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Providing Web Maps for Everyone. Understanding Users and their Requirements

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1 ABSTRACT

In the last years, advancement of digital technologies has led to the development of innovative information and communication applications. Today, geographical digital tools are closely linked to computer-based communication processes, and contemporary (Geo-)ICT is extensively used in a wide range of different applications. However, for taking full advantage of these tools across society – including special needs groups – manifold open issues still have to be considered referring to topics such as e-inclusion. Interest is rising on enabling visually impaired to make use of web map applications, especially web-based city maps. Due to demographic change – associated with the rapid aging of population and the increasing number of people with age-related visual impairment – this is particularly in recent times. Unfortunately, the access and use of currently available web map applications is difficult or even impossible for visually impaired. Hence, several questions pertaining to the appropriate design and implementation of web maps for visually impaired are still open: (1) How to design and configure user interfaces of web map applications for visually impaired? (2) Which functionalities need to be implemented? (3) Which map content is demanded by visually impaired? (4) Which kind of graphical and non-graphical map design is most useful to enhance accessibility? The *AccessibleMap* project aims to investigate the above mentioned questions and to develop methods to make web-based city maps more (easily) accessible and usable for visually impaired. A prototype web map application is developed.

2 INTRODUCTION AND RESEARCH QUESTION

Rapid advance of information and communication technologies (ICT) has changed the way we communicate, exchange information, and catch up on contents. Virtual globes, web mapping services, GPS, and many other geographical digital tools are closely linked to computer-based communication processes. This opens up new opportunities for E-inclusion. The concept of E-inclusion focuses on widespread web accessibility for all users, enabling everyone to benefit from ICT. It tends to support participation of everyone in all aspects of today's information society. The concept of E-inclusion is in line with the goals defined by the *Digital Agenda of Europe* which generally aims at "(…) to chart a course to maximize the social and economic potential of ICT, most notably the internet (…)" (EC 2010: 3). In addition, the *i2010 Initiative on E-inclusion* targets at "(…) to realize an inclusive information society, that is, an information society for all" (EC 2007: 2).

Hence, the concept of E-inclusion focuses on *digitally* including disabled users who cannot (fully) access and use web-content. This refers to persons with vision deficiency such as people with reduced, i. e. limited vision, colour-blind, and blind users. In fact, these target users are very heterogeneous as – for instance – they embody elderly people which due to age-related visual impairment experience similar difficulties in retrieving web content. Thus, demographic change and the growing number of elderly people underline the outlined demand.

In this context special interests arise in terms of web-based maps. As by studying a map, users create a mental or cognitive map and can *understand* space in a better way (Tolman 1948). Alike maps in general, web-based maps are crucial means in terms of helping people to orientate themselves in physical space, and to guide from place to place. By enhancing mobility skills, (web-based) maps improve the quality of life and support a more active life and aging. A person who is mobile can better perform autonomously daily-life activities, and can hold up social networks (UN Habitat 2006; WHO 2007). Thus, (web-based) maps are important assistive (Geo-)ICT-based solutions. This refers especially to the urban space, where city maps can enhance individual sense of confidence, autonomy, competence, and feeling of safety. Generally, these maps

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can be used for the discovery of urban space, i. e. the location and spatial relation of streets, crossings, and landmarks etc.

However, even though different types of assistive technology and visual aids (e. g. screen reader, braille display, text to speech technology) as well as guidelines and standards of accessible web design have been developed, for this special needs group it is currently difficult or even impossible to make use of the available web-based maps. Research is still needed to provide accessible graphical and cartographic information (i. e. maps) on the web for visually impaired. Several questions on appropriate design and implementation of web-based maps for visually impaired exist: (1) How to design and configure user interfaces of web map applications for visually impaired? (2) Which functionalities need to be implemented? (3) Which map content is demanded by visually impaired? (4) Which kind of graphical and non-graphical map design is most useful to enhance visual accessibility? To answer these questions major importance refers to understanding the user group *visually impaired* and their requirements.

