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Conceptual Model of a Software Accessibility Evaluation System

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Abstract: *The percentage of people with disabilities has increased, with 1.3 billion people worldwide having some form of disability. Advancements in technology have made it easier for people with disabilities to access resources. However, many computer systems and software lack built-in accessibility features, making accessibility assessment software tools crucial for creating an accessible digital environment. They serve to automate the collection of interface usage data, its analysis, or the solution of potential problems in providing digital accessibility. These tools record user interactions, analyze accessibility issues, and make recommendations for improvement. In this regard, this paper aims to propose a high-level conceptual model of a software accessibility evaluation system's prototype. The main objective is to study attributes of software quality and existing systems for evaluating accessibility.*

1. INTRODUCTION

The development of software technologies in the direction of offering more complex functions and services is caused by the need for digitization of businesses. At the same time, for a business to be competitive and sustainable, many of its activities must be carried out in a digital environment. Therefore, due to the coverage of an increasingly wide range of functionalities, the software becomes more and more complex, and from there also arise many problems related to ease of use and more precisely, related to its trouble-free use by users with special needs or specifically, with their accessibility.

According to the World Bank, 15% of the world's population experiences some form of disability, and the prevalence of disability is higher in developing countries (World Bank, 2023). The World Health Organization states that approximately 1.3 billion people experience a significant disability, or 16% of the world's population, i.e. 1 in every 6 of us (World Health Organization (WHO), 2023). Obstacles to the full social and economic inclusion of people with disabilities may be related to inaccessible physical environments and transportation, lack of assistive devices and technologies, non-adapted means of communication, gaps in service provision, and discriminatory prejudice and stigma in society (World Bank, 2023).

The provision of an accessible digital environment is of particular importance for the development of software and to be adapted to the needs of users with different types of disabilities. Part of the development of accessible software technologies is the accessibility testing and evaluation systems. Their primary task is to derive information about how easily users can work with a piece of software and provide recommendations for improving future designs and implementations. Accessibility assessment is formalized through international standards that offer recommendations and give guidelines for the technical implementation of common problems in software development related to its use by people with disabilities. For example, accessibility

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testing tools are often based on US federal government Section 508 and the Web Content Accessibility Guidelines (WCAG) of the W3C (Ismail & Kuppusamy, 2022; Jo et al., 2022; Marthasari et al., 2023; Navarro et al., 2022).

In this regard, **the purpose of the current paper** is to propose a high-level conceptual model of a software accessibility evaluation system's prototype. The main objective is to study attributes of software quality and existing systems for evaluating accessibility.

2. LITERATURE REVIEW

2.1. Software Quality Attributes

Software developers are faced with the challenge of creating products based on the user experience and combining aesthetics, functionality, ergonomics, and the ability to quickly perform tasks, while at the same time having to comply with the limitations imposed by digital devices and the special needs of end users.

Software quality is crucial for various reasons, including user satisfaction, customer retention, reduced costs, brand reputation, competitive advantage, compliance and standards, maintainability and scalability, risk mitigation, and adaptability to change. High-quality software ensures a positive user experience and contributes to customer loyalty by meeting expectations and providing value.

Reduced costs can be achieved by identifying and fixing bugs early in the development process, which is more cost-effective than addressing issues later. A positive brand reputation for high-quality products can increase trust and credibility in the market.

Compliance with standards ensures that software meets regulatory requirements and is suitable for specific use cases. Maintainability and scalability are also benefits of quality software, as well-structured code, thorough documentation, and best practices make it easier for developers to update and extend the software over time.

All of these benefits are considered in the software product quality model inscribed in ISO/IEC 25010:2023(en). It categorizes software quality into eight main characteristics functional suitability, performance efficiency, compatibility, usability, reliability, security, maintainability, and portability (International Organization for Standardization, 2023). Each of these is composed of a set of related sub-features. The group of functional suitability includes functional completeness, functional correctness, and functional expediency. Productivity efficiency refers to resource utilization, capacity, and time behavior. Compatibility is associated with coexistence and interoperability.

According to ISO/IEC 25010:2023(en), accessibility is a sub-characteristic of usability, together with appropriateness recognisability, learnability, operability, user error protection, and user interface aesthetics. Reliability includes maturity, availability, fault tolerance, and recoverability. The characteristic "security" includes sub-characteristics: confidentiality, integrity, non-repudiation, accountability, and authenticity. Maintainability is associated with modularity, reusability, analysability, modifiability, and testability. The final characteristic of the quality model is portability, which refers to adaptability, installability, and replaceability.

According to the standard, accessibility is associated with the degree to which a product or system can be used by people with the widest range of characteristics and abilities to achieve a specific goal in a specific context of use. Some of the other characteristics in the quality model can be measured quantitatively, others only qualitatively (International Organization for Standardization, 2023).

