Nafath

by Mada

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Interdisciplinary Synergies: Pioneering Advances in Assistive Technologies and Digital Accessibility

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About Mada

Mada – Assistive Technology Center Qatar, is a private institution for public benefit, which was founded in 2010 as an initiative that aims at promoting digital inclusion and building a technology-based community that meets the needs of persons with disabilities (PWDs). Mada today is the world's Center of Excellence in digital accessibility in Arabic.

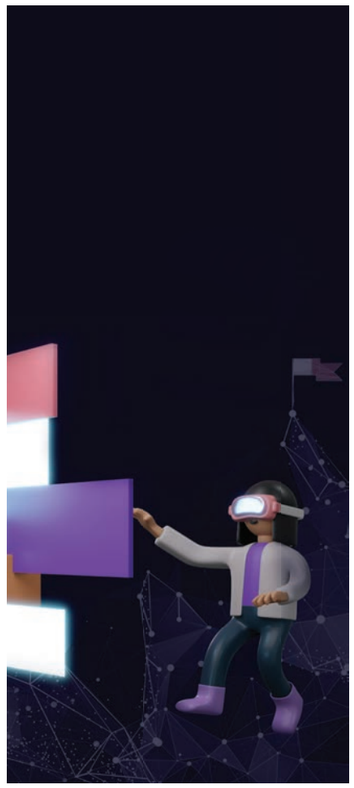
The Center works through smart strategic partnerships to enable the education sector to ensure inclusive education, the community sector through ICTs to become more inclusive, and the employment sector to enhance employment opportunities, professional development and entrepreneurship for persons with disabilities.

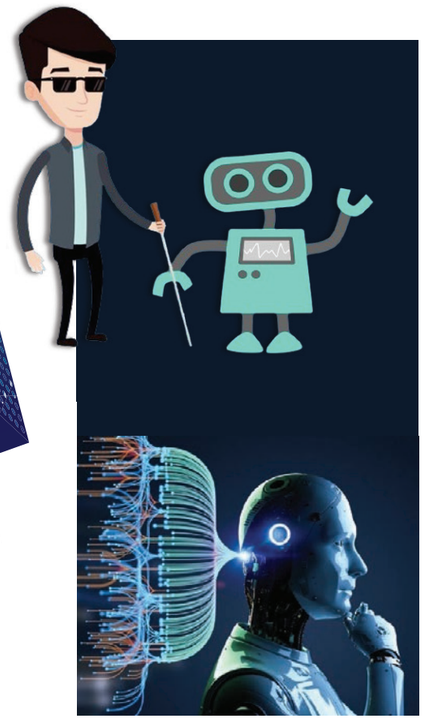
The Center achieves its goals by building partners' capabilities and supporting the development and accreditation of digital platforms in accordance with international standards of digital accessibility. Mada also raises awareness, provides consulting services, and increases the number of assistive technology solutions in Arabic through the Mada Innovation Program to ensure equal opportunities for the participation of persons with disabilities in the digital society.

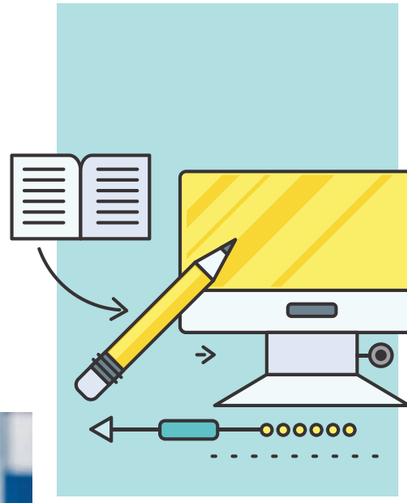
About Nafath

Nafath aims to be a key information resource for disseminating the facts about latest trends and innovation in the field of ICT Accessibility. It is published in English and Arabic languages on a quarterly basis and intends to be a window of information to the world, highlighting the pioneering work done in our field to meet the growing demands of ICT Accessibility and Assistive Technology products and services in Qatar and the Arab region.

Content Page







NAFATH 2024

Majlis | مجلس

Nafath

Open call for papers

Nafath is a quarterly magazine and workshop event known as Majlis Nafath.

Majlis Nafath aims to showcase the latest research, advancements, and knowledge sharing in the field of digital inclusion. In each edition, we invite innovative research and perspectives through a new call for papers, fostering a cycle of innovation and collaboration in these fields. Nafath periodical is available in both English and Arabic. Its aim is to support the growing need for accessible ICT and Assistive Technology in Qatar, the Arab region, and the world.

Why publish with us?

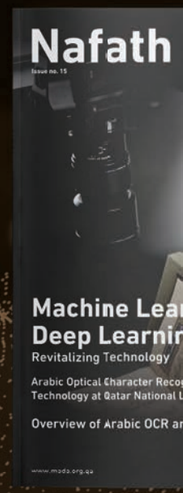
All accepted and presented papers will be published in Nafath periodical, under an ISNN reference, on paper, and on digital support. Nafath is a member of CrossRef (http://www.crossref.org/) and every paper in our digital library is given a DOI. The proceedings will be submitted for indexation by Google Scholar.

Submissions

We invite the submission of papers exclusively in English or Arabic, which have to be formatted in accordance with Nafath template guidelines (For more details about the instructions, please visit Instruction for Authors - Nafath periodical by Mada). Authors may submit their papers through our online submission portal available at: nafath.mada.org.qa

Main Topics

- Interdisciplinary Synergies: Pioneering Advances in Assistive Technologies and Digital Accessibility
- The role of Next-Generation User Interfaces to support People with Disabilities
- The Rise of Cutting-edge Tools for Autism and Learning Hurdles
- The Role of Digital Accessibility in Shaping Resilient and Inclusive Smart Cities



NAFATH 2024 Majlis | مجلس

About the 1st Edition of Majlis Nafath

Q1-2024

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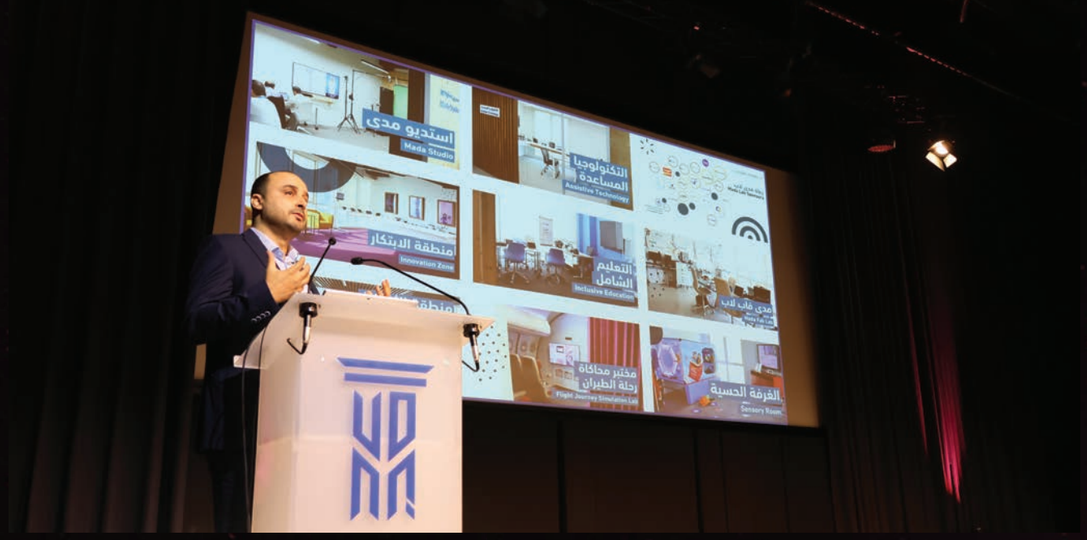
جامعة الدوحة للعلوم والتكنولوجيا
UNIVERSITY OF DOHA FOR SCIENCE & TECHNOLOGY

The 1st edition of Majlis Nafath presented a platform to discuss the recent research outcomes on assistive technology, sign language processing, and educational techniques for visually impaired students, which underscore the evolving intersection of technology and accessibility. The event reveals the potential of AI to revolutionize assistive solutions, enhancing independence and facilitating personalized learning experiences for individuals with disabilities. Challenges such as ethical dilemmas and the necessity for inclusive designs are acknowledged, emphasizing the need for a holistic approach to technological development. The presentation of a sign language project illustrates technology's role in promoting inclusivity and communication within the deaf community. Meanwhile, innovative strategies for teaching mathematics to visually impaired students highlight the importance of accessible educational tools. This collective insight stresses the importance of multidisciplinary collaboration to overcome obstacles and leverage technology for social inclusion, advocating for continuous innovation to ensure equal opportunities for all individuals with disabilities.

Keywords
Majlis Nafath,
Digital Accessibility,
Assistive Technology.



Introduction

Mada Assistive Technology Center launched the first edition of the quarterly event "Nafath Majlis" under the title "Interdisciplinary Synergies: Pioneering Advances in Assistive Technologies and Digital Accessibility," sponsored by the University of Doha for Science and Technology (UDST). The event sheds light on digital accessibility and assistive technology, improving digital inclusivity and enabling people with disabilities to live independently and integrate into all aspects of life. It addressed the community and research layers of the Mada Innovation Program [1]. The Nafath Majlis is held quarterly through events, workshops, seminars, and discussions before releasing the quarterly "Nafath" newsletter, showcasing the latest research and relevant scientific papers. The "Nafath" newsletter highlights the latest developments in innovation, digital accessibility, and assistive technology worldwide. The Nafath Majlis serves as a platform for presenting, discussing, and exchanging experiences about these developments, bringing together technology professionals, innovators, experts, researchers, and specialists in the field. It also allows interested students to expand their knowledge and explore the latest technological innovations through interactive workshops, enabling them to discuss topics presented by official speakers.

The first edition of the Nafath Majlis focused on specific topics that will be highlighted in the current "Nafath" newsletter issue. The sessions and workshops further explored the challenges hindering people with disabilities from accessing certain digital classifications, websites, and intelligent applications. They will also discuss ways to develop and adapt digital content to be more inclusive, thereby reducing the digital divide for people with disabilities [2].

Keynote Speeches

Distinguished speakers shared their insights on various topics at the forefront of assistive technology and its application to enhancing the lives of individuals with disabilities. Their talks encompassed advancements in AI, the development of new projects for sign language, and educational strategies for visually impaired students, highlighting the intersection of technology and accessibility.

AI and Assistive Technology:
Applications and Challenges, by Dr. Belkacem Chikhawi, UDST, Qatar

Dr. Chikhawi delved into the rapidly evolving field of Artificial Intelligence (AI) and its integration into assistive technologies. He outlined the vast potential AI holds in transforming the lives of individuals with disabilities through personalized learning algorithms, intelligent prosthetics, and voice-assisted devices. Despite the promising applications, Dr. Chikhawi also addressed the challenges, including ethical concerns, the need for user-centric design, and the importance of ensuring these technologies are accessible and affordable. His talk emphasized the necessity for a multidisciplinary approach to overcome these obstacles and realize the full potential of AI in assistive technology.

Jumla Sign Language Project:
An Overview, by Dr. Oussama El Ghoul, Mada Center, Qatar

Dr. El Ghoul presented the innovative Jumla Sign Language Project, an initiative to bridge communication gaps for the deaf and hard-of-hearing community. He outlined the project's goals to create a comprehensive digital library of sign language interpretations, making information and communication more accessible [3]. Dr. El Ghoul discussed the collaborative efforts behind Jumla, highlighting how the project leverages technology to preserve and standardize sign language, ensuring inclusivity and equal opportunities for all. The project exemplifies how technology can be harnessed to support cultural and linguistic diversity while promoting social inclusion.

A Perspective on Technology and Visually Impaired Students' Learning of Mathematics, by Dr. M. Corlu, UDST, Qatar

Dr. Corlu offered a compelling insight into the challenges and opportunities in teaching mathematics to visually impaired students. He discussed innovative technological solutions that facilitate a more inclusive learning environment, such as tactile graphics, audio-based instruction, and interactive software designed for visually impaired learners. Dr. Corlu emphasized the importance of adaptive learning tools that cater to the unique needs of these students, enabling them to explore mathematical concepts independently and effectively. His talk underscored the critical role of technology in democratizing education and providing visually impaired students with the tools they need to succeed academically.

