WADcher: a Unified Web Accessibility Assessment Framework

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***Abstract*— This paper presents the architecture of Web Accessibility Directive Decision Support Environment (WADcher), a unified web accessibility assessment framework for large-scale assessment of compliance against web accessibility recommendations and legislations. It aims to provide customized support for various user groups like web commissioners, web developers and accessibility experts. To achieve this, the WADcher platform offers tools and interfaces like an Observatory for visualization of the assessment results, a Decision Support Environment for expert reviews and Application Programming Interfaces (APIs) to existing tools.**

Keywords- web accessibility; WCAG; WAD; web accessibility standards; EARL.

I. INTRODUCTION

The web is a fundamental resource related with many aspects of daily life, e.g., work, leisure, education, commerce and social networking. Beyond this, access to services offered through the web provided by public authorities is important for all citizens to stay informed, interact with authorities, fulfill obligations and apply for benefits. To ensure access for disabled, elderly and other disadvantaged persons to websites and mobile applications of public authorities and essential web resources of the private sector, the EU Web Accessibility Directive (WAD) on the "accessibility of the websites and mobile applications of public sector bodies" came into force on 26/10/2016 [11]. The WAD's accessibility requirements describe what must be achieved to enable the user to be able to perceive, operate, interpret and understand a website, a mobile application and related content. WAD aims to ensure that the websites and mobile applications of the public sector are made accessible on the basis of internationally acknowledged accessibility requirements.

When aiming for web accessibility, it is inevitable to establish procedures to analyse how well the web can be used by people with different disabilities, i.e., assess the accessibility status of a website. Having an automated way to assess the accessibility of web pages opens the way to perform large-scale analysis of web accessibility [5][6]. Large-scale accessibility evaluations of the Web are not yet well established. This may be due to the dependency of computational resources for large-scale analysis [1][7]. Current assessment tools have a number of limitations, among others, they cannot detect all issues, manual checking with accessibility experts is still needed [9]. Moreover, the majority of current automatic accessibility assessment tools does not produce results in a standardized machine-readable format as Evaluation and Report Language (EARL) [12].

To push forward efforts in making web sites accessible European-wide, monitoring of the accessibility status of particularly public web sites by the EU has become part of WAD. For this purpose, the European funded research project WADcher aims to develop an integrated platform to verify the compliance of websites and mobile applications of public sector bodies with the accessibility requirements set out in the WAD, and subsequent Commission implementing decisions on monitoring methodologies [13] and model accessibility statements [14]. WADcher will provide APIs to automatic web accessibility assessment tools, so any third-party tool can be connected to WADcher by just using the corresponding APIs. The WADcher platform will provide support to conduct automatic assessment using any tool that is registered and supports the published WADcher APIs. Additionally, WADcher will provide a workbench to support manual checking conducted by accessibility experts and the production of customized reports for different target user groups in a standardized machine-readable EARL format. The WADcher system is built on proven state-of-the-art accessibility assessment tools and will provide an easy-to-use, cost-effective, harmonised accessibility periodic monitoring platform that is transparent, transferable, comparable and reproducible to meet the European standard EN 301 549 V1.1.2 (2015-04) [15] as specified in the WAD. WADcher will provide a management layer that supports assessment and tracking of the accessibility requirements set out in the WAD.

The Directive encourages both Member States and the Commission to promote use of such compatible tools. This paper elaborates on the following aspects: the state of the art of tools for accessibility validation, also considering studies conducted in WADcher to gather user requirements, the

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main use cases identified for the pilots of WADcher and the general design and architecture.

The rest of this paper is organized as follows. Section II describes the carried-out State of the Art Analysis. Section III describes the user requirements collected from users in specific countries. Section IV addresses WADcher architecture approach. Section V provides details about the use cases. The acknowledgement and conclusions close the article.

II. STATE OF THE ART ANALYSIS

In order to review the state of art in WADcher among the many tools available to developers for assessing the accessibility of websites, various open tools as well as well-known commercial solutions for web accessibility services were examined. As a first source of information the list of tools provided by the W3C Consortium was considered, focusing first on those that check compliance against the WCAG 2.0 guidelines and support at least the English language (so, we have excluded tools like Hera FFX [1] and Vamolà [8], for example). Then, we looked at those supporting analysis of at least both (X) HTML and CSS, and covered most guidelines (thus we discarded those considering for example only colors) and that are freely accessible, available either online or as desktop applications. On the commercial side, we examined various tools such as those offered by imergo [10], Deque Systems [16], Siteimprove [17] and Make Sense [18]. The analysis conducted considers also the free Deque plugins for Chrome and Firefox – aXe plugins [19] – and the Siteimprove Accessibility checker for Chrome [20].

