Artificial Intelligence for Web Accessibility – Conformance Evaluation as a Way Forward?

Artificial Intelligence (AI) for Web Accessibility: Is Conformance Evaluation a Way Forward?

Shadi Abou-Zahra
World Wide Web Consortium (W3C)
2004, Route des Lucioles BP93
06902, Sophia-Antipolis, France
+33 4 92 38 50 10
shadi@w3.org

Judy Brewer
World Wide Web Consortium (W3C)
32 Vassar Street, G 515
02139, Cambridge, USA
+1 617 253 2613
jbrewer@w3.org

Michael Cooper
World Wide Web Consortium (W3C)
32 Vassar Street, G 515
02139, Cambridge, USA
+1 617 253 2613
cooper@w3.org

ABSTRACT
The term "artificial intelligence" is a buzzword today and is heavily used to market products, services, research, conferences, and more. It is scientifically disputed which types of products and services do actually qualify as "artificial intelligence" versus simply advanced computer technologies mimicking aspects of natural intelligence.

Yet it is undisputed that, despite often inflationary use of the term, there are mainstream products and services today that for decades were only thought to be science fiction. They range from industrial automation, to self-driving cars, robotics, and consumer electronics for smart homes, workspaces, education, and many more contexts.

Several technological advances enable what is commonly referred to as "artificial intelligence". It includes connected computers and the Internet of Things (IoT), open and big data, low cost computing and storage, and many more. Yet regardless of the definition of the term artificial intelligence, technological advancements in this area provide immense potential, especially for people with disabilities.

In this paper we explore some of these potential in the context of web accessibility. We review some existing products and services, and their support for web accessibility. We propose accessibility conformance evaluation as one potential way forward, to accelerate the uptake of artificial intelligence, to improve web accessibility.

CCS Concepts
•Computing methodologies~Artificial intelligence •General and reference~Computing standards, RFCs and guidelines •Information systems~World Wide Web •*Security and privacy* •*Networks~Network services* •Social and professional topics~Management of computing and information systems

Keywords
Artificial Intelligence; Machine Learning; Assistive Technology; Accessibility for People with Disabilities; Web Standards; Testing; Conformance; Verification; World Wide Web.

W4A '18, April 23-25, 2018, Lyon, France

ACM ISBN 978-1-4503-5651-0/18/04…$15.00
https:// doi.org/10.1145/3192714.3192834

1. INTRODUCTION
The concept of artificial intelligence dates back to the early days of computer science in the 1950s [3]. During this period, there were several waves of successes and setbacks, and an elaboration of the different disciplines involved. Today we seem to be within another phase of popularity and progress with increasing applications being introduced, including for industrial development, healthcare, and consumer electronics. For example, IBM's Watson uses "artificial intelligence", and attempted to be better at diagnosing cancer than human doctors [18]. Also Alexa by Amazon, Cortana by Microsoft, Google Home Assistant by Google, and Siri by Apple use aspects of artificial intelligence to deliver higher quality services.

It is for debate when applications and services can be considered as intelligent rather than merely mimicking intelligent behavior [16]. The sheer advances in computing power available at relatively low pricing and large-scale open datasets available through the internet facilitate pattern recognition and categorization to a degree thought for decades only to be possible by intelligent agents. Yet besides this philosophical debate on the scope and boundaries of artificial intelligence, recent advances in machine learning, natural language processing, computer vision, and many more are undisputed.

These technological advances provide immense opportunities for the inclusion of people with disabilities throughout all aspects of daily life. For example, smart assistive technologies such as smart wheelchairs for people with reduced mobility [9] and smart canes for blind people [15] use these advances in artificial intelligence to provide improved products and services. Yet artificial intelligence also offers many opportunities beyond these specialized solutions. For example, advances in speech technology allow for multi-modal computer interfaces that can be used more intuitively by a broader set of end-users, including by people with disabilities. In fact, there is a propagation of assistive technologies in mainstream products.

In this paper we focus on the application of artificial intelligence to improve accessibility of the world wide web. That is, we focus on making web-based interfaces accessible for people with disabilities rather than on web-enabled products and services. In particular, the field of assistive robotics [8] is out of scope of this communication paper. We also use the colloquial meaning for the term "artificial intelligence" rather than a particular formal definition. Specifically, we refer to the growing number of applications that use artificial intelligence techniques, such as machine learning and predictive analytics, to provide more qualitative image and voice recognition, natural language processing, and emotional and cognitive analysis.