Overview of the Accepted Papers

Technology-Enhanced Learning Environments for learners with disabilities

Ilahi et al.'s paper focuses on enhancing Technology Enhanced Learning Environments (TELE) for learners with disabilities through assessment analytics. Despite the progress in e-learning personalization for people with disabilities, the integration of assessment analytics remains largely untapped. The paper introduces a novel scenario model for assessment analytics aimed at developing a recommendation framework tailored to the needs of learners with disabilities. This framework leverages learners' preferences, accessibility needs, and assessment data to recommend the most suitable learning and assessment resources in an online learning context. The main critical points of the paper are:

- The design of an ontological scenario model centered on assessment analytics, addressing the gap in personalized e-learning for learners with disabilities.
- The framework is innovative in its comprehensive approach to recommendation, considering learners' profiles, including their preferences and accessibility requirements, alongside their performance data.
- The framework aims to enhance the accuracy and relevance of resource recommendations by integrating assessment analytics, fostering a more inclusive and effective learning environment.

- The research identifies a lack of existing models that fully incorporate e-accessibility and e-assessment analytics to personalize learning experiences for individuals with disabilities.
- The proposed framework and its underlying models are anticipated to contribute significantly to educational technology by facilitating accessible learning through personalized recommendations based on robust assessment analytics.

Contactless Health Diagnosis Using Generative Artificial Intelligence

Abdenour Hadid's pioneering paper, *"From Mind-Reading to Health-Reading Machines: Towards Contactless Health Diagnosis using Generative Artificial Intelligence,"* delves into the burgeoning field of leveraging generative AI for non-invasive health diagnostics. By examining the subtle correlations between facial features, expressions, and underlying health conditions, this research seeks to innovate how health monitoring and diagnostics are conducted. Envisioning a future where technology like "magic" mirrors and "smart" glasses can unobtrusively monitor and diagnose health issues from facial cues, Hadid proposes a shift towards more accessible and continuous health management tools. This work highlights the intersection of computer vision, generative AI, and healthcare, aiming to create computational models that can understand and interpret the visual indicators of health conditions directly from a person's appearance. The work of Hadid covered the following points:

- Hadid's research underlines the potential of using generative AI and computer vision to detect health abnormalities through facial structures and expressions. This would offer seamless integration into daily life for continuous health monitoring.
- The study showcases innovative applications, such as home mirrors that monitor physiological and emotional states and smart glasses that assess patient pain levels, exemplifying the shift towards non-contact, proactive health management.
- The work also acknowledges the challenges in developing these AI-driven diagnostic tools, including privacy concerns, data scarcity, the necessity for large-scale computational resources, and the need for multimodal analysis to enhance accuracy and reliability.
- Emphasizing collaboration across disciplines, Hadid calls for a joint effort between biomedical and computer sciences to refine these technologies and ensure they are efficient, explainable, and trustworthy.
- The paper illuminates the future possibilities of contactless health diagnosis and critically addresses the ethical and technical hurdles that must be overcome to realize this vision fully.

Exploring the Impact of AI in Assistive Technology

In the comprehensive study *"Enhancing Accessibility: Exploring the Impact of AI in Assistive Technologies for Disabled Persons"* by Dr. Reshmy Krishnan and Dr. Sivakumar Manickam, the transformative potential of Artificial Intelligence (AI) in assistive technologies is meticulously examined. Addressing the needs of approximately 15% of the global population experiencing some form of disability, this paper investigates various AI-driven models and their applications in aiding disabled individuals. Through a detailed analysis of prior research and current developments, the study underscores AI's critical role in improving the quality of life for people with disabilities by enhancing their independence, communication, mobility, and access to information. The integration of AI with Assistive Technology and the Artificial Intelligence of Things (AIoT) devices marks a significant advancement, offering a glimpse into the future where assistive devices are supportive, intuitive, and adaptive to the user's needs. The paper addressed the following highlights:

- Impact of AI on Assistive Technologies: The paper highlights AI's revolutionary advancements to assistive technologies, facilitating a more inclusive and accessible digital environment for individuals with disabilities. AI's role in developing smart and adaptive assistive devices enhances user experience and autonomy.
- Diverse Applications of AI: It details various AI applications in assistive technologies, such as speech recognition, computer vision for object recognition, gesture recognition, and motion control, demonstrating AI's versatility in addressing a wide range of disabilities.
- Challenges and Future Directions: While acknowledging significant progress, the study also points out challenges such as data scarcity, privacy concerns, and the need for high computational power. The study discusses the future implications of AI in assistive technologies, emphasizing ongoing research and the potential for AI to further bridge the gap between ability and technology.
- Real-world Examples and Research: The paper incorporates examples from current research, including smart wheelchairs, wearable devices for gesture recognition, and systems for cognitive assistance, to illustrate the practical application and effectiveness of AI-enhanced assistive technologies.
- Conclusion on AI's Transformative Potential: The study concludes on a hopeful note, reaffirming the belief that AI can significantly improve accessibility and independence for disabled persons and advocating for continued research and development in this promising field.

Accessible Metaverse: An Expert Opinion

"Is the Metaverse Accessible? An Expert Opinion" by Christina Yan Zhang and Khansa Chemnad delves into the burgeoning domain of the Metaverse, exploring its accessibility for individuals with disabilities. The paper scrutinizes the core elements of the Metaverse, such as immersion, real-time interaction, and user-generated content, considering their potential to make digital realms more inclusive. The expert opinion talks are part of the outcomes addressed in the paper Accessible Metaverse to raise awareness about inclusivity [4].

The analysis juxtaposes the innovative solutions provided by augmented reality (AR) and virtual reality (VR) technologies against significant challenges like the digital divide and the necessity for adaptive technologies. Despite these hurdles, the Metaverse offers promising avenues for self-determination, social interaction, and economic participation for people with disabilities, highlighting its potential benefits and the obstacles that must be surmounted to ensure it serves as a genuinely accessible and empowering platform.

Demo Talks

Jose Rubinger presented a demo talk entitled *"Enhancing Digital Accessibility and Learning Outcomes: Key2enable's Assistive Technology for Children with Disabilities"* by Yusra Sayed and Sabrin Shaikh. The talk comprehensively examines Key2enable's assistive technology and its impact on children with disabilities. This technology, including the Key-X device and Expressia platform, facilitates communication, learning, and independence for children with motor impairments and neurodivergence. Through an exploratory study involving ten children, the paper highlights the transformative potential of these tools in fostering motivation, engagement, and integration into mainstream education.

The study demonstrates how Key2enable's solutions, by merging hardware and software, offer a holistic approach to digital accessibility and cognitive stimulation. Observations from the research indicate significant progress in participants' abilities to engage with educational content and social interactions, underscoring the role of motivation in utilizing assistive technology for educational purposes and leisure.

Conclusion

The dialogues on the integration of technology in accessibility and education for individuals with disabilities have shed light on the transformative power of AI and digital innovations. By addressing both the potential and the challenges of these technologies, it's clear that a focused, collaborative effort is essential to making accessibility universal.

Innovations in sign language digitization and specialized educational methodologies demonstrate significant strides toward inclusivity. However, the journey towards accessible and equitable solutions for all individuals with disabilities continues.

The emphasis on user-centric design, ethical considerations, and the need for multidisciplinary collaboration underscores the path forward. As technology evolves, so must our commitment to leveraging it in ways that dismantle barriers and foster a more inclusive society for individuals with disabilities.

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Insights Unveiled in the Latest Publications from Mada Edge

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Mada Qatar Assistive Center Qatar's recent compilation of research outcomes, "Insights Unveiled in the Latest Publications from Mada Edge," provides a comprehensive exploration of the advancements and challenges in digital accessibility and inclusion. The collection spans various topics, each focusing on different aspects of technology's role in facilitating a more inclusive environment for individuals with disabilities.

Keywords
Mada Edge, Digital Accessibility, Assistive Technology.

Introduction

Digital technologies have heralded a new era of opportunities and challenges in accessibility and inclusion. As the world becomes increasingly interconnected through the internet and various digital platforms, ensuring these spaces are accessible to everyone, including people with disabilities, has never been more critical. The Mada Center Qatar, a beacon of innovation and advocacy in the field of digital accessibility, has been at the forefront of research aimed at dismantling barriers and fostering an inclusive digital environment for all individuals. The present paper presents an overview of the latest publications of Mada Edge, the research unit of Mada Qatar Assistive Technology Center.

Digital Accessibility and Artificial Intelligence

The paper "Digital Accessibility in the Era of Artificial Intelligence—Bibliometric Analysis and Systematic Review" explores the crucial role of artificial intelligence (AI) in advancing digital accessibility for individuals with disabilities, such as visual, auditory, motor, or cognitive impairments [1]. Conducting a comprehensive review of academic articles from 2018 to 2023, this study sifted through 3,706 articles from five scholarly databases, including ACM Digital Library, IEEE Xplore, ScienceDirect, Scopus, and Springer, ultimately focusing on 43 articles that offer significant insights into AI applications for enhancing digital accessibility. The research introduces a classification framework categorizing the findings into applications, challenges, AI methodologies, and adherence to accessibility standards. The findings underscore a significant emphasis on AI solutions for visual impairments while identifying a notable gap in

research for other disabilities such as speech and hearing impairments, autism spectrum disorder, neurological disorders, and motor impairments. This discrepancy suggests a need for a more inclusive research approach to provide equitable support across all disability communities. Furthermore, the paper highlights non-compliance with established accessibility standards in current systems, calling for a paradigm shift in designing AI-driven solutions to ensure comprehensive support for people with disabilities. This study emphasizes the imperative of incorporating accessible AI technologies to avoid exclusion and discrimination, advocating for a holistic approach to digital accessibility that accommodates the varied needs of individuals with disabilities.

Is the Metaverse Accessible?

The paper "Accessible Metaverse: A Theoretical Framework for Accessibility and Inclusion in the Metaverse" explores the potential of the Metaverse to enhance digital accessibility for people with disabilities [2]. Through qualitative analysis and expert opinions from various fields, the paper examines the Metaverse's current inclusivity, its design principles, and the challenges and opportunities it presents regarding accessibility. The research identifies significant advancements in incorporating assistive technologies into the Metaverse. Yet, it also highlights notable gaps, particularly in achieving interoperability across different virtual environments and integrating assistive technologies at the foundational level.

The study proposes a comprehensive framework for future research and policy interventions to promote inclusivity within the Metaverse. This framework emphasizes technological innovation, user-centric design, universal access, and global standards for accessibility. It underscores the importance of involving individuals with disabilities in the design process to ensure the Metaverse is built with accessibility at its core.

The paper contributes to the ongoing discourse on digital accessibility in the Metaverse, offering insights into its complexities and a roadmap for future exploration and development. It argues for a multifaceted approach incorporating technological advancements, ethical considerations, legal compliance, and continuous research to create an inclusive and accessible digital realm for all individuals.

Collaborative Play for Autistic Children

Under the auspices of the QRDI-QNRF-funded project titled “Multisensory Tangible Technologies for Inclusive Collaborative Play between Children with Autism Spectrum Disorder and their neurotypical Peers,” we have successfully published two papers. These publications lay a solid foundation for the experimental phase of the project, offering valuable insights into the development and application of multisensory tangible technologies to facilitate inclusive play.

The research paper titled "The what, where, who, why, which, and how of collaborative play involving autistic children in an educational context: a contextual inquiry" delves into the intricacies of collaborative play among autistic children within educational settings [3]. Given the pivotal role of play in child development and its educational significance, this study aims to unravel the dynamics, methodologies, challenges, and technological barriers affecting collaborative play among autistic children. Conducted in two distinct environments—an inclusive international school and a center for children with disabilities in Qatar—this study leveraged a mixed-method approach, incorporating 45 interviews with therapists, teachers, and parents alongside 48 observational sessions with autistic children. Through inductive reasoning and thematic analysis, the research identified six principal themes, encapsulated as the '5W-H'—who, where, what, why, which, and how—detailing the actors, locations, tools, purposes, senses, and processes involved in collaborative play. Additionally, the observations revealed four central themes focused on the nature and potential of collaborative activities. These findings are instrumental in informing future research and educational practices, offering deep insights into enhancing collaborative play and, consequently, the learning experiences of autistic children.

The systematic literature review on the "Co-design of Technology Involving Autistic Children" underscores the significance of involving autistic children in co-designing technologies tailored to their needs [4]. This involvement ensures that the resulting products are not only accessible but also optimally beneficial to this diverse group. The study meticulously analyzed 2482 papers from six significant databases, with 82 fulfilling the criteria for in-depth analysis. It highlights the complexity of engaging autistic children, who may have a wide range of communication abilities, including those who are minimally verbal or non-verbal. The review categorizes the findings into four main themes: advancements in co-design goals and outcomes, factors influencing participant selection, fundamental co-design techniques, and strategies for overcoming co-design challenges. It brings to light the critical need for inclusive practices and equitable support in the co-design process, advocating for the adaptation of technologies and methodologies to meet the varied needs of autistic children effectively. This approach enriches the design process and ensures the development of more relevant and impactful technological solutions.

