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A Review on Mobile Augmented Reality for Learning Data Structures and Algorithms

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Abstract: ***Data Structures and Algorithms (DSA) are essential components of computer science education; however, many students find these concepts difficult to understand due to their abstract nature and the limitations of traditional teaching methods. Conventional approaches such as lectures and textbooks often fail to effectively demonstrate the dynamic behavior of data structures and algorithms. Augmented Reality (AR) has emerged as a promising technology that can enhance learning by providing interactive three-dimensional visualizations within a real-world environment. This paper presents a review of existing research on the use of AR in education, with a particular focus on its application in teaching Data Structures and Algorithms. The study analyzes current AR-based learning systems, highlighting their advantages as well as their limitations, including restricted interactivity and lack of motivational features. Based on the findings, the paper identifies research gaps and discusses the potential of integrating gamification and personalization techniques in mobile AR environments to improve student engagement and learning outcomes.***

Keywords: Augmented Reality, Data Structures and Algorithms, Interactive Learning, Gamification, Visualization.

I. INTRODUCTION

Immersive technologies include Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR). These technologies enable interactive digital experiences by integrating virtual content with the real or simulated environment. Data Structures and Algorithms (DSA) form the foundation of computer science and software development. These concepts play an essential role in problem solving, programming efficiency, and system design. Data structures such as stacks, queues, linked lists, and trees are widely used in programming to organize and manage data effectively. However, many students find DSA difficult to understand because the concepts are abstract and involve dynamic processes that are not easily represented using traditional teaching approaches **[1]**.

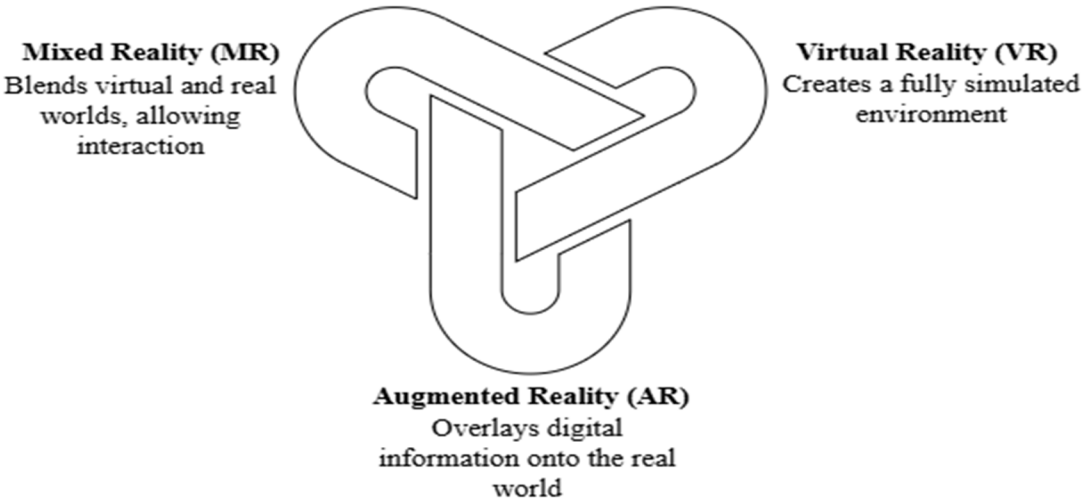


Fig. 1. Types of Immersive Technologies

In many educational institutions, DSA is typically taught through lectures, textbooks, and two-dimensional diagrams. While these methods help explain theoretical principles, they often fail to demonstrate how data structures operate during algorithm execution. Operations such as insertion, deletion, and traversal involve step-by-step changes in data organization, which can be difficult for students to visualize using static learning materials [2]. As a result, learners may struggle to fully understand the behavior of algorithms and data structures.

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Augmented Reality (AR) has emerged as a promising technology for enhancing learning experiences by integrating digital content with the real-world environment. AR allows virtual objects, animations, and three-dimensional models to be displayed through mobile devices such as smartphones and tablets. This interactive visualization enables learners to observe and manipulate digital elements in real time, making complex concepts easier to understand [3].

In recent years, AR has been widely explored in educational domains such as science, engineering, and medical training. Studies have shown that AR-based learning environments can improve student engagement, motivation, and knowledge retention by providing immersive and interactive educational experiences [4]. These features make AR particularly useful for teaching subjects that involve complex spatial or procedural processes.