2. AI FOR WEB ACCESSIBILITY TODAY

Many uses of artificial intelligence for accessibility seem to focus on products and services to support people with disabilities in their interaction with the physical environment [13]. Examples include using smart glasses with face recognition capability to help blind people identify other people as well as their facial expressions [1]. Yet artificial intelligence can also support people with disabilities in their interaction with information technology. Applications such as Facebook's "automatic alt-text" feature [23] support people with visual disabilities to engage more equally on the world's largest social media platforms. Yet this is only the beginning; artificial intelligence promises to be a game changer in digital accessibility.

2.1 AI-Based Image Recognition

Facebook, Google, and Microsoft, among others, introduced image recognition functionality that can be used to support accessibility. For example, Microsoft's CaptionBot compares uploaded images with millions of related images indexed by the Bing search engine, to provide automatically generated descriptions of the images [10]. As the repository of pre-indexed data continually grows, and with the help of machine learning techniques, accuracy of these types of services is rapidly growing. This functionality helps to better index web content, in particular for advertisement in social media context. However, this functionality also allows people using screen readers to better understand the content of images without text alternatives.

2.2 AI-Based Voice Recognition

Already several years before this latest wave of image recognition functionality, Google announced automatic captioning of YouTube videos through voice recognition [6]. In his blog post in 2009, Ken Harrenstien describes the benefits of this functionality for people who are deaf and hard of hearing, in addition to better search engine indexing, which is the primary use-case for Google. Paired with the pre-existing translation functionality from Google, captioning also benefits many more users who are not fluent in the language spoken in the videos. That is, artificial intelligence use for captioning is not only a mainstream tool for accessibility but also for broad inclusion.

2.3 AI-Based Text Processing

Beyond image and voice recognition, there have also been many advances in text processing, which are increasingly built directly in word processing software, such as Microsoft Word. These provide automatic summarization functionality that is based on information extraction and abstraction [17]. Together with other advances in the field of natural language processing, these provide text adaptation solutions for many people with cognitive and learning disabilities. For example, to automatically simplify the text in terms of volume or reading level, to split long passages of text into smaller sections, and to extract key terms from passages and link them to customized glossaries and dictionaries for the particular reader's needs [19].

2.4 AI-Based Affective Computing

Another growing field is affective computing, where the systems recognize the emotional state of their users. An example of this is Microsoft's Emotion API offered as part of the "cognitive services" package [11]. With this, developers can use the built in camera of the laptop, tablet, and mobile phone to recognize the current moods of the users. Affective computing is often used for image and voice recognition. In some cases, it is used to adapt computer interfaces for people with behavioral disorders, such as with anxiety [12] and autism [14]. Currently these types of disabilities are generally not well addressed in web accessibility. With artificial intelligence and affective computing approaches this gap can now be better bridged.

3. CURRENT LIMITATIONS OF AI

While Facebook's "automatic alt-text" feature [23] is undoubtedly an improvement for many users relying on text alternatives, it also has limitations. For example, Sassy Outwater-Wright, director of the Massachusetts Association for the Blind and Visually Impaired, describes the Facebook "beard quandary" [20]. Apparently beards and other body parts are particularly emphasized in the automatic text alternatives, which leaves the users often puzzled about their true relevance. Also the relative order and relationship between the different pieces of information extracted from the images are often unclear to the users. For example, "two people standing, beard, feet, outdoor, water" [20]. While this is better than no description at all, it shows two endemic issues: (1) the accuracy of the automatically generated text alternatives is generally insufficient, and (2) the determination of what is important to describe is neither with the content author nor with the user, but with the automated algorithm.

3.1 Accuracy

Wrong, confusing, and otherwise inaccurate text alternatives for the majority of images shared on social media may not have as serious consequences as in other situations. Inaccurate text alternatives for some images such as instructional diagrams and informative charts could have serious consequences; in extreme cases, possibly even threat to personal health and safety. The current rate of accuracy for automatic image recognition does not provide sufficient reliability to eliminate the need for text alternatives provided by the author.

In particular, the international standard for web accessibility, the W3C Web Content Accessibility Guidelines (WCAG) [4] requires that text alternatives serve the *equivalent purpose* of the images that they describe. That is, images need to be understood in the context of their surrounding content and their intended purpose, in order to provide useful text alternatives for accessibility. The accuracy and reliability of automatically generated text alternatives drops further in relation to this particular web accessibility requirement [20].

