence of different approaches across all users (visually and manually impaired, people with strollers, etc.) thus bringing together knowledge from "both worlds". We have created one model of navigation map which can be by automatic transformations converted into routable map either for visually or for manually impaired users. Developed model was tried out on 1 square kilometer are in Prague old town and tested in navigation system Naviterier and independently developed application for wheelchair users.

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