According to ISO/IEC 25010:2023(en), accessibility can be defined or measured either as the degree to which a product or system can be used by people with certain disabilities to achieve specific goals with effectiveness, efficiency, freedom of risk, and satisfaction in a particular context of use or through the presence of product properties that support accessibility (International Organization for Standardization, 2023). In this regard, the question arises whether means exist to measure the properties of products that determine their affordability. Measurement is all about testing and evaluating the accessibility of software.

2.2. Software Accessibility Evaluation

Software quality for accessibility is crucial for creating an inclusive user experience. It ensures software is usable by individuals with diverse abilities, allowing a broader range of users, including those with disabilities, to access and interact with the application. This ensures legal compliance, as accessibility regulations and standards are established in various regions and countries.

According to the opinions of various authors, it can be summarized that testing is mostly done by users who follow a pre-written script with tasks (Ara et al., 2023; Budake et al., 2023; Maqbool & Herold, 2024; Rahal et al., 2023; Rodríguez et al., 2023). The purpose of testing is to obtain feedback from users in the form of quantitative and/or qualitative data. The assessment is carried out by software quality experts and for this reason, is also known as expert evaluation. It can also be performed as a result of the tests carried out. The accessibility evaluation is carried out after choosing an appropriate method, the implementation of which may involve users and representatives of some of the other teams involved in the development of a given system, such as designers and developers.

The studies carried out indicate that the stages of the accessibility testing and evaluation process are not precisely distinguished, both by international standards and by specialists in the field. Some authors study only the accessibility evaluation process (Badzio et al., 2022; Faraji Sabokbar et al., 2021; Faria & Abreu, 2023; Floriano et al., 2022; Núñez et al., 2019; Valtolina & Fratus, 2022), others only the testing process (Johnson & Lilley, 2022; Mateus et al., 2021; Oncins, 2021; Pandey et al., 2022; Seo & Rogge, 2023; Sík-Lányi & Orbán-Mihálykó, 2019), but in the literature they are rarely united in a comprehensive accessibility research process. No information was also found on a clear grouping of the applied methods and means, which corresponds to their phased application. In a previous study, the author made attempts to derive a unified process of web accessibility audit, which consists of the following stages: planning; research; evaluation; reporting, and subsequent control (Nacheva, 2022). The web accessibility audit process is based on a controlled business process, the input of which is the user requirements, formed research objectives, and a prototype of the web system under investigation. As output artifacts of the process, web accessibility audit reports and recommendations for improving web accessibility are obtained. However, in the literature, we do not find an analogous process of auditing software accessibility, which we consider to be a potential field for the development of scientific knowledge in the field of software quality and, in particular, ensuring its accessibility.

Several companies often do not implement any methods and means of testing or evaluating the accessibility of the products they develop. It relies solely on the subjective judgment of developers, designers, and managers, who are usually not familiar with the details of accessibility issues in software. In these cases, we cannot speak of the observance of a structured work process (business process) of accessibility research, since it is mainly based on decision-making, discussion, and professional cooperation to achieve certain results - creating accessible software. The nature of this way of working means that the structure of the workflow will be different each time.

Software accessibility evaluation tools assess software applications or websites for accessibility to individuals with disabilities. These tools cover aspects like screen reader compatibility, keyboard navigation, color contrast, alternative text for images, focus indicators, captions and transcripts, text resizing, and form accessibility. Popular tools like WAVE, Axe, and NVDA help developers identify and address accessibility issues, creating a more inclusive digital experience for all users (Gaggi et al., 2019; Nganji, 2018; Pamuji et al., 2023). These tools help developers create more accessible digital products for all users.

WAVE is an online tool that provides detailed accessibility reports, visual representations of web pages with annotations, and error identification. It supports the evaluation of dynamic content (WebAIM, 2023). Axe is a browser extension and command line tool that integrates with various development environments and browsers employs rules based on WCAG, provides actionable insights, and allows automated testing (Deque Systems, Inc., 2023). It supports popular web browsers and applications, allows customization of settings, and supports braille displays.

WAVE and Axe focus on evaluating web content, while NVDA is a screen reader software applicable to various digital environments. WAVE and Axe are used by developers and designers to test and fix accessibility issues, while NVDA is used by individuals with visual impairments to access digital content (NV Access, 2023). WAVE and Axe support automated testing, while NVDA requires manual interaction for evaluation. WAVE and Axe are widely used during the development phase, while NVDA is used by end-users for real-time interaction with digital content. The choice of tool depends on the specific needs and workflows of the user or development team.

