Douglas Cunningham, Petra Hofstedt, Klaus Meer, Ingo Schmitt (Hrsg.): INFORMATIK 2015
Lecture Notes in Informatics (LNI), Gesellschaft für Informatik, Bonn 2015

Development towards a generally applicable process to inspect and verify accessibility of web pages

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Abstract: Due to the onward process of inclusion of people with disabilities, a growing number of handicapped people start using the internet as a source of information. The World Wide Web Consortium (W3C) group, whose task it is to focus on web standards to make the web more accessible, named Web Accessibility Initiative (WAI), built a set of guidelines to achieve this objective. The Web Content Accessibility Guidelines (WCAG) 2.0[2], which is the current version of the ruleset, do unfortunately not provide enough techniques to cover most peoples' needs. Neither does it supply a practical method to test the compliance of its specifications. This paper provides a critical view on all guidelines of the WCAG, expands them to include more kinds of disabilities and recapitulates the revised rules with a set of practically applicable approaches to enable testing, using freeware or open source tools. The Examination of the WCAG is accomplished by investigating selected rules in terms of psychology as well as medical and educational science. Furthermore, a list of techniques is created, that could lead to an improvement of the quality of website testing results. Recapitulatory, concrete proposals for continuative research are presented.

Keywords: Accessibility, WCAG, Accessible websites

1 Introduction

Inclusion, the process of allowing people with disabilities to participate in normal life, has been an ongoing process for many years. One side-effect of this process is, that a growing number of handicapped people starts using the internet as information source or for activities like online-shopping or partaking in social media.
Unfortunately, the web lost its capabilities concerning cross-device usage, in the course of development towards 'Web 2.0' (def. [O'R06]). The approaches to supply the user with websites providing Software as a Service (SaaS) or Desktop as a Service (DaaS) is often based on heavy usage of client-side scripts, which prevents assistive software from being able to gather all information on a web page.
In 1997, the W3C founded a group to focus on accessible web pages, the WAI. This group released the first version of their Guidelines in 1999, the second one in 2008. The currently valid release WCAG 2.0 was adopted by the International Organization for Standardization (ISO) in 2012 [ISO12b]. The WCAG 2.0 will be referred to as the WCAG below. Notable changes are the switchover from backward to forward compatibility and the new structure of the guidelines themselves.
Unfortunately, the WCAG do not include guidelines to make websites accessible for people with cognitive impediments, like text complexity or readability of text. Neither do they

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[2] The WCAG are published online: [CRCV08]

include any testing methods for their guidelines.
To enable assistive technologies to recognize the semantics of Hypertext Markup Language (HTML) elements more precisely, the WAI introduced the Accessible Rich Internet Applications (ARIA) [CC14], which primarily provides a huge list of roles an element can take. The ARIA Standard is a completed W3C Recommendation since March 2014 and thus not fully implemented in current browsers. In fact, the major browsers provide all partial support [Can15].

2 Implementation in Germany

Mindless of the fragmentariness of the WCAG, the German legislative enacted the 'accessible information technology act', *Verordnung zur Schaffung barrierefreier Informationstechnik nach dem Behindertengleichstellungsgesetz (BITV)*, to regulate the accessible presentation of websites of public institutions. Initiated by the *DIAS GmbH* (`http://www.dias.de/`), the Project Barrierefrei informieren und kommunizieren (BIK) provides a testing framework to validate the compliance of websites with the BITV. The testing procedures are mostly rather complicated to perform and focus on the BITV very strictly.
After all the derival of guidelines, the BIK-test has lost the focus to test accessibility for people with disabilities in favor to comply with the applicable law.

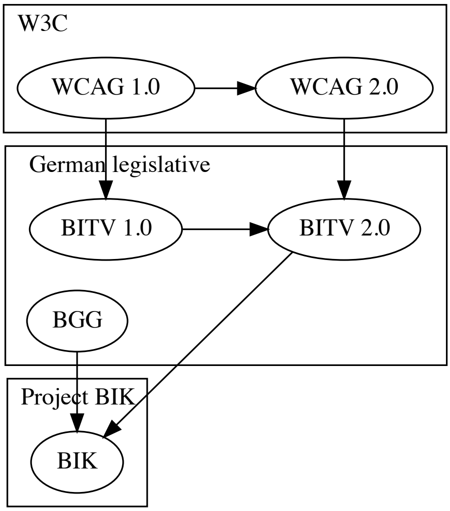

Fig. 1: Development of the BIK-test.

