

# An Adaptive, Explainable and Lightweight Framework for Real-Time Web Content Accessibility

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## ABSTRACT:

The rapid growth of web-based information systems has increased the cognitive and environmental cost of accessing digital content, particularly for users with diverse accessibility needs. Many existing AI-driven accessibility solutions rely on cloud-based, computationally intensive models that raise concerns related to latency, privacy, and energy consumption. In this paper, we propose an adaptive, explainable, and lightweight AI-driven framework for real-time web content accessibility that aligns with sustainability principles. The framework dynamically adjusts textual complexity and presentation using interpretable linguistic analysis and implicit user behaviour, while operating entirely on the client side to minimize computational overhead and carbon footprint. We introduce three core components: (i) an Adaptive Readability Optimization (ARO) algorithm for real-time text simplification, (ii) a Behaviour-Aware Personalization Model (BAPM) that incrementally learns user preferences using implicit interaction signals, and (iii) an Explainable Difficulty Classification Framework (EDCF) for transparent content difficulty assessment. Experimental evaluation demonstrates significant improvements in readability, low processing latency, and energy-efficient operation suitable for sustainable AI deployment. The proposed approach highlights how lightweight, explainable AI systems can contribute to inclusive and sustainable digital ecosystems.

**Keywords:** Cognitive Web Accessibility, International Classification of Function (ICF), Cognitive Impairments, User-Centred Design and Inclusive Web Design.

## I. INTRODUCTION:

The increasing reliance on digital platforms for education, communication, and knowledge dissemination has intensified the need for accessible and sustainable web technologies. While artificial intelligence has enabled advanced content processing and personalization, many AI-driven accessibility solutions depend on large-scale models and server-side computation, leading to increased energy consumption, latency, and privacy risks. These challenges conflict with the principles of sustainable and inclusive technology development.

Users with cognitive, linguistic, or perceptual differences—such as dyslexia, attention-related challenges, or limited language proficiency—

often experience cognitive overload when engaging with complex web content. Existing accessibility tools primarily focus on static visual customization or rule-based text simplification, offering limited adaptability. Conversely, machine learning-based systems, though effective, introduce computational and environmental overhead that limits their scalability in real-world settings.

In this context, there is a growing need for AI-driven accessibility frameworks that are not only adaptive and effective but also lightweight, explainable, and energy-efficient. This paper addresses this gap by proposing a client-side accessibility framework that leverages interpretable algorithms and implicit user

behaviour to dynamically adapt web content in real time.

The primary contributions of this work are:

- An Adaptive Readability Optimization (ARO) algorithm that performs real-time, linear-time text simplification using interpretable linguistic metrics.
- A behaviour-Aware Personalization Model (BAPM) that incrementally adapts accessibility preferences based on implicit reading behaviour, reducing user effort and computational cost.
- An Explainable Difficulty Classification Framework (EDCF) that provides transparent, rule-based assessment of content difficulty, supporting trustworthy AI.

By emphasizing lightweight computation and explainability, the proposed framework aligns with the objectives of AI-driven sustainability and inclusive digital transformation.

## II. LITERATURE REVIEW

The research on \*\* spans theoretical analysis and data driven methods.[1] The study by Stefan Johansson et al. (2025) introduces an ICF core set for cognitive web accessibility, aiming to bridge the gap between cognitive impairments and web design practices. The research identifies 46 ICF categories covering areas such as attention, memory, perception, and problem-solving, and maps them to practical design considerations. The authors emphasize that designers often lack understanding of cognitive impairments, which leads to ineffective accessibility solutions. By using ICF as a structured framework, the study enables designers to better understand user limitations and create inclusive interfaces. This work highlights the importance of focusing on cognitive functions rather than medical diagnoses, which aligns closely with the proposed project

approach.[2] Research by Richard D. Hortizuela (2022) reviews the current state of web accessibility for people with cognitive disabilities. The study finds that most accessibility efforts prioritize visual and physical impairments, leaving cognitive accessibility largely neglected. It identifies key challenges such as information overload, confusing navigation, and complex instructions, which significantly affect users with ADHD, autism, and memory impairments. The paper concludes that there is a strong need for improved frameworks and design strategies to support cognitive users, supporting the motivation behind this project.[3] Recent research on inclusive web accessibility proposes a shift from static compliance models to user-centred and customizable interfaces. Instead of one-size-fits-all solutions, systems allow users to adjust features such as text size, contrast, and layout based on their cognitive needs.[5] A systematic review of Assistive Technology for Cognition (ATC) highlights how digital tools can support cognitive functions such as memory, attention, and task management. The study uses the ICF framework to classify cognitive support systems and shows that technology can effectively assist users in performing daily tasks.