The project *AccessibleMap,* funded by the Austrian Federal Ministry of Transport, Innovation & Technology within the Benefit program (started in April 2011), addresses the above-mentioned questions. The *AccessibleMap* project is based on the research results of the *AmauroMap* project (funded by the Internet Foundation Austria in 2010; Wasserburger & Neuschmid 2010). The main objective of the *AccessibleMap* project is to develop and improve usage of web-based maps according to the requirements of visually impaired people. Therefore a prototype of a web map application is developed that is executable on PCs and mobile devices.

3 ANALYSIS AND SPECIFICATION OF USER REQUIREMENTS

Within the *AccessibleMap* project constructive co-operations between users and target group experts as well as developers are principally seen as a fundamental precondition for and a central aspect of the application development process.

The *AccessibleMap* project analysis and specification of user requirement is based on a literature review as well as on a user survey, focusing on the above outlined target user groups. Therefore an online questionnaire was designed using the internet survey tool SurveyMonkey (URL 18) according to the principles of empirical social research. The survey was developed in close co-operation between the different project partners (ICT-experts, GI-experts, target user group experts).

The questionnaire design is based on the results of the comprehensive literature review which covers literature from e. g. Web Cartography, Modern Cartography, Special Needs Cartography, and Cybercartography (Hennig & Zobl 2011). From reviewing the literature available on the topic, it became obvious that detailed information on design and implementation of web map applications for visually impaired is mostly missing. Thus the questionnaire was particularly designed to get response on open questions regarding user interface design and functionalities, map design, and map content.

The questionnaire consisted of 55 open and closed questions addressing the different types of visual impairment. The questions referred to:

(1) Demographic issues (sex, age, education, profession, place of residence etc.);

(2) Aspects regarding the visual impairment of the participants (type, extent and timing of the visual impairment etc.);

(3) General characterization of internet user behavior (extent of internet use, use of digital devices, use of assistive technology and visual aids etc.);

(4) General characterization of web map user behavior (extent of use, problems, purposes etc.);

(5) User needs on map content (user group specific information, supplementary links, etc.);

(6) User preferences on the graphical and non-graphical user interface design (access and use) including functionalities;

(7) User preferences on the (carto-)graphical and non-(carto-)graphical map design (cartographic means of design, use of additional information media like photos, audio signals, verbal description etc.).

The survey was carried out in autumn and winter 2011. The study was spread across Austria, Germany and Switzerland by Email, telephone and face-to-face propaganda. The data collected by the survey was preprocessed (identifying valid and invalid responses such as responses of non-visually impaired), statistically analyzed (e. g. frequency distribution, measures of central tendency), interpreted, and integrated in existing knowledge, experiences and other research findings.

4 TARGET GROUP SPECIFIC USER REQUIREMENTS

The *AccessibleMap* user survey resulted in 199 returned and 158 valid questionnaires. The valid questionnaires are grouped under three subgroups of target users as follows:

- people with reduced and limited vision: 59 %,
- colour blind: 4 %, and
- blind: 37 %.

Because of the large number of issues covered by the questionnaire, only selected items are presented in the following.

4.1 General use of the internet and web map applications

The majority of the 158 (valid) respondents indicates to make strong use of the internet. 63 % of the interviewees use the internet several times per day. To make full use of the internet, assistive technology and visual aids are required by 85 % of the respondents (Table 1). In this context voice output, screen reader, braille display, and magnification software are the most popular tools.

Assistive technology & visual aid		**Blind** (n=59)	**Limited vision** (n=99)	**All (n=158)**
Braille display	An electro-mechanical device for displaying Braille characters by use of raising dots through holes in a flat surface. This enables blind people to read text output on the computer.	88 %	10 %	39 %
Braille embosser	A Braille printer that renders text as tactile Braille cells.	25 %	3 %	11 %
Magnification software	Software for enlarging text on the computer screen (e. g. screen magnifier, ZoomText).	3 %	57 %	41 %
Optical Character Recognition (OCR)	Software used to convert scanned text into information that the computer can recognize. This software – along with PC and scanner – gives visually impaired people access to almost all printed material.	53 %	9 %	25 %
Screen reader	A software application used to identify and interpret text presented on the computer screen into spoken words. Common screen readers are Window-Eyes from GW Micro, JAWS from Freedom Scientific, etc. NVDA is an open source screen reader that gets well-known nowadays.	80 %	24 %	45 %
Voice output	A text-to-speech (TTS) system converts normal language text into speech.	88 %	31 %	53 %

Table 1: Used assistive technology and visual aids (multiple replies possible).