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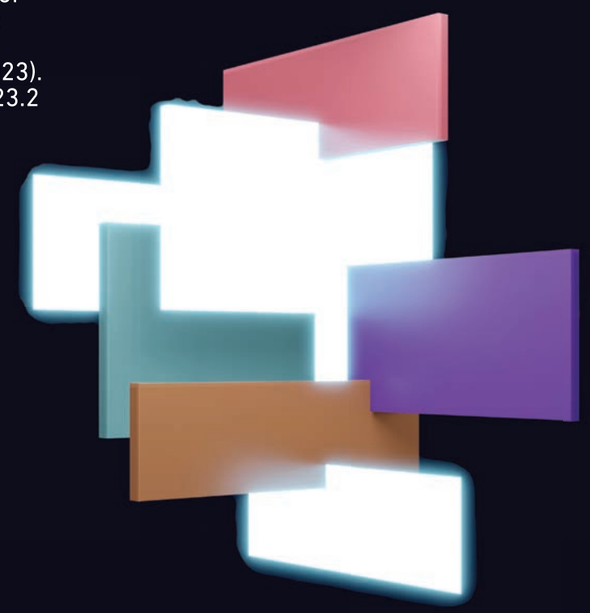

Is the Metaverse Accessible?
An Expert Opinion

Abstract

The Metaverse, a collective virtual shared space created by the convergence of virtually enhanced physical and digital reality, has raised questions about its accessibility for people with disabilities. Studies have explored the potential of the Metaverse to transcend traditional accessibility barriers, offering innovative solutions through augmented reality (AR) and virtual reality (VR) technologies. The core elements of the Metaverse, including immersion, real-time interaction, persistence, interoperability, decentralization, and user-generated content, serve as the foundation for a digital universe intended to be inclusive and accessible to all, including people with disabilities. However, significant challenges remain in ensuring equitable access for all users. These challenges include the digital divide, the need for adaptive technologies, and the potential for the Metaverse to exacerbate the existing inequalities in access to information and resources. Despite these challenges, the Metaverse has the potential to provide people with disabilities with opportunities for self-determination, social interaction, and economic participation through accessible workspaces and communities.

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Keywords
Metaverse; Disability; Accessibility; Inclusion

Introduction

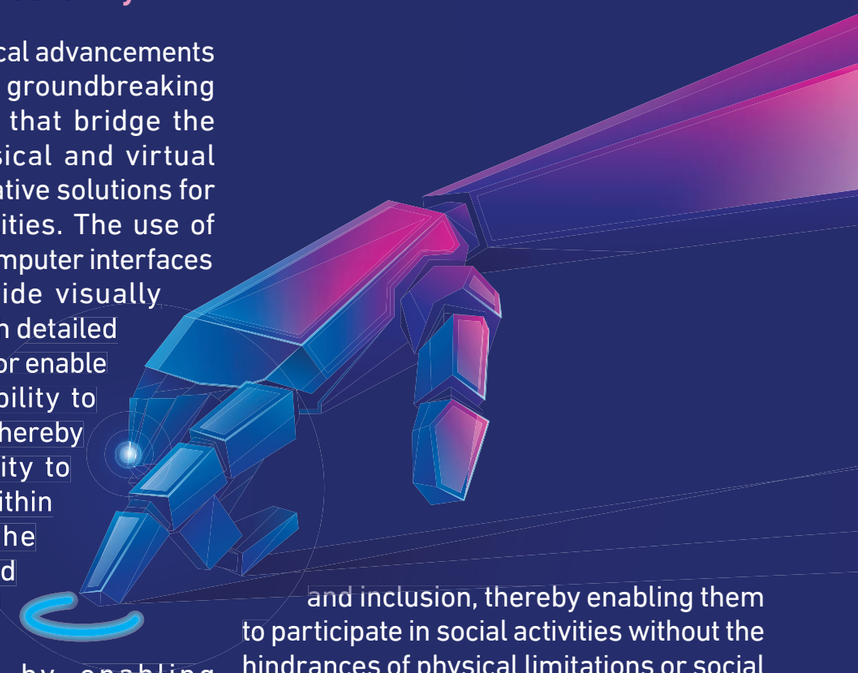
The advent of the Metaverse, a collective virtual shared space created by the convergence of virtually enhanced physical and digital reality, has ushered in a new frontier for digital interaction, education, and commerce. However, as this digital universe expands, questions arise about its accessibility for people with disabilities, a crucial aspect that determines the inclusivity and universality of this emerging technology. Studies have begun to explore the potential of the Metaverse to transcend traditional accessibility barriers encountered in physical spaces, offering innovative solutions through augmented reality (AR) and virtual reality (VR) technologies. For instance, Kye et al. discuss the educational applications of the Metaverse, including the use of AR for medical education, highlighting the potential for immersive learning experiences that can accommodate diverse learning needs [1] Conversely, challenges such as the digital divide and the need for adaptive technologies remain significant concerns that could limit accessibility for individuals with disabilities. This paper aims to critically analyze the accessibility of the Metaverse for people with disabilities, examining both the opportunities for enhanced engagement and the obstacles that may hinder their full participation.

Metaverse Core Elements and Digital Accessibility

In the evolving landscape of the Metaverse, its core elements—immersion, real-time interaction, persistence, interoperability, decentralization, and user-generated content—serve as the foundation for a digital universe intended to be inclusive and accessible to all, including people with disabilities. Accessibility within the Metaverse can be defined as the capacity for individuals, regardless of their physical, cognitive, sensory, or situational disabilities, to engage fully with virtual environments and experiences. The intersection of Metaverse principles with digital accessibility suggests a promising avenue for enhancing the inclusivity of virtual spaces, though this potential is tempered by significant challenges in ensuring equitable access for all users [2]. Digital accessibility in the Metaverse is crucial for ensuring everyone can participate equitably. The Metaverse's potential to transcend physical limitations through avatars can empower people with disabilities to engage in activities and communities that might be difficult in the real world [3]. In the context of the Metaverse, digital accessibility encompasses the ability for everyone, regardless of their abilities or limitations, to fully participate and engage in its virtual environments and experiences. This requires considering not just physical limitations but also cognitive, sensory, and situational constraints.

Theoretical Advances and Challenges in Accessibility

The Metaverse's theoretical advancements are paving the way for groundbreaking assistive technologies that bridge the gap between the physical and virtual worlds, providing innovative solutions for individuals with disabilities. The use of haptic suits and brain-computer interfaces could potentially provide visually impaired individuals with detailed environmental feedback or enable those with limited mobility to control avatars directly, thereby enhancing their capacity to navigate and interact within virtual spaces. [4]. The utilization of AI-powered systems holds the potential to significantly enhance accessibility by enabling seamless customization of interfaces and user experiences to suit individual preferences [5]. These systems offer the ability to personalize avatar interactions, information presentation, and navigation, thereby catering to a diverse range of cognitive styles and physical limitations. The potential of immersive environments for virtual rehabilitation and therapy also presents a significant opportunity, offering interactive and engaging ways to practice social interactions, manage anxiety, or address PTSD in safe virtual settings [6, 7]. Avatar creation and personalization offer a unique opportunity for individuals with disabilities to enjoy enhanced representation



and inclusion, thereby enabling them to participate in social activities without the hindrances of physical limitations or social prejudices [8]. Virtual workspaces and online learning environments are increasingly democratizing access to education and employment opportunities by enabling individuals to participate in conferences, collaborative projects, and other academic activities from anywhere in the world [9]. These technological advancements have the potential to break down traditional barriers to education and employment by providing a level playing field for individuals from diverse backgrounds and locations. Metaverse's virtual communities provide opportunities for community development and cooperation [10]. These platforms enable individuals confronting similar

difficulties to connect and form support networks, transcending geographical and physical limitations.

Despite significant advancements, numerous obstacles remain to be overcome in making the Metaverse completely inclusive and accessible. One of the most pressing challenges is providing universal access to the necessary hardware and software, including affordable and adaptable VR equipment, user-friendly interface design, and widespread internet connectivity, to prevent further marginalization [11]. Another concern is data privacy and security, as personal information shared in the Metaverse could result in discrimination, necessitating robust security measures and ethical guidelines to safeguard users. Furthermore, the immersive nature of the Metaverse raises ethical questions regarding mental health, ownership of virtual representations, and the risk of exploitation [12, 13]. Overcoming these challenges is essential for realizing the Metaverse's full potential as an empowering and inclusive space for individuals with disabilities.

Leveraging the Metaverse for Insights into Disability Experiences

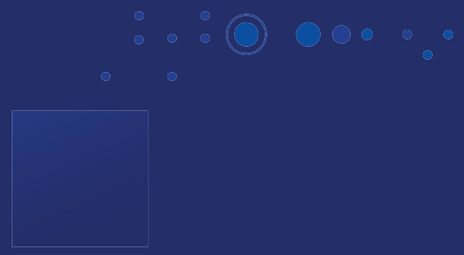
The metaverse presents a unique opportunity for gaining insights into the experiences of individuals with disabilities in digital spaces and for advancing digital accessibility and disability empowerment [2]. By simulating various accessibility challenges, virtual environments can mimic physical and sensory limitations, such as mobility restrictions by adjusting gravity and terrain and sensory impairments by modifying audio and visual settings. This simulation allows users to test different assistive technologies and design features, providing valuable feedback for improvement. Controlled studies within these environments can evaluate the impact of accessibility features on user performance and engagement, informing the development of real-world solutions. Specific use cases, such as VR exposure therapy programs like Bravemind for veterans with PTSD, VR games for motor and cognitive rehabilitation like Mindmaze: Endeavor, and VR pain management experiences like SnowWorld, illustrate the metaverse's potential for understanding and enhancing digital accessibility and empowerment for individuals with disabilities [14–16].

Ensuring Inclusivity and Accessibility in the Metaverse

The Metaverse is constantly evolving, so accessibility frameworks must be flexible and adaptable. Ongoing research, user feedback, and data analysis will be crucial for continually improving accessibility over time. Universal Design principles, interoperability standards, and principles of user agency and control are crucial for crafting a cohesive approach to digital accessibility in the Metaverse. These frameworks advocate for flexible, user-controlled, and universally accessible virtual experiences and underscore the importance of continuous improvement and user involvement in design processes. To ensure the Metaverse is inclusive and accessible for all users, regardless of their abilities, it's essential to prioritize accessibility from the outset [17]. To make the Metaverse more accessible, it is essential to integrate accessibility principles into the core design philosophy, establish clear guidelines and standards, and involve people with disabilities in the design process to address their needs directly. A user-centered design and co-creation approach is crucial, which requires user research with diverse participants, utilizing participatory design methods, and embracing iterative development for continuous improvement of accessibility features. To address specific accessibility challenges, alternative control methods for physical accessibility should be developed, sensory accommodations like text-to-speech and audio descriptions should be provided, clear interfaces for cognitive accessibility should be designed, and the affordability and availability of necessary hardware and software should be ensured. By adopting these strategies, the Metaverse can become a space where everyone can navigate, interact, and participate fully, fostering an inclusive digital world.

Enhancing Digital Accessibility in the Metaverse

The Metaverse is becoming increasingly accessible through a range of technological solutions, tools, and best practices that cater to users with disabilities. These include evolving VR/AR interfaces that offer alternative control methods, such as eye-tracking, voice commands, haptic feedback, and brain-computer interfaces, which provide users with motor limitations with additional ways to interact. AI-powered assistance tools, like text-to-speech and voice recognition software, as well as AI-powered virtual assistants, are enhancing the user experience for those with visual or auditory impairments by providing guidance and support [18]. Companies like STRIVR and Oculus VR are leading the way in creating accessible virtual reality experiences tailored for training, education, and therapy, demonstrating the significant potential for inclusive content development. Additionally, the adoption and extension of existing accessibility guidelines, such as the WCAG and W3C Accessibility Guidelines, into the Metaverse are crucial for ensuring a consistent and interoperable experience across various platforms, paving the way for a more inclusive digital universe.



Emerging Technologies and Accessibility

The potential of emerging technologies, such as cryptocurrency and blockchain, in shaping the development of the metaverse is significant, with far-reaching implications for accessibility and inclusivity [19], particularly for individuals with disabilities. By leveraging the decentralization offered by blockchain, the metaverse can reduce its dependence on centralized platforms [20], thereby enabling the creation of accessible environments that cater to the unique needs of people with disabilities. Cryptocurrency can facilitate a thriving internal economy, providing new opportunities for economic participation through microtransactions and decentralized asset ownership, benefiting creators and service providers with disabilities. Additionally, the implementation of smart contracts on blockchain can enable the establishment of automated, inclusive governance systems that promote equal rights and opportunities for all users [21].

