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(Review Article)

Human-centred artificial intelligence for adaptive and accessible user interfaces in augmented reality educational platforms with AI-Agent Interaction

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Abstract

The field of education is changing very fast, and the artificial intelligence and augmented reality are influencing it. Still, the development of augmented reality systems that are inclusive to everyone is a challenging task. The existing architectures are often used as black boxes, thus ignoring the learners with disabilities. This study therefore engaged in all-round research on human centred artificial intelligence and how the technology can transform the augmented reality. The overall idea is to make a hard tool flexible learning, responsive and reachable. The research employed structured literature review methodology, which involved conducting a survey of academic evidence from a variety of literature databases, such as IEEE Xplore, ACM Digital Library, ScienceDirect, SpringerLink, and Google Scholar, including 2005-2025. It was observed that there is a real need for an interactive link between the sense of interaction and the adjustment of the interface in real-time. In addition, the research study revealed that multi-agent roles may improve the engagement of a student, although the system has to regulate these agent interrelationships to avoid cognitive overload. The most effective way to minimize automation bias was shown to be approval-based monitoring, which requires the automation system to generate a change suggestion and for the human to confirm the change before it is implemented. Through the paper, the authors concluded that the disadvantages of immersive learning are caused by the gap that exists between the capabilities of technology and human needs. The proposed research is to bridge this gap by proposing an agent-driven inclusive augmented reality (ADI-AR), a four-layer model that integrates pedagogical scaffolding, interaction sensing and human governance.

Keywords: Human-Centred Artificial Intelligence; Augmented Reality; Adaptive User Interface; Accessibility; Multi-Agent Systems; Inclusive Education

1. Introduction

The concept of traditional teaching methods is being superseded in the educational system of all over the world. These are becoming learning environments from which people can experience, rather than read. Institutions are moving towards an immersive learning space, not based on traditional learning spaces due to the development of digital technologies at an incredible rate and the omnipresence of internet. This change in paradigm moves the emphasis of education from "how to teach in general. There is currently a rising need to have learning systems that are flexible as well as individualised, systems that are capable of catering to the different needs of learners and their preferences. The main means of this transition is Artificial Intelligence (AI). The adaptive teaching capacity of AI is what offers the potential for learning to adapt to a student and his/her pace and way. The contemporary educational process is

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increasingly leaning towards personalisation, which has become technologically dependent on AI, thus enhancing student engagement and performance in their education [4,5].

Merging the technologies Augmented Reality (AR) and Artificial Intelligence is a major aspect of this shift. In the traditional e-learning systems, the content delivery by teachers has been digitised [6]. However, these e-learning systems have a lack of spatial interactivity which is required when acquiring complex skills. These systems also neglect the physical needs, and the cognitive needs of all learners [6]. Extended Reality (XR) is a solution to these problems. XR technologies are emerging technologies that project virtual content onto a real-world space. This overlay enhances student's perception and facilitates situated learning. The building of AR environments was a difficult task in the past. There were several challenges on board this process [7]. If a teacher didn't know how to code, it was often difficult for them to make the content.

AI has shifted from a reactive to a proactive approach in software. These agents are able to sense, think and act independently. This is helping with the change thanks to Large Language Models (LLMs). Large Language Models enable AI to be a colleague in the classroom [8]. The agents working on natural language instructions with the help of LLM generate educational content, thus bridging the human-cognitive computation interface [9,10]. Moreover, AI agents are functioning as multiple agents as mentors, peers and evaluators. If such an arrangement is made, students will have exclusive support and feedback systems will build in ways that will encourage heavy cognitive involvement [11].

Yet, there is a design deficit in such systems with particular reference to inclusiveness and accessibility. Many of the current applications tend to be rather algorithmic in their approach and the created interface becomes rigid rather than flexible when applied to the wide range of constraints faced by learners with disabilities. As a remedial paradigm, Human-Centred Artificial Intelligence (HCAI) has been suggested. HCAI proposes building of AI systems that complement human abilities without reducing the agency of users, are reliable, ethically pertinent [12], and a learner-friendly philosophy that tries to eradicate the inflexibility of current designs.

