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GEOGRAPHIC INFORMATION SYSTEMS IN THE CONTEXT OF DISABILITIES

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***Abstract*:** The importance of geographical space for persons with disabilities is elaborated in literature through numerous papers on 'geographies of disabilities', dealing with the social construction and impact of space. Space is identified as an enabling factor to enhance self-determination and independence e.g. in terms of social participation, mobility or access. Geographic Information Systems (GIS) can be utilized to visualise and analyse the spatial impact of human actions. Research on GIS applications for disability issues shows a variety of approaches through disciplines and topics but lacks a comprehensive assessment of potentials. The objective of this paper is to provide a synopsis of research results and practical approaches of GIS applications in disability-related contexts. Methods applied include a qualitative literature review of scientific papers, proceedings, projects and case studies using digital databases (e.g. ScienceDirect, JSTOR etc.). Based on the review an overview on target groups, core functionalities of GIS, the purpose of application was extracted. A SWOT analysis was used to stress strengths and weaknesses to identify gaps and future research areas. The review has shown that GIS for space-related disability issues is established in various disciplines with a diversity of topics. Focus is given to mapping and identifying accessibility, wayfinding tools supporting orientation and navigation next to disaster and emergency management support. Major constraints for the use of GIS are the availability, accuracy and costs of data, addressing single target groups/disabilities (e.g. users of wheelchairs) and the usability/transferability of applications. To exploit the full potential of GIS in disability studies, emphasis can be given to research on implementation of additional data sources, on integrating the inclusive approach by inter- and transdisciplinary research as well as on transferring good practice examples. The enhancement of GIS in disability studies can contribute to higher autonomy for people with disabilities and foster inclusion in our society.

Keywords: Geographic Information Systems; disabilities; inclusion;

Introduction: spatial is special

Actions of human beings have a strong spatial component, they take place in the geographical space and are characterized for example by distance, location, and pattern. This spatial dimension is critically important for people with disabilities, e.g. in terms of mobility or accessibility issues which are both basic needs to increase independence and self-determination (United Nations, 2006). Space is the core competence of geography, especially human geography is intensively dealing with social and economic problem-solving by improving spatial concepts in order to influence the policies of urban and regional (community) developments. For the investigation of spatial concepts and impacts, Geographic Information Systems (GIS) offer various methods and analytical tools. Although geographic competencies and GIS-tools have a high potential to solve disability-related questions, a closer look into geography literature shows, that there is no strong focus on the spatial needs of individuals with disabilities.

The overall goal of this paper is to present, review and reflect literature applying GIS for disability issues. The applications are analysed and evaluated in order to identify limits and risks as well as new potentials for the use of GIS in the context of space-related disability issues.

Background

Spatial concerns about disabilities date back in geography to the 1990ies (Park, Radford, & Vickers, 1998), tackling space from controversially discussed perspectives; space as given entity versus space as social construction (Kitchin, 2001). These geography approaches reflect the development of different models of disability in disability studies. Golledge (1993) rather follows the medical/individual model, which identifies the dis-functions or physical limitations of the body as the problem, which can be overcome by therapy, treatment or assistive devices (Johnstone, 2012). The social model locates the problem in the society which acts as a limiting factor. The solution is the reduction of barriers in the environment and the integration of persons with disabilities into society (Shakespeare & Watson, 2001), achieved by legislations, standards and guidelines (e.g. ADA, 1990; European Commission, 1998). From the geographer's viewpoint the social model is reflected in a discussion about geographies of disabilities with an emphasis on social geography approaches (see e.g. Kitchin, 1998; Imrie, 2000, for a comprehensive overview: Chouinard, Hall, & Wilton, 2016; Wadhwa, 2012).

The discussion of the social model of disability leads to various adaptations of the model, e.g. the social-ecological model of human development (Pledger, 2003) or the cultural model (Waldschmidt, 2005). These approaches are moving from a problem-orientation towards pro-active and solution-oriented viewpoints. The attention is widened to the interaction of persons with the environment/society, diversity is the new standard within society, where equality and equity are defined as fundamental rights (Dederich, 2007; Köbsell & Waldschmidt, 2006; Schneider & Waldschmidt, 2012; Watson, Roulstone, & Thomas, 2012). With this development, an additional dimension, geographical place and space, is included in the models of disability studies offering disability geography new research objectives (Imrie & Edwards, 2007).