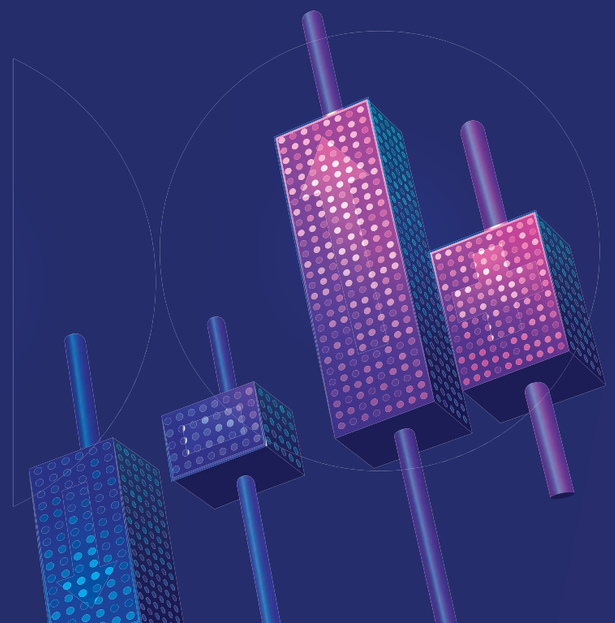
Ensuring that the benefits of cryptocurrency and blockchain technologies do not exacerbate the digital divide remains a challenge. It is crucial to give serious thought to ensuring accessibility, affordability, and the availability of essential skills and resources, particularly for individuals with disabilities who ought to be able to participate fully. In addition, security and privacy concerns are of utmost importance, as decentralized platforms may expose users to increased risks of scams, hacking, and data breaches [22]. To mitigate these risks, robust security measures must be implemented, and users must be educated

on best practices. Furthermore, there is a need to address the current lack of accessibility considerations in blockchain and cryptocurrency initiatives. Developers and platform creators must prioritize accessibility standards and adopt user-centered design principles to ensure that the metaverse becomes a truly inclusive space where inclusivity is not just envisioned but realized.

Societal Implications

The potential of the Metaverse to effectuate transformative change in the realm of disability empowerment and digital accessibility is vast and far-reaching. Its impact extends to the very fabric of societal attitudes towards disability and accessibility, as it provides individuals with disabilities with unparalleled opportunities for self-determination and participation. Through virtual environments, individuals can express themselves, engage in social interactions, and engage in economic activities through accessible workspaces and communities [2]. By allowing users to customize their avatars and experiences, the Metaverse challenges traditional notions of disability, highlighting individual strengths and capabilities rather than limitations. This shift in perspective has the potential to foster a more inclusive and accepting society. Metaverse has stimulated the development of innovative assistive technologies by presenting unique challenges that drive the creation of more intuitive, user-friendly, and cost-effective solutions for both virtual and real-world accessibility. This has necessitated a reevaluation of accessibility standards to encompass a wider array of needs, including sensory, cognitive, and situational, encouraging the integration of inclusive design principles across diverse environments, products, and services.

The Metaverse has the potential to foster greater empathy and understanding among users who are not disabled by offering simulated disability experiences that shift the focus from limitations to abilities and potential. By doing so, the Metaverse can help encourage a culture that values inclusivity, empowering individuals with disabilities and challenging societal stereotypes and discrimination. Furthermore, the Metaverse can provide safe spaces for self-expression and community building, enabling individuals with disabilities to advocate for greater inclusion and equal rights [23]. Ultimately, this shift towards inclusivity has the potential to lead to a more respectful society.



Conclusion

In conclusion, the Metaverse holds tremendous potential for enhancing digital accessibility and empowering individuals with disabilities. By prioritizing accessibility, addressing specific challenges, leveraging emerging technologies, and fostering collaboration among stakeholders, we can ensure the Metaverse becomes an inclusive and empowering space. Ethical and legal considerations, along with future research directions, will play a crucial role in shaping an accessible and equitable digital frontier. Achieving this vision requires a concerted effort from all stakeholders involved in the design, development, and governance of the Metaverse. Future research should focus on refining legal frameworks to enhance inclusivity, formulating decentralized governance that supports equitable access, and devising solutions to bridge socioeconomic disparities. Additionally, it is crucial to conduct in-depth investigations to assess the long-term psychological and social effects of metaverse immersion on individuals with disabilities, to ensure the accessibility of avatar-based interactions, and to evaluate the balance between artificial intelligence and human-centered design in meeting comprehensive accessibility demands. Adopting this comprehensive approach will be instrumental in advancing our understanding and fostering an inclusive metaverse environment.

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Enhancing Accessibility
Exploring the Impact of AI in Assistive Technologies for Disabled Persons

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Abstract

As per the World Health Organization, approximately 15% of the global population experiences some form of disability. The integration of Assistive Technology with Artificial Intelligence of Things devices has witnessed significant advancements. This paper, through research, aims to identify various assistive models utilized in diverse studies focusing on the application of Artificial Intelligence. Starting with past research studies in this area and emphasizing the manifold and noteworthy roles of AI in assistive technologies, the paper delves into the prospective applications of AI in the future of assistive technologies.

Keywords
Assistive Technologies, Artificial Intelligence, AIoT, Dragon natural speech, Amber script, Voice Access, Speech note.

1 Introduction

Communication is a key factor in leading a fulfilling life. For people with communication disorders, this can be a major obstacle. An assistive technology is a tool or device used to assist people in carrying out their daily activities. A digital accessibility focuses on making digital content and technologies accessible to everyone, including people with disabilities. Assistive technologies have come a long way in helping people with disabilities live more independent and fulfilling lives. With the advancements in artificial intelligence (AI)[1], these technologies are becoming even more powerful and effective. In this paper, we will explore the latest trends and developments in AI-based assistive technologies for disabled persons. How AI is revolutionizing accessibility, how AI is breaking down barriers for Individuals with Disabilities, how AI is creating a more inclusive digital environment.

2 Assistive Technologies

Assistive technologies are devices or software that help people with disabilities perform tasks that they would otherwise have difficulty doing. These technologies can range from simple tools like wheelchairs and hearing aids to more complex devices like speech recognition software and prosthetic limbs [1].

The goal of assistive technologies is to bridge the gap between a person's abilities and the demands of their environment. With the help of these technologies, people with disabilities can improve their quality of life, increase their independence, and participate more fully in society. As a cutting-edge journal covering the use of artificial intelligence (AI) and other cutting-edge technologies, the Assistive Technology Journal is proud of its position [9].

Type of Assistive technologies

- Visual:
  Individuals with limited vision, color blindness, or blindness.
- Auditory:
  Individuals with hearing impairments.
- Motor:
  Individuals with tremors and spasms, slowness of the muscles, or restricted fine motor control.
- Cognitive:
  Individuals who struggle with reasoning and problem solving, memory problems, learning impairments, or attention issues.

In order to improve a person with a disability's independence, mobility, communication, and general quality of life, assistive technologies are essential. The following are a few of the main advantages of assistive technology for the disabled:

- Increased Independence
- Enhanced Communication:
- Improved Mobility
- Access to Information
- Employment Opportunities
- Inclusive Education
- Social Inclusion
- Health Monitoring
- Environmental Control
- Customization and Personalization
- Empowerment and Self-Esteem
- Legislation and Advocacy

3 Role of AI in Assistive technology

The integration of Assistive Technology with devices and machine learning in the realm of Artificial Intelligence of Things (AIoT) has experienced significant advancements —from now on referred to as AIoT—devices and machine learning. Artificial intelligence has revolutionized the field of assistive technologies. With its ability to learn, adapt, and make decisions, AI has opened up new possibilities for people with disabilities. AI-based assistive technologies can analyze data, recognize patterns, and make predictions, making them more efficient and effective than traditional assistive technologies. In general, people with impairments participate in society more when they are not faced with hurdles. Under these circumstances, assistive technology, or AT, directly lowers the challenges that individuals with impairments face on a daily basis [10].

AI can also be integrated into existing assistive technologies, making them smarter and more user-friendly [11,12,13]. For example, AI can be used in prosthetic limbs to analyze the user's movements and adjust accordingly, providing a more natural and comfortable experience.

4 Previous Research

Junior et al.'s [14] research introduced a system framework leveraging computer vision and machine learning within an IoT network, supported by cloud computing, aimed at enhancing capacity. In this setup, images captured by an IoT device are transmitted to an edge component (IoT node) for processing. This processing includes object identification, distance computation, and conversion of the gathered data into audible commands, intended to offer guidance to individuals with visual impairments.

In Su et al.'s investigation [16], they presented the development of a finger-worn gadget tailored for visually impaired individuals to recognize traditional Chinese characters. This device operates on a micro IoT processor. The setup worn on the index finger comprises a compact camera and buttons. These components capture images by detecting the position of the index finger in relation to the printed text. Visually impaired users utilize the buttons to capture an image, triggering an audio output of the corresponding Chinese character via a voice prompt.

Lee et al.'s [17] research introduced a smart wearable system for interpreting American Sign Language (ASL), employing deep learning techniques and sensor fusion. This fusion integrates six inertial measurement units (IMUs) to enhance the system's performance and functionality.

The IMUs are affixed to each fingertip and the back of the hand to detect

sign language gestures, allowing the proposed method to operate without limitations imposed by the field of view.

The model reaches an average recognition rate of 99.81% in case of dynamic ASL gestures. Integrating the ASL recognition system with ICT and IoT technology offers a viable solution to aid hearing-impaired individuals in communication with others.

Al Shabibi and Kesavan [18] introduced an affordable smart wheelchair solution utilizing an Arduino Nano microcontroller and IoT technology. This system offers various features aimed at assisting disabled individuals, particularly those from low-income backgrounds who may not have access to expensive smart wheelchairs or the necessary assistance to complete daily tasks independently. The cost-effective smart wheelchair, suitable for a diverse spectrum of disabled individuals and built around the Arduino Nano, comes with features including a Wi-Fi module for connectivity, a fall detection module with voice message alerts through the IFTTT platform, obstacle detection with a buzzer, hazard lights using LEDs, a voice recognition system, and joysticks for wheelchair control.

Sharma et al. [19] introduced DeTrAs, an Internet of Health framework employing deep learning techniques to support individuals with Alzheimer's disease.

It operates through three key components: a recurrent neural network-based prediction model for Alzheimer's disease utilizing sensory movement data, and an ensemble method for tracking abnormalities in Alzheimer's patients, consisting of two distinct parts:

a) An emotion detection scheme based on convolutional neural networks.

b) a natural language processing scheme based on timestamp windows; and lastly, an IoT-based assistance system for Alzheimer's patients. The evaluation of DeTrAs shows a nearly 10–20% enhancement in accuracy compared to various other existing machine-learning algorithms.

5. Applications of AI as assistive technologies [1,10,11,12,13]

Speech Recognition and Natural Language Processing (NLP).

Advanced technological solutions have been developed to convert spoken language into written text. These tools leverage intricate algorithms and artificial intelligence (AI) to analyze and interpret spoken words, translating them into precise and readable text in real-time. This bridging of the gap between spoken and written communication not only facilitates accessibility but also offers an effective means of expression for individuals with disabilities or limitations. These tools seize audio input, undergo intricate processing via advanced speech recognition systems, and produce corresponding written text. This empowers users to communicate, generate content, and interact with others through written language. Given their capacity to improve accessibility and inclusivity, speech-to-text tools have evolved into indispensable resources for individuals dealing with speech impairments, hearing impairments, motor disabilities, dyslexia, and various other conditions.

Dragon natural speech: Dragon Systems [3], is a speech recognition software package. The software, designed for Windows personal computers, operates on both 32-bit and 64-bit editions of Windows 7, 8, and 10. Version 15, available in Professional Individual and Legal Individual editions, was released in August 2016.

Amberscript [2] stands out as an outstanding speech-to-text tool, offering numerous advantages for individuals with disabilities. With its advanced technology and user-friendly interface, Amberscript serves as a dependable and precise solution for transforming spoken language into written text. Amberscript employs cutting-edge speech recognition algorithms and AI technology, guaranteeing a high level of accuracy when transcribing spoken words.It has User-Friendly Interface. It provides versatile integration options, enabling users to seamlessly incorporate the tool into their preferred devices or software.