Such versatile systems are based on machine learning (ML) techniques. Supervised and reinforcement learning algorithms are used to identify behavioural patterns in users that is then used to reconfigure interface layouts dynamically in real-time. It is important that these models are designed to be accessible to as many students as possible, which means using Universal Design by the developer [13]. Other technologies such as Natural Language Processing (NLP) and gesture recognition are required in order to overcome barriers to access, thereby allowing pupils with physical and/or cognitive disabilities to control lessons through speech and/or body movement. This study integrates immersive technology, intelligent agents and ethical design as a way to show how AI can be applied practically to create learning environments that are inclusive.

1.1. Statement of the Problem

The field of education appears to be the best area of application for the combination of Artificial Intelligence and Augmented Reality, but what is currently being done is hindered by design decisions that cause blocks of exclusivity. The assumption of existing systems is normally transcoded visual acuity, a normal cognitive function, and normal motor control, all of which exclude students with disabilities and make the immersive experience unfeasible for a large percentage of learners.

The technical difficulty of the natural opaqueness of AI-driven adaptation is huge. They are also autonomous, which means that they alter the user interface and/or the content of the teaching regularly, but without clear explanations about why they change it. This kind of obscurity will undermine students' confidence and force actors to be a passive recipient of algorithm-generated decisions and become a passive participant.

On top of that, most of the existing AI agents are text-based or voice-based, and even the few that are multimodal don't leverage the spatial and multimodal capabilities that are offered by Augmented Reality. Thus, it is necessary for the learners to balance themselves in various types of interactions that has greater learning activity load. If there's no rational system of control that regulates power between the AI and the human consumers, the technologies will be disjointed without dependable control and without a single system of governance.

To address these gaps, this study proposes an architecture of Human-Centred AI that aims to increase agency of the user in learning and therefore strike a balance between the needs of adaptive learning and immersive learning experiences and the ethical need to support different learners in the learning process.

The aim of this study was thus to bring together evidence on architectural requirements, multi-agent pedagogical roles, AI-based accessibility technologies, and human oversight mechanisms, and incorporate this evidence into a human-centred model for adaptive and accessible AR education.

The need of this research is due to the shift of education to Industry 5.0. Creating and using Augmented Reality content is a matter of urgency, and should be accessible to all [14]. According to Al-Ansi et al. [15] the barriers to the development of Augmented Reality are very high. There is a need to carry out this research as it offers a guideline for teachers who do not have technical skills. The framework enables these teachers to produce content with the help of the intelligent agents. This helps to reduce the barriers to the teachers' technical skills. Also, educational institutions are starting to use more complex hardware. This situation can lead to an increasing digital divide. This study is important for the safe guard of students with disabilities from being marginalized with the use of immersive technology. This research aims to develop a model that changes the interface in response to the user.

The reference area of this research is established in the territory of software architecture and interaction design specifically on the topic of Augmented Reality educational platforms. The investigation looks at adaptive user interfaces and smart agent systems, and goes deeper to consider the use of Artificial Intelligence technologies that can be used to improve accessibility in higher education and vocational learning environments. Significantly, this study has not addressed the hardware engineering aspect of the AR devices and has left out AI application that is meant to cater to school administration functions. The analysis finally focuses on the methods in Machine Learning since this is the only method that becomes relevant to the interface adaptivity and the assistive features, which the system provides.

The results of this study have a significant weight to policymakers and educational leaders who are required to assume the custodianship of the implementation of Artificial Intelligence in academic institutions. This study is a stepping stone that can be used in developing good governance structures that can be implemented in the modern-day schools taking into account the ethical aspects between various agents of the school.

Moreover, it addresses a significant knowledge gap in the existing literature, and will be useful for software developers and interface designers. This gap is related to the use of Machine Learning in the field of accessibility. The research provides a realistic approach to methodology that enables developers to use automation and protect user agency. Thus, the study could be utilized as a prescriptive pattern to design and construct intelligent and reliable systems.

Finally, students with disabilities could be the target of the implication of the work. The paper aims to contribute to the creation of inclusive learning contexts where visually or motor-impaired students can compete on an equal footing through the application of a Human-Centred test of the AI technologies. This approach is in line with the concept of autonomy of the individual learner, as well as with the pedagogical commitment to academic inclusion of all learners.

2. Materials and Methods

The research method that was used was a structured literature review and qualitative content analysis. The researcher used these methods in the attempt to answer the objectives of the study. This methodological structure, the identification and selection of scholarly evidence. This is also a design process that includes the critical analysis of academic evidence. This evidence is related to human-centred A.I. and Augmented Reality in the field of education. The aim of the research is to develop a comprehensive conceptual structure. This is a conceptual framework that has been integrated based on the available empirical studies.