In addition to supporting WCAG 1.0 and WCAG 2.0, some of the considered tools allow web designers and developers to check the accessibility against additional national guidelines: MAUVE [1][3], for example, enables the user to select the Stanca Act for the assessment; Asqatasun the French guidelines (RGAA); AChecker [22] and imergo the guidelines of the German government (BITV); Siteimprove extends the available guidelines to the Japanese Industry Standard (JIS).

When analyzing the tools' features, various technical aspects were considered: firstly, the audit depth, that is the assessment scope (if tools can assess single web pages and/or entire websites, and also password protected pages); secondly, the type of input needed (e.g., URL, file upload, directly entered code). We have also checked if they allow the customization of accessibility audits, for example if the developer can specify the guidelines or their priority level for the assessment.

Moreover, focus on the presentation of test results was given. First, we identified the report type: if it is mainly code-oriented, statistical, or graphical (or a mix of these). Then, we looked at the differentiation they make between different types of problems: errors, warnings, potential problems and information that usually require additional manual check. In the end, we observed both the summarizing overview and the full report of the assessment that they provide, and the kind of filtering that it is possible to apply to the results in order to get specific information.

Among free accessibility assessment tools, Asqatasun, TAW Web [23], the A11Y Machine [24], WaaT [2] allow the web designer/developer to evaluate more than a single web page at a time (Total Validator [25] allow to evaluate entire websites in the Pro version). The assessment scope of the commercial services is extended to more than one web page at a time, except for Deque's Amaze [26]. The extension of MAUVE to evaluation of multiple pages at the same time is under development.

Customization of accessibility audits is supported by the majority of the free tools (9 out of 12): AChecker, Asqatasun, Cynthia Says, imergo, MAUVE, TAW Web, the A11Y Machine, Total Validator, and WaaT. However, there are different levels of customization: some of them allow the selection of the preferred guidelines only (among those supported) while others allow also the selection of the priority level of the guidelines.

Regarding the presentation of the assessment results, a summarizing overview is mostly supported, which provides the total number of issues encountered, divided into the different kinds of problems found during assessment (errors, warnings, info/potential problems,), and some kind of filtering is also possible at this stage. Moreover, some of the tools – such as MAUVE, which is code oriented – provide the entire source code with errors and warnings highlighted, and each problem has a link to the corresponding W3C success criteria and techniques description.

The majority of the tools do not provide visualization of the errors/warnings on rendered web page, since they are mostly code-oriented. WAVE is the only free tool that provides this kind of report, even if it provides also the pinpointing of problems in the source code. Regarding commercial solutions, Deque's aXe browser extensions allows the developer to highlight issues on the running web page; Siteimprove extension provides this kind of pinpointing too. Thanks to its customised rendering engine, imergo® provides a detailed analysis of the accessibility issues of a website as perceived by the user in a browser.

The A11Y Machine, Siteimprove Intelligence Platform and WorldSpace Comply [27] provide, in the full report, a dashboard that keeps tracks of the accessibility improvements, allowing the monitoring of the accessibility status over time. As regards other more specific information provided in the full reports, only the A11Y Machine provides the pinpointing of problems in the DOM.

All the tools analyzed provide some sort of filtering of the results: among them, we found that Asqatasun is the only one that provides the filtering of reports by Web content type. An interesting feature offered by Siteimprove – both the Intelligence Platform and the browser extensions – is the possibility to filter the results taking into account the role of the user (Editor, Webmaster, and Developer). Deque Systems, instead, offers different services, each one tailored on the accessibility competence of the user: for example, Amaze is thought for developers who are not accessibility experts, while comply is addressed to accessibility managers and experts.

From our analysis, we can identify three main findings. Firstly, reports provided are mainly code-oriented: the

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visualization of fails and warnings on the rendered web page is a feature that could be useful for not accessibility experts and commissioners, who are not primarily interested into details related to the code to be fixed. Another feature that is not frequently supported is the locating of accessibility issues in the DOM that, on the other hand, is an information that could be useful for accessibility experts and developers. Secondly, other useful features that are not currently supported are related to the filtering of the results. In the summarizing overviews, it is always provided filtering by status of the issues and by priority level of the guidelines, but the possibility of filtering issues by web content type is never given to users. This kind of filtering could be provided also in the full report, as Asqatasun does. It would allow web developers and accessibility experts to better manage their work of fixing errors, by considering problems related to an aspect at a time. The last missing feature that we can point out is the possibility to filter the full report by the frequencies of the errors detected (e.g., single or common issues); as for the web content type filtering, it could be useful especially for the accessibility experts' audience.