VoiceAccess is a mobile application from Google [4]. It can control mobile phone using voices in sending text messages, image messages, voice messages and video messages.Windows also provides in built voice recognition applications as default in PCs.Apple also provides voice assistive applications for controlling the device using voice.

Speechnote is another technology[4] reliable and secure web-based speech-to-text tool that enables you to quickly and accurately transcribe your audio and video recordings, as well as dictate your notes instead of typing, saving you time and effort. With features like voice commands for punctuation and formatting, automatic capitalization, and easy import/export options, Speechnotes provides an efficient and user-friendly dictation and transcription experience.

Audible is helpful for individuals with reading problems. Kurzweil 3000 is a Natural Text - to - speech voices (over 70 languages). PCX 550 Wireless eliminate's or reduces noises for concentrating. SuperTalker[4]: allows users to record information for 16 minutes.

Predictive Text and Autocorrect.

AI algorithms predict user input and correct spelling, aiding individuals with motor disabilities or difficulties in typing. It eases communication for those with conditions affecting fine motor control.

Mouseware [5] is an affordable head-wearable

device that enables hands-free operation of computers & smartphones. Mouseware helps you to operate smart devices with any operating system hands-free. This helps people with various conditions use computers without the need for a mouse or any pointing device. There are various switches such as foot switch, finger switch etc to work mouse or any pointing device

Snap&Read[5] Universal is effective to utilize by those individuals who have reading problems. Co:Writer Universal is a word prediction software. Mathtalk: allows users to solve math equations. Spanish Talking Calculator: speech technology that would read out the numbers inputted. Inspiration: help's users organize information visually.

Ginger help's check spelling and definition of words. Watch Minder help's manage day to day activities. Conversor Personal FM is helpful for individuals with hearing issues. TrackerPro is computer input device that takes the place of a mouse. Mobile Connect is a personal hearing assistant for visual impairment.

Computer Vision for Object Recognition

AI-based computer vision can identify and describe objects in the environment. Assists individuals with visual impairments in navigating their surroundings by providing information about the objects around them.

Tobil: A purpose-built[7] speech generating device controlled with your eyes to communicate and access Windows. Eye tracking is a technology that is used to see where a person is looking on a computer screen. The technology can also be used to control the computer. Instead of using a traditional keyboard and mouse, you control it by using your eyes.

Smart glasses: are a revolutionary[7,15] form of wearable technology that combines augmented reality (AR) and artificial intelligence (AI) to provide users with a hands-free, interactive, and immersive experience. These futuristic glasses are equipped with a display screen, camera, sensors, and AI algorithms, enabling users to access information and interact with the digital world seamlessly. By utilizing AI algorithms, smart glasses can recognize objects and text in the user's surroundings. This allows individuals with visual impairments to receive audio descriptions of their environment, enabling them to navigate more easily and independently. Smart glasses equipped with AI can provide real-time translation of foreign languages. The AI capabilities of smart glasses enable facial recognition, allowing users to identify people they encounter. This feature can be extremely helpful for individuals with cognitive disabilities or memory impairments, as it assists in social interactions by providing information about the people they are engaging with.

Gesture Recognition and Motion Control.

AI interprets gestures and motions, enabling users to interact with devices using physical movements. It benefits individuals with mobility challenges who may find traditional input methods difficult.t.

- Lift ware:
  The mealtime [6] brings people together it's more than a we nourish our spirit and our relationships but tremor whether from essential tremor or Parkinson's disease takes away from this experience forcing people to focus instead on the basic task of eating. The liftware spoon cancel hand tremor and take the frustration out of eating for the first time. This technology actively stabilizes a person's tremor and the device so small that it fits in your hand. The spoon works by sensing a person's tremor and intelligently stabilizing itself to make the food's journey from the plate to the mouth much easier

- Personalized Interfaces:
  AI adapts interfaces based on user preferences and needs. It creates customized user experiences, making technology more user-friendly for individuals with various disabilities

  Weighted cutlery, smart technology like liftware spoon[6], built-up utensils, and universal cups are assistive devices for eating. Weighted cutlery can be helpful for individuals with tremor however it is important to note that not everyone benefits from this type of assistive device. liftware spoon is also designed to improve stabilization against tremors or shaky hands although these can be a more expensive option.

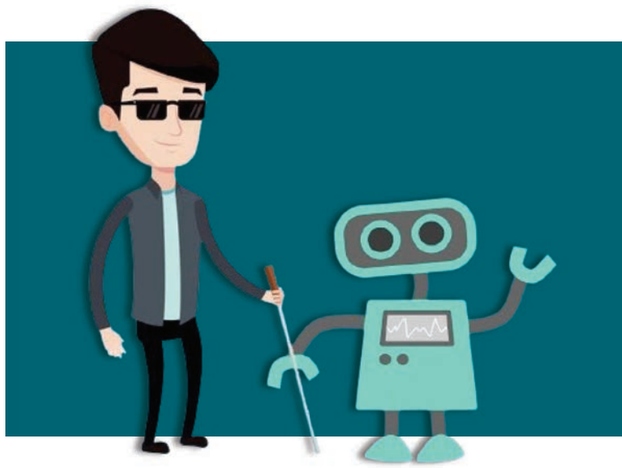
  Another option is a universal cup and this device can be useful for those with limited grip and dexterity. It is called universal because it can be used with other items like a toothbrush or a razor. A plate guard can be easily attached and detached from round plates and is used to prevent food from being pushed off the plate at mealtime.

- Cognitive Assistance
  AI plays a crucial role in improving cognitive assistance for disabled persons by enhancing the capabilities and effectiveness of cognitive support technologies. AI algorithms can analyze and understand individual cognitive needs, preferences, and challenges. It also can analyze contextual information, such as location, time, and user activities, to provide more contextually relevant and timely cognitive assistance.

AI enables cognitive assistance systems to learn and adapt to the changing cognitive abilities and needs of users over time.

Access Map [8] is an online and mobile app that helps users find accessible places. This app would find your required place which is nearest to you. You can request for ramp for disabled persons when making the request for visiting.

Assist Me is a mobility assistance app that allows users to request help and communicate their needs to service providers. This app functions as part of a broader system that employs computer vision and machine-learning methodologies within the IoT network, leveraging cloud computing to enhance capacity. Images captured by an IoT device are transmitted to an edge element (IoT node) for processing, where object identification, distance computation, and the conversion of this information into audible commands take place. This system is designed to offer guidance for individuals with visual impairments [14].



6 Future Implications of AI-based Assistive Technologies

AI technology has the potential to significantly improve the lives of disabled persons across various aspects. Here are some key impacts of AI on enhancing the lives of individuals with disabilities:

- natural language processing and voice recognition technology enable individuals with mobility impairments or visual impairments to control devices and access information using voice commands, making technology more accessible and inclusive.
- AI-powered smart home systems can automate tasks such as controlling lights, appliances, and temperature, allowing individuals with mobility limitations to manage their environment without assistance.
- Speech-to-text and text-to-speech conversion algorithms enable individuals to express themselves, interact with others, and engage in social activities, fostering social inclusion and reducing communication barriers.
- AI-powered prosthetic limbs can adapt to the user's movements and intentions, providing a more natural and seamless user experience.
- Personalized prompts, reminders, and cognitive support systems powered by AI algorithms assist individuals in memory retention, task management, and decision-making.
- AI-enabled tools can facilitate job accommodations, assist in task completion, and open up new avenues for work for individuals with disabilities.
- AI-powered diagnostic systems can assist in the early detection and monitoring of medical conditions. Robotics and exoskeletons integrated with AI algorithms enhance physical rehabilitation efforts, enabling individuals with mobility impairments to regain strength and independence.

7 Conclusion

In summary, the development of assistive technologies, particularly those that use artificial intelligence, represents a significant step toward a future that is more accessible and inclusive. Beyond just being convenient, AI-based assistive devices have a revolutionary impact on the lives of people with a range of abilities. The paper emphasizes the numerous and significant uses of AI in assistive technologies. These technologies, which range from computer vision and speech recognition systems to natural language processing, are empowering people with disabilities by removing obstacles and promoting their independence. The given example highlights AI's adaptability and potential to improve many people's quality of life.

But even as we celebrate these developments, it's important to acknowledge the difficulties that still lie ahead. It is crucial to carefully balance privacy issues, ethical issues, and the requirement for universal accessibility to guarantee that everyone can benefit from AI-based assistive solutions and that no one is left behind.

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From Mind--Reading to Health-Reading Machines

Towards Contactless Health Diagnosis using Generative Artificial Intelligence

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Abstract - **Generative Artificial Intelligence (AI) has recently shown impressive results across a wide spectrum of tasks. Inspired by the emerging notion of mind-reading machines and by the medical evidences indicating that some diseases and brain disorders produce facial abnormalities and interrupt normal facial expression formation, we are 1) establishing, in close interaction with medical practitioners, the basic understanding of the correlations between visual patterns and health conditions, and 2) developing novel computational models, based on Generative AI, to learn the identified correlations. Devising computational models for detecting abnormalities reflective of internal diseases based only on visual information is a highly intriguing research problem. The goal is to achieve ground-breaking results in unobtrusive health diagnosis and to gain insight into the correlation between face, body, and mind. This work has the potential to open new research directions in several fields and to bridge the gap between the research activities conducted in several disciplines like engineering and medicine. This article explains the main idea behind contactless health reading using generative artificial intelligence.**

Keywords
Generative Artificial Intelligence; Health Diagnosis; Computer Vision; Deep Learning.

1. Introduction

Inspired by generative artificial intelligence together with medical evidences indicating correlation between facial symptoms and some internal diseases (e.g., [1-4]), our work aims to devise computational models for detecting abnormalities reflective of diseases in person's facial structures and expressions based only on visual information. This would help designing futuristic unobtrusive technologies for health diagnosis and monitoring that people can effortlessly use in their daily lives without any contact. Imagine a "magic" mirror at home which unobtrusively monitors your physiological health measurements (e.g., heart rate and blood pressure), recognizes your affect states (e.g., stress and fatigue) and diagnoses possible diseases (e.g., imminent stroke or kidney infection) by only observing your face while you are in front of the mirror for activities such as shaving, brushing your teeth, or washing your face. Such a "magic" medical mirror could, for instance, provide real-time feedback information about your health condition and even act as an assistive and therapeutic device by displaying a realistic 3D face avatar for engaging emotional interaction and preventive activities. As a second example, imagine a doctor wearing "smart" glasses which can unobtrusively estimate the pain of neonates and post-surgery patients that are incapable of articulating and expressing their pain experiences. During the past decade, there have been numerous research and development efforts in the field of wearable health-monitoring systems that were motivated by the need to monitor a person's health status outside of the hospital [5-6]. However, most current techniques for health monitoring typically require users to strap on bulky sensors, chest straps or sticky electrodes. This obviously discourages regular use because the sensors can be uncomfortable or encumbering. Hence, to make health monitoring part of the fabric of everyday life, we believe that there is a need for new technologies that are comfortable (e.g., non-invasive and contact free), simple to use and unobtrusive. The idea of using computer vision for non-contact healthcare and wellness has the promise to improve the future of healthcare by enabling proactive and unobtrusive personal health, mental and activity management. It would enable long-term daily health monitoring at home, which is important for the treatment and management of many chronic illnesses, neurological disorders, and mental health issues such as diabetes, hypertension, asthma, autism spectrum disorder, depression, drug addiction, etc.

On the other hand, the development of generative AI models is already raising some concerns about privacy preservation and the potential emergence of super intelligent systems without adequate safeguards. Generative AI can indeed reveal sensitive health data or unintentionally produce biased or incorrect information due to biases in its training data. Moreover, generative models usually require large amount of high-quality unbiased data to operate - which is lacking in medical domain. Other equally important issues include the latency for generating high-quality samples and the massive computing power which is needed to train generative models. All these issues are important to be taken into consideration to effectively capitalize and guarantee beneficial use of generative AI.

The aim of this article is to explain the main potential and challenges behind contactless visual health reading using generative artificial intelligence, and to point out some future directions.

2. Motivations

Faces can be seen as projector panels of the mechanisms that govern our emotional behaviors and health (see Figure 1 for potential health conditions that can be reflected from a face). Automatic analysis of face patterns and movements (e.g., in terms of the activity of the facial muscles causing the visible changes in facial expression) for medical monitoring and diagnosis is indeed an exciting area of research. For instance, researchers at Massachusetts Institute of Technology (MIT) have published the pioneer work [6] pointing out the possibility of measuring heart rate, respiratory rate, and heart rate variability from face images acquired by a webcam under controlled settings. Moreover, researchers from the University of Southern California have shown, in preliminary investigations published in the prestigious Journal of Neurology, that eye movements could help in diagnosis of neurological disorders such as Parkinson's disease [1].