3 Contradictions and obsolete guidelines

In addition to the unappreciated groups of handicapped people, some of the guidelines rely on obsolete perceptions. Other rules do not scrutinize the reasons in a penetrative manner, so that the levels of conformance do not have a realistic basis. The most demonstrative examples are examined below in a critical way.

3.1 Flashes

In *WCAG 2.3: Seizures*, the *Three Flashes or Below Threshold* is introduced. This limitation is based on data by *Harding, G.F.A* from 1975, but used in the work of *Harding*, that was used to create the WCAG (cf. [BEG$^+$02]). Numerous papers written by other authors before 1975 reference data collected by *Gibbs* in 1935 (cf. [GDL35]), e.g. [Qua39, Gib49, LHF59].
It is not sure, that these values are still valid, since the influence of media to the people and society has boomed since then. As measured by the media-usage of 6-12 year olds[3], people use more digital media today and start using it at younger age. The cerebral habituation has never been investigated, so it is not clear, if a brain, that is photosensitive may acclimatize to flickering over the years. In 1975, when the data was collected, computer monitors were all based on the Cathode Ray Tube (CRT) technology. *"Flat panel displays"* were introduced in the 90's (cf. [Bou95]) and one of their advantages is a non-flickering image, which changes the way the photoreceptors are stimulated. This means, the same type of flickering may cause different impressions on Thin-film transistor (TFT) than on CRT displays, as the frequency of the flickering may also cause interferences with the flickering of the CRT and influence the experienced frequency. TFT-monitors use other techniques and therefore refresh rates between 60 and 75 Hz as confirmed by *Grundig*.
But the flashing frequency is not the only epileptic trigger. Epilepsy patients often show signs of an oncoming seizure hours before [LE02]. In this state, the patient is much more sensible to any kind of stimuli, so they react to flickering on lower frequency. Additionally, the seizure risk is dependent on other values, like the flashing percentage of the visual field and the relative luminance of the flash [CRCV08]. In summary, one needs to question if the current threshold is still a realistic value. As flashes can be counted as animations[4], the usage of flashes contradict the *WCAG 2.2.2: Pause, Stop, Hide*, as the user must be able to turn animations off. This topic will be discussed in detail later.
Another kind of flickering not discussed in the WCAG is the usage of multicolor background images with high contrast. When the page needs to be scrolled, the contrast changes with the moved image. When using a checkerboard pattern with fixed field sizes, the scrolling in different speeds leads to a different frequency of a full change in contrast. The frequency is calculated with the scrolling speed v ($\frac{\mathrm{px}}{\mathrm{s}}$)[5] and the grid size l (px) as in (1):

$$f = \frac{v}{2 \cdot l} (\mathrm{Hz}) \tag{1}$$

The following shows some sample calculations derived from data using a screen with a resolution of 1920 by 1080 pixels. To use scrolling speed, that is near realistic, *Facebook* (`http://www.facebook.com`) was chosen, as a highly frequented page, where scrolling

[3] *KIM-Studie* 2014: [FPR14]
[4] A flash is a "rapidly changing image sequence" [CRCV08, #general-thresholddef].
[5] px: Definition found at [JEL13, #absolute-lengths]

is essential. A scrolling speed of approximately 800 $\frac{\text{px}}{\text{s}}$ was found. As shown in [HJ94, p. 87], 96% of photosensitive people react to a frequency span between 15 and 20 Hz. Depending on the personal scrolling speed, high-contrast patterns can produce flickering in very critical frequencies, as shown examplarily in figure 2.