Structured literature reviews offer a high degree of transparency according to Snyder [16]. Snyder [16] also claims that these reviews are of high standard of rigour. Structured literature reviews have a set of procedures for the literature search process and for the literature analysis process. The particular way in which this is done guarantees methodological robustness in the choice of studies. According to Kitchenham and Charters [17] a structured literature review requires a well-designed research strategy. This is one type of research strategy that involves structured evidence to solve a research problem. This methodical visibility increases the trustworthiness of the analysis for the reader and also decreases the researcher bias in the course of the analysis.

2.1. Data Sources

The paper reviewed a rich body of scholarly literature and technical reports about the intersection of artificial intelligence (AI), augmented reality (AR), and inclusive education around the world. The basic retrieval system used was multidisciplinary scholarly databases and the area of search was in computing, education and engineering fields.

These are the major repositories used: Scopus, Web of Science, IEEE Xplore, ScienceDirect, SpringerLink, Google Scholar and the ACM Digital library.

2.2. Study Selection Process

A multi-stage screening protocol was used to determine relevancy and quality. First, the titles were weeded out to exclude those not related to AI or AR. In order to check the correspondence with adaptive interfaces, adaptability of agents in collaboration and their immersive education, abstract screening was conducted as a follow-up. Among the publications that had gone through title and abstract scrutiny, full-text scrutiny was applied to see if concepts were appropriate and methods were clear. Focus was keenly paid to the assimilation of agents in AR spaces as well as accessibility provisions. This meant that only high quality evidence was used in subsequent analysis.

2.3. Search Strategy and Search Strings

For the review, a structured data-extraction template and a strictly defined search protocol was used. The keywords followed the thematic focus of the study and the key keywords were human-centred artificial intelligence, adaptive user interfaces and augmented reality education. The additional terms, such as intelligent agents in learning, agentic AI, accessibility technologies, and multimodal interaction were also included. It used the Boolean operators to reduce the results and to obtain the accurate matching results for the research objectives.

The search terms used were: ("Human-Centred AI" OR "HCAI") AND ("Augmented Reality" OR "AR") AND ("Education" OR "Learning") AND ("Intelligent Agents" OR "Multi-agent systems") AND ("Accessibility" OR "Inclusion"). The peer-reviewed journal articles and conference papers were given priority in retrieval and the good quality conceptual studies were also included. As agent-directed immersive learning is still a new and emerging field, it was necessary to incorporate such theoretical work in order to gather the recent theoretical developments in the field of knowledge.

2.4. The validity and reliability of the Review

The included studies were reviewed in terms of validity of their methods and analysis, being transparent. Standardised reporting protocol enhances the quality of the structured reviews as reported by Moher et al. [19] Empirical studies were evaluated with their research design and rigour of their assessment procedures, whereas conceptual frames were evaluated on their theoretical coherence and architectural sophistication. Empirical and conceptual scholarship incorporation are a sign of the development of agent-based AR based learning systems. A set review protocol ensured consistency of data collection and prevented biases.

2.5. Data Extraction Procedure

The selected publications were analysed by using a structured data-extraction template to find an analytical consistency. The information on a study was captured in detail and easier to synthesize on the architectural, pedagogical and accessibility level. The second type was a structured literature review, which included a scoping exercise to chart out the current state of education scholarship in the field of artificial intelligence-mediated education in the planning phase of the review. In this exercise, it was possible to detect groups of research and filtering parameters.

2.6. Method of Data Analysis

The findings of the study were examined by qualitative content analysis. This analysis was used to combine the information from the chosen studies. The studies selected were coded according to themes to reveal common design patterns and conceptual boundaries in the area. Thematic clustering was developed on four analytical areas. Agent architecture in Augmented Reality (AR) environment and pedagogical role distribution and Artificial Intelligence (AI) driven assistive technologies and human-centred oversight mechanisms are these specific areas.

The analysis was conducted in themed synthesis manner as described by Thomas and Harden [20]. This is a particular method of developing descriptive themes and analytical themes. Data were analyzed comparatively to draw some commonalities. The study also revealed gaps in the existing research. The approach of analysis facilitates developing knowledge for the study. The method is to transform the separate evidence into a conceptual framework for the research.