Despite these advantages, the application of AR in computer science education—particularly for teaching Data Structures and Algorithms—remains relatively limited. Existing AR-based systems mainly focus on visualization of algorithm operations but often lack additional features such as adaptive learning mechanisms and motivational learning strategies [5].

Educational research also suggests that incorporating gamification techniques such as points, levels, and rewards can increase student motivation and encourage active participation in learning activities. Similarly, personalized learning approaches that adapt educational content based on a student's performance can improve learning outcomes and support different learning styles [6].

Therefore, there is a growing need to explore how mobile Augmented Reality can be effectively combined with gamification and personalized learning approaches to improve the teaching and learning of Data Structures and Algorithms. This paper presents a review of existing research on AR-based educational systems related to DSA learning, analyzes their advantages and limitations, and identifies research gaps that can guide the development of more effective AR-supported learning platforms.

II. LITERATURE REVIEW

Recent advancements in educational technologies have introduced new methods for improving student engagement and understanding. Augmented Reality (AR) is one such technology that combines digital content with the real-world environment, allowing learners to interact with three-dimensional objects and simulations. In computer science education, AR has the potential to transform abstract topics such as algorithms and data structures into visual and interactive experiences. Existing research related to AR-based learning can be grouped into several categories including AR for algorithms and data structures, AR educational frameworks, AR combined with gamification techniques, and AR-based learning applications.

A. Core AR for Algorithms and Data Structures

Several studies have explored the use of augmented reality to visualize algorithms and data structures.

The study Augmented Reality for Learning Algorithms: Evaluation of Its Impact on Students' Emotions Using Artificial Intelligence examined how AR visualization influences students' emotions and engagement while learning algorithms. The results showed that interactive visualization allows students to better observe algorithm behavior, which improves motivation and understanding of algorithmic processes [1].

Another study, Visualization of Data Structures Using Augmented Reality, presented an AR system designed to demonstrate operations such as insertion, deletion, and traversal in different data structures. The research reported that students using AR visualization were able to understand abstract operations more clearly compared to traditional learning methods [2].

Earlier work, Augmented Reality for Teaching Data Structures in Computer Science, introduced an AR-based educational tool that allows learners to interact with three-dimensional models of data structures. The system enabled students to observe algorithm execution step-by-step, helping them better understand computational processes [3].

These studies indicate that AR visualization can play an important role in transforming theoretical programming concepts into interactive learning experiences.

B. AR Education Frameworks and Technology

A number of researchers have proposed frameworks and technological approaches for integrating AR into educational environments. The research An Augmented Reality Framework for Education: Deep Learning Integration and Impact Evaluation introduced an AR-based educational framework designed to improve interactive learning experiences. The study showed that combining AR visualization with intelligent technologies can enhance students' understanding of complex topics [4].

Another study, Exploring Teachers' Competences to Integrate Augmented Reality in Education, investigated the readiness of educators to adopt AR technologies in teaching environments. The findings revealed that teacher training and technological awareness are important factors for successful AR integration in education [5].

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The research Exploring the Role of User Experience and Interface Design Communication in Augmented Reality for Education emphasized the importance of user-centered design in AR applications. The study suggested that effective interface design improves usability and enhances the learning experience [6]. Similarly, Augmented Reality: Current and New Trends in Education reviewed current developments in AR technologies and highlighted their increasing use in educational environments, especially in STEM learning [7]. Another study, Educational Opportunities and Challenges in Augmented Reality, analyzed both the advantages and limitations of AR adoption in education. The authors concluded that AR can significantly improve conceptual understanding when combined with appropriate instructional design [8].

C. AR with Gamification Approaches

Gamification techniques are frequently integrated with AR systems to improve student engagement and motivation.

The systematic review Personalized Gamification: A Technological Approach for Student Education—A Systematic Literature Review discussed how adaptive gamification techniques can personalize learning experiences. The study found that personalized learning environments can improve student participation and learning outcomes [9].

Another study, Integrating Augmented Reality, Gamification, and Serious Games in Computer Science Education, explored how AR combined with game-based learning techniques can support computer science education. The results suggested that integrating AR with challenges, rewards, and game elements enhances student engagement and understanding [10].