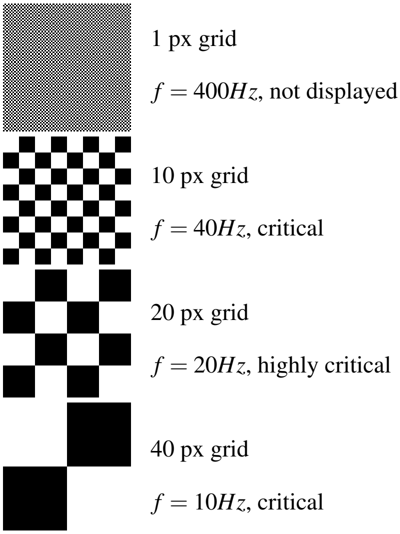

Fig. 2: Usage of a checkerboard of different grid sizes at a scrolling speed of 800 $\frac{\text{px}}{\text{s}}$.

3.2 Cognitive Load Theory

Before any information can partake in the cognition process, the human brain must perform complex perceptive and filtering tasks. This process is illustrated by the Model Human Processor (MHP), "an engineering model of human performance" [Gei06, p. 30ff]. The stimuli encounter the sensory organs and are converted into nerval impulses. These impulses are processed by the perceptual processor and buffered into their respective visual or auditory image store in the working memory. Only now is the cognition process performed by the cognitive processor. The amount of data that needs to be evaluated to participate in this process is a significant factor of the duration until information is processed.

The *Load theory* by Lavie [LHdFV04] claims that every person owns a limited perceptual buffer. This means that any cognition process uses a more or less vast amount of the available capacity, depending on the complexity of the task. When the provided information contains additional stimuli carrying other information, the perception will need more time. The cognition of information is also harder for the person [Gol15, p. 142f].

People with cognitive disorders feature shortcomings in one or more parts of the cognitive system [Pfl91, p. 166]. This leads to either a smaller cognitive capacity or a higher load. On both sides, there is a need to provide simple and clear structured information in order to allow these people to perceive it.

The Guidelines *WCAG 1.4.2 Audio Control* and *WCAG 2.2.2 Pause, Stop, Hide* deal with time based media, like audio, video and animations. The guidelines suggest, that for automatically started content of these types, a mechanism to disable it needs to be provided. The problem is, that when distractive content is started automatically, searching the mechanism to turn it off is a cognitive challenge, that people that depend on turning it off may not be able to find. This means, that these rules do not meet their aims since they should rather require that content must not be distractive at all.

3.3 Wrong interpretation

Many websites that claim to be accessible provide a method to enlarge the content of the website using buttons. This seems to be a misinterpretation of *WCAG 1.4.4 Resize text* and *WCAG 1.4.8 Visual presentation; Nr. 5*, which instructs that websites "can be resized without assistive technology up to 200 percent without loss of content or functionality." Every major browser[6] supports this technique by default, so there is no need to provide additional methods to zoom in the page. Rather important is to have the layout of the page enabled to be zoomed without changing the usability or the contents.
The derivate towards the BITV lead to other misinterpretations. After BITV 2.0 §3(2), only an overview of the website needs to be fully accessible using the German Sign Language (gsg) [ISO10] and *Leichte Sprache* (`http://www.leichtesprache.org/`), an approach to create rules to provide a maximum understandable language. This means, the legal requirements can be complied without having to ensure the accessibility of the vast part of the provided information.

4 Shortcomings in the WCAG

4.1 Cognitive and cerebral handicaps

Since the WCAG focuses primarily on the semantics and visual scopes of websites, the understandability of content is not respected in the same manner. This might be due to the complex calculations of text readability, if it is possible to define it at all. *WCAG 3.1.5 Reading Level* proposes, that all texts should be readable for any person with a "lower secondary education level" as described by the *UNESCO* [UNE97]. This might often be difficult to define by website editors and does cost high effort. So, a possible approach towards automatization of determination of text reading ease must be found.
Although multiple measuring techniques for text complexity exist, most of these were created with the target to define the minimal level of education the reader needs to have achieved to understand the text, like the *Flesch-Reading-Ease* [Bau03, p. 35f], [Fle48] or the *Gunning-Fog-Index* [Gun68]. In his master thesis (cf. [Ott09]), Niels Ott suggests techniques to describe text complexity using Lexical Frequency Profiles (LFPs), which were introduced by Laufer and Nation [LN95]. Ott further describes a process, to allow

[6] Regarding *Google Chrome*, *Microsoft Internet Explorer*, *Mozilla Firefox*, *Apple Safari* and *Opera* according to [Sta15]

automated computation of LFPs. This could be an approach to retrieve readability data from web page contents, and to define thresholds for cognitive disabled people.
To implement this kind of guideline, it must be determined, that not only presented text must follow the rules, but also auxiliary ones, like alternative descriptions for images and other objects or definitions for expressions.