2.7. Ethical Considerations

Only published academic sources of secondary data were used. There were no human subjects involved in the research process. Thus, accurate citation became the focus of the ethical responsibility of the study. One of the main concerns was also to avoid plagiarism. All the consulted sources are acknowledged in the list of references for this study.

The Methodology has some limitations.

3. Results

This chapter reports the results of the structured review of literature that is relevant to this study. The methodological approach elaborated in Chapter Three is followed here, and the analysis is conducted with the help of secondary data, which is gathered from selected scholarly publications. The data analyzed are the data obtained from peer-reviewed journal articles, conference papers, and conceptual framework studies related to human-centred artificial intelligence, Augmented Reality (AR) education, adaptive interface systems, and interaction with intelligent agents. The reviewed studies were analyzed using qualitative content analysis, which aimed to recognize patterns, and areas of consensus across literature. Codes created in the review process were sorted into themed categories, related to the research objectives. The themes are used to explore the application of human-centred AI principles in AR educational environments. The results are presented in sequence of the research objectives to make it easy to understand.

3.1. Architectural requirements for integrating AI agents into AR for real-time adaptation.

One of the primary conclusions in the architectural studies is that there should be a close coupling relationship between interaction and sensing and adaptation logic in agent-driven AR learning platforms. It is shown in the analysis that successful changes in interfaces in real-time do not occur in isolation. These changes depend on the constant sensing of user actions. These changes also rely on feedback loops between interface events and instructional decisions [21] These are the parts that connect the events at the interface to instructional decisions.

The concept of modularity is the subject of recent frameworks in the educational technology area. These are frameworks that also emphasize the power to generate dynamic content. The literature review indicates a change in the research on extended reality. This research now centres on the interaction layers and centres on modules for system customisation [22]. These platforms need to have certain elements related to user profiling. The architecture should also contain elements to capture the context. The study of agentic frameworks indicates that one of the requirements is shared context management [23]. When the various modules for content and narrative share the same memory for their communication, then the system is achieved.

However, these are particular studies and there is always a common limitation. The research studies are not validated in actual classroom. Numerous systems have shown it to be feasible for the users. In a real classroom, the need of the students to accessibility varies [22,21]. In the field of education, however, there is no blue print with regards to technology. This blueprint aims to build a platform for Agent Coordination and Accessibility and Oversight that is an Augmented Reality platform.

3.2. The effectiveness of Multi-Agent Pedagogical Roles for Scaffolding and Cognitive Load Management.

The talk shows that for pedagogical agents and student engagement; the relationship is complex. The effectiveness of the agents depends on the design of the roles. Mentor roles have the most significant impact on the performance and motivation [24].

The finding also indicates a trade-off in terms of cognitive load of the student. Motivation and critical thinking could be enhanced by social roles such as peer agents. However, these roles also add the mental processing demands to the student [25]. This additional burden is a risk factor in AR settings. This is because the student is already provided with a lot of attention for interaction. If there is no post-calibration of the scaffolds, then the learner can leave them and have too much support and social interaction. The learner can leave the supports and social interaction too much unless scaffolds are post-calibrated.

Meta-analysis has shown that the presence of the agent does not always reduce cognitive load. The decreases in the load are not large. These cuts are chosen based upon design decisions like media capability, how the agent should look like and more [3]. Conscious decisions must be made about when to intervene for cognitive loads by the agents. At least the patterns of a multi-agent dialogue such as co-construction assist students having low prior knowledge [26]. However, the analysis reveals that such advantages have to be weighed against the danger of the clutter on the interface.

3.3. Capabilities of AI Driven Assistive Technologies for Accessibility Barriers

Based on the literature review of access to assistive technologies, AI-supported assistive technologies are found to be beneficial for gaining independence and interaction. These two most efficient technologies have been analysed as Computer Vision (CV) and Natural Language Processing (NLP) technologies. For the navigation and access to information of visually impaired users, there is a deep learning recognition [27]. It is possible to resolve visual impairments and hearing impairments, if the tools can be adapted to the requirements [27] using recognition pipelines.

There is a divide between technical capability and inclusive usability in the field of education. The literature reviews reveal that the majority of research is concerned with visual impairment. Existing research on motor disabilities and cognitive disabilities is not enough [28]. The level of accessibility will be determined by adoption conditions. The complexity of the tool and the price of the tool and the training needed for the tool are among these specific conditions. Technical accuracy is not the only determining factor in these systems. Use of Artificial Intelligence tools can enhance the time efficiency of the task for the student. The use of these tools can also enhance the efficiency of communication [29]. However, those specific benefits to the user are diminished with poor interface design.