Similarly, Designing Gamified Application: An Effective Integration of Augmented Reality to Support Learning presented a gamified AR learning application that incorporates scoring systems and achievement levels to motivate students. The study reported improved learning motivation and knowledge retention [11].

Another framework, An Innovative Multi-Layer Gamification Framework for Improved STEM Learning Experience, proposed a multi-layer gamification model that supports student engagement through reward systems and progress tracking mechanisms [12].

These studies demonstrate that combining AR visualization with gamification techniques can create more engaging learning environments for students.

D. AR Learning Systems and Applications

Several studies have also focused on the development of practical AR-based learning applications.

The research Development of an AR-Based AI Education App for Non-Majors introduced a mobile AR application designed to help non-major students understand artificial intelligence concepts through interactive visual learning [13].

Another study, Towards a New Learning Experience through a Mobile Application with Augmented Reality in Engineering Education, developed a mobile AR application for engineering education that allows students to interact with three-dimensional models in real time, improving conceptual understanding [14].

Finally, the systematic mapping review A Systematic Mapping Review of Augmented Reality Applications to Support STEM Learning in Higher Education analyzed the growing use of AR technologies in higher education. The study highlighted that AR provides immersive visualization and interactive learning environments, particularly in STEM disciplines [15].

Overall, existing research indicates that AR technologies have significant potential to improve visualization and engagement in education. However, many current systems primarily focus on visualization and still lack integrated features such as personalized learning mechanisms and comprehensive gamification frameworks.

TABLE I Comparative Analysis of Existing AR-Based Learning Systems

REF	AUTHOR / YEAR	FOCUS AREA	TECHNOLOGY / APPROACH	KEY CONTRIBUTION	LIMITATIONS
[1]	Gómez-Ríos et al., 2025	Algorithm learning	AR visualization with AI emotion analysis	Improves student engagement and understanding of algorithm behavior	Focuses mainly on emotional analysis rather than system design
[2]	Raut et al., 2025	Data structure visualization	AR-based 3D models	Helps students visualize operations such as insertion and deletion	Limited interaction and learning assessment

[3]	Narman et al., 2020	Computer science education	AR learning environment	Demonstrates data structures through interactive models	Early prototype with limited scalability
[4]	Kaviyaraj & Mohan, 2025	AR educational framework	AR with deep learning integration	Enhances learning through intelligent visualization systems	Limited evaluation with real learners
[5]	Nikou et al., 2024	AR adoption in education	Teacher competency analysis	Identifies skills required for integrating AR in classrooms	Focuses on teachers rather than student learning systems
[6]	Kiourexidou et al., 2024	AR interface design	User experience analysis	Highlights importance of intuitive AR interface design	Does not focus on specific learning subjects
[7]	Kamińska et al., 2023	AR trends in education	Review of AR technologies	Identifies current and future trends of AR in education	Broad analysis without specific implementation
[8]	Lai & Cheong, 2022	AR learning challenges	Educational AR implementation study	Explores benefits and limitations of AR in education	Focused mainly on physics learning
[9]	Ristianto et al., 2025	Personalized gamification	Systematic literature review	Demonstrates importance of adaptive gamification for learning	Not specifically focused on AR systems
[10]	Lampropoulos et al., 2023	AR + gamification	AR serious games	Shows improved engagement in computer science learning	Limited large-scale evaluation
[11]	Farooq et al., 2022	Gamified AR learning	AR application with reward system	Improves student motivation and participation	Focused on gamification rather than algorithm learning
[12]	Zhao et al., 2021	Gamification framework	Multi-layer gamification system	Enhances long-term engagement in STEM education	Does not include AR visualization
[13]	Kim & Shim, 2022	AR learning application	Mobile AR learning app	Simplifies complex AI concepts for non-major students	Limited to specific subject content
[14]	Criollo-C et al., 2021	AR mobile learning	Mobile AR educational application	Bridges gap between theory and practical understanding	Limited interactive learning features
[15]	Mystakidis et al., 2021	AR in STEM education	Systematic mapping review	Shows growing adoption of AR in higher education	Lacks practical implementation analysis

III. RESEARCH GAP

The literature review shows that Augmented Reality (AR) has been widely explored as a tool for improving visualization and interaction in educational environments.

Many studies have demonstrated that AR can enhance student engagement and help learners understand complex concepts through three-dimensional models and interactive simulations. Research has also shown that AR-based learning systems can improve motivation and knowledge retention by providing immersive educational experiences [1]–[4].

