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JACCES

JOURNAL OF ACCESSIBILITY AND DESIGN FOR ALL

ISSN: 2013-7087

VOLUME 8 ISSUE 2

2018

DOI: 10.17411/jacces.v8i2

www.jacces.org

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MONITORING FOR ACCESSIBILITY IN MEDICAL UNIVERSITY WEBSITES: MEETING THE NEEDS OF PEOPLE WITH DISABILITIES

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Received: 2017-10-16 | Accepted: 2018-09-08 | Published: 2018-11-30

Abstract: Currently, students consider the Internet as an efficient tool and technology and the Websites of universities play a significant role in their daily activities. Due to the increasing number of students with a disability, accessibility of these Websites is essential. Thus, in the current study, the Websites of medical universities of Iran were investigated to identify accessibility issues if any exists. The homepage of Websites of the medical universities of Iran was evaluated using the AChecker and FAE tools. Moreover, the web pages of each university were evaluated by FAE. To examine the differences in accessibility issues rate among three types of medical universities, Kruskal–Wallis test was performed. The results showed that all three types of universities have accessibility issues. Amongst 50 university websites, only 2 out of them did not display any accessibility problem based on Achecker tool. The score of FAE tool showed that the websites of all Iranian universities of medical sciences are in the NI-R category, which indicates that the accessibility has not been considered in the design of those websites. Moreover, according to Spearman's correlation test, there was a significant inverse correlation between the score of homepage and the number of known problems (P-value= 0.043). Furthermore, there was a significant correlation between the homepage score and score of other pages (P-value <0.001). The accessibility of medical universities' Websites is not in an optimal situation, which severely affects the achievement of universities' visions and missions concerning expanding medical education and improving educational equity. Therefore, it is necessary to make fundamental modifications in this respect. To do so, university, as well as web developers should pay special consideration to accessibility guidelines to make their Websites more accessible.

Keywords: Accessibility; Access to Information; Academic Medical Centers; Disabled Persons; User-Computer Interface; Internet/standards.

Introduction

Currently, the Internet has become a part of everyday life (Bargh & McKenna, 2004). The realisation of high quality and easy communication has been one of the positive effects of the Internet on people's everyday life. The Internet has made it possible to do a lot of activities, such as access to banking services, from home and with far less effort and difficulty (Tyler, 2002). Websites are considered a key component to the survival of an organisation such as a university in today's competitive world (Ahmet Mentes & Aykut Turan, 2012). The use of websites has quickly become an essential part of the academic life. Universities and institutions of higher education use Websites to transfer their distinctive, high-quality aims to students (Anctil, 2008; Saichaie, Morphew, Hartley, Hanson, & Steinke, 2014). Websites are the primary communication channel to do web-based assignments, access information and promotional activities (Bairamzadeh & Bolhari, 2010).

Volume 8, Issue 2. (CC) JACCES, 2018. ISSN: 2013-7087

Students tend to use the Internet as an efficient tool and technology (Peng, Tsai, & Wu, 2006) and so university Websites play a very significant role in their daily life as well as in student admission processes in higher education institutions (Saichaie et al., 2014). University Websites often include scientific resources, information, news and organisational policy. Moreover, access to other services of a university such as course selection and the library is provided through the University Website (Kane, Shulman, Shockley, Ladner, et al., 2007). Generally, universities have large and complex Websites that include a subset of Websites related to different parts of the university such as registration, colleges and different departments(Hasan, 2012). Determining the parameters of a well-designed Website is not easy to do because the complex nature of the Websites depends on users' expectations (Lee & Koubek, 2010). So, Website designers should consider many parameters including accessibility, quality, information security and other parameters (Cocquebert, Trentesaux, & Tahon, 2010). The accessibility of a Website plays a significant role in responding to users' needs and expectations.

The tendency toward using the internet is increasing among people with disabilities (Harrison, Barlow, & Williams, 2007) who are prevented from active participation in educational opportunities by various inaccessibility problems (Parry & Brainard, 2010). The disability may be sensorial (such as hearing and vision), emotional and mental. For each of these cases, there are special assistive tools to help people browse web pages. These tools are a combination of software and hardware such as screen readers, voice recognition and Braille displays (Paciello & G., 2000). Since people with disabilities benefit from such tools for effective access to the internet (Harper & Yesilada, 2008), the accessibility of a website plays a major role in fulfilling the users' needs and expectations (McMullan, 2006). A Website designed to be flexible enough to be compatible with all these tools is called an accessible Website (Slatin & Rush, 2003).

Those with disability are only able to use web pages that are compatible with the assistive technologies. Website designers are hence required to meet website users' needs by considering accessibility during the design process (Cebi, 2013; Cocquebert et al., 2010). According to the available literature, the current issues with web accessibility need to be thoroughly evaluated. In fact, while the designers of a large number of university websites have failed to provide equal accessibility for all groups of users (Bradbard & Peters, 2010; Bradbard, Peters, & Caneva, 2010), higher education institutions are firmly recommended to have their websites designed by professionals who can provide all groups of users, including the disabled individuals (e.g. students), with equal accessibility (Solovieva & Bock, 2014).

Regarding the growing role of university Websites, their accessibility is essential for those with a disability. The number of students with disability is increasing; in 2008, 11% of students in the US were in this group (Scott, 2009). Therefore, accessibility of university Websites has become more important. Since faced with non-accessible university Websites, students with disabilities cannot have access to needed information and so their participation in university activities will be reduced. Furthermore, this issue will affect social justice and equal access to education (Kane, Shulman, Shockley, Ladner, et al., 2007). Therefore, university Websites' administrators are required to identify the problems associated with the accessibility of these Websites. This can identify the Websites' weaknesses and the areas, which need improvement, so an usable Website is provided for all users. To understand the accessibility barriers of university Websites, web accessibility evaluation is needed. Web accessibility evaluation is performed to determine how well the web can be accessed by disabled individuals (Harper & Yesilada, 2008).

Previous studies on university website accessibility

Various studies have discussed the accessibility of higher education institution websites. In this regard, Kurt (2011) evaluated the homepage accessibility of 10 Turkish university websites. Multiple techniques were applied to review the sample of homepages according to the standards of

Worldwide Web Consortium. Based on the results, all homepages had some accessibility problems (Kurt, 2011). In addition, Fernández et al. in 2010 studied the accessibility of 77 Spanish university websites. The results showed that the websites were not accessible; in fact, only 0.9% of web pages were accessible (Fernández, Roig, & Soler, 2010).

Moreover, Da Silva and Alturas (2015) evaluated Portuguese higher education institution websites in terms of accessibility maturity level according to the European Commission standards. Based on the findings, the accessibility maturity level of Portuguese institution websites was low on average; however, there was a great potential to improve the accessibility of websites (da Silva & Alturas, 2015).

Also, Aziz et al. (2010) used EvalAccess 2.0 to evaluate the accessibility of 120 websites of higher education institutions in Malaysia. The findings indicated several accessibility issues (Aziz, Wan Mohd Isa, & Nordin, 2010).

In a previous study, Kane et al. evaluated the accessibility of 100 homepages of top international universities and examined their compliance. According to the results, accessibility problems were found in many top universities, and there were major variations in accessibility among universities from different countries(Kane, Shulman, Shockley, & Ladner, 2007). In another study, web accessibility of Jordanian universities was evaluated, and multiple shortcomings were observed in most websites. Variations in accessibility standards were also found when evaluating the websites by different tools (Kamal & Alsmadi, 2016).

Another study examined the websites of Cyprus higher education institutions. As the findings indicated, no institution could pass all tests without error, and all websites failed one or more of WCAG 2.0 guidelines. Accordingly, modifications were considered necessary to meet the accessibility criteria (Işeri, Uyar, & Ilhan, 2017).

In another study, homepage accessibility of 51 websites, attributed to special education departments, was examined using Achecker and Bobby software. These tools were used to determine if the websites met the minimum requirements; the number of accessibility errors in each website was measured using one of these tools. Based on the findings, most homepages (97%) had accessibility problems (Ringlaben, Bray, & Packard, 2014).

In a developing country such as Iran with its focus on digital technologies, accessibility gets further importance to achieve inclusive service delivery. Numerous universities are currently using information technology to develop and enhance medical education (Ward, Gordon, Field, & Lehmann, 2001). In Iran, the Deputy for Education of Ministry of Health and Medical Education pays extra attention to promoting equity in higher medical education. It is hence focusing on various issues including equal access to online E-learning services. Therefore, in order for the Ministry of Health and Medical Education to reach its goal of equity in education, university websites and online services should be equally accessible by all people including those with disabilities.

Considering the importance of university website accessibility and lack of research on the accessibility of Iranian medical university websites, this study aimed to evaluate Iranian medical university websites and raise the web developers' awareness regarding the accessibility of these websites for disabled people.

Methodology

Sample

To conduct this descriptive - cross-sectional study, first, the list of Governmental Universities of Medical Sciences was identified (50 universities) through the Website of Ministry of Health of Iran("Medical Universities in Iran," n.d.). Deputy Ministry for Education of the Ministry of Health of Iran has ranked and categorised the medical universities of Iran into three types (1,2,3) based on their educational and research output. The type 1 universities are the best in the country.