Computer vision is used in Augmented Reality (AR) education systems to help the understanding of gestures. Learner gets conversational support using NLP technology. However, in the case of these specific features, there is a technical risk if the features are not in line with industry standards. Many studies have a weak reference to accessibility standards. The lack of standards diminishes the practical inclusion goal [28]. The results of the research indicate that it is feasible to create an assistive Artificial Intelligence. The real challenge, however, is to embed these tools in immersive interfaces. This integration needs to occur in such a manner to create minimal barriers for the system's user.

3.4. The Impact of Human Oversight, Automation Bias and Trust in Adaptive Systems.

One of the key findings is that opaque automation and high system autonomy result in automation bias and low trust. The analysis demonstrates user's confirmation bias in these systems. Users do not check the recommendations of the system [30]. The research evidence indicates that users like hybrid decision models.

Trust is situational, it's risk-dependent and transparent. The analysis demonstrates that transparency and values increase trust. Trust becomes less when it is uncertain and opaque [3]. Bias harms occur when the user is unable to challenge the results, or even the recommendations [18]. The key elements of the model require the participation of stakeholders throughout its life.

But it is supported by the evidence of the use of approval-driven adaptation. The model is that a suggestion is made by the system and an explanation is provided by the system why the change is needed. However, the system must ask the user to confirm the change before it will be made. Themes of trust and bias reinforce the need for the human to not be pushed out of the loop.

3.5. Integrated Evidence for Inclusive Agent-Driven AR Frameworks Aligned with UDL focuses on the integration of evidence with AR frameworks aligned with UDL.

Based on the final analysis, there is conceptual support for inclusive AR. However, in reality, the field is split. It is reported that non-responsive layouts create an obstacle. The following studies state that adaptive interfaces are essential for fair learning [31]. Flexible engagement is supported by frameworks based on Universal Design for Learning (UDL) [18]. However, the analysis reveals that it is quite common for validation to be restricted to simulations.

The synthesis indicates a strong break in between different strands of disciplines. While AR scholarship is dedicated to the immersive affordances, it does not give much consideration to accessibility issues. In contrast, agentic AI research concentrates on collaborative designs over inclusive designs of user interfaces [32,33]. This fragmentation highlights the need to have an exclusive, Human-Centred AI framework which cohesively connect accessibility, multi-agent dynamics and adaptive mechanisms with an overall framework that ensures inclusion.

4. Discussion of Findings

Based on the results of this study, it is observed that there is a gap in the development of immersive learning systems in a structural form. As long as the developers developed the platform in a modular manner, the real-time adaptation is technically possible. However, the studies provide a record of evidence that these designs do not consider accessibility requirements early in the design process. Technical performance is frequently given more importance than the user in the system. The current systems are running quick. However, these existing systems are not necessarily available to students with varying needs.

The findings of multi-agent systems have a conflict between support of the agent and the cognitive burden of the student. Students are more engaged in classroom with agent roles like mentor or peers. The same functions, however, raise mental demands to deal with the Augmented Reality (AR) environments. As per literature review, this type of cognitive load is reduced when there are oversight mechanisms and transparency. A paradigm of adaptation which is motivated by approval is thus sown as a critical approach to resolve this tension in system architecture, which entails giving the system contextual intelligence whilst maintaining learner agency.

Today's school environment is polarized. The field of architectural design, agent-based and accessibility engineering remain isolated and offer no means toward the crystallisation of an inclusive learning experience in an inclusive way. The system architecture and instructional scaffolding, assistive technologies and systems of oversight have to be developed. The findings from the review reinforce the need to develop the methodology in an integrated way to advance the field and serve as a good sign that this is essential in the creation of educational platforms that can be accessed by all children.

This chapter reported the results of the content analysis of secondary sources. The analysis was conducted on the human-centred Artificial Intelligence (AI) for Augmented Reality (AR) learning platforms. The results demonstrate the need for real-time technical pipelines for Augmented Reality adaptation. These are specific pipelines that have to integrate the sensing by the user, modelling of the context and the logic of the adaptation. There is evidence in the literature to verify these environments are suited to the use of multi-agent roles. However, the evidence also shows that what design choices the system makes are related to how much cognitive load the learner must have in order to learn. AI to assist can alleviate barriers. However, without usability and without standard it is not possible to achieve practical inclusion. Analysis of trust reveals that there is a need for oversight to minimize automation bias. The results are a justification for the Agent-Driven Inclusive Augmented Reality (ADI-AR) Framework. This framework is explored in the last chapter.