3.2 Accountability

With artificial intelligence it is easier to create assistive technology and accessibility features that do not only convert content from one form to another, but can actually interpret the content; for example, to translate passages of text from one reading level to another, or to symbols for augmentative and alternative communication (AAC). This is comparable to sign-language interpretation through human interpreters, where the interpreter heavily influences the quality of the information being relayed from the source to the recipient. With artificial intelligence this human factor is replaced by an algorithm. The information is filtered by the parameters of the algorithms, and the biases built into the algorithms and the training data. While also human interpreters are prone to biases, they can more easily adapt to the context of different situations. With automated systems much of the accountability is moved outside the context of interpretation.

3.3 Sensitivity

Products and services with artificial intelligence technology tend to be internet-based, and to collect lots of highly sensitive data about their users, in order to provide optimal functionality. Particularly in the context of accessibility and assistive technology this poses risks to privacy, security, and even safety for people with disabilities. For example, text adaptation services have detailed information about the reading capabilities of their users. As this information is stored on servers, it is subject to being compromised and exposed. Alone the knowledge of who uses such an assistive service can be highly sensitive information. While this issue applies to most internet- and cloud-based services, it is especially relevant to accessibility.

4. POTENTIAL APPLICATIONS FOR AI

Despite the immense potentials that artificial intelligence offers for web accessibility, its current limitations do not yet allow it to be a reliable replacement for implementing web accessibility standards [20]. Artificial intelligence still has long ways to go in many areas before it can be considered to be sufficient for providing equivalent access for people with disabilities – if it ever reaches that stage in all areas of accessibility. It seems more likely that the introduction of artificial intelligence for web accessibility will happen gradually. This includes gradual application of artificial intelligence advances to different areas of web accessibility as well as gradual increase of artificial intelligence applications within the different areas.

4.1 Web Browsing

Many examples of artificial intelligence for web accessibility focus on supporting people with disabilities to browse and interact with the Web. Examples, such as image and voice recognition, text and content adaptation, as well as affective computing demonstrate the potential for accessibility. However, these examples are likely only scratching the surface of the true potentials of artificial intelligence.

4.1.1 Advanced Technologies

The Web is continually growing in rich functionality as well as in scope. It moved away from the rather static and document-oriented beginnings to highly interactive and complex applications of today. This often requires new approaches for accessibility. For example, the W3C Accessibility Rich Internet Applications (WAI-ARIA) [5] is a standardized taxonomy to provide additional semantics on the role and state of web objects. Initially this was developed to support screen reader users by communicating the role and state of objects, such as a button or menu. Artificial intelligence could provide more mechanisms to not only detect such objects, but also to also detect their behavior and relationship to other objects within the content.

The Web is also continually converging with other technologies, to provide more advanced functionality. For example, augmented and virtual reality are becoming part of the Web. The interactions with such applications are highly complex and require new approaches for web accessibility. For example, simple text alternatives are not sufficient to describe virtual reality scenes. Depending on the zoom level, text alternatives need to describe scenes from the perspective of the viewer. For example, one view could be “hallway with two doors” rather than the exact shape of the doors. Other views in this scene could be “door with a knob” and “round golden metal knob with a keyhole”. Simply aggregating the text alternatives from the individual objects would be overwhelming. Instead, the relevant information needs to be extracted and abstracted for the particular user. Artificial intelligence could provide this type of functionality.

4.1.2 Personalization

An important part of web accessibility is the adaptability of content to the needs and preferences of individual users. This could be mere visual adaptation of the content, such as changing the text font, size, and spacing, to more substantial content adaptation. Particularly the advances in natural language processing provide several examples of how artificial intelligence could support such content adaptation.

However, many people do not really know what kind of adaptation they need. They might not understand why they prefer or struggle with particular types of content, and what changes they would need to improve their user experience. Artificial intelligence could learn about the needs and preferences of users, to better support content adaptation. This includes situational needs and preferences, which is particularly relevant for people with changing conditions, such as different types of behavioral disorders and chronic conditions.

4.2 Web Authoring

Besides supporting users, artificial intelligence can also support the authoring of accessible web content. Many of the same applications used for accessible web browsing could be reversed to support the authoring process. For example, Ken Harrenstien of Google points out how the YouTube automatic captioning functionality supports content authors in creating captions [6]. While human verification is still required to ensure the quality of the captions, this approach can in many cases lead to significant reduction of effort. Similarly, also image recognition can be used to reduce the effort required for providing text alternatives, and natural language processing can be used to reduce the effort required for providing understandable text.