4.2 Readability, legibility and comprehensibility

Most of the information on the internet is in text form. In *WCAG 1.4.8 Visual presentation*, some guidelines are presented to improve legibility and comprehensibility. Since readability refers to the perceptibility of single characters and legibility to the perceptibility of an amount of coherent characters [DIN98], it is necessary to have text readable in order for it to be legible. In DIN 1450 [DIN13], characteristics of fonts and text presentation are defined. The WCAG provide rules for text design concerning contrast (*WCAG 1.4.6 Contrast (Enhanced)*), line spacing, alignment and scaling, as well as text authoring rules like maximum characters per line. Unfortunately, there is no rule for minimal size of continuous text, since there are several standards defined for minimum font size.
The German project *Leichte Sprache* has created a set of rules to make text understandable to a maximum number of people by defining rules for readability, legibility and comprehensibility [Spr13]. Their suggested minimum font size is 14 pt, which equals $1^1/_8$ em.
The standard minimum font size according to ISO 9241-302:2008 [ISO12a] is 16 arc minutes, giving a font size of 1.1 mm or 4 px.
In order to create websites, that change their layout appropriate for any end device, the Responsive Web Design (RWD) approach recommends to use a minimum font size of 1 em [Ert13, p. 133ff].
Since text can be resized by the browser, there is no need to provide a very huge font. But in order to implement a web site that is state of the art, a font size of 1 em should at least be used.
Leichte Spache provides a very good set of rules, that could be adopted into a WCAG successor, like avoiding fonts with serifs or italic displayed text. Also, the authoring rules provide outstanding approaches to achieve easily understandable text.

4.3 Partitioning classes of accessibility

The WCAG approach to classify the accessibility of websites groups the compliance with the guidelines in three conformance levels:

A Minimum
AA Mediocre
AAA Maximum

To achieve any of the conformance levels it is necessary, that, according to [CRCV08], “the Web page satisfies all the [...] Success Criteria, or a conforming alternate version is

provided." This means, there is no distinction between guidelines, that provide users with a better usage of assistive devices and the direct accessibility, like easy reading or definitions of technical expressions. A better approach would be, to partition the two classes and evaluate them separately. A short investigation whether the guidelines affect the information retrieval for people or machines yields, that 25 of them focus on human interaction, 13 on semantic readability for assistive technologies and 22 on both. This means, a website could achieve an AA-Level without being usable for people with cognitive disabilities just because of semantically correct content.
To allow a distinction if a website is good for assistive technologies or for human cognition, there is a need to implement two different levels of accessibility achieved. This would allow a more explicit definition of a page's accessibility.

5 Proposed changes to the WCAG

5.1 Flashes

As already pointed out, the flash frequency threshold needs to be reviewed. As an addition to the *WCAG 2.3: Seizures*, the need for a new success criteria is revealed, that demands the investigation of images, that fill "25% of any 10 degree visual field on the screen" for the way they change contrast when scrolled at a distinct scrolling speed. The biggest problem is that the scrolling speed is not only different for every person, but also for every website. While websites with a lot of text will be scrolled slower in order to follow the text, pages with image content are scrolled way faster to "jump" from one image to the next one. To achieve to measure the effective change of contrast, the contrast changing frequency on TFTs needs to be investigated.
In addition, a study must verify that any photosensitive person who takes part is not in "aura" status (cf. [SLN+95]) in the moment of testing. This would lead to falsified results.

5.2 Automatic determination of text complexity

Testing texts on websites manually would enormously raise the testing effort. So it is mandatory to use an automated testing of texts. A good entry point is the combination of different text-complexity-measuring systems described by *Niels Ott* [Ott09]. When a system based on this thesis can be realized, it can provide a very distinct value to describe the reading ease. If it should turn out that it is not possible to create an automated test, the WCAG still need to specify a more concrete value measured with one specified method for the determination of understandability.