Several studies have focused specifically on the visualization of algorithms and data structures using AR technologies. These systems allow students to observe operations such as insertion, deletion, and traversal through interactive visual models, which helps in understanding abstract computational processes [2], [3]. However, most of these systems mainly concentrate on visual representation and do not provide advanced features that support long-term learning engagement.

In addition, recent research highlights the importance of gamification techniques and personalized learning approaches in improving student motivation and participation in educational activities [9]–[12]. Gamification elements such as rewards, levels, and challenges can make learning more engaging, while personalization mechanisms can adapt learning content according to the learner's progress and abilities. Despite these benefits, only a limited number of AR-based learning systems integrate both gamification and personalization features within a single educational platform.

Furthermore, many existing AR applications in education focus on general STEM subjects or specific domains such as physics, engineering, or artificial intelligence [8], [13], [14]. The use of AR for teaching core computer science topics, particularly Data Structures and Algorithms, remains relatively underexplored. Current implementations are often limited in scalability, interactivity, and structured learning design.

Therefore, there is a clear need for the development of more advanced AR-based learning environments that combine interactive visualization with motivational and adaptive learning strategies. Integrating mobile AR technology with gamification and personalized learning mechanisms can create a more engaging and effective educational platform for teaching Data Structures and Algorithms. Addressing these gaps can help improve students' conceptual understanding and provide a more interactive learning experience for complex programming topics.

IV. PROPOSED FRAMEWORK

Based on the limitations identified in existing research, this paper proposes a conceptual framework for a mobile Augmented Reality (AR) based learning system designed to support the understanding of Data Structures and Algorithms (DSA). The goal of the proposed framework is to combine interactive AR visualization, gamification techniques, and personalized learning mechanisms to improve student engagement and conceptual understanding.

The proposed framework consists of several interconnected components that work together to create an effective learning environment. These components include the user interface layer, AR visualization module, learning content module, gamification module, and personalization module.

The user interface layer acts as the primary interaction point between the learner and the system. Through a mobile device such as a smartphone or tablet, students can access the learning application, scan AR markers, and interact with visual representations of data structures. A simple and intuitive interface ensures that learners can easily navigate through different learning activities.

The AR visualization module is responsible for generating three-dimensional models and animations of data structures and algorithm operations. Using AR technology, abstract concepts such as stacks, queues, and other structures can be displayed as interactive 3D objects within the real-world environment. This visualization enables students to observe operations such as insertion, deletion, and traversal step by step, making it easier to understand algorithm behavior.

The learning content module provides structured educational materials related to data structures and algorithms. This module includes explanations, examples, and interactive demonstrations that guide students through different topics. The content is organized in a progressive manner so that learners can build their understanding gradually.

To enhance motivation and engagement, the framework integrates a gamification module. This component introduces elements such as points, levels, rewards, and challenges within the learning process. By completing tasks or correctly performing operations on data structures, students can earn rewards and advance to higher levels. These features encourage active participation and make the learning experience more engaging.

The framework also includes a personalization module that adapts the learning process based on the student's performance and progress. By analyzing learner interactions and results, the system can recommend appropriate learning activities or adjust the difficulty level of tasks. This adaptive approach helps accommodate different learning styles and supports individual learning needs.

Overall, the proposed framework aims to create an interactive and engaging learning environment for computer science education. By combining mobile AR visualization with gamification and personalized learning strategies, the framework has the potential to improve students' understanding of abstract programming concepts and enhance their overall learning experience.