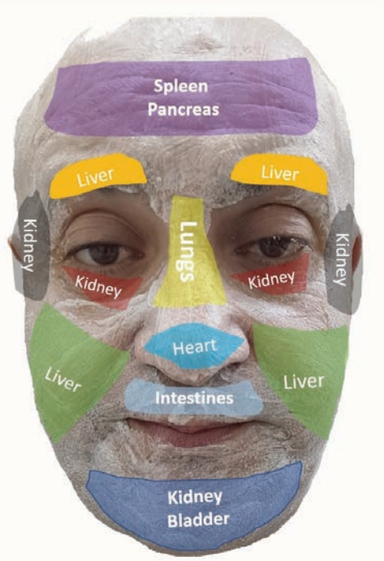

Figure 1.
Several internal diseases may have face symptoms.

Moreover, children with autism usually share some similar facial features (such as wider eyes, a wider mouth area and a broad upper face area but a shorter middle region of the face with a flattened nasal bridge). These signs are so subtle that they may not be noticeable for a human eye. They are however computationally very distinguishable. So, tools for early diagnosis of children with autism are important as they can improve a child's chances for a successful therapy. Many other diseases also produce facial abnormalities and interrupt normal facial expression formation (Figure 1). For instance, facial asymmetry is one of a number of traits associated with stroke problems; a white ring bordering the colored part of the eye can be a sign of fatty deposits caused by high cholesterol; eye twitching, also known as myokymia, is usually caused by random muscle contractions and may be triggered by lack of magnesium; a drooping eyelid can be a sign of a stroke, lung cancer, eye strain or stress; cracked lips are sometimes caused by anemia due to iron deficiency and may also be a sign of diabetes and so on. Furthermore, chronic affect states such as pain, stress, anxiety, and depression can also carry a wide array of pathophysiological risks, including cardiovascular disease, cerebrovascular disease, diabetes, and immune deficiencies, to cite only a few. New unobtrusive technologies that automatically recognize such states from the facial patterns and movements can be extremely powerful, both diagnostically and therapeutically. As a diagnostic tool, the technology could help individuals and clinicians gaining insight into the conditions that consistently provoke such states. As a therapeutic tool, the technology could be used to automatically initiate interventions. Inference of user's complex mental states (including emotions, cognitive states, intentions, beliefs, desires and focus of attention) from nonverbal cues and observed behavior is currently the challenge of the ongoing efforts toward mind-reading machines.

We aim to lay the core foundations for using computer vision and generative AI in healthcare by 1) establishing, in close interaction with medical practitioners, the basic understanding of the correlations between facial visual symptoms and health conditions, and 2) developing novel computational models that encode the identified correlations. While our primary focus is on health measurements that can be reflected from the face patterns and movements, other body parts and behavioral characteristics such as gait and gestures can also be considered in longer-term investigations, as such cues also convey health signals.

Our efforts are focusing on developing novel AI models for futuristic technologies that will enable us to continuously monitor our health and track our progress in all stages of life and diseases. The idea of using computer vision along with generative AI is appealing as it has the promise of enabling proactive and unobtrusive personal health management.

3. Challenges

Detecting abnormalities reflective of internal diseases in patient's facial structures and expressions based only on visual information is a highly intriguing and under-explored research problem. The critical issues concern the establishment of basic understanding of the correlations between facial visual symptoms and health conditions and then the development of new AI models that encode the identified correlations. We need to devise algorithms that would enable the construction of AI models from data representing health measurements and physiological processes occurring at different time scales and across a wide range of people and ages. The fundamental challenge of vision-based face analysis for healthcare partially lies in the enormous richness of the face patterns and the high complexity of the facial movements, e.g., due to no-rigidness. This raises several fundamental questions such as: how computer vision systems can differentiate between signs of diseases and make-ups and disguises, based only on visual information? which kinds of features (e.g., color, texture, motion, or depth) are most effective to diagnose a given disease? what facial regions (e.g., lips or eyes) are associated to what diseases? which kinds of data sensing technologies (e.g., thermal or 3D imaging) are necessary for detecting a given anomaly? how to efficiently infer complex mental states (e.g., stress) from subtle facial changes? can machine vision transcend human abilities in visual health diagnosis? how to enable computer vision to interact best with medical science? how to identify enough number of patients with particular disease for constructing representative and balanced datasets? Can generative AI help in creating synthetic samples for training AI models? how generative AI can be used while preserving the privacy? what is the degree and nature of the correlation between face, body, and mind? All of these are challenges that require thorough exploration.

Moreover, while generative AI has shown immense potential in various domains, its resource-intensive nature may hinder real-time usage and scalability. In fact, the large-scale generative AI models require significant computational resources and electrical power to operate, resulting in elevated energy consumption and significant carbon emissions. Consequently, this may restrict their deployment in real-world applications. Future efforts are then needed to design novel and efficient architectures capable of generating high-quality samples in real-time, vital for constrained platforms like in edge computing.

As generative artificial intelligence models can be considered in their early stages, here are some of the key challenges that still must be tackled to ensure applicability in healthcare:

3.1. Handling Sensitive Data

Health data refers to information that relates to the health status of a person. This is considered as highly sensitive data and is subject to additional precautions and strict rules [7]. AI models should incorporate adequate measures beyond pseudonymization and encryption.

3.2. Data Scarcity

Among the main challenges in using AI in healthcare is the lack of enough samples for training the models. Generative AI models usually require a large amount of high-quality and unbiased data to operate. Although generative AI models can be used to produce synthetic data for training, other strategies can be devised for scenarios with limited data [8].

3.3. Imbalanced Classes

A prevalent issue encountered in healthcare applications is the “class imbalance” problem, signifying disparities in the frequencies of positive samples (samples with a given disease) compared to the negative samples (samples without the given disease). Developing data-driven AI models from imbalanced datasets require additional attention [9].

3.4. High Computational Power

Large-scale computing infrastructures are usually necessary to maintain and develop generative models [10]. For example, diffusion models could require millions or billions of images to train. To train such large datasets, massive computing power (clusters with hundreds of GPUs) maybe be needed. Moreover, due to the very large-scale of generative AI models, there may be latency present in the time it takes to generate a sample.

4. Directions

4.1. Multimodal Analysis

Visual symptoms, physiological signals, affect states and some internal diseases are correlated and should be studied in a multimodal framework [11]. For instance, a high blood pressure under stress emotional state should not be considered as a serious warning. Of importance is also the combination of complementary information provided by different sensor data.

4.2. Collaboration Between Biomedical and Computer Sciences

Although generative AI can offer elegant solutions to many challenges on healthcare, it is essential to acknowledge that AI is not a complete solution that can replace human experience. The aim of AI is to support the clinicians as many problems necessity a through comprehension of the underlying medicine. This calls for a multi-disciplinary approach at the frontiers of computer vision, medicine, neuroscience, and psychology. The close collaboration between clinicians and researchers in all these disciplines is essential.

4.3. Sensing Beyond the Visible Light

Visual images acquired using conventional 2D cameras and/or at visible spectrum may have inherent restrictions that hinder the inference of some specific health details in the visual world [12]. One promising approach for dealing with those limitations is using images acquired beyond the visible spectrum and/or using non-conventional imaging (e.g., depth).

4.4. Data Efficient Modeling

Among the main challenges in using AI in healthcare is the lack of enough samples for training the models. Generative AI models usually require a large amount of high-quality and labeled data to operate. Although generative AI models can be used to produce synthetic data for training, other strategies can also be devised for scenarios with limited data. This includes few-shot learning [13], transfer learning [14], and domain adaptation [15] which offer the potential to enhance the AI performance when data is scarce.

4.5. Federated Learning and Privacy-Preserving Modeling

To alleviate concerns about patient privacy, federated learning is often suggested [16]. Federated learning is a collaborative approach to train machine learning models, not requiring an exchange of data from client devices (e.g., hospital) to global servers. The raw data on edge devices can be used to train a model locally, increasing data privacy. Then, each edge device shares its model's parameters to "reconstruct" the final model in the server.

4.6. Explainable and Trustworthy Modelling

Lack of transparency is among the barriers to ubiquitous use of AI in healthcare [17]. To strengthen trust, people need to understand how the AI technology works. Clinicians should indeed be confident in the AI systems. A possible step towards trustworthy AI is to develop explainable AI. Explainable AI aims to design models capable of generating decisions that a human could understand and interpret. This will strengthen the trust in AI models.

5. Conclusion

The integration of generative AI promises a paradigm shift in healthcare. However, with every innovation comes skepticism. The development of generative models in healthcare may indeed raise concerns about privacy protection and the potential emergence of super-intelligent machines without adequate safeguards. Generative AI can unintentionally reveal sensitive data or produce incorrect information due to biases in the training data.

Moreover, generative models usually require large amount of high-quality, unbiased data to operate. Other issues concern the latency for generating high-quality samples and the massive computing power which is needed to train generative models. So, at the end, can we really trust the outcomes of generative AI models for critical operational decision in healthcare? This call for explainable and trustworthy generative AI research.

In conclusion, generative AI will surely play a pivotal role in the future of healthcare. It is a powerful tool that can transform the way we interpret and understand healthcare data. While there are challenges to overcome, the potential benefits far outweigh the hurdles.

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Enhancing Digital Accessibility and Learning Outcomes

Key2enable's Assistive Technology for Children with Disabilities

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Abstract - This paper showcases how Key2enable's assistive technology works as a holistic solution comprising hardware and software that can enable people with severe disabilities to communicate, learn, engage, and autonomously use technology. This is an exploratory study and will develop a pathway to new developments in the field of assistive technology and portray how motivation plays a key role. The sample consists of 10 children with motor impairments and on the neurodivergence spectrum. There is insufficient research on this relatively small population and this study aims to address how using the right technology for cognitive stimulation can significantly accelerate progress and bring equal opportunities to all in this constantly changing digital world.

Keywords
assistive technology, children, disability, motor impairments, neurodivergence, motivation, digital accessibility, mainstream education, communication.

Introduction

Key2enable's innovative AT solutions exemplify this transformative potential of empowering individuals with disabilities, offering them avenues for independent living, communication, and engagement by addressing a spectrum of disabilities and fostering digital accessibility.

Today, AT isn't merely a technological tool but a catalyst for societal change. Despite its crucial role, there exists a notable gap in the literature regarding its impact. Key2enable's AT solutions have enabled children with disabilities to seamlessly integrate into mainstream education, focusing on their abilities rather than limitations. By combining hardware and software components, these solutions offer a holistic approach to education, providing an alternate pathway to learning. Introducing the right tools early on supports timely intervention, facilitating the achievement of developmental milestones crucial for a child's overall growth and learning trajectory (Berhman, 2021).

One striking observation is the immediate curiosity and motivation displayed by children when introduced to Key2enable's solutions. Motivation has been a major reason why children are using Key2enable's assistive technology not just for pursuing education but also for leisure purposes.

The primary use of any assistive technology is to assist an individual with disabilities to function independently. This sense of independence not only enhances their well-being but also promotes their participation in the community. It paves the way for inclusion and also helps these people lead a more dignified life. According to WHO, by the year 2030, a minimum of 1 billion people will need some form of assistive product in their lives. Despite the benefits of assistive technology and the understanding that it is a global need, access to AT remains limited.

This paper sheds light on the transformative potential of Key2enable's AT solutions, emphasizing the pivotal role they play in promoting inclusivity, independence,

and dignity for individuals with disabilities. Through in-depth exploration and analysis, it aims to contribute to the evolving discourse on assistive technology and its profound societal impact.

Key2enable's Assistive Technology

Key-X: The Key-X represents a groundbreaking advancement in assistive technology, offering a comprehensive solution for individuals with motor limitations. It features an electronic panel equipped with 11 touch-sensitive keys, meticulously positioned to optimize usability. By utilizing just nine keys in sequential pairs, users gain intuitive control over character input and computer commands, coupled with precise management of the mouse pointer. The placement of the keys, which are notably larger and spaced further apart compared to traditional keyboards, significantly simplifies their use and allows for operation using one's feet or even by blinking. Moreover, the brightly coloured buttons and symbols have been designed based on educational research and expertise, ensuring accessibility and creating an interactive experience.

Expressia: Expressia stands as an innovative online educational platform, tailored to the diverse needs of special educators, medical professionals, and parents/caregivers of Persons with Disabilities (PoDs). At its core, Expressia offers two primary modes: Alternative Communication and Cognitive Stimulation. The Alternative Communication feature serves as a pivotal resource for fostering communication skills in individuals with temporary or permanent speech difficulties, seamlessly integrating into daily interactions. Meanwhile, the Cognitive Stimulation mode provides a versatile platform for creating tailored tasks and engaging activities, aimed at enhancing cognitive functions such as thinking, concentration, and memory. With its adaptable framework, Expressia enables the formulation of personalized tutoring or activity methods, aligning with various curricula, syllabi, and formats.