6 Tools proposed for web page testing

To allow anyone to test websites for accessibility, the whole process must depend on freeware or open source tools that can be run on any major operation system. The suggested

approach is using an open source browser and a maximum number of browser plug-ins, that support the testing procedure.
The selection of the browser is done by comparing the HTML5-compliance of current browsers, as *WCAG 4.1 Compatible* instructs to "Maximize compatibility with current and future user agents". The website `https://html5test.com/` provides a testing framework to show the HTML5-compliance of browsers. This page provides test results for the most current browsers with their distinct results. The results provided by *html5test* have been compared with the ones we determined ourselves in table 1. Since neither *Microsoft Internet Explorer* nor *Apple Safari* provide native Linux versions, the browsers can not be used for testing on Linux systems and are therefore discouraged to use for website testing.

	Provided result	Determined
Google Chrome	39; 501	42; 523[7]
Opera	26; 497	29; 519
Mozilla Firefox	35; 449	37; 449
Apple Safari	8.0; 396	8.0.4; 396
Microsoft Internet Explorer	11; 336 Preview[8]; 343	N/A

Tab. 1: Comparison of HTML5-compliance of mainstream browsers by version and score (Max. 555); tested on *Mac OS X 10.10.2*.

This means, there might be minor differences between the presentation in these browsers, but when development tracks the compliance with standards, testing with the best complying browser means testing for forward compatibility.
The results for Opera and Chrome respectively Chromium, its open source fork, are rather close, as both browsers could be used for website testing. Both browsers are based on *WebKit*, an open source HTML rendering engine. Since *Google Chrome* is the most used browser focus is set on it.
The first add-on, which allows several tests is *WebDeveloper* (`http://chrispederick.com/work/web-developer/`). This add-on provides a huge toolkit for website examination and allows to verify a vast part of the WCAG, mostly the semantic parts.
To check the contrasts of anything displayed on the website, a very handy tool comes with the *Color Contrast Analyzer* (`http://accessibility.oit.ncsu.edu/tools/color-contrast-chrome/`). This add-on scans the page for any visible content, that provides at least a contrast level of 3:1, 4.5:1 and 7:1 for all contrast thresholds mentioned in the WCAG.
Another test for visual impaired people is testing for types of Color Vision Deficiency (CVD). A very good add-on for *Google Chrome* is provided through *Spectrum* (`http://lvivski.com/spectrum/`), a simple tool, that changes the colors of any website according to what they look when perceived with a distinct CVD.
To perform markup analysis, a great assistance is provided by *Google Chrome* itself by providing the *Chrome Developer Tools* [Goo15], that allow live manipulation of the Document Object Model (DOM) and Cascading Stylesheets (CSS), as well as tools to measure loading times and other features. Finding HTML elements, that do not comply with standards is easily possible, as well as finding out, how the browser processes corrupt HTML. Checking any page for tags and attributes is much simpler than searching in plain source

code.
Since most guidelines must be evaluated by a human, there may exist more add-ons to support the human-driven testing procedure but the operation purpose depends on the personal knowledge of the testing person.

6.1 Required Hardware

To perform a realistic test on "flashes", the contrast change by time, additional hardware is needed. Since there is no proposed testing procedure in the WCAG or the BIK-test, a possibility to perform correct tests had to be discovered.
The company *PCO* (`http://www.pco.de/`), developer of "highend scientific camera systems", suggests testing with a specifically programmed camera. They suggest testing with a low resolution camera with high color depth and a frame rate with at least 120 frames per second, doubling the TFTs refresh rate. Using their Application Programming Interface (API), an automatic determination of contrast changes in any visual field on the screen could be performed and alerted.
Though it is contradictory to develop a device, that might not be affordable for every person that wants to check a website, it is still possible to estimate the compliance with the thresholds, like the BIK-test suggests [DIA11], but allows a more exact examination in case of further investigation.