Measures

The accessibility evaluation of websites can be performed manually by experts or by applying automatic tools. Automatic tools provide web designers with cost-effective measures to evaluate the accessibility of various websites (Barricelli, Sciarelli, Valtolina, & Rizzi, 2017; Ivory, Hearst, Ivory, & Hearst, 2001)) through methods not requiring human interventions. Automatic evaluation tools can help designers quickly identify potential accessibility issues. They can provide fully-automated checks and help designers with manual review. These tools can be frequently applied to large numbers of web pages (Harper & Yesilada, 2008). One of the automatic online tools for accessibility evaluation is AChecker, which was developed in 2010 by Greg Gay and Cindy Qi Li (Gay & Li, 2010). AChecker is a reliable tool for assessing the accessibility of websites and has been used to examine the accessibility status of websites in several studies (AkgÜL & Vatansever, 2016; Alahmadi & Drew, 2016; Youngblood, 2014). Also, it has been accredited by the World Wide Web Consortium and introduced in the consortium portal (W3C, 2016). It ("AChecker : IDI Accessibility Checker:," n.d.) processes three levels of problems: likely problems, known problems, and potential problems. Known problems refer to issues previously identified as definite barriers to accessibility. These problems should be resolved by appropriate modifications in web pages. Likely problems are those perceived as probable barriers. Finally, potential problems are issues unidentifiable by AChecker. Human decisions are required for both likely and potential problems (Gay & Li, 2010).

Functional Accessibility Evaluator (FAE), introduced by the University of Illinois, is another automatic tool and open source software, used to evaluate the accessibility of a website or web page according to the W3C Web Content Accessibility Guidelines (WCAG) 2.0 (level A and AA). For every category, FAE presents scores ranging from 0% to 100% and reports a qualitative status code considering the percentage of passed tests for each website: not applicable; not implemented (0-50% of tests passed); partially implemented (50-94% of tests passed); almost complete (95-99% of tests passed); and complete (100% of tests passed) (Table 1). Generally, FAE is a reliable tool, which has been used in several studies to examine the accessibility status of websites (Ahn & Hwang, 2010; Kane, Shulman, Shockley, & Ladner, 2007).

In this study, the homepages of medical universities were evaluated on May 2018 using the AChecker and Functional Accessibility Evaluator (FAE) automated accessibility testing tools based on WCAG. Moreover, 25 web pages of all selected universities were also analysed using the Functional Accessibility Evaluator.

Procedure

This study first evaluated the percentage of medical university websites, which conform to accessibility standards, i.e. Web Content Accessibility Guidelines (WCAG) 2.0, and would pass automated web accessibility tests. It then sought to identify the differences between the accessibility issues detected in the currently available types of medical university websites.

The number of accessibility errors of homepages of selected universities was determined by AChecker tool using WCAG 2.0 guideline (level AA). To measure the accessibility scores of homepages, as well as 25 of the web pages of each of the 50 selected universities, FAE tool was applied. In order to assess the web pages, the evaluation level was set to (level two).

Moreover, to examine the differences in accessibility issues rate among three types of medical universities, Kruskal–Wallis test was performed. Statistical analysis carried out using SPSS software.

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Results

The number of accessibility problems for three types of universities are presented in Table 2-4. The websites of Mashhad University of Medical Sciences and Birjand University of Medical Sciences did not respond to Achecker and FAE tools, respectively.

Table 1. FAE implementation score definitions.*

Abbrev	Score	Status	Description
C	100	Complete	This means all rules have passed.
R	0	Required Manual Checks	Manual checks are required to determine if accessibility requirements have been met.
AC	95-99	Almost Complete	Almost Complete means that you seem to understand the accessibility requirements of the rules and are close to fully implementing their requirements on all pages within the website.
PI PI-R	50-94	Partial Implementation	Partial Implementation means that you may understand at least some of the accessibility requirements. "-R" means there are required Manual Checks.
NI NI-R	0-50	Not Implemented	Incomplete means that you do not understand the accessibility requirements of the rules or did not consider accessibility in the design of the website. "-R" means there are required Manual Checks.
na	-	Not Applicable	No markup was found that identified a known or possible accessibility issue

*Adapted from FAE official website (“Functional Accessibility Evaluator,” 2018)

All three types of universities showed accessibility issues (Tables 2-4). The highest number of known problems was reported in Urmia University of Medical Sciences (n= 1060), while the lowest number was attributed to Tabriz University of Medical Sciences (n= 0) and Kurdistan University of Medical Sciences (n= 0). Also, the highest homepage score was attributed to Guilan University of Medical Sciences (n= 42), while the lowest score was related to Shahid Sadoughi University of Yazd (n= 0). In addition, assessment of 25 pages of websites showed that the highest score was related to Torbat-e-Heydarieh University (n= 39), while the lowest score was reported in Shahid Sadoughi University of Yazd (n= 0).

Table 2. The accessibility problems and score for type 1 universities.

Universities (URL)	Homepage					Webpages D=2, pages=25	
	Achecker			FAE		FAE	
	KP[a]	LP[b]	PP[c]	Score	Status	Score	Status
Shiraz University of Medical Sciences	991	7	843	20	NI-R	27	NI-R
Ahvaz Jundishapur University of Medical Sciences	354	0	703	26	NI-R	27	NI-R
Mashhad University of Medical Sciences	-	-	-	26	NI-R	29	NI-R
Iran University of Medical Sciences	57	0	701	10	NI-R	14	NI-R
Tabriz University of Medical Sciences	0	0	0	31	NI-R	31	NI-R
Tehran University of Medical Sciences	76	0	1023	30	NI-R	31	NI-R
Shahid Beheshti University of Medical Sciences	63	9	780	38	NI-R	36	NI-R
Isfahan University of Medical Sciences	42	1	706	26	NI-R	28	NI-R

Universities (URL)	Homepage					Webpages D=2, pages=25	
	Achecker			FAE		FAE	
	KP[a]	LP[b]	PP[c]	Score	Status	Score	Status
Kerman University of Medical Sciences	13	0	601	17	NI-R	22	NI-R

[a]KP= Known Problems; [b]LP= Likely problems; [c]PP= potential problems

Table 3. The accessibility problems and score for type 2 universities

Universities (URL)	Homepage					Webpages D=2, pages=25	
	Achecker			FAE		FAE	
	KP	LP	PP	Score	Status	Score	Status
Urmia University of Medical Sciences	1060	9	1195	11	NI-R	11	NI-R
Baqiyatallah University of Medical Sciences	882	8	1615	16	NI-R	19	NI-R
Lorestan University of Medical Sciences	379	0	931	5	NI-R	9	NI-R
Semnan University of Medical Sciences	394	0	876	9	NI-R	10	NI-R
Babol University of Medical Sciences	18	18	755	34	NI-R	32	NI-R
Kashan University of Medical Sciences	225	0	1363	14	NI-R	14	NI-R
Zanjan University of Medical Sciences	162	1	600	11	NI-R	12	NI-R
Guilan University of Medical Sciences	158	9	839	42	NI-R	34	NI-R
Ardabil University of Medical Sciences	100	4	646	33	NI-R	35	NI-R
Shahed university	106	0	739	17	NI-R	23	NI-R

Universities (URL)	Homepage					Webpages D=2, pages=25	
	Achecker			FAE		FAE	
	KP	LP	PP	Score	Status	Score	Status
Arak University of Medical Sciences	84	0	1201	5	NI-R	11	NI-R
Zahedan University of Medical Sciences	85	1	651	30	NI-R	35	NI-R
Qazvin University of Medical Sciences	71	1	1206	9	NI-R	17	NI-R
University of Social Welfare and Rehabilitation Sciences	23	6	770	36	NI-R	34	NI-R
Hormozgan University of Medical Sciences	28	0	428	30	NI-R	32	NI-R
Hamadan University of Medical Sciences	15	0	151	14	NI-R	16	NI-R
Mazandaran University of Medical Sciences	13	5	880	11	NI-R	23	NI-R
Birjand University of Medical Sciences	9	5	1791	-	-	-	-
Kermanshah University of Medical Sciences	15	9	798	30	NI-R	32	NI-R
Golestan University of Medical Sciences	299	0	1549	24	NI-R	22	NI-R
Shahid Sadoughi University of Medical Sciences	2	0	7	0	R	0	R
Rafsanjan University of Medical Sciences	2	0	226	10	NI-R	9	NI-R

Table 4. The accessibility problems and score for type 3 universities

Universities (URL)	Homepage					Webpages D=2, pages=25	
	Achecker			FAE		FAE	
	KP	LP	PP	Score	Status	Score	Status
Alborz University of Medical Sciences	657	0	957	5	NI-R	15	NI-R
Bushehr University of Medical Sciences	237	1	1038	32	NI-R	33	NI-R
Sabzevar University of Medical Sciences	57	0	705	31	NI-R	26	NI-R
Bam University of Medical Sciences	255	0	3311	11	NI-R	10	NI-R
AJA University of Medical Sciences	182	0	904	17	NI-R	20	NI-R
Jahrom University of Medical Sciences	154	0	625	25	NI-R	28	NI-R
Shahroud University of Medical Sciences	112	12	696	33	NI-R	35	NI-R
Dezful University of Medical Sciences	65	0	289	11	NI-R	7	NI-R
Qom University of Medical Sciences	47	0	764	16	NI-R	13	NI-R
Shahrekord University of Medical Sciences	63	0	731	26	NI-R	30	NI-R
Zabol University of Medical Sciences	35	12	490	34	NI-R	35	NI-R
Yasuj University of Medical Sciences	500	4	959	20	NI-R	22	NI-R
Gonabad University of Medical Sciences	360	0	449	13	NI-R	19	NI-R
Ilam University of Medical Sciences	11	5	657	31	NI-R	31	NI-R
North Khorasan University of Medical Sciences	55	6	697	26	NI-R	26	NI-R
Fasa University of Medical Sciences	3	12	485	35	NI-R	33	NI-R
Torbat Heydarieh University of Medical Sciences	77	2	465	33	NI-R	39	NI-R

Universities (URL)	Homepage					Webpages D=2, pages=25	
	Achecker			FAE		FAE	
	KP	LP	PP	Score	Status	Score	Status
Kurdistan University of Medical Sciences	0	0	0	30	NI-R	33	NI-R
Jiroft University of Medical Sciences	837	8	1025	11	NI-R	10	NI-R

The mean of accessibility known problems for all Websites was 192.51±268.765. Furthermore, the mean of known problems of Websites for type 1 universities was 199.50±338.889, followed by 187.73±281.088 for type 2 university and 195.11±236.068 for type 3 universities (Table 5).