WADcher aims to provide developers, designers, accessibility experts and policy makers an integrated and personalised web accessibility support environment by also addressing the aforementioned issues of existing tools.

III. USER REQUIREMENTS ANALYSIS

The design of the WADcher framework is based on both analysis of existing tools, as presented in previous section, and the needs of target users. In order to identify and analyse the needs of the various target users involved, we carried out three main requirements elicitation activities: questionnaires, interviews and a workshop. In particular, for the questionnaires, 148 people across five countries (Ireland, Italy, Greece, Austria, and Germany) filled in the provided online questionnaires. As for the interviews, one interview was done in Germany and it involved a web content author/ accessibility expert; other two interviews were conducted in Italy and involved a web content editor and a web editorial staff member. In addition, a workshop was organized in which about forty people composed of mainly web developers, content writers and accessibility experts participated.

A first general consideration is that people involved in our elicitation activities have limited knowledge of accessibility assessment tools, and they usually encounter difficulties in considering both accessibility and evaluating it in their projects. Regarding web commissioners, if they do not take into account accessibility is because of lacking knowledge and competences, and lack of time and resources. Web developers and accessibility experts, instead, cannot work towards ensuring that websites and application meet the accessibility standards because of commissioner's imposition, lack of time, knowledge and for budget limitations.

When working to ensure accessibility with the automatic assessment tools, the main difficulties regard the inclusion of dynamic content in the evaluation process, the restrictions imposed by Content Management Systems, and some limitations of such tools, such as: the detection of several false positives; they do not perform a thorough check (often not all guidelines are covered); the limited guidance on how to fix the detected issues, and more and clearer information (explanation, suggestions, examples) about the errors is desirable.

Based on their knowledge of available accessibility assessment tools, they recommended the features they would expect from them. Among those, the following were indicated: adaptation of the report to the technical level of the user, by providing one more technical report addressed to developers, and one addressed to commissioners and content authors; analysis of dynamic content, suggestion for JavaScript frameworks and libraries; giving a percentage measure of the overall accessibility level reached.

IV. WADCHER FRAMEWORK ARCHITECTURE

The core components of the WADcher framework were designed by taking into account the requirements presented in the previous section and they can be split into four logical layers (See Figure 1.).

The **knowledge layer** includes all the knowledge/data needed for the proper functioning of the large scale components (e.g., list of web sites to be evaluated, guidelines and policies to be considered in web accessibility assessment, rule sets, etc.) as well as the knowledge/results that will be extracted (e.g., ontologies [28] that describe the guidelines of WCAG 2.x and ARIA standards in a semantic manner, etc.).

The **service layer** includes all the core software components of the large-scale cloud-based architecture. This layer includes an **Evaluation manager** component that interacts with the registered tools (Imergo, MAUVE and WaaT) and the WADcher knowledge base, it also contains the **Test sample definer** that creates automatically test samples based on methodologies like, e.g., UWEM [3], which are limited either by the number of maximum pages or the focus on a specific technical aspect (e.g., certain web

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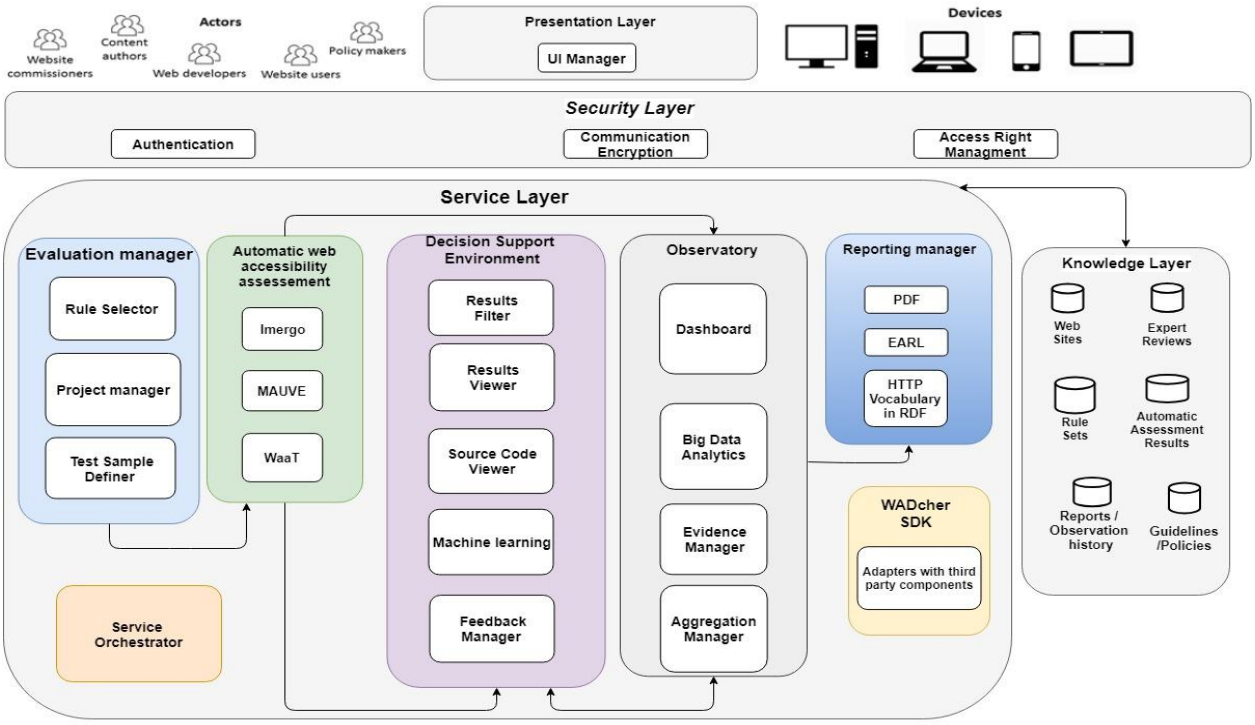

