Method for Designing Accessible Web Content in The Web Space of "Paisii Hilenarski" Plovdiv University

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Abstract—The article addresses the problem of accessibility of dynamic web content that is created when developing web pages and services. It discusses basic issues about the accessibility of digital objects and web page content. The aim of the article is to present a method for designing accessibility in the creation of dynamic web content in websites of Paisii Hilendarski Plovdiv University. The developed method is presented through the life cycle of its model, which is applied in parallel with the implementation of a software process in the renewal of the web infrastructure of the university. The method is built on standards, principles, guidelines, accessibility criteria, and techniques for creating and validating web content of the Web Accessibility Initiative. The main standards to which the method adheres are the Web Content Accessibility Guidelines and the Technical Specifications for Accessible Rich Internet Applications. It has been tested in the design and implementation of part of the web content of the web infrastructure of the university created after 2020, which is accessible through the main domain https://uni-plovdiv.bg and many of its sub-domains.

Keywords—accessibility, web content, method for designing and implementing accessibility, WCAG

1 Introduction

The content of web pages on the Internet has a variety of semantic and semiotic information. Web elements often carry a specific semantic and symbolic meaning for the user. Such elements are the glyphicon, the icon, the website logo, the navigation, the web format, etc. The creation of semantic and semiotic meaning of web page elements is achieved through many and different technological standards for photos, graphics, models, charts, diagrams, mind maps, digital maps, etc. The elements that make up web content on the Internet are commonly called digital objects [1]. They can be identified and automatically modeled through the so-called "media type" also known as a Multipurpose Internet Mail Extensions (MIME) [2]. MIME type indicates the nature and format of a document, file, or assortment of bytes.

The task of digital objects is to present specific information to the user in a synthesized manner. One of the significant problems facing digital objects is the question of their accessibility as web content. Web content accessibility refers to the ability of a

user who has a certain cognitive disability or mental problem, such as reduced vision, hearing impairment, colour blindness, motor limitation, etc., to clearly perceive the informational meaning. According to the Web Accessibility Initiative (WAI) [3], the meaning of the term accessible is the ability to make web content more accessible to users with various types of cognitive difficulties and mental problems. WAI is part of The World Wide Web Consortium (W3C) and proposes, supports and develops many accessibility strategies, standards and methods. Accessibility is an issue that, in addition to being closely related to the semantic and semiotic nature of digital objects, concerns the overall appearance, layout and content of web pages. Including font and text size, colour palette, as well as the structure of the web page view. In cognitive science, there is a broad sense covering human cognitive ability, where the main thing is the creation and use of systems of symbols with a certain meaning established by social conventions [4]. At the beginning of the 20th century, Charles Peirce called this process semiosis, and the science that studies it Semiotics [5]. In the field of computer science, semiotic view is a debated term that a number of authors explore as an approach to the visual representation of information resources [6, 7, 8]. In the early stages of the development of The World Wide Web (WWW), analyses were made of the relationship between metaphor represented semiotically and the form of web pages containing icons and hyperlinks [9]. According to [10] who studied the semiotic nature of web pages in the web space, the WWW content is said to has small images that are user-friendly and attractive for navigation. This kind of digital objects act as guides for the user in cyberspace. The source summarizes that the web space is made up of a network of icons, indexes and symbols. In this sense of semantic and semiotic perception, the problem addressed in this article is the development and application of a method for designing accessibility of web content based on established and well-known standards, guidelines, principles and tools. The aim of the article is to present a method for designing accessibility in the creation of web content and its application model used for the needs of the web infrastructure of Paisii Hilendarski Plovdiv University. In the applied aspect, the role of the method is to guide the analyst, designer, developer, etc. in building the accessibility of digital content on the university's local web network.

2 Setting

The question of the accessibility of digital objects in the web space can be considered in a different aspect and sense, according to the information that the object carries; physical device and the browser on which it is rendered; the appearance of a web page, the technology through which it is visualized, the degree of accessibility, etc.