Based on the Kruskal-Wallis test, the mean number of known problems, likely problems, and potential problems was not significantly different among different types of medical universities of Iran (Table 5). Moreover, the mean scores of homepages and 25 web pages of university websites were not significantly different among three types of medical universities of Iran, based on the Kruskal-Wallis test (Table 5).

Table 5 Average accessibility problems and score based on university type

		Type1 Mean (SD)	Type2 Mean (SD)	Type3 Mean (SD)	Total Mean (SD)	P-value
AChecker	KP	199.50 (338.89)	187.73 (281.09)	195.11 (236.07)	192.51 (268.77)	0.798
	LP	2.13 (3.68)	3.45 (4.75)	3.26 (4.57)	3.16 (4.46)	0.751
	PP	669.63 (298.48)	873.5 (464.37)	464.37 (662.17)	812.67 (526.22)	0.372
FAE Homepage		24.89 (8.27)	18.62 (12.07)	23.16 (9.70)	21.53 (10.69)	0.238
FAE D=2, pages<=25		27.22 (6.24)	20.48 (10.77)	24.47 (9.84)	23.27 (9.90)	0.340

According to Spearman's correlation test, there was a significant inverse correlation between the score of homepage and number of known problems (r= -0.293, N= 49, P-value= 0.043); in other words, lower scores were associated with more errors. Also, there was a significant correlation between the homepage score and score of 25 web pages (r= 0.929, N= 49, P-value <0.001); in other words, the higher homepage score is associated with the higher score of other pages.

Discussion

The internet has the potential to affect educational systems fundamentally in the next future. Thus, universities are faced with concerns about providing the applicants with better online access to needed information. While non-educational services also are offered by medical universities (. e.g. healthcare services), the users of these Websites include wide range of the community and therefore it is necessary to take fundamental measures to address accessibility issues.

To our knowledge, this study is the first step toward assessing the accessibility status of medical universities.

There are special tools and guidelines that can help web developers to make Websites more accessible. Nevertheless, unfortunately, the present study showed that medical university websites of Iran are not accessible enough. Lazar et al. in a study entitled “Web accessibility in the Mid-Atlantic United States: a study of 50 homepages” revealed that 98% of studied Websites present accessibility issues(Lazar, Beere, Greenidge, & Nagappa, 2003). Similarly, many studies conducted on university Websites have revealed that they also have severe accessibility problems(Comeaux & Schmetzke, 2007; Espadinha, Pereira, da Silva, & Lopes, 2011; Kamal & Alsmadi, 2016).

The results of the current study showed that the accessibility of most websites of Iranian medical universities is not suitable and needs to be addressed in order to resolve accessibility problems.

No statistically significant differences were found between the known accessibility problems and the types of medical universities (p>0.05).

Type 1 universities were expected to have a superior status, whereas the opposite was discovered (Table 5). This can be attributed probably to more complexity(Hackett, Parmanto, & Zeng, 2005) for type 1 universities Websites. Although it is expected that accessibility issues should not be ignored while increasing complexity of design, content, and images on Websites. This shortcoming gradually makes it difficult for universities to fascinate applicants with the desired characteristics(Veloutsou, Lewis, & Paton, 2004).

In this study, scores of homepages assessment showed a significant relationship with the scores of reviewed web pages (25 web pages). Moreover, there was a significant inverse correlation between the score of homepage and number of known problems; in other words, lower scores were associated with more errors. Therefore, it can be concluded that the homepage is a proper representative of the entire website; in fact, if the homepage of a website has accessibility problems, other web pages of that are likely to have similar problems. It is clear that other kind of websites should be evaluated to find out if the same relationship exists or not. Nevertheless, regarding that, there was a very strong relationship (r= 0.929, N= 49, P-value <0.001) between accessibility score of the homepage and score of 25 web pages of each website, thus, it seems that our study results can be generalised to other types of websites too.

The score of FAE showed that the websites of all Iranian universities of medical sciences are in the NI-R category, which indicates the designers' misunderstandings about the accessibility needs of websites. Therefore, designers of Iranian medical university websites should evaluate the accessibility of those websites and take requred actions to solve any related problems. It should be kept in mind that online tools should be merely used as assistive tools to inform website designers about the accessibility status of websites.

Regarding the results, various reasons are considered as possible causes; Some researches have shown that one of the main problems is that many web developers do not see accessibility as a priority(Erickson, Trerise, VanLooy, Lee, & Bruyère, 2009; Lazar, Dudley-Sponaugle, & Greenidge, 2004). The other reason is some Websites are created in limited time and or restricted budget which these restrictions prevent the use of the professional Website designers (Erickson et al., 2009; Steinau, Díaz, Rodríguez, & Ibáñez, 2003). Even some of them are unaware of the importance of the Website for the success of the university(Erickson et al., 2009). In a study on web accessibility policies and practices of about 700 community colleges (a 79% response rate) in the US, nearly half of the respondents regarded all three types of barriers as issues for their campus (Erickson et al., 2009).

Disabled people are considered as a part of universities different groups of applicants. Regarding that university Web sites has an essential role in motivating international student choice of the host country. Thus, the accessibility barriers may lead to lose the university potential national and international applicants with disability. Disabled staffs are also another group of university website users challenged by accessibility issues. Since Iranian medical universities are responsible for a wide range of health services, the disabled community in the country, as a whole, can be regarded as a group of medical university website users. These people will all have to deal with accessibility issues when using university websites.

Conclusion

The results of assessing the accessibility of Iranian medical universities' Websites revealed that their accessibility was not in suitable condition. This will strongly affect the achievement of universities' visions and missions regarding medical education expansion and improving educational equity.

Currently, paying attention to the issue of accessibility of Websites is very important. The findings of this study showed that even websites that were not identified by Achecker were categorised in the NI-R category by FAE and should be reviewed by specialists. Therefore, the use of one single online tool for determining the accessibility of websites is not adequate, and it is preferable to apply more than one instrument. Although automated tools seem adequate for obtaining general knowledge about accessibility issues, more detailed information cannot be collected without a combination of automated tools and manual testing by a group of professionals (e.g. web developers, webmasters, and content managers).

Considering the growing significance of websites in the provision of relevant information to different stakeholders, Iranian medical universities should ensure the accessibility of their websites by all users including the disabled. Thus, the university, as well as web developers, should pay special consideration to accessibility guidelines to make their Websites more accessible. Therefore, universities need to hire skilled information technology experts and website designers to develop websites which are equally accessible by current and future students with normal conditions or disabilities. Accessibility tests should also be performed to ensure the satisfaction of accessibility needs and prevent future accessibility issues.

The present study has been done on May 2018. At the time of the present study, WCAG 2.0 was the latest accessibility criteria guideline. The current recommendation of WCAG is 2.1, which is published at 5th June of 2018. This change may affect our findings by detecting more accessibility issues, as WCAG2.1 extends WCAG2.0 by integrating new success criteria, supporting definitions, and guidelines for organising the additions, along with some additions to the conformance section. However, WCAG2.1 uses the same conformance model as WCAG2.0; therefore, websites that conform to WCAG2.1 also conform to WCAG2.0 guidelines. Nevertheless, it is recommended to carry out future studies based on WCAG2.1 to better understand accessibility issues. Furthermore, web developers are suggested to adopt WCAG2.1 as a new conformance target to improve the accessibility of websites.

Limitations

Since this study was limited to Iranian medical universities, its results cannot be generalised to other types of universities or organisations. Nevertheless, the results can provide web developers and organisations concerned about website accessibility with valuable information. Additionally, websites are dynamic and constantly being updated or reconstructed; all of which may change the results found in this study.

Acknowledgments

This article is extracted from the research project (code 15924) which is funded by the School of Allied Medical Sciences, Shahid Beheshti University of Medical Sciences.