Figure 1. WADcher's architecture overview

content types). The **Rule Selector** allows the user to select the rule set or subset of rules to be used for the validation of the testing sample. Through the **Project manager component,** the user defines the properties needed for a project which can be run multiple times having receptive versions. By that, the monitoring of a website at different times became possible.

Then, the results from Evaluation manager are provided to the **Automatic Web Accessibility Assessment** component, which contains all the available tools (imergo, MAUVE and WaaT) and performs the evaluation which produces an EARL report that is provided to the Decision Support Environment and the Observatory modules.

The **Decision Support Environment (DSE)** aims at empowering accessibility experts who conduct expert reviews and web commissioner to govern the accessibility policy, statements, etc. in order to achieve this it contains components like, the **Results viewer** component which presents the results to the user and provides assistance in solving detected issues, through solutions, examples and informations about the technology related to the issue. The **Results filter** provides filtering and grouping options (e.g., errors, cannot tells, web content type) for the results presented in Results viewer and Source code viewer, in addition the **Source code viewer** component provides access to the source code of the evaluated URL and enables the user to find issues inside the source code as well as on a rendered preview**.** Furthermore, the **Feedback manager** enables accessibility experts to provide valuable feedback to the Decision Support Environment, which is considered for the refinement of rules. The goal is to make the DSE as autonomous as possible with the use of **Machine learning** algorithms that enable the automatic refinement of the rules by continuous usage.

The DSE communicates with an **Observatory** module running also on a cloud environment, contains a **Dashboard** component that presents to the user the different projects according to the WADcher Observatory data model. The responsibility for performing periodic assessments on large sets of monitored web sites and triggering notifications when the accessibility level alters between different times assumed by the **Evidence manager**, moreover the **Aggregation manager** is responsible for aggregating different types of assessment results (i.e., results coming from automatic, semi-automatic and manual tests performed by accessibility experts). In addition, a **Big data analytics** component aggregates all the testing results and, through advanced visualization mechanisms, allows the efficient monitoring of the quality of large volumes of web content.

In order to generate the final report, the data from the Observatory are send to a **Reporting manager** component, which provides the final report in various types. The supported report types are:

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i. A PDF report containing all the errors and cannot tells of the evaluated web page(s).
ii. An EARL-based report of the detected errors and cannot tells.
iii. A PDF version of the EARL-based report, containing all the information of the EARL-based report in human readable format.
iv. A report containing all the HTTP content transferred between WADcher and the server that hosts the evaluated web application, using the HTTP Vocabulary in RDF.

The **Service Orchestrator** is responsible for the management of the notifications between all WADcher's components.

Furthermore, a **WADcher SDK** provides a web-based API to enable access to the services of WADcher to other external applications.

The **security layer** is responsible for the security, authentication and access rights management.

The **presentation layer** includes all the user interfaces that enable user interaction with the large-scale services and through the UI manager component, presents the results in a unified matter regardless of the device used.