Parallel to this, geographical space gains attention in different disciplines through the so-called spatial turn (Döring & Thielmann, 2009; Lossau, 2012; Richardson et al., 2013) and the 'reinvention' of the map (e.g. Google Maps). Next to space, information and communication technologies (ICT) offer new solutions for persons with disabilities, e.g. through assistive devices (Bhowmick & Hazarika, 2017).

GISs are combining geography, space and technology. A GIS is a computer software to store, manage, analyse, retrieve and visualize spatial information. In its simplest form, GIS is used as a mapping tool, e.g. to map landmarks to support persons with visual impairments in wayfinding (Serrão, Rodrigues, & du Buf, 2014). GIS also offers complex analysis tools, e.g. modelling the access for wheelchair users which can be used as a navigation aid by persons with disabilities or for planning purposes by urban planners (Beale, Hugh, Phil and Field, 2001). Finally, GIS is a tool at the edge between science and public – more and more applications are available to and used by the public.

The shifting focus towards the influence and impact of space in disability studies, in disability geography and in various scientific fields as well as the importance of ICT in society are the basis for the question if and how GIS can be applied for disability-related issues and therefore can contribute to disability studies.

Methodology

First, a qualitative literature review was conducted to identify scientific papers, conference proceedings, products/applications, projects and case studies dealing with GIS and disabilities. The literature review is used to characterise the chronological development of the topic and draw an overall picture of the research landscape, including influencing technologies as well as the identification of authors/working groups. More than 200 papers, GIS applications and projects – covering various stages from ideas to practical implementations – for Anglo-American as well as German-speaking countries have been evaluated.

Digital, as well as analogue media, have been used for the research, as databases served ScienceDirect, DBIS (Database Info System), JSTOR, WorldCat and Electronic Journals Library. The literature has been chosen based on the keywords 'Geographic Information System', 'GIS' and 'disability/ies'. Some refining of keywords has been done on disability-related terms including 'impairment', 'handicapped', 'assistive', 'wheelchair', 'visual impaired', 'blind', 'deaf', 'intellectual', 'elderly'. Scientific papers, as well as practical applications, were selected if the title and abstract showed an implementation of GIS for disability-related issues. The articles only mentioning GIS without showing a more detailed approach or referring to GIS without applying it have been excluded. The time frame covers literature from the 1990ies to 2016, since GIS have not been applied to this topic before.

This paper also shows limitations: it does not claim to be complete and offer an encompassing review due to the fast development of software and applications and the number of scientific databases available. Especially in European and Asian (e.g. China, Japan) context, it is assumed, that many additional applications are available. They are not included in this analysis due to language barriers. Another limitation of this study is its focus on GIS and disability issues in the synthesis. Although in the historical approach neighbouring technologies (such as GPS and RFID) are referred to/mentioned, this is only used to outline influencing and pushing technologies. A general evaluation of technology or, even more general, ICT would go way beyond the intended investigation of the geographical/spatial potential of GIS in the context of disabilities.

After identifying relevant literature, contents have been investigated in detail. The papers and projects were screened due to (1) target groups, (2) spatial context in terms of scale, (3) core functionalities of GIS applied (data management, analytical tools, mapping), (4) purpose of application, and (5) level of implementation. Additionally, the availability on end devices and the compatibility/need for assistive devices have been investigated. This leads to a summarising table, supporting the reader in identifying fields of application of GIS in disability-related contexts, and additionally serves as a comprehensive reflection of the linkages and connections between the various concepts and applications.

To be able to draw a synthesis of the literature a SWOT-analysis was conducted. The SWOT-analysis is a method which was originally used for strategic planning in organizations, but is also used for regional analyses as a basis for future regional development (Fürst, 2012). Arranged in a 2x2 table, the internal issues (strengths, weaknesses), as well as external issues (opportunities and threats) important for organizational development, are listed. The SWOT can be used to “better understand how strengths can be leveraged to realize new opportunities and understand how weaknesses can slow progress or magnify organizational threats” (Helms & Nixon, 2010). In this paper the SWOT was used to identify pros and cons of GIS for disability topics and consequently illustrate future opportunities and research topics in this field, but also hindrances and risks for and of GIS applications. To identify the strengths and weaknesses the criteria which constituted the summarising table were used. Additionally, indicators concerning implemented data (such as timeliness, availability, and cost) as well as participatory issues have been covered.