2.1 General perception

It can be tentatively assumed that the accessibility of a digital object can vary from the impossibility of perceiving its meaning to its full semantic understanding by the user. The informational meaning of the digital object as a criterion for perception represents an upper limit of the accessibility range. In other words, if the informational meaning of the digital object is perceived by the user, it means that the user interface

and technology do not represent a barrier to accessibility. Formally speaking, accessibility is the degree to which a digital object can be easily understood by a large number of users.

Definition: *accessibility* is the degree to which a digital object can be clear, comprehensible and easy-to-digest by a large number of users.

Often, the concept of accessibility of web content is mistakenly confused with the non-functional requirement of "usability". The second concerns how easy or difficult a system or functionality can be used, while accessibility is the measure of understanding the informational meaning conveyed by the display of a digital object on a web page with a certain technology.

2.2 WAI standards, principles and guidelines

The standards, principles, guidelines, methods, means, etc. for accessibility are developed in accordance with WAI directives to the World Wide Web Consortium (W3C). The documents, technical reports, educational materials, including some of the software tools, are written by working groups and interest groups that are part of WAI or related to the Initiative. WAI's basic documents are a set of guidelines that are internationally recognized as the standard for web accessibility. These include: Web Content Accessibility Guidelines (WCAG), User Agent Accessibility Guidelines (UAAG), Authoring Tool Accessibility Guidelines (ATAG), Technical Specifications for Accessible Rich Internet Applications (ARIA) [11], etc. These documents address different areas, components and degrees of web accessibility. During the construction of the method for designing the accessibility of web content, for the needs of the web infrastructure of Paisii Hilendarski Plovdiv University, the WCAG standard was used as the main document. Its current versions, which serve for guidance, software development, education, etc., are WCAG 2.0, 2.1 and 2.2. WCAG 2.0 was published in 2008, while WCAG 2.1 in 2018. WCAG 2.2 draft is scheduled to be finalized by September 2022, and WCAG 3.0 has been worked on since 2021 [11]. WCAG is used by web designers and developers, policy makers, purchasing agents, teachers, and students. WCAG 2.0, 2.1 and 2.2 has several layers including overall principles, general guidelines, testable success criteria and collections of sufficient techniques, advisory techniques, and documented common failures with examples, resource links and code. This WCAG structure was used as a basis for developing a specification with criteria of requirements for satisfying the accessibility of web content in the network of Paisii Hilendarski Plovdiv University. WCAG has success criteria at three levels: "A", "AA", "AAA". The basis for determining conformance to WCAG is the success criteria from the WCAG standard [12].

Example Scheme with accessibility satisfaction criterion: The scheme of criteria by which requirements are created in the specification of the method for designing accessible web content for the needs of the web infrastructure of the university is composed of: Principle, guideline, success criteria, situation for sufficient and advisory techniques or failures of WCAG, technique code, technique description link, WCAG application reference. In general, this is also the structure of the documentation in WCAG.

Scheme C01G94: Principle: Perceivable, Guideline 1.1: Text alternatives, success criteria: Level A, sufficient techniques: Situation A: If a short description can serve the same purpose and present the same information as the non-text content: G94: Providing short text alternative for non-text content that serves the same purpose and presents the same information as the non-text content, technique description and application reference in WCAG technique description and application reference [13].

WCAG guidelines 2.0, 2.1 and newer working versions 2.2 and 3.0 need to be followed when developing websites and web application user interfaces to be accessible to people with cognitive and intellectual disabilities. In software development, they are applied at different stages of the software process, as they are envisioned in the requirements for the site or web application, and their implementation starts from the design. In the European Union, websites and mobile applications that are intended for the public sector must comply with WCAG principles. According to the Web Accessibility Directive in force since 22 December 2016 [14], people with cognitive disabilities are given better access to public web services. The Accessibility Directive is currently harmonized with WCAG 2.1.