Even though the interviewed persons show a high level of internet usage, only 56 % point out to use web maps. Respondents mentioned different reasons therefore:

(1) Web map applications are not (easily) operable, i. e. not (easily) usable.

(2) Web map applications do not provide verbal descriptions of their content.

(3)Web map applications cannot be interpreted by screen reader, Braille display or voice output.

(4) Users lack knowledge on the existence of web-based maps.

(5) Users make use of voice-operated navigation devices instead of web map applications.

Hence, the provision of voice output and textual, i. e. readable descriptions is a fundamental requirement to enable usage of computer applications including web map applications to these users. In terms of web map applications this refers to the user interface as well as the map content. While blind users generally rely on assistive technologies and visual aids, also 36 % of the persons with low, i. e. limited vision ask for information in audio output format, and 35 % demand for written texts explaining the map content.

4.2 Requirements on user interfaces

During the last years several graphical and textual user interfaces providing specific features focusing on the needs of visually impaired have been designed and implemented (e. g. The European GUIB: graphical and textual interfaces for blind people). As stated by GOLLEDGE, RICE & JACOBSEN (2006: 183) "… multimodal interfaces (implemented as graphical, audio, textual, and haptic user interfaces) are becoming increasingly important in many areas, including geospatial information processing". Addressing different senses enables users to access and use information according to their personal preferences and capabilities (GOLLEDGE, RICE & JACOBSEN 2006). Experiences, expertise and findings on user interface design which complies with the demands of visually impaired are also useful for the implementation of user interfaces providing web maps for visually impaired.

Thus, for instance, literature emphasizes that accessible user interfaces should only use simple visual design avoiding patterned or complex backgrounds and provide buttons and menus (most) relevant to the users to reduce the complexity of user interfaces (Hung 2001; Jacobson 1998). Therefore, the most important functionalities for the users need to be specified and implemented. Here, the survey shows that the respondents make use of web maps for several purposes: Most of the interviewees point out to use web maps for address search (44 %) and navigation (37 %). Only 18 % use web maps to discover a (city) area, i. e. finding points and areas of interest (museums, public buildings, health care services and facilities, features on public means of transport such as bus routes, stops, public parks etc.). Accordingly web map applications must enable easy searches, navigation and discovery functionalities, besides providing basic map functionalities such as zoom and pan.

	Colour & Contrast	**Annotation**	**(General) Presentation**
Buildings	Light red (buildings without annotation being e. g. residential buildings) Dark red (buildings with annotation being e. g. buildings of public interest) Alternative presentation mode: buildings in light and dark grey	Dark red characters on a white halo to guarantee contrast If at all, only the first character of a word (substantives) is written with capital letter, others are written in lower case letters	Availability of annotations depends on the level of detail, i. e. zoom level
Streets	Generally: white Important streets (e. g. major streets): yellow	Black If at all, only the first character of a word (substantives) is written with capital letter, others are written in lower case letters	
POIs	Different colours (mainly the fundamental colours, high saturation) Providing generally high contrast to the surrounding	Black with light yellow-orange background Annotation (incl. further information on the POI) is presented (information window) in the map if the user single-clicks the icon	Information is presented in the map depending on users' interests and preferences (visible/ invisible) Simplified and generally-accepted symbols
Areas	Open, i. e. green space: green water bodies: blue other areas: light brown	Black characters on a white halo to guarantee contrast If at all, only the first character of a word (substantives) is written with capital letter, others are written in lower case letters	Availability of annotations depends on the level of detail, i. e. zoom level

Table 2: Selection of preferences of visual impaired people on cartographic design of web maps (N=99); light green: representation mode of Google Maps, and light red: representation mode of digital Vienna city map.