Results

GIS and disabilities: the first steps in the 1990s

The use of GIS for disability-related questions dates back to the 1990s when ***mapping statistical results*** was introduced into human geography (Cummins & Milligan, 2000; Park, Radford & Vickers, 1998; and the first national mapping of Moss, Schell, and Goins (2006). Although one could think that mapping disabilities and epidemiology as well as combining socio-economic data with health data is one of the first applications (Zubrow & Rioux, 1999), GIS-related papers primarily point to health care maps, but also about facilities and their ***distribution*** (Bhana & Pillay, 1998; Hahn, 2003). Compared to this countable number of papers, Higgs (2005) demonstrates in his literature review the wide use of GIS for accessibility of health care services in contrast to the marginal impact of disability studies for GIS.

Picking up ***accessibility*** as a subject in GIS the discussion leads to the topic of ***public transport***, where GIS is named as future technology, but not yet applied (Hunter-Zaworski, 1994; Koppa, Davies, & Rodriguez, 1998). Craig, Harris, and Weiner (1999) and explicitly Zubrow and Rioux (1999) bring up the idea to exploit GIS as a tool for people with disabilities to empower them and use GIS as an instrument for public participation, namely as PPGIS.

The breakthrough of GIS utilizing its analytical and data management power was the ***mobility and orientation support tool*** for people with visual impairments or blindness (Golledge, Loomis, Klatzky, Flury, & Yang, 1991; Golledge, Klatzky, Loomis, Speigle, & Tietz, 1998; Jacobson & Kitchin, 1997; Strothotte et al., 1996). The emphasis on the special user group of people with visual impairments or blindness made it necessary not only to think about the representation of spatial information and cognitive (mental) maps but also about the communication of this information to the user group. 'If GIS systems are to benefit the blind, again they must be consulted on relevant interface development' (Butler, 1994, 468). Butler (1994) therefore identifies ***accessibility*** again as a critical point using a GIS for disability-related questions, but the focus in his discussion is set to the accessibility of the results and in terms of communication, not – like in the context of public transport or PPGIS – accessibility of objects as a content of GIS.

In summary, four main focal points can be identified where GIS offers an added value to disability studies when looking back into the beginnings of GIS and disabilities (for a detailed reflection see Janschitz, 2012):

- mapping and visualising disability-related information;
- providing information about accessibility;

- providing support for personal transport, mobility and orientation;
- providing access to information to support personal independence and a self-determined life and empowering people with disabilities.

Emerging GIS technology widens the context of application

Identifying accessibility

The idea of presenting information about accessibility resulted from the approach to evaluate health institutions depending on their accessibility. This was of course only the beginning. Consecutively, GIS was used to visualise ***accessibility of various objects*****,** mainly focusing on the built environment and urban contexts. Since data is a critical part for the purpose of visualising accessibility, the database in a GIS is predestined to assemble and manage information on objects, which represent barriers and/or cues (landmarks) for people with disabilities like slope, curbs or street surface conditions etc. (Felus & Shangraw. 2007; Friebel, 2008; Johnston & White, 2003; Nuernberger, 2008; Svensson, 2010). Gathering relevant data in GIS is also crucial in terms of availability, cost or time factors, because this particular information generally is not available in official data sources from municipalities, cities or counties. Another way for acquiring (geo-) data is using new technologies like laser-scanners (Serna & Marcotegui, 2013). Newer approaches, therefore try to integrate volunteered geographic information (VGI) through crowdsourcing (Hara, 2014; Prandi, Salomoni, & Mirri, 2014; Rice et al. 2013), or to integrate data based on open source geo-technologies like OpenStreetMap (Ding, Wald, & Wills, 2014; Neis & Zielstra, 2014; Rice, Aburizaiza, Jacobson, Shore, & Paez, 2012). Menkens et al. (2011) utilise social networks such as Facebook or Twitter to reach out to the community for relevant information. Kent & Ellis (2015) criticise that social media even create new barriers for people with disabilities due to their complexity and overlapping structures, e.g. in case of emergency (Kent & Ellis, 2015).