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EVALUATION OF IMAGE ACCESSIBILITY FOR VISUALLY IMPAIRED USERS

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Received: 2018-02-15 | Accepted: 2018-10-13 | Published: 2018-11-30

Abstract: The accessibility of website images is influenced by the availability and accuracy of descriptive text and its compatibility with the images' complexity and purpose. Image accessibility evaluation cannot be fully affected through applying one method, and it can be enhanced by the inclusion of processes that consider the quality of descriptive text for images. The evaluation of descriptive text quality may initially involve human evaluation and then use of an automated evaluation tool to provide a counterpoint. In this paper, an analysis is presented of a dataset of 120 complex and informative images found on universities' Web-based systems. This is supplemented with a detailed analysis of HTML image attributes and elements. Human and automated analyses of content are combined, and the information is integrated to inform the evaluation's outcome. Our analysis illustrates a lack of accurate usage of HTML image attributes and elements, such as alt and longdesc. The findings provide insight into improving image accessibility by applying multiple evaluation methods and auto-generated descriptive text. This paper will be of interest to Web accessibility developers and researchers.

Keywords: image accessibility, descriptive text, alt text, visually impaired, human evaluation, automated tool evaluation.

Introduction

Accessibility evaluation is an important equity step in assessing the effectiveness and usefulness of online materials for users with disabilities. Pipino, Lee, and Wang (2002) considered accessibility a part of the data quality dimensions that they proposed. Using data quality assessments, the authors defined accessibility as "the extent to which data is available, or easily and quickly retrievable" (Pipino et al., 2002, p. 2). The ready availability of data to all users is the core dimension that affects data quality in any Web-based system. This quality encompasses the accessibility of media content, such as images and videos, and the availability and accuracy of text that describes images for visually impaired users. In providing descriptive text, the main considerations that developers should consider are the images' complexity and purpose.

Accessibility is a complicated matter that involves the consideration of many aspects, including the features of systems, the characteristics of disabled user groups, the effects of embedded files, and the roles of assistive technologies. Considering these varied aspects, a multi-method evaluation scheme is well-matched to measuring accessibility and design development plans for specific Web-based systems such as university information systems. Aware that a single approach cannot accurately measure accessibility rate, many scholars (Biswas, Duarte, Langdon, Almeida & Jung, 2013; Gómez-Martínez et al., 2015; Sun & Strybel, 2017) have highlighted the vital contribution of combining methods to achieving favourable results. However, multi evaluation methods for image accessibility on university Web-based system has not been addressed in detail.

Using the above mentioned considerations as bases for evaluating large data sources on the World Wide Web may enable organisations to understand accessibility problems, develop image accessibility solutions, and improve the accessibility rates of current systems. To these ends, we conducted human and automated evaluations to measure the accessibility of university Web-based systems. This study's main aim is to highlight the importance of including human evaluation in image accessibility testing, as human evaluation is the only current means of measuring the accuracy of descriptive texts. Also, this study provides details on HTML image attributes and elements' usage on university Web-based systems. From this analysis, elements of design for future accessibility-smart solutions can be used to create quality descriptive text with usable tools, even for complex images. A further aim is to highlight significant image accessibility barriers that prevent visually impaired users from receiving the same information from an image as their sighted peers.

The following sections discuss multi-method accessibility evaluation and present the methods adopted in this study and the findings that we derived.

Related Work

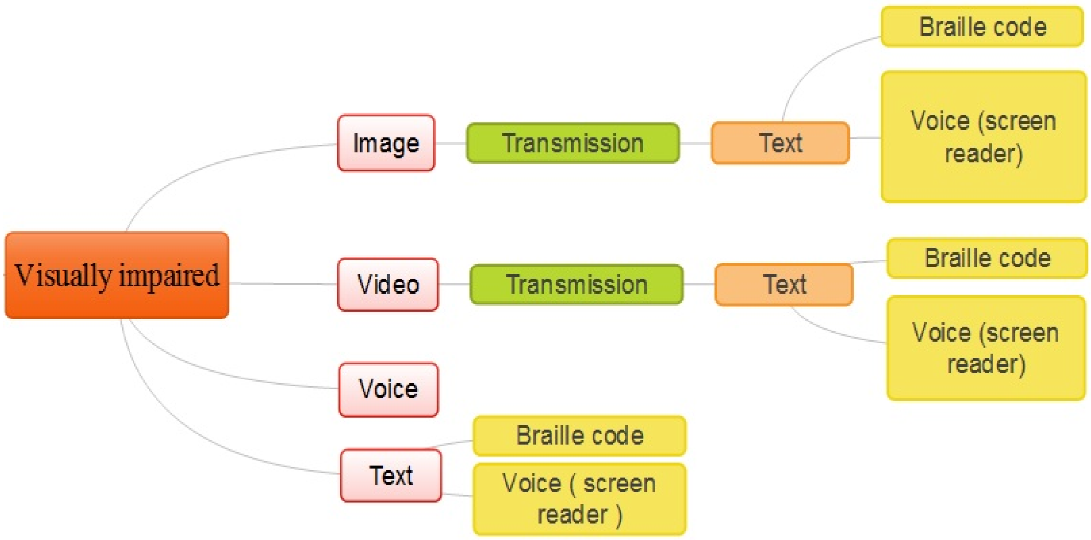
The literature was reviewed to identify the key issues related to evaluating image accessibility for visually impaired users. This section discusses multi-method accessibility evaluation (human and automated), with emphasis on the accessibility of images on Web-based university systems.

Visually impaired Characteristics

A sensory disability is defined as a disability that relates to one or more of the human senses, such as vision impairment, hearing impairment, or both (Oliver, 2017; World Health Organization, 2010). Vision-impaired individuals are the primary stakeholders in this study. Vision or visual impairment is a health condition of the eyes that cannot be corrected with standard solutions such as glasses. The World Health Organization (2010) defines three categories of vision impairment (severe, moderate, and mild impairment) and three categories of blindness based on visual acuity tests. Many people with disabilities who are blind have some vision (including those with light sensitivity), very low or limited vision, or limited peripheral vision. Some visually impaired individuals have no light perception at all (World Health Organization, 2010). Understanding the characteristics of visually impaired users helps to determine the accessibility barriers as they interact with Web-based systems.

Heuristics ease the identification and prioritisation of characteristics for specific disabled groups. For visually impaired users, a missing text description of an image is a barrier (W3C, 2018). Moreover, visually impaired individuals use assistive software screen readers to interact with Web-based systems; thus, for example, if an image does not have descriptive text, they cannot access that image. Figure 1 illustrates the heuristically determined priority characteristics that should be applied for visually impaired users while they interact with images, video, voice and text. For example, images must be transferred to descriptive text; then, a screen reader can read it or print it as Braille code.

Figure 1. Heuristic priorities based on the characteristics of visually impaired users.



Accessibility of University Websites

Accessibility evaluation is a vital equity step in assessing the effectiveness of online learning materials for students with disabilities. In an empirical study (Alahmadi & Drew, 2016), researchers assessed the websites of 60 top universities globally and in the Oceania and Arab region. They found 30,944 (37%) homepage errors in 180 evaluated pages. The study indicated no significant improvement in the accessibility of university websites between 2005 and 2015. Additionally, no significant difference in accessibility was found among top-ranking universities in developed or developing countries (Patra & Dash, 2017; Ringlaben, Bray & Packard, 2014; Zap & Montgomerie, 2013).

Educational Web-based information systems advance academic success among users with disabilities as long as the systems are designed for accessibility. Online courses provide enhanced solutions for students who experience barriers to attending traditional courses because of sensory or physical disabilities. Of all users with disabilities, visually impaired individuals are the most strongly affected by inaccessible educational systems (Paciello, 2000).

Fichten, Jorgensen, Havel and Barile (2006) demonstrated that most students with disabilities that they surveyed indicated that they need adaptive assistive technologies, such as screen readers and voice recognition software (VRS), to effectively interact with a university Web-based system. Visually impaired users typically rely on screen reader software (e.g., Jaws) based on text-to-speech techniques (TTSs), VRS (e.g., Dragon Naturally Speaking), and Braille note-taking devices and keyboards when interacting with university Web-based systems. A screen reader is characterised by a simple mechanism that scans a screen for text and then audibly reads the content for a user to hear. Screen readers offer accessibility solutions and provide visually impaired users a sense of independence, but similar to other programs, they also suffer from certain limitations. For example, screen readers can only read text; they cannot read other media content, such as images or Flash animations. If a descriptive text for an image is not available or incorrect, then the screen reader cannot convey the image content to the user (Crow, 2008). Understanding current image accessibility problems may lead to better understanding of challenges among visually impaired users, help to develop a solution, and increase educators or developer awareness.

Current Web-based university systems can benefit from evaluating image accessibility with respect to visually impaired users' characteristics and needs (Rodriguez-Ascaso, Boticario, Finat & Petrie, 2017). To ensure accessibility, developers should also take into account the requirements for descriptive text of images for visually impaired users to effectively access images as well as the possible impact of image accessibility on learning and study for visually impaired users when evaluating an entire Web-based university system.

Multi-Method Accessibility Evaluation

Using a multi-method approach to evaluation is the best way to measure accessibility and design development plans for Web-based systems, such as university websites, because accessibility is a complex, multi-faceted issue. A single method cannot guarantee improvement in accessibility rates, as indicated in many studies (Masri & Luján-Mora, 2011) that underscored the essentiality of combining approaches to achieve excellent results. Other studies (Gómez-Martínez et al., 2015) showed that using experimental methods and user-centred design tests is a unique direction in determining and rectifying the most critical problems faced by disabled users as they interact with Web-based systems.

