AI-INTEGRATED ARKIT: REAL-TIME COGNITIVE INTERACTION FRAMEWORK FOR IOS APPLICATIONS

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Abstract

This research investigates the integration of Artificial Intelligence (AI) with Apple's ARKit framework to develop a Real-Time Cognitive Interaction Framework for iOS applications. The study employs a secondary qualitative data analysis method to explore how AI can enhance user engagement and cognitive interaction within augmented reality (AR) environments. Thematic analysis is utilized to identify recurring patterns and themes from existing literature, focusing on the intersection of AI, AR, and user experience. Findings suggest that AI integration can significantly improve contextual understanding, personalization, and real-time adaptability in AR applications, leading to more immersive and intuitive user experiences.

Keywords: AI integration, ARKit, Augmented Reality, Cognitive Interaction, Real-Time Adaptability, Personalized User Experience, Machine Learning, Computer Vision, iOS Applications, Contextual Awareness

I. INTRODUCTION

The rapid evolution of augmented reality (AR) technologies has significantly reshaped the way users interact with digital content, creating experiences that are more immersive, interactive, and contextually aware. Unlike traditional user interfaces, AR allows digital objects to coexist and interact with the physical environment in real time, offering novel opportunities in education, healthcare, gaming, retail, and industrial applications. Among the tools enabling this transformation, Apple's ARKit framework stands out as a powerful platform for developing iOS AR applications. ARKit provides developers with a robust set of tools for motion tracking, scene understanding, and rendering virtual objects seamlessly within the real world, supporting experiences that are visually realistic and spatially coherent [1].

As AR applications grow in complexity, there is an increasing demand for enhancing their cognitive interaction capabilities enabling systems to perceive, interpret, and respond to user behavior intelligently. Cognitive interaction focuses on understanding user intent, preferences, and environmental context, which allows applications to adapt dynamically and offer personalized experiences. Integrating Artificial Intelligence (AI) with ARKit presents an opportunity to bridge this gap, leveraging machine learning algorithms, computer vision, and predictive analytics to create responsive and intelligent AR systems. By doing so, AR applications can move beyond static visual overlays to become interactive, context-sensitive platforms that enhance engagement and user satisfaction [2].

Problem Statement

Despite ARKit's ability to create visually compelling and immersive augmented reality experiences, many existing AR applications lack the cognitive interaction necessary to adapt dynamically to users' behaviors, preferences, and real-world contexts. Most AR applications operate based on predefined rules or static content placement, which limits their responsiveness and personalization. As a result, users often experience generic interactions that fail to fully engage them or leverage the potential of AR technology. This limitation is particularly critical in domains such as education, healthcare, and retail, where adaptive and personalized interactions can significantly improve learning outcomes, patient engagement, or consumer experiences [2].

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Integrating AI into ARKit offers a promising solution to this problem. AI-driven AR systems can interpret user gestures, predict behavioral patterns, and adapt virtual content based on contextual cues in real time. However, there is currently limited research on effective strategies for embedding AI within ARKit frameworks to enhance cognitive interaction. Challenges include seamless integration of machine learning models, real-time processing constraints on mobile devices, and maintaining the balance between system intelligence and user experience. Addressing these gaps is essential for advancing AR applications from visually immersive tools to intelligent, adaptive platforms capable of delivering highly personalized user experiences.

Aims and Objectives

Aim:

To explore the integration of AI with ARKit to develop a Real-Time Cognitive Interaction Framework for iOS applications.

Objectives:

- To analyze existing literature on AI and ARKit integration in iOS applications.
- To identify key cognitive interaction challenges in current AR applications.
- To propose a framework for integrating AI into ARKit to enhance cognitive interaction.

II. LITERATURE REVIEW

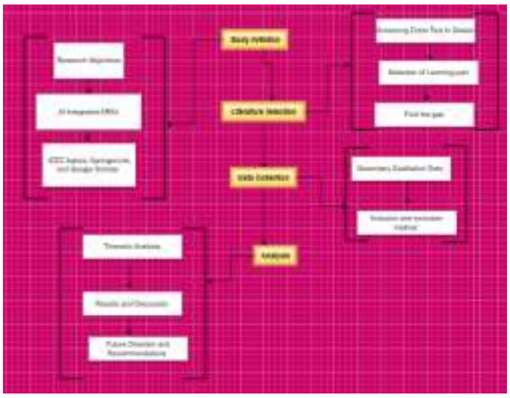

Fig 1: Flow of the Review

Structured Literature Review Approach followed the following steps:

I. **Identification of Relevant Studies:** Systematic search of academic databases to gather studies on AI and ARKit integration.