The synthesis resulted in the 4-layer structure shown in Figure 1. The layers relate contextual sensing to specialized pedagogical agents, governance by the learner(s), and multimodal output that is accessible.

IEIAF is a resource for teachers that can assist them in implementing inclusive agent-driven AR frameworks aligned with UDL.

The end goal is that there's conceptually support for inclusive AR. In the real world, however, there is no unity in the field. Some studies show that layouts that are unresponsive to research are barriers. Based on these studies, it seems there is an unmet need for adaptive interfaces to support equitable learning [31]. An approach to Universal Design for Learning (UDL) [18] for flexible engagement is offered. But as the analysis shows, in most cases only simulation can be used as a means of validation.

The synthesis indicates a strong break in between different strands of disciplines. AR scholarship is centred around the immersive affordances but has not given much consideration to accessibility problems. However, studies on agentic AI narrow their attention to collaborative designs and forget about the inclusive aspect of interface design [32, 33]. This fragmentation highlights the need to have an exclusive, Human-Centred AI framework which cohesively connect accessibility, multi-agent dynamics and adaptive mechanisms with an overall framework that ensures inclusion.

The findings of this study showed that immersive learning systems lack structures in their development. Modular platform design allows for real-time change when the developers use it. But the research shows that these designs do not take into account accessibility requirements from the start of the design process. The user is not considered when working out the technical aspects of the system. Things process quickly these days. But these current systems may not be available to students for whom they need them.

The results concerning multi-agent systems pose a dilemma between what the agent would like to support and the cognitive load of the student. Mentors and peers enhance student participation in the classroom. At the same time, the same functions may lead to increased cognitive load to overcome the Augmented Reality (AR) environments. Based on the results found in the literature, this cognitive load is reduced with the presence of oversight mechanisms and transparency. This tension in system architecture can therefore be interpreted as a need for a paradigm of adaptation motivated by approval which is one of the ways to solve the problem in the system.

Education is so divided today. Today's educational environment is very polarised. It is still hard to bring the literature of architectural design, agent-based and accessibility engineering into a single integrated learning process in a really inclusive way. A meaningful difference between the system architecture and instructional scaffolding, assistive technologies and frameworks of oversight exist that must be elaborated. Review results emphasise the need to continue with an integrated methodology to progress the field and demonstrate this is the path to platform in education for all learners.

The findings of the content analysis of the secondary sources were presented in this chapter. The analysis in this particular situation was for Human-Centred Artificial Intelligence (AI) in Augmented Reality (AR) learning platforms. The results show that there is a need for real-time technical pipelines for Augmented Reality adaptation. These specific pipelines need to link the user's sensing and the modeling of the context and the logic of the adaptation. This has been corroborated in literature, using multi agent roles in such environments. It is also shown from the evidence that the cognitive load of the learner is also influenced by the design decisions of the system. AI can help to overcome obstacles. But because of lack of usability and standards, the inclusion is impractical. A study of trust showed a need for supervision to reduce automation bias. The results are consistent with the Agent-Driven Inclusive Augmented Reality (ADI-AR) Framework. A framework is discussed in the last chapter.

After several steps the synthesis was completed to form the four-layered structure shown in Figure 1. The following layers refer to contextual sensing, special pedagogical agents, learner-controlled governance and accessible multimodal output.