7 Conclusion and Outlook

Since the WCAG are still very fragmentary, and a lot of guidelines can not be tested using currently available tools, a lot of research needs still to be done to allow an objective view on accessibility of web pages. There is also a need to change the regrettable loss of focus on people that feature other types of handicaps than visual impairments. The approach towards the creation of a global set of guidelines is done rather good by the WCAG, but the first version had more practical definitions, especially the focus on HTML features. The WCAG 2.0 guidelines are held very rough and leave therefore space for interpretation that may lead to both good and bad results. The German implementation exposes even more gaps. Starting from estimation of compliance instead of providing specific tools, to testing of obsolete techniques that should not be used anyway.
The next steps towards better testing of websites that can be named from the conclusions of this paper are surely not the only fields where research is needed. Nevertheless, some suggestions to achieve the required techniques to fulfill the described shortcomings are made below.

7.1 Automatic semantics testing

Some testing steps are easier to achieve with automatic processing than manually by an untrained person. Since most semantic rules concern nesting and attributes of HTML elements, a vast part of the WCAG can be tested by analyzing the HTML document. Fortunately, there are several techniques to dissect HTML documents, like the DOM [HRC$^+$04]. This allows to perform analysis on markup concerning e.g. correct markup usage or avoidance of obsolete HTML elements. In addition, the basic tests for syntax validity can be verified using the W3C validator (`http://validator.w3.org/`). Most tests must however be done manually at the moment, since they require mental work and therefore need to be rated by a human.

7.2 Automatic front-end testing

Since verifications of questions like "does the alternative text for this image make sense?" need to be answered by a person, automatization of the testing is hard to achieve. For most parts add-ons can help answering, but the determination of results must be done by a human. But automatization can be achieved step by step. An approach to enable automatic testing for not only the static parts of a website, but also dynamic content, could be achieved by using front-end testing tools. One developer of *Mozilla* created a list of front-end testing tools for websites [Dub12]. The steps preformed by the testing tool are defined in configuration scripts, that advise the framework what to do. Some tools even simulate mouse interaction.
When combined with a system that acts like a web crawler for the one page to test, this system could dynamically create the configuration for the testing framework and create a flow to check every page. If this can be achieved, the particular content tests can be executed automatically for every page or after each content-changing event. As the development of techniques for miscellaneous types of content progresses, testing may be integrated into this workflow.
With this approach, a maximum automatization of the entire testing procedure can be achieved over time.

7.3 Development of a text measuring engine

The most complex step, but also that one, that could maximize the amount of test automatization is the development of a system, that can perceive and evaluate text and afterwards rate its comprehensibility. This means immense effort to achieve, since the system must contain accumulated knowledge about the grammatics and a huge dictionary of every single language aimed to work with. This could force the usage of some kind of distributed database that is aware of correlations between the words. This knowledge of relations is a characteristic feature of graph databases [RWE13, p. 4], and thus an approach to create a linguistic processor on top of a graph database system seems to be very very promising.
In their paper [MP14], *Klaus Miesenberger* and *Andrea Petz* suggest some approaches to achieve a kind of toolkit, that can be used to verify easy readability using "linguistics and language technologies". They suggest, that the whole process of content creation should be accompanied by tools to analyze, check and translate text to simpler language. This approach could avoid, that very complex texts don't even go online if tools are integrated into the authoring workflow.

Acknowledgment

This work was supported by *Ferdinand Haimerl* with continuous professional input and frequent feedback.

List of acronyms

API Application Programming Interface

ARIA Accessible Rich Internet Applications

BIK Barrierefrei informieren und kommunizieren

BITV Verordnung zur Schaffung barrierefreier Informationstechnik nach dem Behindertengleichstellungsgesetz

CRT Cathode Ray Tube

CSS Cascading Stylesheets

CVD Color Vision Deficiency

DaaS Desktop as a Service

DOM Document Object Model

gsg German Sign Language

HTML Hypertext Markup Language

ISO International Organization for Standardization

LFP Lexical Frequency Profile

MHP Model Human Processor

RWD Responsive Web Design

SaaS Software as a Service

TFT Thin-film transistor

W3C World Wide Web Consortium

WAI Web Accessibility Initiative

WCAG Web Content Accessibility Guidelines

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