While many of these applications already exist, they are often not built directly into the production workflow, such as into the content management systems and code editors used to create and maintain the web content. For example, unlike YouTube, Facebook currently does not provide an option for editing automatically generated text alternatives, whereas such an option could potentially help improve the accuracy of the image recognition functionality. Also, currently few web accessibility evaluation tools seem to be implementing the existing capabilities of artificial intelligence. For example, Preety Kumar, CEO of Deque, indicated that they exploring potential uses of Microsoft’s Azure to improve functionality of their tools [21].

Yet applications beyond image and voice recognition to support the web content authoring process are ever so important. For example, artificial intelligence could support accessible web content design. This includes the visual, user experience, and information design of web pages and entire websites. Similarly to automatic captioning such applications may have broader relevance than accessibility but could help tackle aspects of web accessibility that are currently hard to implement. For example, artificial intelligence approaches, such as predictive analytics, can help detect potential barriers in the web content during authoring by learning about people with disabilities.

5. POSSIBLE AVENUE FORWARD

One of the fundamental limitations of artificial intelligence for web accessibility is lack of accuracy and reliability. Specific, narrowly defined tasks, such as detecting headings that have not been marked up as such, could more easily achieve the required level of accuracy than broader tasks, such as providing adequate text alternatives for images within context. On the one hand, many recent developments in the field of artificial intelligence are fairly new and experimental. Trends show that they are likely to improve quite quickly and to get deployed more widely [21]. Already today, there is a selection of cloud-based artificial intelligence services from Amazon, Google, Microsoft, OpenCV, amongst others. Applications built using these services are continually improving in terms of overall reliability.

On the other hand, many of these services are not specifically built for accessibility, even though they have big impact on accessibility. The accuracy and reliability of these services for the specific use in web accessibility could potentially be improved with training data that is specific to people with disabilities. For example, if accuracy of automatic image recognition is not only measured against which objects are depicted in images, but also against how well resulting text alternatives serve the *equivalent purpose* of images, then they would not only serve the purpose of search engine indexing but also better address the accessibility needs of people with disabilities.

Such training data for accessibility purposes is generated from web accessibility conformance evaluation. Particularly content that has been evaluated with input from human experts is invaluable data for machine learning for current artificial intelligence applications.

Accessibility conformance evaluation services do not only have the training data, but also the internal business case to pursue artificial intelligence to provide more cost-effective products and services. For example, Level Access, an accessibility evaluation tool vendor, describes the application of artificial intelligence to provide more robust tooling [7]. It is likely that other conformance testing tool vendors are equally experimenting with artificial intelligence for similar purposes – to detect accessibility barriers more efficiently.

This same functionality for detecting accessibility barriers can be used to support accessible content authoring. It can also be reversed to provide assistive browsing functionality. For example, detecting wrongly coded buttons implies recognizing the buttons (such as by detecting the shape, size, and placement of an active area). In fact, the algorithm may even be able to "guess" the correct behavior and labels for wrongly coded buttons. That is, in addition to authoring support, evaluation services could also provide code augmentation.

This idea of augmenting inaccessible websites with improvements from third-parties is not new. Both crowd-sourced approaches, such as Accessmonkey [2], and facilitated approaches, such as User1st [22] exist. However, with artificial intelligence code augmentation could be more automated based on training data from conformance evaluation. Code augmentation using artificial intelligence could be additional service from conformance evaluation providers directly to website users, or indirectly through assistive technology vendors.

6. CONCLUSION

In the recent years we have witnessed many advances in computer science, which are commonly referred to as "artificial intelligence". Indeed, many of these advances are driven by machine learning in the context of big data, to provide functionality so far mostly known from science fiction. Particularly several new consumer electronics products with advanced natural language processing give a glimpse of the potential capabilities available at relatively affordable costs.

For people with disabilities there are immense potential, many of which have been hardly researched. This includes image and voice recognition products and services that are being publicly deployed by large providers, including by Amazon, Facebook, Google, and Microsoft among many more. Yet in some circles such applications are barely considered "artificial intelligence". More advanced uses in affective computing and predictive analytics promise yet more.