Biometric accessibility evaluation tools are less common than traditional tools, but they can be used to assess the usability and accessibility of biometric authentication systems. Biometric authentication offers enhanced security, user convenience, inclusivity, efficiency, and reduced fraud compared to traditional methods like passwords or PINs (Shaheed et al., 2024). However, privacy concerns, security vulnerabilities, intrusiveness, and the cost of implementation are some of the cons. Biometric data is unique and personal, raising privacy concerns. The accuracy and reliability of biometric systems can be influenced by factors like environmental conditions, hardware quality, and individual variations (Sasikala, 2024). Security vulnerabilities can be susceptible to hacking or spoofing attempts. Intrusiveness may be experienced by some users due to concerns about data storage and use. Accessibility challenges may arise for individuals with certain disabilities, such as fingerprint recognition (Dargan & Kumar, 2020). Lack of standardization in biometric technology may lead to interoperability issues and varying levels of accessibility across different systems.

Considerations for accessibility evaluation tools include usability testing, user feedback surveys, and security audits. Usability testing provides insights into user experience and potential accessibility challenges, while user feedback surveys allow gathering opinions and concerns

from users, including those with disabilities. Security audits identify potential security vulnerabilities but focus more on security aspects than user experience or accessibility.

Usability testing tools like Lyssna (former UsabilityHub) and Optimal Workshop can be used to gather user experience insights and assess the overall usability of biometric authentication processes (Lyssna, 2023; Optimal Workshop Ltd., 2023).

Considerations for biometric authentication evaluation include accuracy and error rates, adaptability, user feedback, security and privacy, customization, and compliance with accessibility standards. High accuracy is crucial for successful authentication, and biometric systems need to be highly customizable and adaptable to accommodate users with diverse needs.

Biometric evaluation tools are less common, and organizations often rely on a combination of usability testing, user feedback, and adherence to accessibility standards. Customization and adaptability are essential for biometric systems to accommodate users with diverse needs. While usability testing tools can help gather insights into user experience, customization features in biometric systems are crucial.

While there may not be specific biometric accessibility evaluation tools readily available, usability testing platforms can play a role in assessing the overall usability of interfaces, including those incorporating biometric authentication. Organizations should also consider specific aspects related to biometric systems, such as accuracy, adaptability, and compliance with accessibility standards, to ensure inclusive user experiences.

3. CONCEPTUAL MODEL OF A SOFTWARE ACCESSIBILITY EVALUATION SYSTEM

The development of a software accessibility evaluation system should focus on exploring users' mental models, providing maximum freedom for testing, receiving quantitative data, and tracking rules for building accessible interfaces. Challenges include users being out of their comfort zone when using unusual devices, research needing to be conducted in a laboratory or moderator-controlled environment, providing unambiguous data presentation, and combining opportunities for moderated and unmoderated accessibility research. Despite these challenges, the development of an accessible assessment system is crucial for improving user experience and software accessibility.

Mainly, the software evaluation tools can be based on working with:

a. questionnaires to obtain feedback on satisfaction with working with the system or application under study;
b. log files, in which the results of the operation of the system or application on the server side are recorded;
c. interactions with the applications – e.g., these could be the screen taps and gestures performed when interacting with the mobile device, based on which the achieved performance can subsequently be established and respectively the number of errors made. Similar, for example, are A/B tests;
d. biometric data – behavioral and/or physiological, of which facial expression analysis, audio recording processing (voice analysis), and gaze tracking are most commonly used in accessibility research. It should be noted that depending on the type of disability, different biometric data should be analyzed.

Based on this, a high-level conceptual model of the software accessibility evaluation system is proposed in Figure 1, illustrating the general types of activities performed by biometrics processing systems.

The system aims to integrate multiple modules with versatile purposes but faces challenges in implementing it due to technological features and architecture. It should consider the appropriate architectural pattern for integrating internet application and biometric system functionality, specific hardware devices for recording biometric data, the need for specialized modules for processing biometric data, physical storage of application data, and user identification approach. This requires a complex system with numerous components and integration of current technologies. We propose two main modules: Biometric Data Processing Engine and Reports. The first one is responsible for the preprocessing of raw data, scoring of processed biometrics, and creating decision models. The second module represents biometric data heat maps, and descriptive statistics and generates reports about users' behavior patterns.