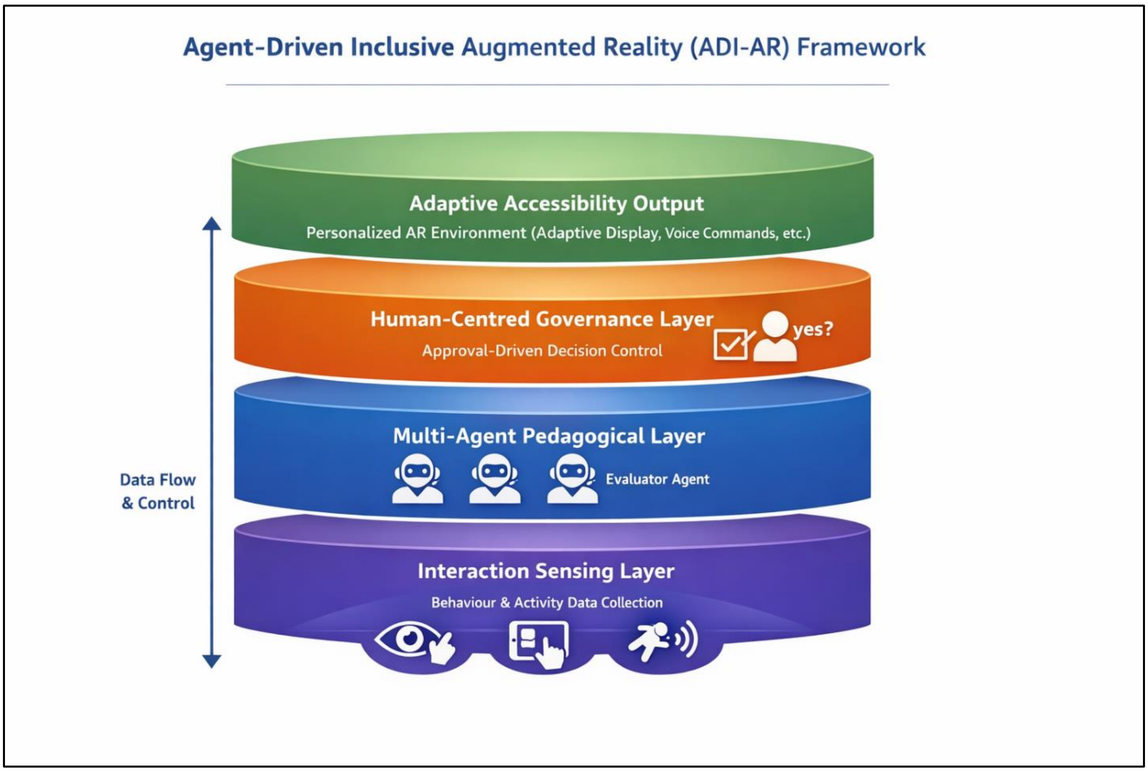

Figure 1 Agent-Driven Inclusive Augmented Reality (ADI-AR) framework.

5. Conclusion

This study investigated the use of human-centred artificial intelligence in augmented reality platforms. There were many goals that the study would like to achieve to design user interfaces that are adaptive and accessible. It was started because most immersive systems are 'rigid'. Such fixed systems tend to marginalize students with disabilities. To address this issue, the study examined the architectural needs, the functions of the pedagogical agents and the capabilities of AI tools, and the role of human oversight. Automated solutions can't solve the issue of automation bias without human supervision. This study used a structured literature review and content analysis of a qualitative approach. The results indicated the need for real-time pipelines for effective adaptation. These pipelines have to link the user's sensing with change to the interface. The research also demonstrated that multi-agent systems are good scaffolding for the student. However, these systems need to be carefully planned. This is because the agents have the capacity of increasing the cognitive load of the student. Computer vision and natural language processing (NLP) were identified as very helpful assistive technologies for making information accessible. Such tools need to be designed in accordance with universal design to be effective. Finally, it was confirmed that the human control is essential to keep the learner's trust and agency.

The effectiveness of augmented reality as a learning experience is limited to the balance between algorithmic optimisation and human control, the authors conclude in this paper. The use of high technology is not sufficient to build inclusive learning environments. Moreover, the existing body of research is still significantly divided, and technical architectures are often not related to the consideration of accessibility and pedagogical approaches.

A coordinated effort is required to prevent the digital divide from increasing. Education needs to provide human agency and allow models to be accepted and designs to be included by humans. This way, the learning platforms are intelligent and fair to all students. Human-centred AI is the much-needed bridge for this change. It brings augmented reality from a new display method to a sustainable and accessible educational system.

The Agent-Driven Inclusive Augmented Reality framework is proposed to be based on three elements: interaction sensing, multi-agent pedagogical support, human-centred governance and adaptive accessibility output. This is important because it shifts the focus from accessibility being an interface add-on to making it an architectural design concern. The framework should be explored longitudinally in real classrooms and across a range of disability groups in the future.

Compliance with ethical standards

Disclosure of conflict of interest

The author declares that there is no financial or non-financial conflict of interest related to this study.

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