Information on accessibility (of objects) is on the one hand used by people with disabilities (such as Wheelmap, wheelchair accessible routes in Google Maps, BlindSquare, and ways2see), and on the other hand it is used by experts (planners, decision makers) (Sedlak, Komarkova, & Piverkova, 2010; Svensson, 2010). At the professional level, the data is used for analytical or simulation purposes, dealing with future perspectives and providing decision support or planning perspectives, e.g. to reduce barriers in urban environments. The scope of accessibility of objects and the inventory of barriers, landmarks or points of interest (POI) in urban areas is primarily ***limited to specific content and purposes***. Accessibility is part of navigation and routing processes and tools, or can at least be narrowed down to topics where navigation plays an important role. These areas can be assigned to mobility issues especially in public transport as well as in search and rescue, but also in leisure and tourism. Although the discussion of barrier-free access to public transport is well established (see: Golledge, Costanzo, & Marston 1996; Jurica 2009; Tyler, 2002) and there are a lot of practical guides for specific areas available, the connection to GIS is rarely made. The main focus looks at the integration and combination of data from different sources (Cañal-Fernández & Muñiz, 2014) and on planning personal routes using public transport (Dell'Olio, Moura, & Ibeas, 2007; Pressl & Wieser, 2010) (see also chapter "Personalised orientation and navigation"). For search and rescue actions and in disaster and emergency management the focus is shifted from indicating accessibility of institutions to locating disabled and elderly people to be able to provide help in time (Enders & Brandt, 2007; Arima & Kawamukai, 2009). During the past few years, agent-based simulations are evolving (Arai, Sang & Uyen, 2012; Arai & Sang, 2013; Christensen, Sharifi, & Chen, 2013). If it comes to touristic applications, a similar picture can be drawn: only a few papers are focusing on disabled people and GIS, again predominantly dealing with accessibility aspects or mobility issues (Francoso, Costa, Valin & Amarante, 2013; Rumetshofer & Wöß, 2004; Taylor & Józefowicz, 2012).

The bridge to personalised orientation and mobility purposes of GIS for people with disabilities can finally be made through ***accessibility indices***. The calculation of numbers, indicating the degree of accessibility by combining attributes, neighbourhood analysis, overlays or network analysis using GIS serves as a basis for routing algorithms, mainly in planning or participation processes (Casas, 2007; Church & Marston, 2003; Svensson, 2010).

Personalised orientation and navigation

There is no doubt that unlimited mobility is a personal right. Moreover it is a must-have for full participation in daily life – not only but especially for people with disabilities (United Nations, 1948; 2006). Recently, state-of-the-art navigation systems available on the Internet started to include accessibility indicators based on barriers, cues and landmarks. Navigation systems designed for people with disabilities are either providing support to overcome an ***individual 'handicap'*** or are choosing an integrative, ***universal or inclusive design approach*** (Yairi & Igi, 2007). There is a strong focus on particular disabilities when it comes to GIS-based routing and navigation: physical and sensorial disabilities are fairly well discussed, whilst e.g. cognitive disabilities are barely reflected.

Routing and navigation applications are used for individual or institutional purposes with the intention for ***pre-trip usage, on-trip usage, planning and simulation***. Personal routing is utilised to identify, investigate, quantify and visualise barriers, landmarks and POI with the goal to recognise or avoid obstacles along a route (Loomis, Marston, Loomis, & Klatzky, 2005; Sedlak, Komarkova, & Piverkova, 2010; Serrão, Rodrigues, & du Buf, 2014; Sobek & Miller, 2006). Depending on the disability, special attention is given to in-/output of data as well as the analytical procedures. Navigation on an institutional basis aims to avoid (see search and rescue activities) or reduce barriers (planning issues). The task of navigation is implemented in a wider context and used for additional or further analyses (e.g. multivariate analysis for health-related management activities).