It is understood from the WCAG principles that it is necessary to carefully design the way in which web content is visualized. Depending on the scale of the web development, it should be envisioned how to realize the visualization of the views of the web pages and its individual digital objects. In some systems with complex web services and high public consumption, such visualization is achieved through a separate module. WCAG principles are applied with varying degrees of success depending on the scale of web development. A web survey confirms that the principles are applied differently across personal web pages and forums, corporate sites, web applications, web platforms, etc. Unfortunately, at the current stage of the development of the Internet and the web space, WCAG is not widely applied even to the websites of public institutions [15, 16, 17].

WAI develops and proposes accessibility principles for W3C technologies such as HTML, XML, SMIL, CSS, SVG, SMIL, etc. Creating a specification of requirements to satisfy accessibility is a difficult and complex task. For the needs of the design and implementation of accessibility in the web network of Paisii Hilendarski Plovdiv University, several specifications have been created in accordance with WAI standards through schemes analogous to "Scheme C01G94". The presented "Scheme C01G94" is a composite component of the "WCAG Accessibility Satisfaction Criteria" specification. The code "C01G94" stands for Criteria, WCAG specific number and technique code.

In addition to the "WCAG Accessibility Satisfaction Criteria" specification, the "ATAG Accessibility Satisfaction Criteria", "UAAG Accessibility Satisfaction Criteria" and "ARIA Accessibility Satisfaction Criteria" specifications were created as part of the accessibility design method in the web network of Paisii Hilendarski Plovdiv University. Their accessibility requirements schemes are created by analogy to the approach of constructing the "WCAG Accessibility Satisfaction Criteria" specification according to the specific content of ATAG, UAAG and ARIA.

2.3 Legislative regulations

Accessibility issues are developed not only through the publication of technology standards and guidelines. For example, Section 508 of the Rehabilitation Act of the United States Laws [18, 19] govern accessibility in the use of information technology in US government offices and agencies. Its analogue in the EU is the European Accessibility Act [20]. These laws and regulations show that societies around the world are becoming more open and communicative towards people with physical or mental problems. WAI maintains a list of legislative acts for Australia, Canada, China, European Union, Japan, USA, etc., according to which websites and applications of public institutions and organizations must maintain mandatory or recommended levels of accessibility [21, 22].

3 Context levels

Designing accessibility for rendering digital objects should be part of the software development process of a website or application. According to WAI, it is essential that several different components of web development and interaction work together in order for the web to be accessible to people with disabilities. These components include: the information, code or markup, assistive technology, authoring tools, evaluation tools, etc. [11]. The preparation of specifications for the application of the accessibility design method for the needs of the web network of the Plovdiv University complies with the specifics of its web infrastructure. Active users are taken into account, which number approximately 20,000. By active users we mean students, teachers, employees, PhD students and associates who have a user account in the university's web system. According to the specifics of its web infrastructure and its consumption, the context on which accessibility depends can be divided into four levels, as shown in Table 1.

The development of a software requirements specification is important for accessibility design, as it is necessary to achieve predictability at the earliest stage of software process implementation. It is recommended that level 1 and 2 accessibility be included in the specification when collecting the non-functional and functional requirements. The physical device can be a well-known phone, tablet, laptop, monitor or TV display, but also a specialized Human Computer Interface. When determining web browser compatibility, it is also necessary to describe type, version, need for plug-in, and other specifics. At level 3, consideration should be given to how dynamism is implemented. Is there automated source code generation from a database while achieving adaptability, responsiveness, fluidity, modelling, etc. of the view of the web page, its main containers, of the digital objects in them, the text and its font, including script elements for dynamic change of the content, position, size, colour of a digital object, etc. At level 4, attention should be paid to the types of digital objects and the technology with which they are created, as a result of which the possibilities for modelling their accessibility should be foreseen. The considered context levels 1, 2, 3 and 4 are laid down in the requirements specification at the beginning of the software process or in parallel at a certain iterative step of the software development [23, 24].