V. INDICATIVE USE CASES

As WADcher aims at providing support for different target groups, those have different requirements and approaches towards furthering accessibility in the web. As has been elicited in the user requirements phase of WADcher, web commissioners mainly require a high-level assessment of their web pages while accessibility experts and web developers need to have the option to drill down to the source code level in order to check for minuscule problems and solve those. Therefore, the usage patterns of these three groups diverge heavily from each other and it is important to understand each approach in order to provide a holistic solution for all users.

Generally, WADcher is designed so that the users, especially those with little knowledge on accessibility assessment, do not have to worry about the report handling between the external assessment tools and WADcher, thus these steps are omitted in the use cases.

As the web commissioners are the focal group who is responsible not only for producing reports but also for triggering assessments and improvements their Use Case shall be explored first.

A. Web Commissioners

The user experience for the web commissioners starts with the Observatory, which represents a summarized representation of all the reports that the web commissioner has issued for resources that belong to him (i.e., web pages he/she is responsible for). Along with the reports, some general statistics regarding the accessibility of the checked sites is also provided. Within the Observatory, the web commissioner has the option to either look at existing or new reports that have been automatically compiled or returned by web developers or accessibility experts. The primary task of the web commissioners is the issuing of new automatic checks. For that, first, the address of the sites to check has to be entered, then, the commissioner selects an automatic assessment tool out of a predefined list. Then, the rules or rulesets (e.g., WCAG 2.0 Level AA) upon which the site should be checked are selected and eventually the assessment process is started. Upon completion of the automatic assessment, the web commissioner is informed and can access the compiled report through the Observatory. These reports can be forwarded to accessibility experts for further investigation or to web developers for improvements both are provided in pre-defined lists in order to assure competent handling.

As the EU Commission under the WAD requires an annual reporting, there is also the option to compile higher-level reports in accordance to national or EU requirements (EU 2018/1523).

B. Accessibility Experts

As most automatic assessment tools are not be able to test every possible accessibility issue in an automatic manner, the returned reports contain issues marked as "cannot tell", which means that the tool is not sure whether there is a problem or not. These need manual checking through accessibility experts.

The use case for the accessibility experts usually begins with a notification that a web commissioner has submitted an automatic assessment report to them and requests for manual checking by the expert. The accessibility expert then logs in to the Observatory and there receives the report for a first quick check on the identified errors and on the rules and guidelines that the sites have been checked for. For a more elaborate assessment, the accessibility expert is then able to drill down to a source code level and make annotations and comments directly to the code. After completing the manual assessment, the expert can send the supplemented report, along with a notification, back to the web commissioner for further action.

C. Web Developers

The main task for web developers is the correction of identified accessibility issues. Therefore, a developer gets notified when a commissioner has submitted a report for improvement. As with the other roles, the developer then logs in to the Observatory to have a quick assessment of the identified issues as well as the rules and guidelines that were checked for. However, the central information for this group is provided on the source code level, which the web developer can drill down to and assess automatically identified errors or the annotations made by the accessibility expert. To support the improvement of sites, some guidelines and best practices are provided alongside the errors. After completing the changes, there is the option to rerun the existing report and forward the results to the web commissioner or to simply return a notification informing about the changes made.

Besides these general use cases, all WADcher users are able to issue automatic assessment requests of web pages

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through the Observatory on their own, for example if a web developer wants to check the accessibility of a newly developed site or an accessibility expert deems a site non-accessible.

VI. Conclusion And Future Work

Digitalization is a rapidly moving on process affecting nearly all areas of our everyday life. Thus, it is of utmost importance that the result of this process will not lead to exclusion of user groups, such as disabled users or the elderly. For this purpose, the WAD directive became into force. However, its implementation requires effective tools for large-scale testing and monitoring of web applications also to ensure a harmonized evaluation and reporting approach throughout Europe. So far, such tools are not available and therefore will be in focus of the WADcher project. Intermediate results of this project are presented in this paper and will be summarized in the following.

The core contribution of WADcher includes an integrated platform, which will offer tools and interfaces as described below to support its main stakeholders (web commissioner, web developers and expert reviewers):

[1] An Observatory with dashboards for data visualization of aggregated assessment results enabling different stakeholders such as web commissioners, policy makers and the general public to monitor changes in the accessibility level of websites.

[2] A Decision Support Environment for expert reviewers to detect barriers that need further manual investigation and guidance to Web developers in repairing accessibility errors

[3] Infrastructure that provides also APIs to existing automatic assessment tools and other external tools like CMSs for checking webpages during design and content authoring to make them “born accessible”.

To evaluate the usefulness of WADcher developments and satisfaction of main stakeholders, we also plan to empirically validate the results of the proposed accessibility infrastructures with the relevant communities in four European countries (Austria, Greece, Italy and Ireland).

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