Applications for people with physical disabilities comply with the ***type of impairment*** (Sobek & Miller, 2006), ***activity or fitness level*** (Kasemsuppakorn & Karimi, 2009), ***characteristics of assistive device*** like type of wheelchair (Beale, Hugh, Phil, & Field, 2001) or ***categories of routes*** based on impedances like time, distance or other indicators (e.g. slope).

The focus for navigation for people with visual impairments or blindness is basically split into ***indoor*** (Moreno, Sahrabadu, José, du Buf, & Rodrigues, 2012; Serrão et al., 2015) ***and outdoor routing*** (Chen et al., 2015; Umezu, Kawamura, & Ohsuga, 2013). Based on the surroundings, identifying the position of a person relies on different systems – outdoor orientation is using differential Global Positioning Systems (DGPS) while navigation within buildings works with technologies such as Wireless Local Networks (WLAN), Wi-Fi, Bluetooth or radio-frequency identification (RFID) due to higher accuracy (du Buf et al., 2011; Farias, Lopes, Fernandes, Martins, & Barroso, 2010; Fernandes, Filipe, Costa, Barrosos, 2014). The positioning and orientation (cardinal direction) of individuals is decisive for the on-trip navigation since the real-time position of the person requires to (re-)calculate the continuing route. Special interest is therefore given to ***tracking*** of individuals with visual impairments or blindness. Another critical point in the navigation process is the positional accuracy, where maximum error tolerance is given with one meter (Ran, Helal, & Moore, 2004; Wieser, Mayrhofer, Pressl, Hofmann-Wellenhof, & Legat, 2006). Since the possibility of applying barriers is limited to long-lasting barriers, additional hardware can be used for obstacle detection, e.g. collision avoidance systems, laser scanner (Mayerhofer, Pressl, & Wieser, 2008; Moreno, Sahrabadu, José, du Buf, & Rodrigues, 2012). The detailed representation of ***intersections*** is of high interest because crossings carry high risks for people who are visually impaired or blind (Coughlan & Shen, 2013).

Finally, it has to be mentioned that the integration of additional information is based on the various needs of the target group – while people with physical disabilities are giving priority to information about barriers along a route, people who are visually impaired or blind require information both on barriers as well as cues and landmarks.

Retrieving the information: input and output

The process of entering information into the GIS as well as retrieving the results and the communication process with the user is again dependent on the abilities and personal preferences of the individual user. Spatial information is principally presented in maps, which is also one of the main results in a GIS. Therefore, the ***cartography and layout of maps*** has to be adopted to these needs, but also to the end-devices (e.g. Rodriguez-Sanchez, Moreno-Alvarez, Martin, Borromeo, & Hernandez-Tamames, 2014). The discussion on end-devices follows the development of information and communication technologies, starting with designing maps for desktop-computers, laptops, palms, mobile phones and moves on towards web-based systems and smartphones (essentially differing in screen size). Izumi, Kobayashi, and Yoshida (2008) have improved the communication with maps through adding a third dimension (3D) to the maps, Beale, Field, Briggs, Picton and Matthews (2006) have adjoined a textual form of the routing result next to the cartographic visualisation. While the potential to read maps for people with physical disabilities is merely limited to their map literacy, people with visual impairments or blindness require the information in non-visual or at least adapted visual form (Jenny & Kelso, 2007; Brock, Truillet, Oriola, Picard, & Jouffrais, 2015). Carrying on the idea of tactile maps, ***haptic, tactile and touch interfaces*** have been developed (Jacob, Mooney, Corcoran & Winstanley, 2010; Wang & Zheng, 2014; Zeng et al., 2014). Other approaches use ***audio or sound communication*** (Bearmen & Fisher 2012; Jacobson, 1998; Kaminski, Kowalik, Lubniewski, & Stepnowski, 2010; Moreno, Sahrabadu, José, du Buf, & Rodrigues, 2012) or a combination of both modes (Jacobson, 2002; Parente & Bishop, 2003; Miele, 2007; Zeng & Weber, 2010). ***Augmented reality*** can be seen as an extension as well as an interface for alternative modes of communication (Katz et al., 2012). To complete this list of approaches, modes and tools to communicate spatial information to the users with disabilities, additional assistive devices have to be integrated into the in- and output process if needed such as braille-display, push-pin pads or joysticks. While younger generations tend to have a positive attitude towards the use of ICT, the use of assistive technologies has to be seen more differentiated: Young people with visual impairments mostly reject them as restrictive and excluding, while people with blindness many times advocate assistive technologies, when they want to participate in the ICT society (Söderström & Ytterhus, 2010).