Table 1. Context levels

Context	Type
Level 1	physical device
Level 2	browser and other "user agents" with which compatibility is achieved
Level 3	dynamism of the web page view and adaptability of the digital object
Level 4	type of digital object according to the technology by which it was created

4 Accessibility design method

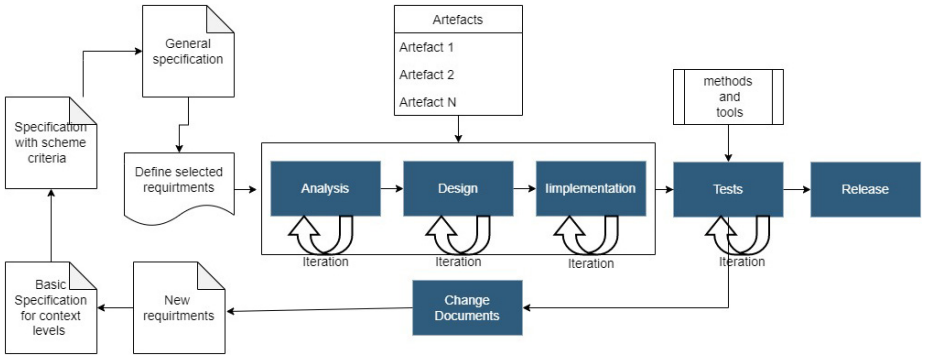

Fig. 1. Model of accessibility design and development method

In this article, we consider a method for designing web content accessibility that is implemented as part of a software process. The method we present through the life cycle of its model is composed of criteria specifications with requirements according to WCAG, ATAG UAAG and ARIA principles, context levels, artefacts for designing and programming software solutions, and an application methodology for quality assurance through a set of inspection tools. There are dozens of software process models and methodologies for their organization and application in the literature. Most software processes have a life cycle composed of similar stages, which are usually: market and needs analysis, return on investment, requirements gathering, architecture and design, implementation, testing and deployment [25, 26, 27, 28]. The life cycle of the model (see Figure 1), which presents the accessibility method, is built from the main stages of the software process, with an emphasis on those in which functionality for the implementation of web accessibility is actively developed. The accessibility design method is independent of a particular software process, but needs to be adapted to the specific software methodology being applied. It complies with modern flexible and iterative practices in software processes. Its application proceeds in parallel with the implementation of the software process according to a certain methodology.

5 Application of the method

The constituent elements of the method are applied at different stages of development. It was created for the needs of designing the accessibility of the pages in the web network of Paisii Hilendarski Plovdiv University in the process of its renewal. Its application begins with an analysis of the current state of the university's web infrastructure. During the analysis, functional and non-functional requirements are collected, and two types of specifications are prepared in parallel. Basic specification with requirements for website and application functioning according to context levels (Table 1) and specialized criteria specifications with accessibility requirements according to WCAG, ATAG UAAG and ARIA principles. In the Specification for context levels, requirements for the context levels from Table 1 are collected, while the specialized specifications are formalized by analogy to "Scheme C01G94". We must clarify that some of the requirements in the basic specification are repeated in the specialized ones, but with technically detailed specifications. These specifications are developed in a series of two to four workshop discussions. Some criteria with requirements are defined without technical precision, therefore their implementation remains in a subsequent iteration. The actual development is presented through the usual stages for most software implementation methodologies. The analysis, design and implementation stages, depending on the methodology used, can be applied once or iteratively. For them, it is essential to develop functionality through pre-created accessibility artefacts. Such artefacts represent guidelines, manuals, best practices, established software solutions, etc., that are known to the software community or specifically created for the purposes of a particular software project. WAI defines a number of such guidelines and artefacts for planning, tips for writing, designing and developing web accessibility, template for accessibility evaluation reports, etc. In the accessibility design method, some of these artefacts are used informally as an established pattern or good practice. The implementation of the artefact in the software process to a functional level in the website or application must satisfy the requirements provided in the specifications. The next stage of the method is the application of appropriate techniques and tools for inspection and evaluation of the system for accessible dynamic views and adaptive digital objects. The basic steps in which accessibility is checked need to include different methods and tools for testing. The steps we recommend for implementation, without following a strict sequence, are:

- tools for validating CSS formatting and HTML code;
- tools with options to turn on and off the formatting and styling of web pages;
- tools for viewing the page in different views corresponding to certain types of colour blindness;
- tools for evaluating and determining colour contrast;
- accessibility validators, offering web page tests for errors while ensuring different levels of accessibility;
- tools assessing the functional accessibility of web pages for accessibility compliance;
- tools for testing a given page with different views from different browser versions.

At the end of the accessibility quality assurance stage, two exits are possible. Repetition of the entire software process cycle as requirements change. The other option is its completion, as the functionality meets the required quality [29].

6 Software tools for testing accessible Internet pages according to WCAG principles

When validating the accessibility of web content, it is recommended to use various tools that help to detect weak points in the code and fix them. Quality assurance tools, particularly accessibility tools, not only point out errors, but also suggest alternative solutions to a given problem. When designing and developing a web-based system, accessibility assessments help identify problems. WAI develops and promotes a number of resources and tools for creating and testing accessible web content. WAI provides a list of assessment tools that can be filtered to find those that meet the specific needs of creating accessible web pages. The source [30] lists characteristics of assessment tools and highlights various aspects to consider in their selection and application. Web accessibility assessment tools are software programs or online services that help determine whether web content meets accessibility guidelines. It should be noted that the tools cannot find absolutely all obstacles limiting accessibility. User test results are based on a limited set of tests and also cannot cover all possible tests. It is not an exception in the assessment to admit deficiencies that are not accounted for by any of the tools.

7 Inspection results

The considered method for designing the accessibility of web content was applied in the development of a part of the web network of Paisii Hilendarski Plovdiv University accessible through the main domain https://uni-plovdiv.bg and many of its sub-domains. Some of the tools that were used to assess the accessibility of the university's web space renovation for the period from May 2020 to May 2021 are Responsive Checker, WAVE Evaluation Tool, Tingtun Checker, AInspector WCAG, ax DevTools, AChecker Web Accessibility, User-Agent Switcher, A11y Validator and Toptal Colorlab, etc. The results of the use of the tools listed above due to their volume is the subject of consideration in a separate publication. In this article, we shall present tests with Tingtun Checker. The web pages of the site https://uni-plovdiv.bg/ examined for the period 01.05.2020 - 01.05.2021 are of the type "Departments" and "Management". They are used in one of the existing scenarios for generating dynamic views, the implementation of which was carried out for part of the web pages using the Vue framework and REST service. During the specified period, a total of 52,792 requests were made to this type of web pages, which is less than 1 percent (0.64%) of the total number of requests to all pages on the website. The university's website is registered and integrated into the Google Analytics system from where the data is extracted. The Tingtun

Checker test results presented (see Figure 2 and Table 3) are based on a set of tests on the accessibility criteria of the application itself. These criteria are based on WCAG 2.1 principles, but are specified according to the specifics of Tingtun Checker's work. For the reader's convenience, Table 2 presents the numbering according to Tingtun Checker documentation, not its compliance in the "WCAG Accessibility Satisfaction Criteria" specification.

Table 2. Automated tests with Tingtun Checker applied

Test Name	Tingtun Checker Criterion
Use alt on img elements	1.1.1
Use of colour	1.4.1
Provide descriptive titles for web pages	2.4.2
Provide links to navigate to related web pages	2.4.5
Provide descriptive headings	2.4.6
Primary language of the page	3.1.1
Provide a submit button to initiate a change of context	3.2.2
Provide descriptive labels	3.3.2
Label groups of form elements	3.3.2
Define ids for elements	4.1.1
Provide unique access keys	4.1.1
Reference elements	4.1.1
Provide role name for div/span with event handler	4.1.2
Use HTML form controls and links	4.1.2
Accessible name for image links	4.1.2
Use the title for frame and iframe elements	4.1.2

The evaluations of the test results are combined into 4 groups of values:

- Total – total number of evaluated attributes;
- Fail – number of inconsistencies;
- Verify – number of attributes to verify;
- Pass – total number of valid attributes.