Human assessment, which involves subjective and objective evaluation, is a consistent component of all accessibility evaluation methods. It enables efficient probing into a specific component of accessibility barriers in specific system functions. One way of obtaining reliable results is to gain an overview of the accessibility status of numerous Web-based systems through manual evaluation by evaluators or users; however, this approach is often excessively time-consuming and costly (Bühler, Heck, Perlick, Nietzio, & Ulltveit-Moe, 2006). Human experts are highly accurate at evaluating accessibility and may use automated evaluation tools (AETs) only as supportive methods.

AETs present advantages in terms of productivity and rely on heuristics to detect guideline violations (Brajnik, 2008). The drawback of these tools is that many fail to effectively evaluate the accuracy of the correspondence between descriptive text for images and the images' complexity and purpose. They are also unable to satisfy the mandatory requirements for Web 2.0 applications because they exhibit restricted crawling capabilities, some evaluate only static-generated HTML content, and they fail to verify dynamically created document object model elements that are critical to rich Internet applications (Velasco, Denev, Stegemann, & Mohamad, 2008; Watanabe, Fortes, & Dias, 2017). Human and AET evaluations are performed on the basis of accessibility standards.

Many accessibility standards, like WCAG 2.1 (W3C, 2018), BITV 1.0 (Bundesministerium, 2011), Stanca Act (Parliament, 2004), and Section 508 (U.S. Department of Justice, 2016), require descriptive text for nontext elements such as images. Table 1 provides a summary for the standard checkpoint/guideline numbers related to the criterion which "all image elements have an alt attribute". Furthermore, Section 508 provides guidelines that require long descriptive text for complex images (Section 508[a]: Text Equivalents, Checkpoint ID 3) and state that all nondecorative images must have descriptive text (Section 508[a]: Text Equivalents, Checkpoint ID 4), essential images should not have spacer descriptive text (Section 508[a]: Text Equivalents, Checkpoint ID 5), and descriptive text for all images must contain all text in the image unless the image text is decorative or appears elsewhere in text in the web page (Section 508[a]: Text Equivalents, Checkpoint ID 11).

Table 1. Summary of Standards and Checkpoint/Guideline Numbers for the Criterion "All Image Elements Have an Alt Attribute".

Standards	Guidelines	Checkpoint no.
WCAG 2.1	1.1 Text Alternatives	Success Criteria 1.1.1
BITV1.0	Group Level 1	Checkpoint 1.1
Section 508	A-text equivalents	Checkpoint ID 1
Stanca Act	Text Equivalents	Requirement 3

Providing descriptive text for media content improves accessibility (W3C, 2018), but this is effective only if the text is readily available and highly accurate. Alahmadi and Drew (2016, 2017a) found that failure to provide descriptive text for nontext elements, including images, is a serious accessibility error. This finding was confirmed by feedback from visually impaired users, who believed that such text is lacking from current Web-based systems (Alalhmadi, 2017a). Web localisers can bridge the knowledge gap and provide high-quality text alternatives when developers combine specialised and general Web accessibility evaluation tools (Vázquez, 2015). Splendiani and Ribera (2014) showed that a primary solution to image accessibility problems is the inclusion of alternative text through the use of decision trees. Multi-method evaluations of descriptive text for images are also expected to drive the discovery of website shortcomings that prevent the provision of accessible images.

Image Accessibility: Descriptive Text for Visually Impaired Users

Individuals describe objects through spoken, written, or typed language. A considerable amount of this language describes all objects in our lives, especially those that are visually based, such as images and videos. This language is likely a wealthy source of information about visual objects as well as methods for how individuals build natural language to describe visual objects (Kulkarni et al., 2013). Necessarily, then, a description of an image should contain a sufficient number of characters to highlight the principal image features. A complex image will require longer descriptions that reflect the main idea carried by the image. This requirement indicates a relationship between the number of characters in a description and the complexity of an image.

Descriptive text for images is necessary for visually impaired users (Connor, 2012). A simple textual description is not enough to convey the correct meaning of a graphic (Fitzpatrick, Godfrey, & Sorge, 2017). Automatically or human-generated descriptive text should lead to high-quality and accurate descriptions that reflect the key features of images. A deficiency in this regard diminishes the effectiveness of Web-based university systems (to which our model was applied). For instance, when an educator uploads a complex diagram, uses only two words to describe it, and neglects in-text explanations, visually impaired users will experience difficulty in understanding such important learning content.

Web-based university systems are characterised by a variety of images with equally varying purposes (Rice, 2012). An example is an image intended to deliver learning content. Each type of image needs a specific method of description, depending on the image's purpose; there are complex or simple images, and some images are used as learning content, while other images are informative. HTML 5 (Connor, 2012; W3C, 2018) provides the necessary attributes and elements to add descriptive text for an image based on its purpose and type. Alt attributes are widely used to add alternative (description) text for nontext elements. In-text description is another method of describing an image with appropriate text in the paragraphs around the image on the web page. A null alt attribute adds a null value instead of text in the alt attribute. Table 2 provides a summary a summary of these attributes and its usages.

Table 2. Summary of HTML Attributes and Elements to Describe Images (W3C, 2018).

Image category	Example	Attribute/elements	Function	Number of characters
Complex	Diagrams, graphs, maps, and	Longdesc attribute, area attributes, and figure elements	Add long text descriptions	More than 100
Simple	Informative image	Alt attribute	Add short text descriptions	Less than or equal 100
Simple	Decorative images	Null alt attribute value	Add a null value instead of a text description	Null value only
Simple	Functional images	Alt attribute	Add short text descriptions	Less than or equal 100

Moreover, diagrams, graphs, maps, and charts, which are considered complex images and used as learning content on Web-based university systems, necessitate long descriptions (more than 100 characters) that are placed under the images by using longdesc or area attributes, as well as figure elements. Also, MathML, for instance, is used to convert mathematical formulas into text in the absence of an in-text description or alt attributes (Connor, 2012; W3C, 2018). Text images, such as a scanned book chapter, require equivalent text files. Nonlearning images, such as those related to school administration, student accommodation, and alumni records, do not contain learning content. Examples include campus maps, images of boards of directors and related staff hierarchies, and diagrams of university pathways. Nonlearning images also need textual equivalents, but the impact of these images on visually impaired students is less than that of learning images.

More image types are available under W3C classifications (W3C, 2018). Examples include images used to label information, such as telephone icons and file formats (Figure 3), which usually require only one to two words of description. Other examples include images used to supplement information, such as a picture of a set of books (Figure 4) placed next to a textual announcement of exam periods, or images reflecting emotion, such as those featuring triumphant student faces. These images need short text descriptions, probably around 10 words (W3C, 2018). Decorative images, such as a partial rendering of a page design or text link, provide appeal to a web page. These images can be described using a null alt attribute value. Finally, functional images, such as logos and icons, require descriptive text that accurately conveys the function represented by each image (around five words; W3C, 2018).

Figure 2. Example of a mathematical formula image.

$$E(r) = 4\varepsilon\left(\left(\frac{\sigma}{r}\right)^{12} - \left(\frac{\sigma}{r}\right)^{6}\right)$$

Figure 3. Example of an informative image conveying file format.

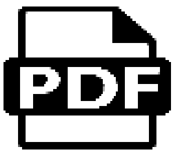
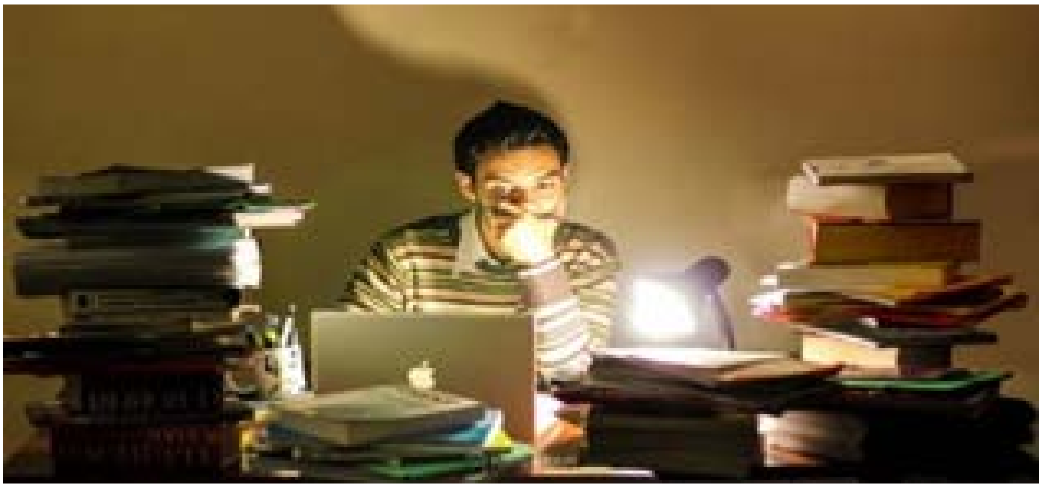


Figure 4. Example of an informative image used to supplement information (e.g., exam period).



Research Methods

This study has a combined quantitative and qualitative design; the methods adopted were experimental strategies that involved human and automated evaluations (Creswell, 2013). This section explains the image accessibility checkpoints and rules that were formulated, provides an overview of human expert- and AET-based evaluations, and describes the data sampling and collection methods used in this study.