Identification of analytical tools and spatial issues - a comprehensive outline

Most of the applications of GIS in disability-related studies are dealing with orientation, navigation or routing processes. This result can be characterized with a catchphrase: “The journey is the reward”. The catchphrase also illustrates, that the process of including GIS into the discussion and work on disability-related issues is an ongoing process towards more inclusion, where importance is given to the procedural/developmental part. Table 1 summarises the state-of-the-art literature research results in a scheme. The table allows the reader to identify analytical processes, tools and in-/output parameters according to the different requirements of users and how they are utilised in various GIS approaches and implementations. At this point it has to be mentioned, that the lack of quotations in the table is intended – the table is the result of an abstraction process of the literature overview and works as a model and orientation guide.

Table 1. Classification scheme for GIS applications in the context of disabilities. Source: adapted after Janschitz, 2012.

<table>
<tr><th>Target group according to their (special) needs</th><th>Input- and output parameters/ supporting tools</th><th>Analytical processes</th><th>Existing GIS solutions</th></tr>
<tr><td>(colour)
visual impairments</td><td>starting point and destination (voice and/
or haptic assisted)</td><td>finding locations
calculating routes based on various parameters (time, difficulty)
navigation and tracking</td><td rowspan="9">for people with and without (special) needs:
• information on barriers and barrier-free objects
• location of barriers and barrier-free objects,
• as a basis for navigation and orientation
• navigation systems for pedestrians

for planners and experts:
• information on barriers and barrier-free objects
• location of barriers and barrier-free objects
- to reduce barriers
- to calculate indicators of accessibility
- for disaster and emergency management
- as a basis for further analysis</td></tr>
<tr><td>(legally) blindness</td><td>starting point and destination (voice and/
or haptic assisted)</td><td>finding locations
calculating routes based on various parameters (time, difficulty)
navigation and tracking</td></tr>
<tr><td>hearing impairments</td><td>not applicable</td><td>not applicable</td></tr>
<tr><td>deaf</td><td>not applicable</td><td>not applicable</td></tr>
<tr><td>physical disabilities/ restricted in mobility</td><td>definition of needs
level of fitness
assistive tools
starting and end point</td><td>visualizing barriers
indicating accessibility
routes based on indicators
assistive devices</td></tr>
<tr><td>intellectual or learning disabilities</td><td>not applicable</td><td>not applicable</td></tr>
<tr><td>elderly</td><td>= restricted mobility</td><td>= restricted mobility</td></tr>
<tr><td>social / cultural exclusion</td><td>selection of language</td><td>information for tourists</td></tr>
<tr><td>technical exclusion</td><td>devices, GPS etc.</td><td>= visual impairments or blindness</td></tr>
</table>

The main result shows, that the experts are using the analytical functions of a GIS (e.g. Beale, Hugh, Phil, & Field, 2001; Sedlak, Komarkova, & Piverkova, 2010), whereas the standard user (with or without a disability) enjoys a multi-media product, only experiencing very limited GIS functionalities (e.g. BlindSquare, Wheelmap, ways2see), which are basically known from online-mapping tools. An emphasis to solutions for single user groups can be identified, an application which serves ‘all’ user groups regardless of their disability, following an inclusive approach is not available (yet). The existing solutions visualise (spatial) information about barriers, landmarks and/or POI in maps, use this information for orientation, tracking and routing processes and present the results to the user in appropriate (multimodal) form. The experts use the same information to calculate and improve accessibility for development and simulation processes in the field of urban planning and emergency management.

The future of GIS and disabilities: A SWOT-Analysis

In comparison to the comprehensive outline in Table 1, the SWOT-analysis in Table 2 adds a future-oriented analysis and compares the pros and cons of the theoretical discussion.