4.3 Requirements on graphical and non-graphical map design

To specify user requirements on map design, users were asked to assess the web map application that they commonly use. While the majority of respondents indicates to use Google Maps (67 % of the respondents who use web maps), the digital Vienna city map (http://www.wien.gv.at/stadtplan) is ranking as second most popular web map (17 % of the respondents who use web maps), due to the large number of respondents living in Vienna. Other web map applications mentioned are Bing Maps, Open Street Maps and other city-specific web-based maps (such as the city map of Berlin: http://stadtplan.meinestadt.de; or the city map of Bern: http://map.bern.ch/stadtplan). Table 2 presents a selection of map design preferences of visual impaired people, based on a comparison between Google Maps and the digital Vienna city map (Fig. 1).

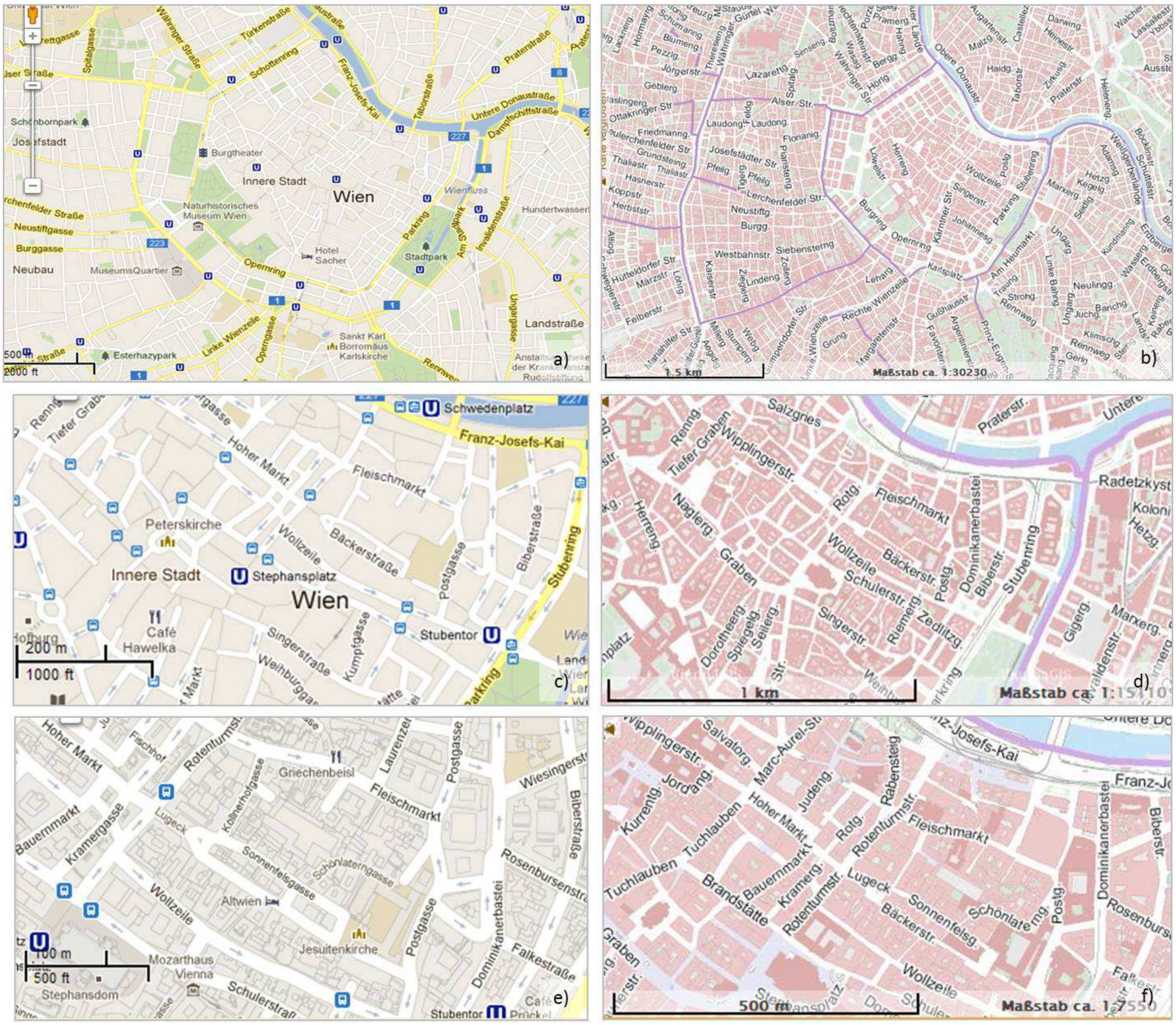

Fig. 1: Google Maps (a, c, e) and digital Vienna city map (b, d, f): selected differences on map design (focusing on the representation of buildings and streets).

In conclusion of the survey results, to improve map design in terms of the needs of visual impaired, attention must be paid mainly to colour contrast between the different objects (areas, buildings, streets etc.), colour design, and labeling (font size). However, due to the wide range of extent and forms of visual impairment literature suggests the provision of functionalities which allow user adjustment on contrast, symbols size, line width, colour combinations and lightness etc. (JEFFREY & FENDLEY 2011). These suggestions are confirmed by the user survey results as well.

As mentioned in chapter 4.2 voice output and textual description of the map content are considered as relevant elements for visually impaired. Accordingly, verbal descriptions of the pertinent map content are needed. Its provision relies on the conception and design of *non-graphical* map content. On this topic a number of recommendations exist (different possibilities of viewer's perspective, anchor-point hypothesis, hierarchy and order of information etc.). In the following only two aspects are explained in more detail.

Generally, when accessing verbal descriptions of maps, i. e. location of features, users prefer information being available at different levels of detail. This means – as also described by Hung (2001) and National Mapping Council of Australia (1985) – voice output and verbal description should be available:

(1) on a very general level, describing the overall situation of a city or a city area with information on e. g. districts ("Show the minimum detail!"),