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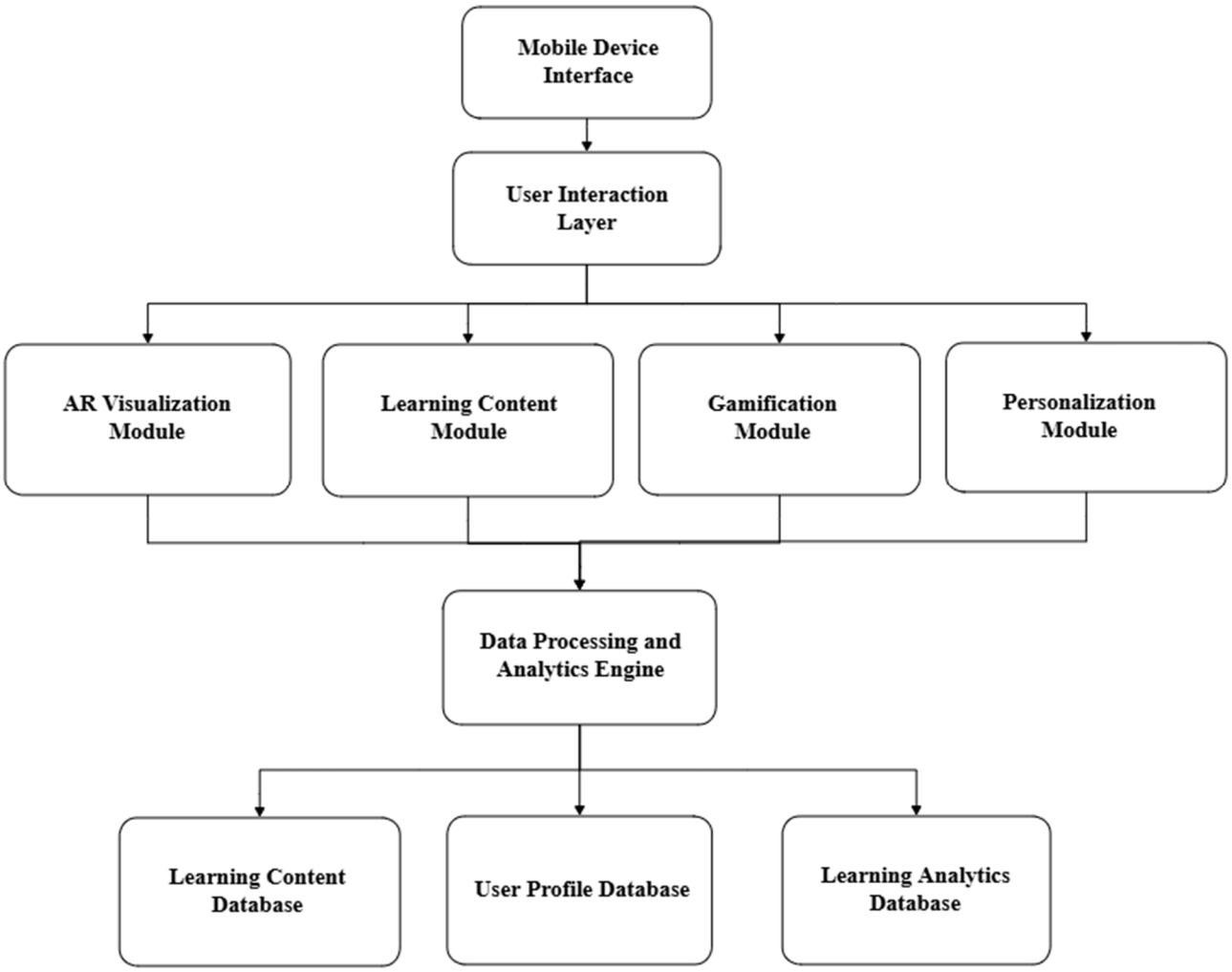