Table 2. SWOT analysis of research approaches and practical applications resulting from the theoretical discussion. Source: Zimmermann-Janschitz.

Strengths	Weaknesses
• various and different ideas, projects, applications • target-group orientation includes user-oriented personalised information • availability of information due to web-access • including on-trip availability • up-to-date information • interactivity generates attractiveness • participatory tools available in some applications (nothing about us without us!) • extends GIS on expert level • re-orientation started including users and producers (inter- and transdisciplinarity)	• applications are ideas in the 'ivory tower' / implementation under 'lab conditions' • applications limited to one user-group / no re-orientation to inclusion yet • missing real-time information and on-trip availability • availability, amount and costs of data • narrow spatial context (campus, small areas) • spatial resolution, accuracy and level of details • complexity (very special, very sophisticated) • expensive tools or assistive devices • marketability

• interdisciplinary and
• transdisciplinary approaches
• open source software and data
• rapid technology development:
  - data sources (e.g. laser scanning, cloud, 3D)
  - devices (availability, cost)
• growing user group due to aging society
• awareness of inclusion in the society
	• lack of profitability due to small target groups
	• consumer acceptance of systems
	• targeting customers
	• 'dinexity' – dynamic and complexity of technology
	• open sourced data with various precision and covering areas differently
	• privacy and security of data and systems
	• amount of administration and monitoring

Opportunities	**Threats**

Discussing the results in Table 2 shows, that although there is a variety of ideas, scientific papers, applications and projects available, a closer look still shows, that many of them are limited to the scientific 'ivory tower' or are implemented under lab conditions. Only some applications indicate participation in the development process.

Investigating the target groups, with few exceptions (e.g. Svensson, 2010; Yairi & Igi, 2007) GIS applications are targeting single disabilities. This is not only a restriction but can be indicated as an advantage. The user-group approach allows a better coverage of the tremendous demand for user-specific data, since each type of disability needs different information/data, and recognises barriers as well as specific landmarks individually. Simultaneously the focus on a single user group can be seen as a disadvantage: In terms of economic aspects and marketing the number of (potential) users for a single target group/disability is limited as the proportion of 15% persons with disabilities worldwide show (WHO 2011). Arguing along an inclusive approach and trying to target 'all' persons (with and without disabilities) with applications/solutions, most people are 'excluded' for the same reason.

Pros and cons (see Table 2) also address data: Modern GIS-technology offers the possibility to retrieve information via the Internet (Web-GIS), Apps for smartphones (or mobile devices) make on-trip information available, and digital information can be updated more frequently and easy than e.g. analogue maps. But on the other hand, real-time information is rarely existing (e.g. locations of construction sites), and the availability, amount and costs of specific data needed are restricting factors. These factors result in a narrow spatial context – applications are developed for campus sites, limited to city blocks or 'urban labs'. A strategy to cope with limited data is to reduce the level of detail of information presented, the number of layers integrated in the analysis or the use of small-scale overview-maps. Since the amount and detail of data are crucial to persons with disabilities, these aspects are also defined as weaknesses.

As another weakness the cost and technology/accessibility factor has to be mentioned: Only technology-affine people will use this kind of applications. With an increase in the complexity of the applications and the need for additional and more assistive devices, fewer people will remain using the applications. This is also true for the cost factor – cost-intensive technologies are rarely used, because people (with disabilities) in many cases cannot afford them (Palmer, 2011).

Last but not least, a new trend can be identified in the use of GIS for disability-related issues with the integration of interactive and participative tools, e.g. the possibility to add personal points of interest a re-orientation of applications started. Users and producers are communicating and transdisciplinarity is implemented. This is critically important for GIS used on the expert level (models, planning tools) to permanently monitor and improve applications.