Methodology: This research aims to demonstrate the efficacy of Key2enable's assistive technology for children with disabilities and its role in fostering motivation and digital independence. It investigates how this technology facilitates communication, learning, and integration into mainstream classrooms.

Sample: A purposive sample of 10 children, aged under 15, with motor impairments and neurodivergence, participated in the study. Consent was obtained from schools and parents across Brazil, United Arab Emirates, and Portugal.

Review of Literature

Recent studies in the field of assistive technology have highlighted the critical importance of technology in empowering individuals with severe disabilities to lead more independent and fulfilling lives. Jones et al. (2023) emphasized the significance of holistic solutions that integrate both hardware and software components, mirroring the comprehensive approach adopted by Key2enable's assistive technology. Their research underscored the effectiveness of such integrated solutions in addressing the multifaceted needs of individuals with disabilities, particularly in facilitating communication, learning, and engagement. Moreover, Smith and colleagues (2022) delved into the nuanced role of motivation in shaping the outcomes of assistive technology interventions. Their study elucidated how intrinsic and extrinsic motivational factors influence the uptake and utilization of assistive technology among individuals with disabilities, highlighting motivation as a key determinant of success in technology-mediated interventions. By considering motivational factors alongside technological innovations, researchers and practitioners can design more tailored and effective solutions that cater to the diverse needs and preferences of users.

Despite these advancements, there remains a notable gap in the literature concerning the application of assistive technology for children with motor impairments and those on the neurodivergence spectrum. This demographic represents a relatively small but underserved population, and existing research often overlooks their unique challenges and requirements. Therefore, this study aims to bridge this gap by exploring the potential of Key2enable's assistive technology in addressing the specific needs of children with motor impairments and neurodivergence. By examining the impact of this technology on cognitive stimulation and skill development within this demographic, the study seeks to contribute valuable insights to the ongoing discourse surrounding assistive technology and its transformative potential for individuals with severe disabilities.

By building upon and synthesizing findings, this paper endeavors to provide a comprehensive understanding of the current state of assistive technology research and its implications for individuals with severe disabilities. Through an exploration of Key2enable's technology and its application within this context, this study aims to advance knowledge and inform practice in the field, ultimately striving towards a more inclusive and accessible society for all.

Scope: The study explores the benefits of Key2enable's assistive technology and the user-friendly Expressia platform. It addresses the lack of research in this area, aiming to inform educators, parents, and medical professionals about effective interventions for children with disabilities.

Data Collection: Primary data was collected through direct observations, questionnaires, and interviews with caregivers, teachers, and doctors. Secondary data from literature supports the findings, focusing on participants' initial digital accessibility challenges.

Results: The study underscores the transformative impact of assistive technology on children's education and social integration. Participants, including those with cerebral palsy and autism, showed increased engagement and learning outcomes with Key2enable's solutions. Over time, children demonstrated enhanced confidence and peer interaction, alongside improvements in mobility and communication skills.

The study also provides preliminary evidence of the positive impact of Key2enable's assistive technology on the communication, learning, and engagement of children with motor impairments and neurodivergence. Quantitative measures, such as standardized assessment scores before and after the intervention, were subjected to inferential statistical analysis to determine the significance of observed changes. Additionally, qualitative data gathered through participant observations, interviews, and feedback sessions were analyzed thematically to uncover nuanced insights into the experiences and perceptions of both the participants and their caregivers. This mixed-methods approach aimed to provide a comprehensive understanding of the effectiveness and potential limitations of the technology, thereby informing future developments and implementations in the field of assistive technology for individuals with severe disabilities.

Sr No.	Demographics	Technology Usage Patterns	Observed Outcomes
1	Age: 12, Gender: Male	Used Key-X for typing and mouse control.	Improved motor control over time. Increased engagement in classroom activities. Enhanced communication skills.
2	Age: 10, Gender: Female	Utilized Expressia for Alternative Communication mode.	Improved speech and language skills. Increased participation in social interactions.
3	Age: 14, Gender: Male	Combined Key-X and Expressia for various tasks.	Enhanced cognitive abilities. Improved academic performance. Increased confidence and self-esteem.
4	Age: 8, Gender: Male	Used Key-X with feet due to mobility limitations.	Achieved independence in computer usage. Improved fine motor skills. Enhanced access to educational resources.
5	Age: 11, Gender: Female	Employed Expressia for Cognitive Stimulation activities	Improved memory and concentration. Enhanced problem-solving skills. Increased engagement in learning tasks.

6	Age: 13, Gender: Male	Utilized Key-X for computer access and gaming.	Experienced increased motivation for learning. Improved hand-eye coordination. Enhanced social integration with peers.
7	Age: 9, Gender: Female	Utilized Expressia for academic tasks and communication.	Demonstrated improved expressive language skills. Enhanced ability to follow instructions. Increased confidence in academic settings.
8	Age: 15, Gender: Male	Used Key-X for typing and Expressia for Cognitive Stimulation.	Demonstrated improved typing speed and accuracy. Enhanced critical thinking abilities. Increased independence in completing academic assignments.
9	Age: 7, Gender: Male	Employed Expressia for communication and learning activities.	Showed increased vocabulary and language comprehension. Improved attention span and focus during learning tasks.
10	Age: 12, Gender: Female	Utilized Key-X for computer navigation and Expressia for academic support.	Demonstrated improved motor skills and coordination. Enhanced understanding of academic concepts. Increased participation in classroom discussions.

Table 1. Participant Demographics, Technology Usage Patterns, and Observed Outcomes.

Imagem 1. Images of children with disabilities using Key2enable's assistive technology.

Conclusion

Key2enable's assitive technology is a great equalizer for children with disabilities. This is evident especially in the case of children with motor impairments and on the neurodivergence spectrum. It is also an efficient and powerful tool for educationists who work with these children in mainstream classrooms and this ensures an equal learning environment to all the children. To see a child who was not able to communicate for the first 5 years of his life and then says his first word with Key2enable's software solution is the clear picture to present the effectiveness or to see a child who was denied participation in a mainstream school can now finally have access to normal schooling says it all. This may just be another equipment for others but for these children it is giving them their right place in the community and tap into the best of their potential.

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Ontological scenario model for learners with disabilities in a recommender framework based on assessment analytics

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Abstract - Technology Enhanced Learning Environments (TELE) have attracted many learners to acquire knowledge and skills at their own pace. But the majority of these environments are not accessible for all categories of learners including learners with disabilities. In fact, some environments may provide content during the learning process that does not meet the profiles of every type of disability. Much research has been developed in the area of personalizing e-learning for people with disabilities. The use of assessment analytics, on the other hand, remains largely unexploited despite its great informative potential, which is elated to assessment data generated by online learning environment. Our proposal focuses on the design of a scenario model for Assessment Analytics to develop a recommendation framework for learners with disabilities. This framework is conceived to retrieve and select relevant learning and assessment resources to learners with disabilities based on their preferences, accessibility needs, and assessment trace data in the context of online learning.

Keywords

Assessment analytics; Recommender System; Disability.

Introduction

The term "disability" refers to any type of limitation that results from the interaction between a person with health problems and the environment [1]. Limitations can influence the quality of life of people with disabilities. This reflects the inability to access education. E-learning devices are a solution to include people with disabilities in education. These devices must be accessible and respond to all profiles of students with disabilities. The accessibility can be defined as the ability of the learning environment to adjust to the needs of all learners and is determined by the flexibility of the environment [2]. Our main objective is to select learning resources appropriate to various profiles of students with disabilities. To achieve this objective, we focus on recommendation techniques. Indeed, there are several recommendation techniques that are designed to provide relevant resources to a learner using certain information about the users and resources. According to [3] recommender systems in TELE must take into account features that are specific to the learning context. These characteristics are: learning goal, prerequisite knowledge, learner characteristics and preferences, learner grouping, learning resources, learning path and learning strategies. Much research has been developed in the area of personalizing e-learning for people with disabilities. Categories of systems developed include Virtual Learning Environment (VLE), Computer Assisted Instruction (CAI) and Intelligent Tutoring System (ITS). Many research works focused on the importance of accessibility in eLearning environments to provide a digital and inclusive education. Learning Environments should include components that are accessible and properly and universally designed to scaffold and enable each and every learner to learn effectively considering her/his abilities, disabilities, and individual learning preferences [4]. This work falls under the heading of learning analytics or educational data mining. The use of assessment analytics, on the other hand, remains largely unexploited despite its great informative potential. Assessment analytics is the analysis of assessment data generated by the online learning environment to improve the field of learning analytics. The added value of this research work is to focus on assessment analytics to develop a Recommendation Framework for learners with disabilities. To tackle our objective, the main research questions are:

- How can e-learning and e-assessment data be used to recommend educational resources?
- Which learner model covers the accessibility needs of each learner?
- What recommendation model based on the e-assessment analytics could be proposed for an accessible and personalized learning environment?

This paper is organized as follows: In section 2, we describe the Background and Related Work. A Recommendation Scenario Model is presented in Section 3. Section 4 provides the Proposed Recommendation Framework. In section 5, we describe the algorithms; and finally section 7 brings the conclusion.

Related Work

The aim of learning personalization is to provide a learner with online learning resources that are relevant to his characteristics. It is therefore needed to have recommender system capable of providing personalized recommendations or guiding the user to interesting or useful resources within a large data space [5]. E-learning platforms used recommender systems to "recommend relevant learning materials to learners and help them make decisions"[6]. There are mainly three approaches recommended in the field of e-learning research: content-based, collaborative-based, and hybrid-based. The majority of work related to recommendations in e-learning "focus on these conventional recommendation techniques" [7]. Content-filtering is one of the oldest recommendation approaches; it builds the user profile according to the characteristics of selected or preferred objects [8]. Content-based recommenders could be defined as systems that recommend according to the attributes or descriptors or characteristics or properties or even variables that represent the recommended items. Collaborative-based recommendation systems try to recommend items similar to those a given user has liked in the past, whereas collaborative filtering recommenders are based on the principle that users with the same personal features will probably like the same items. This approach is based on the tracking of other users' interactions with the system. The Knowledge-based approach matches the user's needs with the user's characteristics, based on items suggestion through logical inferences about the user's preferences and needs [9]. Using analytics, would enable to provide an accurate personalization process. Learning analytics is about measuring, collecting, analyzing, and reporting on data from learners in learning contexts for the purpose of understanding and optimizing learning and the environments in which they take place.

In our research work we focus mainly on assessment analytics, where data related to assessment is considered. The majority of the review research papers focus on Learning analytics in considering a personalization or a recommendation process. In our research work our target learning group is composed of learners with disabilities. It is therefore important to consider digital accessibility.

In this section, we discuss research work related to our research topic. We first focus on recommendation/personalization approaches. In [10] the authors propose an intelligent recommendation system for an online learning environment (EST-in-Line) to provide personalized courses and guide students to choose the most appropriate courses to their profiles. The recommendation technique used in this system is based on association rules. The authors do not address disability and do not exploit assessment analytics. The disability profile includes social, cognitive, and a disability classification model. An ontology-based personalization approach applied in an online learning environment for students with disabilities in higher education is proposed in also [11]. These two works do not address the analytics of assessment for personalization generation. The authors in [12] also proposed a recommendation technique by combining collaborative filtering and ontology to recommend personalized e-learning material to learners by considering learner characteristics. The learning materials are filtered according to the preconditions of the learner's request and the learner's knowledge. A mechanism for personalized search and recommendation of educational objects has been proposed in [13]. The approach is based on an existing trace-based system, and proposes an implementation of personalization services within the ARIADNE tool. The new features implemented concern the filtering of educational objects with respect to the user's preferred language and file format, as well as with respect to the resources consulted by the user. In [14] the authors proposed a hybrid and context-sensitive recommendation approach for museum visits. This approach combines three different methods: demographic, semantic and collaborative, each method being adapted to a specific stage of the visit. A recommendation system based on hybrid filtering of semantic information in communities of practice for e-learning (CoPE) is proposed in [15]. Collaborative filtering has been treated in [16], where authors proposed a recommender system using collaborative filtering of online learning resources. The proposed model contains five main components, namely, learner ontology, learning resource ontology, recommendation engine, Decision Algorithm (DA), and final recommendation component. An ontology-based personalized recommendation system for e-learning to recommend appropriate learning content to learners using collaborative filtering was also proposed [17]. OERs (Open Educational Resources) have been also used in [18] to design a customized OER recommendation approach that takes into account learners' skills, occupations, and accessibility properties to find the most appropriate and high quality OERs. In [19] a novel open ICT accessibility and inclusive design ICT-AID competency framework with a view to support individuals, and education and training institutions on delimiting the required relevant ICT accessibility competencies has been proposed. None of these works has provided a Recommendation Framework for learners with disabilities based on assessment analytics.