The conclusions of the tests are that no accessibility bugs were found. Some of the tests done on web page views are Figure 2. The detailed test report is set out in Table 3.

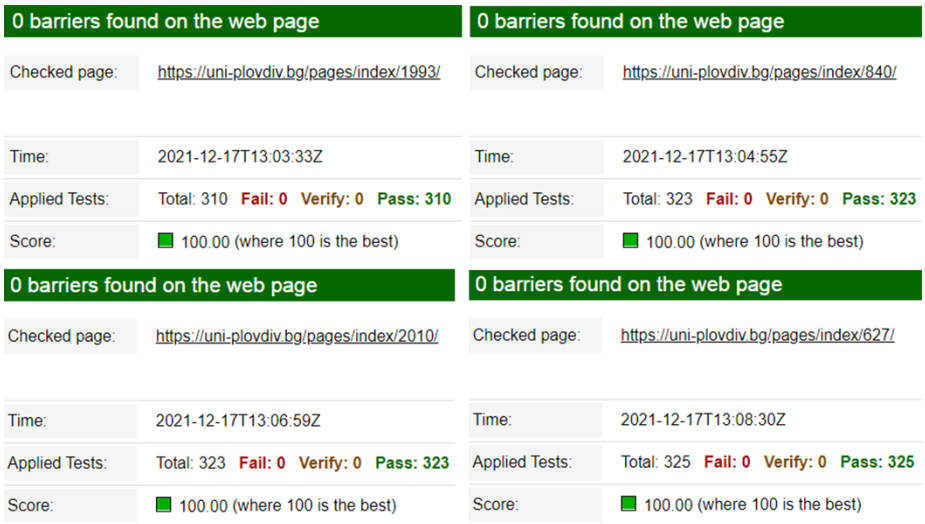

Fig. 2. Accessibility tests of web page views

Table 3. Test results with Tingtun Checker

Page Index	Page Name	Test Result
137	Bulgarian language	Total: 336 Fail: 0 Verify: 0 Pass: 336
148	Organic chemistry	Total: 322 Fail: 0 Verify: 0 Pass: 322
155	Public legal sciences	Total: 349 Fail: 0 Verify: 0 Pass: 349
627	Music	Total: 322 Fail: 0 Verify: 0 Pass: 322
840	Political Science and National Security	Total: 320 Fail: 0 Verify: 0 Pass: 320
1993	Zoology	Total: 307 Fail: 0 Verify: 0 Pass: 307
2000	Sociology and Human Sciences	Total: 296 Fail: 0 Verify: 0 Pass: 296
2003	Electronics, communications and information technology	Total: 338 Fail: 0 Verify: 0 Pass: 338
2010	Algebra and Geometry	Total: 320 Fail: 0 Verify: 0 Pass: 320

8 Conclusion

The article examines the problem of designing accessible web content in the web network of Paisii Hilendarski Plovdiv University. The questions discussed were about the accessibility of digital objects on the web from the point of view of semiotic and semantic meaning, the context in which the digital object is rendered, the degree of accessibility according to WCAG, ATAG, UAAG and ARIA principles, context levels, design artefacts and implementation of software solutions, application methodology for quality assurance through a set of inspection tools, etc. As a result of an in-depth analysis of various accessibility issues, an accessibility design method was developed, which was applied to the accessibility renovation of the university's web

network. Through the creation and application of the method for designing accessible web content, the set goal of the article has been achieved. Based on the discussion in the publication, it can be concluded that the developed method is universal in terms of its applicability and compatibility with methodologies and software processes. The future development of the method is related to the development of the methodology of its application.

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