(2) on a more detailed level providing information on e. g. particular streets (street names) and blocks of buildings („The content should be such that users can not only identify blocks of buildings and the streets surrounding them but also navigate their way from public buildings or facilities. In order to do this users will need to be aware of traffic lights, pedestrian crossings and other relevant facilities!") , and

(3) as in-depth information on particular houses, shops, facilities and services including entrances („It is important to show door access to buildings and businesses, using standard symbols, as well as stairways, escalators, elevator and ramp locations!").

To build a mental or cognitive map including the location or direction of single landmarks (buildings, streets etc.) as well as the relations between these elements, users prefer the usage of *hour system* (e. g. Sánchez & Torre 2010). For instance, the verbal description of the directions of a street or crossroad could be designed as follows (Fig. 2): „Street A diverges at 1 o'clock (respectively 20 degree) from street B. Street A diverges at 11 o'clock (respectively 340 degree) from street B, thus the crossroad looks like as Y crossroad, i. e. triple-trace crossroad."

Fig. 2: Description of location based on hour system (Source: Sánchez & Torre 2010).

Information category	Exemplary information
Tactile	surface of road and footway including changes (sewer cover, surface irregularities), texture paving blocks, curb, steep gradients
Auditory	traffic lights with audio signals, acoustic of the surroundings (water features, traffic noise, underpasses, house walls, large squares)
Olfactory	smell of gardens, stores, coffee houses, and restaurants
General information	name of streets and squares, course of the road and direction (one way street), pedestrian crossings (with layout and detailed description if they are complex, underpasses, cross walks), width of the road, number of lanes, bridges, environment around the roads, current road works, shared cycle- and footways, pedestrian area, entry and exit, walking times in minutes and meters,
Public means of transport	bus stop, tram stop, metro station, taxi ranks, railway stations
Useful buildings and landmarks (Points of Interest POIs, Lines of Interest LOIs, Areas of Interest AOIs)	public buildings (office, government agency, theatre, museum), places of interest, healthcare facility (hospital, doctors' surgeries), supermarkets, shops and stores, restaurants, hotels, parks, open and green spaces
Orientation system for blind people	fences, house walls, bushes, texture of the pavement
Route planning	detailed textual description including time and direction

Table 3: Information to display in city maps required by visually impaired (N=59; multiple replies possible).