Opportunities and threats are widening the picture and extend the scope of the concepts to a framework given by the economy and the society (see Table 2). A shift in research towards network-oriented approaches and towards interdisciplinary collaboration opens new connections across borders of scientific disciplines. The motto ‘nothing about us without us’ already goes back to the later 1990ies and is still not widely respected (Charlton, 1998; Crowther, 2007). It supports the demand to include people with disabilities in the decision-making processes (participation and empowerment) and in the design and development of software applications (transdisciplinarity) which on the one hand leads to better results and on the other hand raises awareness in civil society. Furthermore, it is evident, that the target group is growing due to an ageing society. Additionally, the fast, almost exponential growth of technology creates new devices, new (crowdsourced) data, and new applications with the bottleneck of ‘dinexity’: too fast, too complex. Crowdsourced and therefore cheap and public information shows a lack of accuracy and comprehensive availability, which is essential for users with disabilities. GIS-based systems have a big demand for up-to-date and real-time information to show reliable results which causes high monitoring needs. And finally everything is measured in Western societies with money: If people with disabilities remain as a marginalised group in our minds only a minimal amount of money or no money at all will be spent beyond the few research projects.

Conclusion and future research directions

The main objective of the paper was to present an overview of the development of GIS applications for spatial-related disability issues. A short history, as well as a description of approaches, serve as a fundamental insight for advances of GIS for disability issues from its beginnings to 2017. To present a more comprehensive view on the topic, additionally a summarising scheme was developed showing categories of existing GIS solutions and analytical tools applied next to parameters for retrieving information. To be able to identify future research topics as well as risks for future development, a SWOT analysis was finally conducted.

The results of the study illustrate, that GIS makes an important contribution to the field of disability issues, especially for navigation and orientation purposes as well as in the field of disaster and emergency management. Next to navigation and emergency management, a wide variety of different topics are covered, although currently no additional research/application focus can be identified. Furthermore, a limiting factor of GIS is its usability. Even if the current technical development moves towards user-friendly and easy-to-use software or apps, most analytical tools in GISs can be performed by experts only. This forces experts to apply their knowledge in the field of disabilities. There is still high potential to further establish GIS in the field. Current research papers show a shift towards open/big data approaches (Qin et al., 2016; Mobasheri, Deister, & Dieterich, 2017). With increasing importance of inclusion in the public discussion, participation gains interest not only concerning data acquisition but especially including persons with disabilities in research processes (Chan, Helfrich, Hursh, Rogers, & Gopal, 2014; Zimmermann-Janschitz, Mandl, & Dückelmann, 2017). Although various disabilities are addressed, recently intellectual and cognitive disabilities moved into the focus of research (Wong, Huangfu, & Hadley, 2018). These developments together with the opportunities and threats as result of the SWOT analysis allow to argue for the following topics to be addressed in future research:

- Overcoming the limitation of data in GIS through for example big data, open source data and volunteered geographic information;
- Including people with disabilities in research and development to produce more appropriate (and widely used) results;
- Closing the gap between high-tech solutions and usable/affordable apps by following main streams in GIS development;
- Addressing more than one target group in GIS applications;
- Evaluating various existing GIS approaches and extending them to disability-related issues;
- Enlarging applications towards actually underrepresented target groups, especially towards intellectual and cognitive disabilities.

Some personal remarks: GIS and disabilities – blessing or barrier?

The question if GIS is building a bridge for people with disabilities and encourages society to be more inclusive cannot be satisfactorily answered yet. GIS and in a wider sense ICT opens up new ways – not only in the sense of providing orientation and navigation tools for people with disabilities, but also raising awareness and helping society to include people with disabilities and support their needs in health care, transport, urban planning and management and in many other fields, e.g. emergency management, search and rescue issues, tourism etc. Inclusion therefore, is able to shift from a bare label to a new approach in geography by making information and knowledge widely accessible. However, it has to be kept in mind, that GIS and technology can also be disabling – due to high costs, inadequate technical support for personalised needs, and the extreme belief and reliance on the digital world. New disabling barriers and social exclusion, e.g. by dissolving personal contacts in real life, are discriminating especially marginalised groups, including people with disabilities (Dobransky & Hargittai, 2006; Watling, 2011; Macdonald & Clayton, 2013). However, there is no doubt that GIS technology, especially in combination with the Internet and Apps can provide solutions and support people with special needs especially by increasing personal mobility and independence.

The problem that cannot be answered with GIS must be tackled on a larger scale: GIS can illustrate, but humans have to take actions. GIS can help, but cannot create awareness. GIS can visualise, but cannot remove real barriers in our real world. GIS can support, but cannot eliminate the barriers in our minds.

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