However, a significant drawback of artificial intelligence for web accessibility at this time is a lack of accuracy and reliability. At the current time, artificial intelligence is not mature enough to replace the need for content authors to adhere to accessibility standards and to implement accessibility features. It is questionable if it will ever completely replace that need, but it is unquestionable that it could have a major impact on the authoring and browsing functionalities.

It is likely that artificial intelligence functionality for accessibility will emerge more gradually with initially more simple tasks, such as detecting content structures, to content adaptation and complex interactions, such as in virtual and augmented reality environments. A potential avenue to drive the uptake of artificial intelligence for accessibility is conformance evaluation services – firstly because they have the data and secondly because they have a business case. However, on the long run, ideally artificial intelligence will further support the production of accessible web content from the onset and provide intuitive accessibility features that are built-in by default.

7. ACKNOWLEDGMENTS

This paper was written with support from the WAI-Tools Project, co-funded by the European Commission (EC). H2020 GA 780057.

8. REFERENCES

[1] Asakawa, C. 2016. AI is going to allow blind people to see the world. https://www.ibm.com/watson/advantage-reports/future-of-artificial-intelligence/chieko-asakawa.html

[2] Bigham, J. P. 2007. Accessmonkey. *2007 Accessibility and Computing*. https://dl.acm.org/citation.cfm?id=1328568

[3] Buchanan, B. G. 2005. A (Very) Brief History of Artificial Intelligence. *AI Magazine* (Winter 2005, pp. 53-60), American Association for Artificial Intelligence.

[4] Caldwell, B. et al. 2008. Web Content Accessibility Guidelines (WCAG) 2.0. World Wide Web Consortium (W3C). https://www.w3.org/WAI/intro/wcag

[5] Diggs, J. et al. 2017. Accessible Rich Internet Applications (WAI-ARIA) 1.1. World Wide Web Consortium (W3C). https://www.w3.org/WAI/intro/aria

[6] Harrenstien, K. 2009. Automatic captions in YouTube. From: https://googleblog.blogspot.com/2009/11/automatic-captions-in-youtube.html

[7] Heineman, K. 2016. Trends in Digital Accessibility. From: https://www.levelaccess.com/trends-digital-accessibility-electronic-documents-webinar-qa/

[8] Jaffe, D. 2017. Assistive Robotics. Lecture. Retrieved from: https://web.stanford.edu/class/engr110/2014/05a-Jaffe2.pdf

[9] Leaman, J. and La, H. M. 2017. A Comprehensive Review of Smart Wheelchairs. https://arxiv.org/abs/1704.04697

[10] Microsoft CaptionBot. From: https://www.captionbot.ai/

[11] Microsoft Emotion API. From: http://bit.ly/2gNXMpi

[12] Mobile Health Interventions for Drug Addiction and PTSD. From: http://affect.media.mit.edu/projects.php?id=2928

[13] Morrison, C. 2017. Imagining Artificial Intelligence Applications with People with Visual Disabilities using Tactile Ideation. *19th Conference on Computers and Accessibility*. https://dl.acm.org/citation.cfm?id=3132530

[14] Picard, R. W. 2009. Future affective technology for autism and emotion. https://dx.doi.org/10.1098/rstb.2009.0143

[15] Pinto, M. et al. 2017. Smart Cane for the Visually Impaired. *American Journal of Intelligent Systems*. 7(3): 73-76. http://article.sapub.org/10.5923.j.ajis.20170703.07.html

[16] Schank, R. C. 1991. Where's the AI. *AI Magazine*. 12(4):38. American Association for Artificial Intelligence.

[17] simplish. From: https://simplish.org/

[18] Steadman, I. 2013. IBM's Watson is better at diagnosing cancer than human doctors. *Wired*. Retrieved from: http://www.wired.co.uk/article/ibm-watson-medical-doctor

[19] Texthelp. From: https://www.texthelp.com/

[20] The Impact of Artificial Intelligence on Accessibility. Panel session from the *2017 Boston Accessibility Conference*. From: https://www.youtube.com/watch?v=zQ0dnrjEsI8

[21] The Future of Accessibility with Artificial Intelligence and Robotics. Panel session from the *2017 M-Enabling Summit*. From: http://bit.ly/2mPXMp7

[22] User1st. From: https://www.user1st.com/

[23] Wu, S. et al. 2017. Automatic Alt-text. *2017 Conference on Computer Supported Cooperative Work and Social Computing*. https://dl.acm.org/citation.cfm?id=2998364