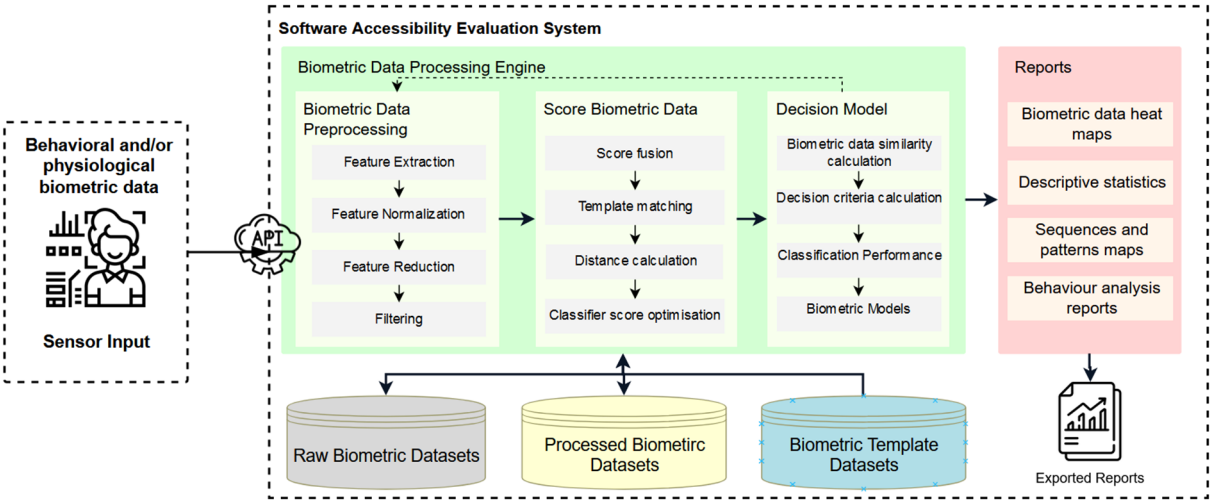

Figure 1. Conceptual Model of a Software Accessibility Evaluation System

Source: Own elaboration

The **Biometric Data Preprocessing Module** involves identifying and extracting distinctive features from raw biometric data, ensuring a condensed and informative representation. Normalization standardizes the data to ensure consistency across samples, removing variations due to different capturing conditions. Feature reduction reduces the dimensionality of the feature space while retaining the most relevant information, improving computational efficiency, and reducing the risk of overfitting. Filtering removes noise or irrelevant information from the biometric data, enhancing the signal-to-noise ratio. These stages collectively contribute to a robust and efficient biometric system by refining the raw input data, making it suitable for accurate matching and identification. Each stage plays a crucial role in addressing challenges associated with variations in biometric traits and environmental conditions.

The **Score Biometric Data Module** involves processing pipeline, including fusion, template matching, distance calculation, and classifier optimization and requires careful consideration of various factors. Template matching criteria include accuracy in matching biometric templates. Distance calculation criteria involve precision in calculating dissimilarity between templates, with lower scores for smaller distances indicating higher similarity. Fusion criteria integrate multiple matching scores for improved accuracy. Classifier optimization criteria

enhance classifier performance through optimization techniques, with higher scores for improved classification metrics. The overall score is calculated by assigning weights to each component based on their importance, and the overall score is calculated by combining the scores from template matching, distance calculation, fusion, and classifier optimization. Adjusting the weights and individual scores based on specific application requirements and priorities is also possible.

The **Decision Model Module** involves similarity calculations, decision criteria calculations, classification performance, and biometric model generation. Similarity calculations measure the resemblance between presented biometric data and stored reference data, providing a basis for decision-making. Decision criteria calculations set thresholds for identification or authentication, balancing security and convenience. Classification performance evaluation assesses the accuracy and reliability of the biometric system, including metrics like accuracy, precision, recall, F1 score, etc. Biometric model generation creates mathematical or statistical models that represent unique characteristics of individuals based on their biometric traits, used for storing reference templates and generating features for classification. The generation of effective models is crucial for the overall accuracy and reliability of the biometric system. The effectiveness of each stage contributes to the overall performance and security of the biometric system.

Future developments should include an architectural model and interactive prototype based on the proposed system. The author should present an architectural model and interactive prototype for future development.

4. CONCLUSION

In conclusion of this publication, it can be summarized that the research on the accessibility of software applications can be conducted through software quality testing and evaluation systems. These types of systems are used to study mostly the functional suitability, reliability, performance efficiency, and usability of the software. Aspects of accessibility testing and evaluation are considered part of usability testing and analysis, from the perspective of the software product quality model formalized in ISO/IEC 25010:2023(en).

The methods and tools of software quality research are diverse. They can be implemented with or without the participation of representatives of the target audience. Software products integrate various technologies, among which biometric data processing-based ones are gaining popularity. Biometric technologies are the most suitable for accessibility research due to their independence from the external environment, high accuracy of the results, improvement of communication capabilities, especially from the human side, and work with mental commands.

The proposed software accessibility evaluation system model is crucial for creating software that is accessible to all users, including those with disabilities. It ensures equal access, legal compliance, and user experience improvement. Such a system will help organizations comply with regulations and standards, avoiding potential legal issues. It also expands market reach by catering to users with disabilities, aligning with corporate social responsibility. Accessible software positively influences a company's brand reputation, increasing customer loyalty. It also improves employee productivity by ensuring workplace applications are usable by all employees, promoting a more inclusive work environment. The proposed system model also fosters innovation and creativity by addressing accessibility challenges.

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