4.4 Requirements on map content

As stated by Horstmann et al. (2006) no specifications exist on objects which – user group independent – should be presented in city maps. Generally, map publisher tend to produce product-specific standards.

Horstmann et al. (2006) provide a list of objects typically presented in city maps. It encompasses elements such as parks and gardens, water bodies (lakes, rivers, sea), different types of streets, squares and places, points of interest (museums, shops, hotels etc.), public buildings (churches, schools, city hall etc.), features referring to public means of transportation (bus routes and stops etc.), bridges and tunnels. All objects are characterized by numerous attributes such as name and number of lanes, one-way or two-way. Apart from information which should generally be available in city maps, the literature review revealed that – compared with sighted people – visually impaired ask for additional information (e. g. Ienaga et al. 2006; Jacobson 1994; Reichert, Kurze & Strothotte 1994). An overview on information to display in city maps required by visually impaired – embodying results from the literature review and the user survey – is presented in Table 3. Furthermore, Bradley & Dunlop (2005: 399) highlight that "… directions consisting of a reduced amount of textual-structural and textual area/ street information, and incorporated sensory, motion, and social contact information are more optimal for helping visually impaired people navigate." This was proved by the user survey as well.

5 SYSTEM DESIGN

The *AccessibleMap* (prototype) application, which is developed to be used either with PC or by mobile devices (e. g. smartphone, tablet PC, etc.), is based on open source software. The service-oriented software architecture is made up of a PostgreSQL/ PostGIS database, Geoserver, Open Layers and PHP Application Server. The use of assistive technology and visual aids – as exemplary listed in Table 1 – is supported by the application. Fig. 3 gives an overview of the basic components of the *AccessibleMap* application.

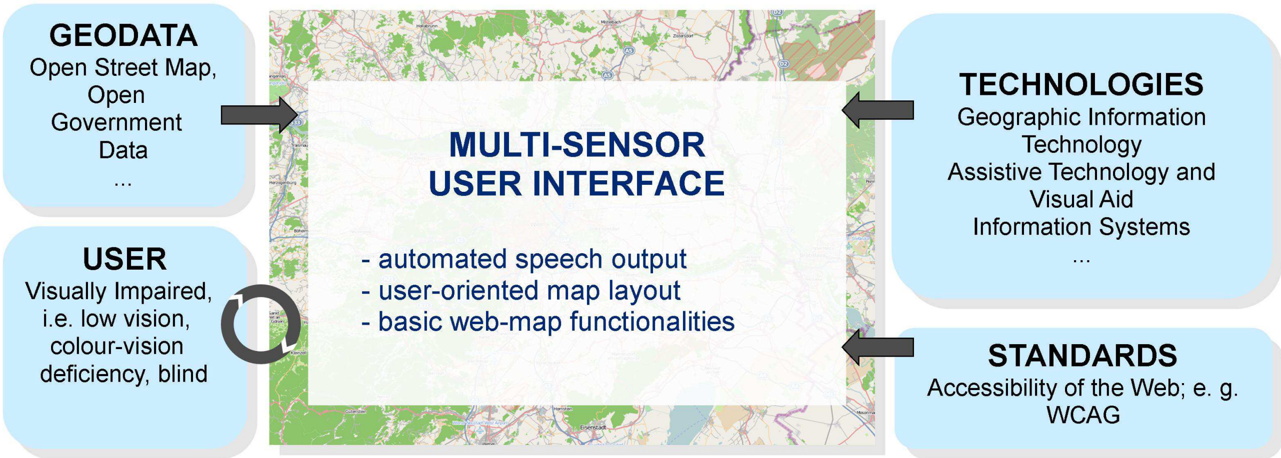

Fig. 3: Components of the AccessibleMap application.

To develop the *AccessibleMap* application a number of common standards as well as web-accessibility standards and guidelines can be used (Table 4). They help to guide the design and implementation of the web-based map application in association with the identified user requirements. However, despite an immense number of standards and guidelines, no specific standards and guidelines regarding the development of web-based maps for visually impaired or blind people exist.