Sampling Method

Examining all web pages against all evaluation criteria is generally impractical (Nietzio, Strobbe, & Velleman, 2008). In this research, many foundational steps were implemented before sample pages from the evaluated systems were chosen. The first step was defining the evaluation goals, and the second was determining the system's features and functions. The third step involved highlighting the characteristics and needs of the target disabled users, and the fourth entailed determining the types and effects of content found in the selected systems. Finally, the types of pages that affected the accessibility of the Web-based systems to the target groups were determined and prioritised to formulate solutions. After the foundational process, a sample of pages from the selected websites was evaluated. Uniform random sampling is necessary for replicable evaluation that enables synchronous or asynchronous comparisons. The sampling process is usually based on an ad hoc procedure, such as page type selection, random walk, and uniform random sampling (Brajnik & Lomuscio, 2007). The choice of sampling method affects the metric design, which should consider the size and complexity of a website during evaluation (Parmanto & Zeng, 2005). If a system is considerably large and complex, the system is highly likely to receive a low accessibility score.

The complexity of Web-based university systems, which contain thousands of pages that comprise many images, can decrease their accessibility. To address this issue, we evaluated both complex and simple images; usually, learning images are complex, and informative images are simple. We also formulated evaluation rules (Section 3.3) to guarantee the optimal judgement of whether an image is accessible or inaccessible.

In this study, we evaluated 120 web pages that included 120 images. In our main research project, we categorised web pages into four categories—video, image, document, and general web pages—based on a published evaluation model (Alahmadi & Drew, 2017b). We evaluated 265 document web pages to examine accessibility problems in all of the document files, 120 web pages that included 120 videos, and 1,000 general web pages to test all general accessibility problems. A total of 1,505 web pages were evaluated in our main project. Based on our assumptions, around 12% of web pages have image accessibility problems. This assumption came from using the Google Search Console tool, the Google search engine, sitemaps to generate the number of all web pages in one Web-based university system, the number of images (excluding decorative or functional images) published on the same Web-based university system, and the number of document files and videos. We found that in the chosen Web-based university systems, 12% of all web pages had images.

Dataset

The examined dataset contained 120 evaluated images published on 120 web pages of 64 Web-based university systems (including 38 Australian universities and 26 Saudi universities). This study was conducted in Australia and supported by the Saudi Ministry of Education. In 2016, among these universities, 9 ranked at the top 100 in the world, 14 ranked above the top 500 in the world, and 41 placed below the top 500, as determined from QS University Rankings (Dobrota, Bulajic, Bornmann, & Jeremic, 2016). The main language used on the web pages was English. The web pages, which contained complex or simple images, were randomly selected for the evaluations. Of the images examined, 37 were embedded on LMSs, such as course content web pages, and 83 were embedded on university web pages, such as online help and library pages; 66 were learning images, and 54 were non-learning images; 92 were considered complex, and 28 were regarded as simple (according to W3C definitions). We excluded decorative or functional images from the evaluations.

Image Accessibility Checkpoints and Rules

In our study, the learning images examined were published on web pages that delivered learning materials, such as course content and library pages. These images constituted a crucial part of the web pages' content. The absence of descriptive text for such images means that part of the learning materials is also missing, thereby affecting the performance of visually impaired students/users. Most of the images are graphs, diagrams, and charts, which are regarded as complex images (W3C, 2018). As previously stated, complex images may require descriptions that are longer than 100 characters; such descriptions can be provided through the use of HTML5 attributes or in-text explanations (i.e., the text surrounding an image on a web page). Nonlearning materials that provide general information to students/users (e.g., administration and alumni web pages) are as important as learning images, except that they do not directly affect the achievements of visually impaired student/users in courses.

Figure 5: Main considerations when creating accurate descriptive text for an image (W3C, 2018).

Image accessibility for visually impaired users necessitates accurate descriptive text that aligns with the images' purpose and complexity (Connor, 2012; W3C, 2018; U.S. Department of Justice, 2016). For this reason, we formulated fundamental rules based on HTML5 attributes and element features as well as WCAG 2.1 and Section 508 standards that guide the evaluation of images embedded in educational Web-based systems. These rules are as follows:

- If an image is complex, then a long descriptive text (or in-text explanation) is required.
- If a descriptive text (or in-text explanation) is long, then the minimum number of characters required is >100 characters (W3C, 2018).
- If a long descriptive text (or in-text explanation) is used, then the accuracy of the description must be ensured.
- If an image is simple, then a short descriptive text is required.
- If a description is short, then the minimum number of characters required is ≤100 characters (W3C, 2018).
- If a short description is used, then the accuracy of the description must be ensured.
- If an image is decorative, then a null attribute can be used.

The rules above (W3C, 2018, 2018; U.S. Department of Justice, 2016) serve as the basic requirements for ensuring that any image is accessible to visually impaired users. Images that are intended to deliver learning content must also have accurate, meaningful, and high-quality text descriptions that are based on course outlines, resources, and strategies.

There are important considerations when evaluating the meaningfulness of descriptive text for an image:

- The descriptive text must describe an image in the form of complete sentences with accurate language, rather than unconnected words (Wu, Wieland, Farivar, & Schiller, 2017).
- It cannot contain acronyms or symbols without definitions (W3C, 2018).
- It must describe image features in the text similarly to human visual descriptions (Vedantam, Lawrence Zitnick, & Parikh, 2015).
- It must describe at least three main layers of statistical diagrams: a top-level summary, the major component layers, and single component explorations (Fitzpatrick et al., 2017).
- It must highlight most of the critical image factors: compositional, semantic, and context factors (Berg et al., 2012).
- It must describe all hierarchical chart components, cascading down from the top to the other components of the chart (W3C, 2018).

Evaluations by Human Experts and Automated Tools

The WCAG 2.1 guidelines (W3C, 2018) were created under the assumption that developers perform expert evaluations in the process of complying with the requirements of accessibility checkpoints. Consequently, the evaluation and accuracy of developed accessible web pages are directly associated with a developer's level of experience. Understanding known and potential accessibility problems is expected to enable developers to create Web-based systems that are characterised by enhanced accessibility and data quality. Bailey, Pearson, and Gkatzidou (2014) compared the reliability of accessibility evaluations carried out by novices versus experts. The authors found that expert evaluations were 76% reliable, whereas novice assessments were 65% reliable. The study partially supports the importance of expert evaluations in resolving the shortcomings of AETs. Expertise is accorded high priority in accessibility evaluations; it is paramount to the successful verification and application of WCAG-based techniques because the expert involvement ensures thorough knowledge of accessibility issues (Yesilada, Brajnik, & Harper, 2009). Nonetheless, an expert evaluation may be inaccurate or miss accessibility problems in web page analysis and thereby cause ambiguity in human evaluation (Brajnik, Yesilada, & Harper, 2010). It should ,therefore, be supported by AETs to reduce the possibility of inaccuracies and lessen the time and effort involved in the evaluation. The use of AETs can be carried out as a second stage of the assessment.

In this study, we used the AChecker (AChecker Adaptive Technology Resource Centre, 2017) automated evaluation tool for many reasons. Firstly, we can extract the evaluation outcome as a PDF or CSV file to add to the research data as a reference. Also, we can check against many guidelines, such as WCAG 2, Section 508, BITV 1.0, and the Stanca Act. AChecker categorises the problems as known, likely, and potential problems. Finally, we can easily go to the checkpoints and the HTML line code that relate to image accessibility problems. In this study, we used AChecker against WCAG 2.0 standard level AAA to test all of the web pages that contained the evaluated images and recorded the problems that were found. Also, we used AChecker as the second stage after human evaluation to validate the accuracy of the human decision and find the causes of any dissimilarities between the two methods. AChecker might provide false positive or false negative outcomes. However, this issue does not impact our study because human evaluation was the main evaluation method used on all of the images.

In image accessibility evaluations conducted by a human expert, the expert is obligated to ensure that the images and their purposes are fully accessible despite their complexity; all of the rules presented in Section 3.1 apply. The human expert not only examines the availability of descriptive text (or an in-text explanation) but also ensures the text' quality and accuracy required by the image's purpose and complexity. In this study, we evaluated each image on the basis of predetermined accessibility variables (Appendix A).

As shown in Appendix A, a number of known, likely, and potential accessibility problems were extracted using AChecker. These problems demonstrate the accessibility issues encountered on the web pages that contained the evaluated images. Appendix A also provides the HTML5 attributes (alt, longdesc, title, src, class, figure element, area) that are typically used as the bases in assessing image accessibility. The availability and accuracy of text descriptions are intended to be used as references in examining the quality of text descriptions and the number of words in such explanations. Complexity variables can be used to understand the purpose of an image, and the image category can be employed to determine whether an image is a learning or nonlearning image. Descriptive text and the words used in titles are designed to enable an analysis of the descriptive text's quality through measurements of the words' meaningfulness. Because we applied our method to university websites, an important requirement was to determine the web page type and system type and whether the images on the university websites included those from library web pages or, in particular, from LMSs.

Evaluation Process Flowchart

The evaluation process is based on testing and analysing HTML 5 code for image attributes and elements. Figures 6 through 9 illustrate examples of HTML 5 image HTML code.