Fig. 2. Proposed AR Learning Framework

V. CONCLUSIONS

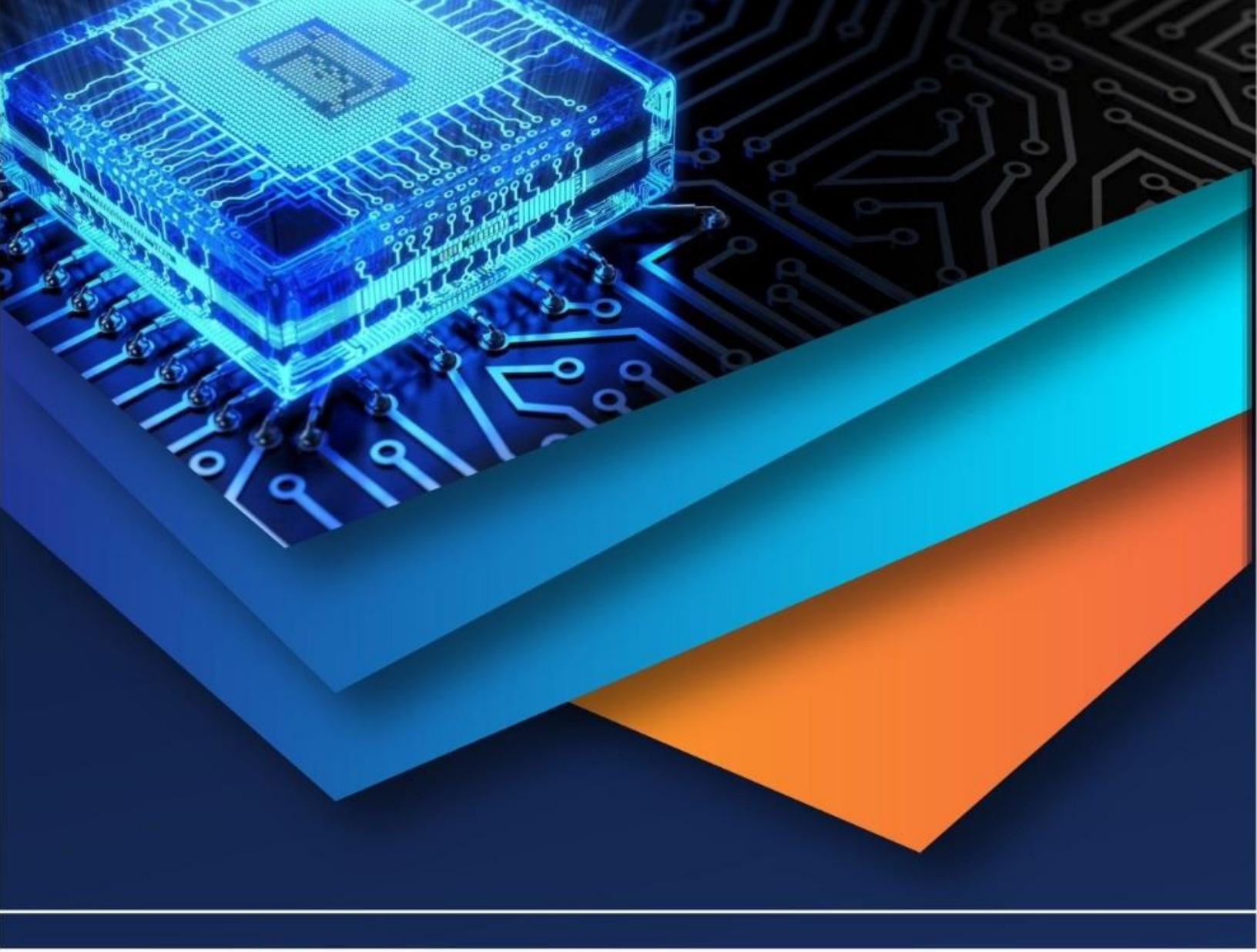
Data Structures and Algorithms (DSA) are fundamental topics in computer science, yet many students find them difficult to understand due to their abstract nature and the lack of effective visualization in traditional teaching methods. This review examined recent research on the use of Augmented Reality (AR) in education and analyzed its potential for improving the learning experience of complex computational concepts. The literature indicates that AR technology can significantly enhance visualization, interactivity, and student engagement by presenting learning content through three-dimensional models and real-time interaction. Several studies have demonstrated the effectiveness of AR in improving conceptual understanding and learner motivation across different educational domains. However, current AR-based learning systems for computer science education primarily focus on basic visualization and often lack important features such as adaptive learning support, gamification mechanisms, and scalable mobile implementations. This review highlights the need for more advanced AR-based educational platforms that combine interactive visualization with motivational learning strategies. Integrating gamification elements such as levels, points, and rewards can encourage active participation, while personalization techniques can support learners with different learning speeds and abilities. Overall, mobile Augmented Reality presents a promising approach for improving the teaching and learning of Data Structures and Algorithms. Future research should focus on developing comprehensive AR learning systems that integrate visualization, gamification, and adaptive learning for more effective educational environments.

REFERENCES

[1] M. Gómez-Ríos, M. Paredes-Velasco, J. Á. Velázquez-Iturbide, and M. Á. Quiroz Martínez, “Augmented Reality for Learning Algorithms: Evaluation of Its Impact on Students’ Emotions Using Artificial Intelligence,” Applied Sciences, vol. 15, no. 15, p. 7745, Jul. 2025, doi: 10.3390/app15147745.