Type of standards & guidelines	**Web content & GUI**	**Cartographical user interface & map design**	**Auditory & visual signals**	**Map content**
General, non-technical	Design guidelines, WCAG 2.0 (URL 1), ATAG 2.0 (URL 2), UAAG (URL 3), ISO/IEC Guide 71:2001 (URL 4)	ISO/IEC TR 19766 (URL 7), ISO/IEC 11581-1 (URL 9)	ISO/TR 22411 (URL 8)	
Technical	XML (URL 5), ISO/IEC TR 29138-1:2009 (URL 6)	SLD (URL 14), CSS (URL 15)		WMS (URL 10), WFS (URL 11), GML (URL 12), SVG (URL 13)

Table 4: General and technical standards and guidelines regarding accessibility of web and map content.

Thus, according to existing standards and guidelines the *AccessibleMap* user interface is developed as a multi-sensory interface. It contains a map component with an optimized cartographic design (map layout). Functionalities are implemented which allow (1) to configure, i. e. select the cartographic design depending on user abilities and preferences, (2) to access verbal descriptions (text and speech output), and (3) to perform basic map operations such as search, zoom, and pan.

Different spatial data sources are used to generate the map content: Open Street Map data (OSM; URL 16) which is created by the user community (i. e. volunteered geographic information), and open government data provided by public administration. Various reasons account therefore: This data is published under the *Creative Commons* license (URL 17) which targets at promoting open and shared data access and use via web services – for *everybody*. Due to the great variety of data and their attributes, these data sources provide a wide range of information, which meets data demanded by the respondents (Table 3). Thus, most general information (street names etc.), tactile information (surface of roads), useful landmarks, etc. is available for the users. Olfactory (e. g. smell of a bakery) and auditory information (e. g. traffic noise), particularly demanded by blind users, is currently still more complicated to provide to the users. Due to the fact that e. g. opening hours vary and traffic impact is changing, it is difficult to deliver such information being reliable and up-to-date.

To perform end-user tests and to provide to the user accurate and reliable data for a testing area in Vienna, the data – originating from the above-mentioned data sources – must be quality checked and processed according to its accuracy, completeness, up-to-dateness, and language (e. g. translation into German language). Afterwards, the data is transferred to particularly designed data models. This is a precondition to transform the data into information, i. e. to spoken or written text, and to facilitate the visually impaired users to hear or read the map content making use of assistive technologies and visual aids (Table 1). Thereby the verbal description is automatically generated. The *automated* approach is required in order to generate verbal descriptions of web-based maps which generally cover wide areas and are based on a wide range of different spatial data. It helps to reduce costs as there is no need for extensive manual, time consuming updates. Furthermore, the approach makes the application flexible so that it can be easily applied in different cities and regions.

For the map layout Styled Layer Description (SLD) technology is used. SLD allows creating a map rendering style according to the user requirements which includes e. g. the configuration of colour design and labeling as well as colour contrast between the different objects (Table 2). The data, i. e. the maps, are provided via Web Map Services (WMS) to the user.

6 OUTLOOK

The presented results, on how to support the access and use of web-based maps for visually impaired, can be seen as a contribution towards E-inclusion and web-accessibility. The comprehensive user requirement analysis (literature review and user survey) gives important input for design and implementation of the *AccessibleMap* (prototype) application. It includes (1) the optimization of the cartographic design, i. e. the map layout in terms of colour, contrast, object size and type, etc. and (2) the automatic generation of a verbal description of the map content respecting the requirement of the users asking for a multi-sensory user interface.

Anyway, especially the verbal description of maps requires a lot of efforts on semantics. To improve the audio and textual output as well as to create meaningful semantic information, spatial data needs to be preprocessed to present information on existing relationships between particular objects (e. g. with regard to distances and directions). More in depth work on semantics will be a main focus of the next tasks of the project and will be based on the results of the user requirements analysis. Ultimately, testing of the prototype application scheduled for autumn 2012 will enhance the integration of the target user group and gain user feedback.

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