Figure 6. Example of an alt attribute.

```
<img src="http://www.acu.edu.au/__data/assets/image/0006/1308975/Units_Results_LEO.png"
alt="displays student portal and links to LEO" class="img-responsive">
```

Figure 7. Example of image HTML code without an alt attribute.

```
<img border="0" width="514" height="348" src="experiment_2_2016_files/image006.jpg"
v:shapes="Picture_x0020_52">
```

Figure 8. Example of image HTML code with alt and title attributes.

```
<img src="/sites/schools-engagement.cdu.edu.au/files/images/my_career_match_how_it_works.jpg"
alt="How it Works" title="How it Works" width="633" height="127">
```

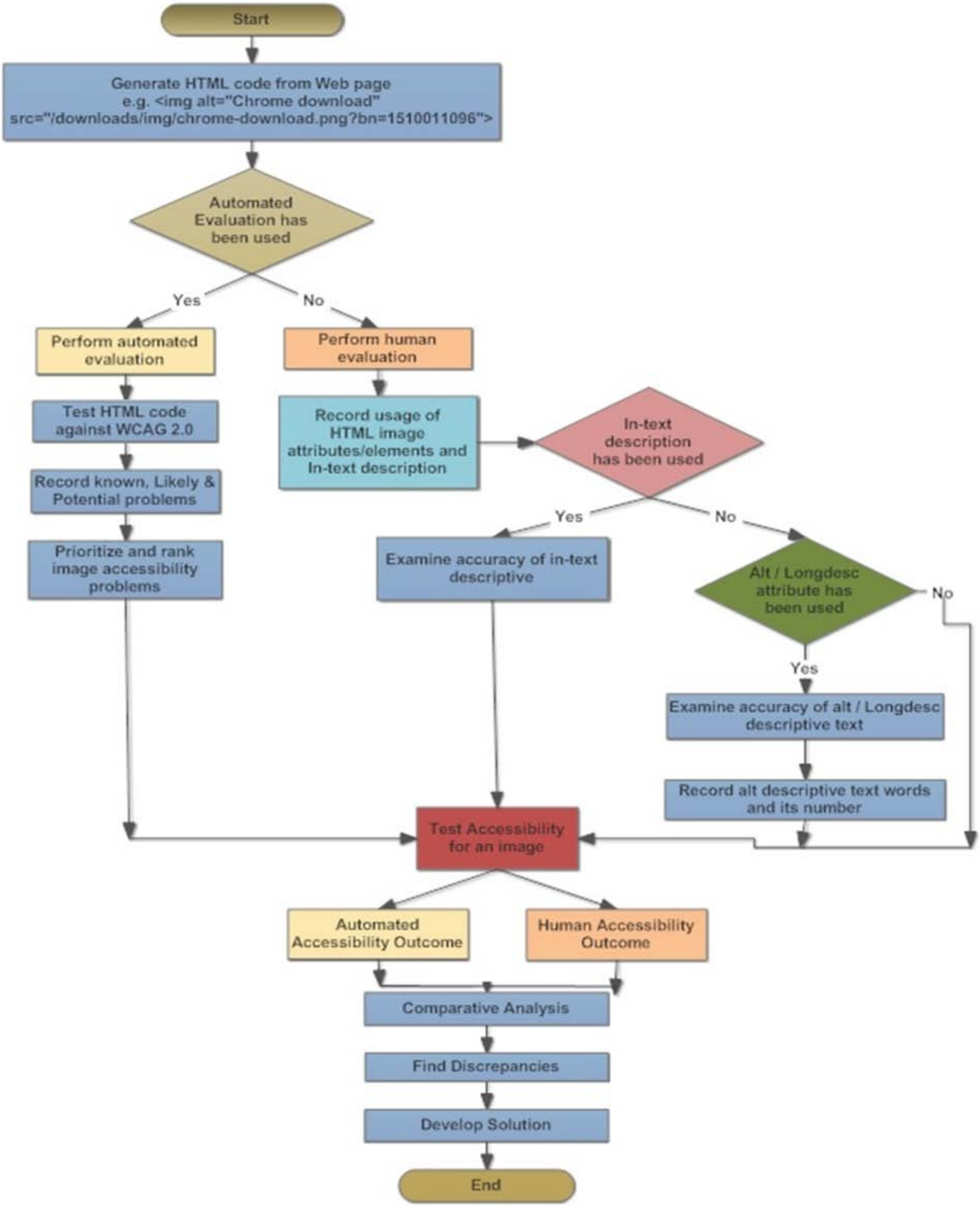
Figure 9. Example of image HTML code with an alt attribute including a NULL value.

```
<img style="WIDTH: 584px; FLOAT: left; HEIGHT: 347px; MARGIN-LEFT: 10px; MARGIN-
RIGHT:10px"alt="NULL" src="/sites/default/files/EBP%20diagram%20Nov%202013.png">
```

Figure 10 provides an overview of the human and AET evaluation process for one image published on one web page. Some essential variables were recorded before the evaluation process, such as the complexity level and image category.

Volume 8, Issue 2. (CC) JACCES, 2018. ISSN: 2013-7087

Figure 10. Human and AET evaluation process for one image.



Findings of the Human Evaluations

After generating the dataset, we analysed the images on the basis of commonly used descriptive statistics. The accessibility problems discussed in this section cannot be identified by AETs. The human evaluation was directed towards the availability of HTML5 attributes and elements, with emphasis on alt and title attributes, in-text descriptions, and the accuracy of the descriptive text.

Availability of HTML5 Image Attributes and Elements

HTML5 image attributes and elements provide accessibility solutions (Connor, 2012). The more adequate the number of attributes and elements used, the clearer the information delivered by a screen reader to visually impaired users (W3C, 2018). As stated earlier, complex images need long descriptions. Our dataset comprised 92 complex images, for which the longdesc attribute was never used. It also contained numerous diagrams, charts, and maps, yet figure and area elements were also disregarded. The src attribute was used for 119 images, and the class attribute was used for 18 images (Figure 11). The title attribute is important because it shows users an image's title before its description. Among the evaluated images, only 15 were given a title attribute. These findings indicated a lack of HTML5 attributes and elements that deliver significant information to visually impaired users and limit the number of accessibility problems encountered in screen readers.

Figure 11. Summary of uses of HTML 5 elements and attributes.

Availability of Descriptive Text (Alt Attribute and In-Text Descriptions)

The alt attribute was used for 99 of the images, suggesting that the developers or publishers were aware of the importance of using it when uploading an image. These images may pass the accessibility tests of AETs and may be considered accessible. In-text descriptions were used for 57 images, and in-text descriptions were used in conjunction with the alt attribute for 46 images. In-text descriptions without the alt attribute were used for 11 images, and the alt attribute without in-text descriptions was used for 53 images. Neither in-text descriptions nor the alt attribute was applied to 10 images (Table 3).

Table 3. Availability of Alt and In-Text Descriptions.

	ALT	NO	YES	Total
In-text description				
Yes		11	46	57
No		10	53	63
Total		21	99	120

As can be seen, most of the evaluated images were accorded an alt attribute and in-text descriptions. Such solutions do not suffer from availability issues. However, the correct usage of image accessibility solutions may influence accessibility but still generate an inaccessible image. To address this problem, we directed the human evaluation not only towards the availability of the alt attribute (as with automated tools) or in-text descriptions but also towards the quality and accuracy of the descriptive text.

The accuracy of the Descriptive Text

The accuracy of the descriptive text reflects its quality. The incorrect use of null values and the inadequacy of word counts influence descriptive text's quality. Among the evaluated images, null values were used 38 times, but the combination of the alt attribute with null values should be used only for decorative images. Given that the developers or publishers of the examined websites used null values for 38 complex or informative images, we can say that these were inaccessible on the basis of W3C definitions and the rules formulated in this study. Table 4 shows the descriptive statistics for the word counts of the descriptive texts written with the alt attribute. The minimum number of words was 1, and the maximum was 316. The mean word count was only 4 words per image. The sum of all of the words in the descriptive texts for all 120 images was 514 words. Only one image had a 316-word descriptive text. Based on W3C definitions and the study's rules, out of the 92 complex images evaluated in this research, only one was accessible.

Table 4. Descriptive Statistics for Word Counts of the Descriptive Texts.

	Minimum	Maximum	Sum	Mean	Std. deviation
Word count	1	316	514	4.28	28.843

A descriptive text with a low word count can be considered accessible if the words used to describe an image are highly meaningful. Correspondingly, we evaluated the meaningfulness of each image's descriptive text with respect to the purpose and complexity. We also analysed all of the texts with the alt attribute, thus generating seven categories of descriptive text. The findings revealed that out of 120 images, only one was fully accessible in terms of meaningfulness with respect to the image's purpose and complexity. Table 5 provides details on the text categories.

Table 5. Descriptive Text Categories.