[2] S. D. Ristianto, A. Putri, and Y. Rosmansyah, "Personalized Gamification: A Technological Approach for Student Education—A Systematic Literature Review," IEEE Access, vol. 13, pp. 55712–55734, Apr. 2025, doi: 10.1109/ACCESS.2025.3552826.
[3] R. Kaviyaraj and U. Mohan, "An Augmented Reality Framework for Education: Deep Learning Integration and Impact Evaluation," IEEE Access, vol. 13, pp. 11234–11247, Mar. 2025, doi: 10.1109/ACCESS.2025.3551656.
[4] H. Ateş and C. Gündüzalp, "The Convergence of GETAMEL and Protection Motivation Theory: A Study on Augmented Reality-Based Gamification Adoption Among Science Teachers," Education and Information Technologies, vol. 30, pp. 17361–17403, 2025, doi: 10.1007/s10639-025-13480-1.
[5] H. Ateş and M. Polat, "Leveraging Augmented Reality and Gamification for Enhanced Self-Regulation in Science Education," Education and Information Technologies, vol. 30, pp. 17079–17110, 2025, doi: 10.1007/s10639-025-13481-0.
[6] S. A. Nikou, M. Perifanou, and A. A. Economides, "Exploring Teachers' Competences to Integrate Augmented Reality in Education: Results from an International Study," TechTrends, vol. 68, no. 5, pp. 1208–1221, 2024, doi: 10.1007/s11528-024-01014-4.
[7] M. Kiourexidou, A. Kanavos, M. Klouvidaki, and N. Antonopoulos, "Exploring the Role of User Experience and Interface Design Communication in Augmented Reality for Education," Multimodal Technologies and Interaction, vol. 8, no. 6, p. 43, 2024, doi: 10.3390/mti8060043.
[8] G. Lampropoulos, E. Keramopoulos, K. Diamantaras, and G. Evangelidis, "Integrating Augmented Reality, Gamification, and Serious Games in Computer Science Education," Education Sciences, vol. 13, no. 6, p. 618, 2023, doi: 10.3390/educsci13060618.
[9] D. Kamińska, G. Zwoliński, A. Laska-Leśniewicz, R. Raposo, M. Vairinhos, E. Pereira, F. Urem, M. Ljubić Hinić, R. E. Haamer, and G. Anbarjafari, "Augmented Reality: Current and New Trends in Education," Electronics, vol. 12, no. 16, p. 3531, 2023, doi: 10.3390/electronics12163531.
[10] G. Koutromanos, A. T. Mikropoulos, D. Mavridis, and C. Christogiannis, "The Mobile Augmented Reality Acceptance Model for Teachers and Future Teachers," Education and Information Technologies, vol. 29, no. 4, pp. 7855–7893, 2023, doi: 10.1007/s10639-023-12116-6.
[11] J. W. Lai and K. H. Cheong, "Educational Opportunities and Challenges in Augmented Reality: Featuring Implementations in Physics Education," IEEE Access, vol. 10, pp. 40278–40294, 2022, doi: 10.1109/ACCESS.2022.3166478.
[12] S. S. Farooq, H. Rahman, S. A. N. Raza, M. Raees, and S. K. Jung, "Designing Gamified Application: An Effective Integration of Augmented Reality to Support Learning," IEEE Access, vol. 10, pp. 161747–161762, 2022, doi: 10.1109/ACCESS.2022.3221473.
[13] J. Kim and J. Shim, "Development of an AR-Based AI Education App for Non-Majors," IEEE Access, vol. 10, pp. 11443–11453, 2022, doi: 10.1109/ACCESS.2022.3145355.
[14] S. Criollo-C, D. Abad-Vásquez, M. Martic-Nieto, F. A. Velásquez-G, J. L. Pérez-Medina, and S. Luján-Mora, "Towards a New Learning Experience through a Mobile Application with Augmented Reality in Engineering Education," Applied Sciences, vol. 11, no. 11, p. 4921, 2021, doi: 10.3390/app11114921.
[15] S. Mystakidis, A. Christopoulos, and N. Pellas, "A Systematic Mapping Review of Augmented Reality Applications to Support STEM Learning in Higher Education," Education and Information Technologies, vol. 26, no. 6, pp. 6635–6663, 2021, doi: 10.1007/s10639-021-10682-1.

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