## III. EXISTING SYSTEM

Current web accessibility systems are mainly based on standards like the World Wide Web Consortium's Web Content Accessibility Guidelines (WCAG). These guidelines focus on making web content accessible for users with visual, auditory, and motor impairments. Most existing systems include:

- Screen reader compatibility
- Keyboard navigation
- Colour contrast adjustments
- Alt text for images

While these features are essential, they primarily address sensory and physical disabilities, not

cognitive challenges. Some modern approaches attempt to support cognitive accessibility by:

- Simplifying text content
- Providing consistent navigation
- Reducing visual clutter
- Using assistive tools (like reading aids or extensions)

However, these implementations are:

- Not standardized
- Not based on a structured framework like ICF
- Often applied inconsistently across websites.

#### **Demerits of the Existing System:**

##### **1. Lack of Focus on Cognitive Impairments**

Existing systems largely ignore users with:

- Memory issues
- Attention disorders
- Learning disabilities

##### **2. Absence of a Structured Framework**

There is no strong mapping between:

- Cognitive limitations
- Specific UI/UX solutions

##### **3. One-Size-Fits-All Approach**

Most accessibility solutions:

- Apply the same features to all users
- Do not adapt to individual cognitive needs

##### **4. Poor Content Readability and Complexity**

Websites often contain:

- Complex language
- Dense information
- Confusing layouts

##### **5. Lack of Personalization**

Users cannot:

- Customize interfaces easily
- Adjust content based on their cognitive ability

##### **6. Inconsistent Implementation**

Even when cognitive features are used:

- They vary from site to site
- There is no standard guideline for developers

##### **7. Limited Integration of Assistive Technologies**

Existing systems do not effectively integrate:

- Memory aids
- Attention guidance tools
- Task simplification features

## **VI. PROPOSED SYSTEM**

The proposed system consists of multiple interconnected modules designed to improve cognitive web accessibility using the ICF framework. The first component, the Cognitive Analysis Module, focuses on identifying and categorizing key cognitive functions such as attention, memory, perception, and problem-solving. This module uses the principles of the ICF (International Classification of Functioning) to understand how different cognitive impairments affect user interaction with web interfaces. By analyzing these functional limitations, the system establishes a strong foundation for designing appropriate accessibility solutions.

The second component, the **ICF-Based Mapping Engine**, serves as the core of the system by creating a structured relationship between identified cognitive limitations and corresponding design strategies. Instead of relying on general

accessibility practices, this module provides a scientific mapping approach where each cognitive challenge is linked to specific UI/UX adaptations. For example, users with memory impairments are supported with consistent navigation and reminders, while users with attention difficulties benefit from reduced distractions and highlighted content. This mapping ensures that design decisions are purposeful and effective.

The **Adaptive UI/UX Design Module** is responsible for implementing the design solutions generated by the mapping engine. It focuses on simplifying the user interface by reducing complexity, improving readability, and organizing content in a clear and structured manner. Techniques such as simplified layouts, proper visual hierarchy, intuitive navigation, and the use of icons and readable fonts are applied to minimize cognitive load. This module ensures that users can easily understand and interact with the website without confusion.

Another important component is the **Personalization Layer**, which allows users to customize the interface according to their individual cognitive needs. This module enables adjustments such as changing text size, modifying layout complexity, and selecting preferred visual settings. By providing flexibility and control to users, the system moves away from a one-size-fits-all approach and supports a more user-centred and inclusive design experience.

Finally, the Evaluation and Feedback Module assesses the effectiveness of the proposed system through usability testing and performance metrics. It measures factors such as task completion rate, user satisfaction, and ease of navigation to determine how well the system supports users with cognitive impairments. The feedback collected is used to refine and improve the system continuously, ensuring better accessibility and usability over time.