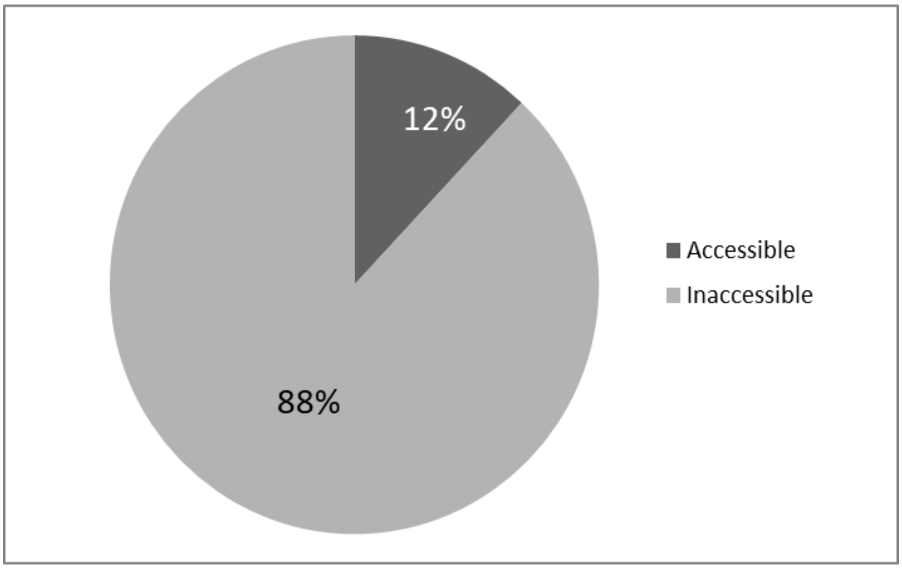
Category	Number of descriptive texts in each category	Example
Complete descriptive text	1	At the first level, we have Federation College and Secondary School. In Federation College at FAST, which . . . diploma.
Incomplete descriptive text	6	Blended learning model with the high-quality resources section highlighted . . .
Meaningless	15	Mapwagga
Link	8	https://www.kfu.edu.sa/ PW2D.jpg
Title	17	A process flow chart
File name	15	Ann16-3.png
Symbol	1	. . .

As previously indicated, the title attribute was used for 15 images. We evaluated each text on the basis of the title attribute usage and found that in eight of the 15 images, the text used for the alt attribute as descriptive text was used for the title attribute as the image's title. We also identified six meaningless title texts, one file name, one link, two null values, and only five complete title texts. Thus, the alt and title attributes were inaccurately used to deliver the images' information.

In-text descriptions also function as accessibility solutions, with long descriptions usually accompanying complex images. We assessed each image and its corresponding in-text description to determine the text's accuracy and completeness. The findings showed that 57 images had in-text descriptions. We found 14 complete in-text descriptions and 43 incomplete ones, indicating that the descriptions insufficiently described the images. The W3C (2017) recommendations indicated that the alt attribute should be employed with in-text descriptions to help visually impaired users understand those descriptions. However, this recommendation was not followed for the in-text descriptions accompanying the 14 images.

To sum up, out of the 120 images evaluated, 15 were accessible, 14 came with in-text descriptions, and one had the alt attribute (Figure 12).

Figure 12. Image accessibility outcomes from human evaluations.



Findings of the Automated Evaluation Tool

The AET revealed 5,641 known accessibility problems in the 120 evaluated web pages; the maximum number of problems on a web page was 520, and the minimum was 0. A total of 564 likely accessibility problems were identified, with the maximum being 97 and the minimum being 0. The evaluation found 52,982 potential accessibility problems, with the maximum being 1,633 and the minimum being 0. AChecker also determined that all of the images suffered from accessibility problems, which all corresponded to violations of the WCAG 2.0 standards, particularly Guideline 1.1 ("Text Alternatives") and Success Criterion 1.1.1, which require the provision of descriptive text for all non-text elements. The top nine image problems identified in the AET evaluation (AChecker) are listed in descending order below:

- Image elements required long descriptions.
- Image elements were missing the alt attribute.
- An alt text was not empty for an image that may have been decorative.
- An alt text did not convey the same information as what the image expressed.
- An embed element was missing a noembed element.
- An image had a title attribute, but the image may have been decorative.
- An image used for an input element was missing an alt text.
- An image used as an anchor was missing a valid alt text.
- An image's alt text was lengthy.

None of the evaluated images passed the AET evaluation. Some images had known problems, some images had likely problems, and others had potential problems. Some evaluators considered an image accessible if it had likely or potential problems only. However, images with these problems should be checked by humans to determine if they are accessible. In this study, we checked all problem types, which resulted in zero accessible images for the AET. There were 61 images that did not have known problems but had likely or potential problems. Some evaluators may have considered these images accessible even though they contained serious accessibility problems. Overall, this finding highlights the importance of considering the involvement of human experts in evaluating, designing evaluation rules, and using advanced evaluation methods, such as data mining.

Discussion

Evaluating image accessibility is an effective step that opens up opportunities to develop practical solutions to ensure equal image access by visually impaired users. Thus, multi-method evaluation of image accessibility provides a vital contribution to achieving favourable results. Human and automated evaluations can work together to assess image accessibility synergistically.

Human evaluation is an essential method for discovering the details of image accessibility problems. Usually, these problems cannot be identified by automated evaluation alone. After recognising whether an image is complex or simple and determining its purpose, the human evaluation process examines all HTML image attributes and elements. In our findings, these attributes and elements saw limited use. Many reasons can limit the use of HTML image attributes and elements. An author's or developer's knowledge regarding accessibility can affect the quality of the accessible image they create (Moreno, Castillo, Williams & Menez, 2015). Moreover, regulating Web accessibility is not an internationally recognised practice (Cleary & Maurer, 2017). Most organisations do not apply accessibility standards, and 75% of them do not enforce accessibility evaluations (Moreno et al., 2015). Organisations use various authoring or content tools (W3C, 2018). A noticeable shortcoming of most of these tools is that they do not facilitate the creation of accessible content and therefore do not provide intelligent features. Innovations like generating automated alternative text, text to speech (TTS), and speech to text (STT) may complete the vision of an adaptive and accessible Web-based system for all users.

Automated evaluation tools provide a list of all image barriers on a webpage. However, when comparing human and automated evaluation, we found that the evaluation outcomes of automated tools might negatively impact Web accessibility in two situations. Firstly, there is a high chance that a web page will be judged as having zero problems even with an inaccessible image uploaded on it. Secondly, there is a high chance that the opposite will occur, when an image is considered inaccessible even when it provides a quality in-text description. This situation leads to no accessible images being found by automated evaluation. In this study, the human evaluation results showed that 15 images were accessible, and their descriptive texts considered the images' complexity and purpose.

Efficiently applying evaluations of HTML image attributes and elements will improve accessibility outcomes. A set of regulations or rules imposed by an organisation may be effective in generating developer and author awareness, resulting in practical improvements. It is vital that accessibility is considered part of the development of any Web-based system. As part of that consideration, adopting a multi-method evaluation process will improve the detection of image accessibility problems.

Conclusion and Future Work

The evaluation method developed in this study is applicable not only to university websites but also to other institutions using Web-based systems and organisations for which effective interaction between online platforms and disabled users is essential. The findings underscored the necessity of probing into images' accessibility and ensuring that system modifications positively affect individual users. The human and automated evaluations trialled here provided insight into how image accessibility problems can be identified and understood. Human evaluation is essential, particularly in cases in which the quality of descriptive text needs to be tested.

The study methods and findings revealed a number of potentially productive directions for future work. We intend to evaluate image accessibility through data mining, with a particular focus on the use of classification algorithms, to compare the results of human, AET, and mining-based evaluations. We plan to illuminate the outcomes of each method and determine how and why such outcomes vary across approaches. The rules developed in this study will be used in the data mining to classify each image case as accessible or inaccessible.

One-size-fits-all user interfaces and content can be a source of inequity, but methodical differentiation diminishes the likelihood that users with disabilities will benefit from image content (Gajos, 2014). The accessibility of images published on Web-based systems, especially university websites, should thus be given more attention. The availability and accuracy of descriptive texts and their compatibility with the image's complexity and purpose should be ensured for all images because the presence of high-quality descriptive texts improves image accessibility (W3C, 2018). The findings derived from this work showed evidence of a lack of awareness by developers/authors, thus negatively affecting image accessibility on the evaluated sites. Apart from increasing developer/author awareness, adaptive approaches can be used to optimise accessibility to users with different disabilities. Employing adaptive content that is tailored to the abilities and characteristics of visually impaired users enhances accessibility when these individuals interact with a Web-based system (Stephanidis et al., 1998). A proper application of this principle is reflected in Wu et al.'s (2017) use of automatic alt-text (AAT) in Facebook. AAT is a technique that applies vision technologies to recognise faces, objects, and themes in images and thereby generates image alt-texts for screen reader users. AAT demonstrates that artificial intelligence techniques can be used to enhance the online experiences of visually impaired users (Wu et al., 2017).

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Appendices

Appendix A

Table of Research Variables From the Dataset.

Variables	Values
Webpage type	{1, Home page} {2, Course content} {3, Administration} {4, Online help} . . .
System type	{1, University website} {2, LMS}
Image category	{1, Learning} {2, Non-learning}
Complexity level	{1, Complex} {2, Simple}
Alt-text availability	{1, Yes} {2, No}
Alt text accuracy	{1, High} {2, Low}
In-text availability	{1, Yes} {2, No}
In-text accuracy	{1, High} {2, Low}
Known problems	Total number of known problems
Likely problems	Total number of likely problems
Potential problems	Total number of potential problems
Alt	{1, Yes} {2, No}
Alt text	Descriptive text (words)
Number of words in text	Total number of words
Longdesc	{1, Yes} {2, No}
Title	{1, Yes} {2, No}

Variables	Values
Title text	Title text (words)
Src	{1, Yes} {2, No}
Class	{1, Yes} {2, No}
Figure element	{1, Yes} {2, No}
Area	{1, Yes} {2, No}
Accessibility outcome	{1,Accessible} {2,Inaccessible}

GEOGRAPHIC INFORMATION SYSTEMS IN THE CONTEXT OF DISABILITIES

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Received: 2018-03-27 | Accepted: 2018-11-06 | Published: 2018-11-30

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

Volume 8, Issue 2. (CC) JACCES, 2018. ISSN: 2013-7087

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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