Ontological Scenario model

In this section we discuss the strengths and weaknesses of the proposed models and approaches that are cited in the related works.

From the comparative study between the personalization approaches proposed by the researchers we found that there is no personalization or recommendation framework for learners with disabilities that take into account both e-accessibility and e-assessment analytics. In this work, the recommendation system suitable for learners with disabilities is the one proposed by [18] since the authors have integrated the preferences and accessibility needs of each learner in the recommendation process. On the other hand, this approach has adopted the specifications of the IMS Access For All standard in order to define preferences, accessibility needs and digital resources.

Some authors proposed a new recommendation service includes two steps of filtering existing resources on the trace server: (1) filtering with respect to the user's preferred language and file format, and (2) filtering with respect to the number of occurrences of the keywords in the title of the resource currently viewed by the user in the title and description of each resource. In the literature, there are models to analyze assessment trace data like [20]. This model relies solely on assessment data to extend the xAPI model. We propose therefore to use this model to exploit the assessment data in the recommendation process, through a scenario model in an accessible environment. To allow reusability and sharing, our recommendation scenario model is built upon an ontological structure enabling the formalized representation of the recommendation process.

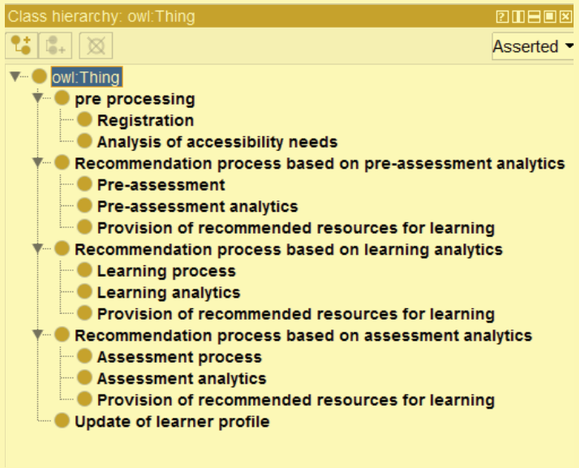
The whole scenario model is oriented to learners with disabilities, at each phase we need to take into consideration the profile of the learners, their preferences, to be able to select and recommend the most appropriate resources. Figure 1 shows the proposed scenario model which is composed of the following five main phases:

- **Phase 1: Pre-processing**
  In this phase two steps are necessary to feed the initial profile of the learner in order to analyze the behavior of the learner by the system:
  - **Registration:** In this step the learner's personal information and preferences are established via a graphical interface.
  - **Analysis of accessibility needs:** The accessible environment will analyze the learner's initial behavior and detect his handicap.
- **Phase 2: Recommendation process based on pre-assessment analytics**
  In this phase three steps must be carried out which are:
  - **Pre-assessment:** An initial test is set by the system to determine the learner's level of prerequisites in the field.
  - **Pre-assessment analytic:s** Based on the previous step, the system analyzes the pre-assessment traces to identify the learner's prerequisites level.
  - **Provision of recommended resources for learning:** In this step a list of resources is established to the learner according to the result of the pre-assessment analytics process.

- **Phase 3: Recommendation process based on learning analytics**
  - **Learning process**: This step represents the learner's engagement in the recommended learning process.
  - **Learning analytics**
  - **The system collects and stores learning traces and updates the learner's profile (preferences, learning style, etc.).**
  - **Provision of recommended resources for learning**
  - **This step represents the provision of recommended resources to the learner based on the learning analytics process.**

- **Phase 4: Recommendation process based on assessment analytics**
  - **Assessment process:** This step represents the learner's engagement to complete an assessment test.
  - **Assessment analytics:** The system collects and stores assessment traces and updates the learner's profile.
  - **Provision of recommended resources for learning:** This step represents the provision of recommended resources to the learner based on the assessment analytics process.

- **Phase 5: Update of learner profile**
  In this final phase, the learner's profile is updated based on the learning analytics and assessment analytics process.



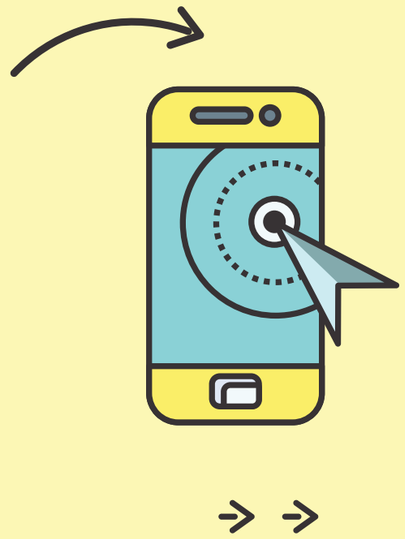


Figure 1. Ontology-based Recommendation Scenario Model

Recommendation Framework for assessment of learners with disabilities

The goal of our proposed recommendation framework is to retrieve and select relevant learning and assessment resources to learners with disabilities based on their preferences, accessibility needs, and assessment trace data in the context of online learning. This Framework can be composed mainly of three models: a model that covers the preferences and accessibility needs of each learner, a model that allows exploiting the assessment trace data and finally a recommendation model.

In the literature we found that the suitable recommender system to recommend resources to learners with disabilities compared to other works is the approach proposed by [18]. Since the authors take into account the preferences and accessibility needs of each learner. The authors do not consider learning and assessment trace data in the recommendation process.

First, we propose to extend this approach by an assessment analytics model from [20] to exploit assessment trace data in the recommendation process. Secondly, we use the recommendation technique (collaborative filtering) based on the learners, the resources and the assessment trace data (the score obtained, number of correct answers, recording time, etc.) instead of the learners' assessments on the learning resources. We have adopted this recommendation technique since it will allow us to focus on the history of users' actions with the system. The framework has been organized in four basic components: a learner profile, an accessibility assessment analytics model, an accessibility learning analytics model and a recommendation model. Figure 2 illustrates the components of the proposed framework. In the following we explain the framework in detail.

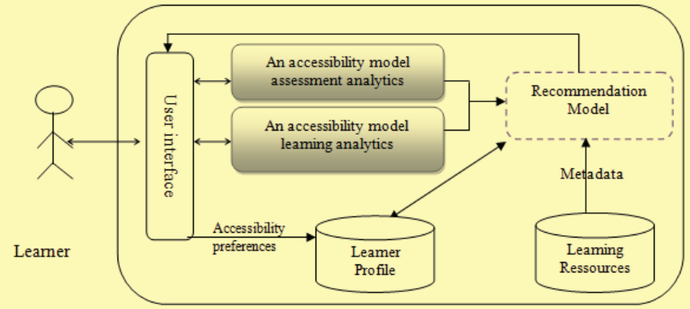


Figure 2. Ontology-based Recommendation Framework for assessment of learners with disabilities

a) Learner Profile: During registration, a new user is asked to enter the following information: 1) personal information (name, gender, date of birth) and current occupation, 2) accessibility preferences, and 3) current education level and skill level (beginner, intermediate, advanced).

b) An accessibility assessment analytics model: This model is the result of combining the two models Accessibility model and the Assessment Analytics model. This combination is done by the relationship between the Learner class of the accessibility model and the Assess_Actor class of the Assessment Analytics model. This model provides assessment trace data to the recommendation model in order to provide relevant learning resources to learners with disabilities.

c) An accessibility learning analytics model: We propose to extend the accessibility model by a subclass Learner_History which is inherited from the Learner class. This subclass contains properties Log_Time, Visied_Digital_Ressource, Duration and LogOut_Time in order to exploit these properties in the recommendation process. The recommendation model can also use knowledge of this model when the learner does not enter his accessibility preferences.

d) Recommendation Model: This model will use accessibility preferences, learning trace data, assessment trace data and the learner's profile to generate personalized recommendations to the active learner. This model works in three steps:

- **Step 1:** We consider this step as a first level of filtering. This step is based on the principle proposed by but we use the initial evaluation results instead of the learners' evaluation (opinion) of the resources. This principle consists of incorporating accessibility preferences and needs into the recommendation process.
- **Step 2:** we consider this step as a second level of filtering by exploiting learning traces data. We will use collaborative filtering based on users. The working principle of user-based filtering is very simple [21]: determine which users are similar to the current user, and then compute a prediction value for each candidate item by analyzing the ratings that the current user's neighbors have expressed on that item. In our work, the evaluations represent the data of learning traces (duration of consultation, number of visits,...) which are collected in an implicit way. This data is used by a matrix (Learners, Resources, Learning Trace) to calculate the similarity between learners and the prediction.

Computing similarity between users:

Similarity between two users (learners) x and y can be measured using Cosine similarity or Pearson Correlation Coefficient (PCC) , we use the PCC similarity measure since it is the best performing measure in user_based collaborative filtering [21], [22] as illustrated in the following formula (1):

$$W(x,y)=\frac{\sum\left(r_{x,j}-\bar{r}_x\right)\left(r_{y,j}-\bar{r}_y\right)}{\sqrt{\sum\left(r_{x,j}-\bar{r}_x\right)^2}\sqrt{\left(r_{y,j}-\bar{r}_y\right)^2}}$$

Rx,j and Ry,j the learning trace data of learner x and the learning trace data of learner y.

rx is the mean score of all learning traces data provided by learner x.

After the calculation of similarity between learners a matrix of size NxN will be generated, where N is the number of learners. Then, to predict the learning resource j not evaluated in the matrix by the active learner x, the K learners who have the highest similarities with this learner will be used as inputs to compute the prediction of j for learner x as illustrated in the following formula (2):

$$P_{x,j} = \bar{R}_x + \frac{\sum_{y=1}^{n} w(x,y)(R_{y,j}-\bar{R}_y)}{\sum_{y=1}^{n}|w(x,y)|}$$

Ry,j represents the learning trace data of learner y on learning object j.

- **Step 3:** we consider this step as a third level of filtering by exploiting the assessment trace data. This time the recommendation model will use the matrix (Learners, Resources, Score) with the rows representing the learners, the columns representing the resources and the boxes representing the assessment results to compute the similarityandpredicttherecommendations.

To generate recommendations to learners with disabilities we have several criteria to be taken into account (accessibility preferences, learning traces data and assessment traces data) which are structured in ontological models. That's why we have proposed two recommendation algorithms for the second and third recommendation steps mentioned above:

a) User_based recommendation algorithm (exploiting learning traces):

1: For each new learner x, retrieve his/her profile and create a vector

2: While there are learners to compare there

3: create a vector for y

4: calculate the similarity between x and y

5: Sort the list of nearest neighbors

6: Get the first 10 nearest neighbors

7: For each learner in the top 10 list do

8: For each resource in a learner's history do

9: If Rate>= 5 Then

10: add resource R to the KNN list

11: EndIf

12: EndFor

13: EndFor

The Rate represents either the duration of consultation of a resource or the number of accesses to this resource.

b) User_based recommendation algorithm (exploiting assessment traces):

1: For each new learner x, retrieve his/her profile and create a vector

2: While there are learners to compare there

3: create a vector for y

4: calculate the similarity between x and y

5: Sort the list of nearest neighbors

6: Get the first 10 nearest neighbors

7: For each learner in the top 10 list do

8: For each resource in a learner's history (assessment result) do

9: If assessment_result(Score) >= 5 Then

10: add resource R to the KNN list

11: End If

12: EndFor

13: EndFor

Score represents the score obtained by the learner after an assessment test. The results of these algorithms will be combined to avoid cold start problems.

Conclusion

In this paper, we are interested in developing a Recommendation Framework for assessment of learners with disabilities. From the state of the art and the comparative study between research works related to our subject we found that the majority of these works do not take into account e-accessibility, and do not focus on e-assessment analytics despite its great informative potential. For this reason, we have proposed a Recommendation Framework for learners with disabilities based on e-assessment analytics. The advantage of this Framework is to ensure accessibility based on the IMS Access for All specification and to exploit the e-assessment analytics that is very little exploited in the related research work in order to recommend learning resources to learners with disabilities. As a next step we intend to design use case scenarios as an instantiation of the proposed scenario and to deploy the framework with learners with various types of disabilities to validate our proposed recommendation process.

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