II. **Thematic Categorization:** Grouping studies based on common themes such as cognitive interaction, AI algorithms, and ARKit functionalities.

III. **Critical Analysis:** Evaluating the methodologies, findings, and limitations of selected studies.

Academic Database and Source Utilization for this study are:

I. IEEE Xplore

II. ACM Digital Library

III. Google Scholar

A. Searching Study:

A comprehensive search was conducted using keywords such as "AI integration with ARKit," "cognitive interaction in AR applications," and "iOS AR frameworks." Studies were selected based on their relevance, citation count, and publication in peer-reviewed journals. The search aimed to identify research that addresses the intersection of AI and ARKit in enhancing cognitive interaction.

B. Selection of Journal Articles:

Selected articles were evaluated for their methodological rigor, relevance to the research objectives, and contribution to the field. Studies that provided empirical evidence, theoretical frameworks, or case studies on AI and ARKit integration were prioritized. The selection process ensured a comprehensive understanding of current research trends and gaps.

C. The Goal of the Review:

The primary goal was to synthesize existing research on AI and ARKit integration to identify best practices, challenges, and opportunities for enhancing cognitive interaction in AR applications. The review aimed to inform the development of a conceptual framework that leverages AI to improve user engagement and adaptability in AR environments.

D. Study of Previous Literature

AI Algorithms in AR Applications

Artificial Intelligence (AI) algorithms have become integral to advancing the capabilities of augmented reality (AR) applications. Machine learning (ML) techniques, including supervised, unsupervised, and reinforcement learning, enable AR systems to identify patterns in user behavior, environmental inputs, and contextual data [3]. Computer vision algorithms play a crucial role in real-time object detection, recognition, and tracking, allowing virtual objects to interact seamlessly with real-world environments. Gesture recognition algorithms also allow users to interact naturally without physical controllers, creating a more immersive experience. Several studies highlight how AI can enhance AR applications by enabling predictive modeling, dynamic content adjustment, and adaptive interfaces [4]. For instance, convolutional neural networks (CNNs) can detect and classify objects within a user's field of view, while recurrent neural networks (RNNs) can track user movement over time to predict future actions. Despite these advantages, integrating AI into AR frameworks like Apple's ARKit poses challenges, including computational complexity, latency, and resource constraints on mobile devices [5]. Ensuring real-time processing without compromising user experience remains a critical concern. Furthermore, developers face difficulties in maintaining robustness across varying lighting, environments, and device hardware. Addressing these challenges is essential to fully leverage AI for enhancing interactivity and personalization in AR applications.

Cognitive Interaction in AR Environments

Cognitive interaction in AR environments refers to the system's ability to perceive, interpret, and respond to user behavior and environmental context intelligently. Unlike traditional AR applications, which primarily overlay digital content on physical spaces, cognitive AR adapts dynamically to user actions, intentions, and preferences. Studies indicate that enhancing cognitive interaction significantly improves engagement, retention, and overall user satisfaction [6]. For example, AR applications can adjust virtual content based on the user's gaze, gesture, or historical behavior, creating more intuitive and natural interactions. Cognitive models powered by AI analyze user inputs in real-time, enabling applications to anticipate needs and provide proactive guidance [7]. However, many existing AR applications lack these advanced capabilities, limiting their ability to respond effectively to dynamic user requirements. Current implementations often rely on predefined rules or static interaction models, resulting in less personalized experiences. To overcome these limitations, AI techniques such as reinforcement learning and adaptive neural networks are increasingly used to enhance real-time decision-making [8]. Developing robust cognitive interaction models for AR remains a critical research area, as it requires balancing responsiveness, accuracy, and computational efficiency within the constraints of mobile hardware and AR frameworks like ARKit.

Integration of AI with ARKit

Fig 2: AI with ARKit

The integration of AI with Apple's ARKit framework has emerged as a promising approach to enhance augmented reality applications. ARKit provides robust tools for environmental mapping, motion tracking, and

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plane detection, which can serve as the foundation for AI-powered enhancements [9]. By combining ARKit's capabilities with machine learning models, developers can implement advanced functionalities such as facial recognition, object detection, gesture analysis, and environmental understanding. For example, AI models can process ARKit sensor data to detect and classify objects in real-time or predict user movement for smoother interactions. Despite these advancements, research highlights the lack of comprehensive frameworks that address the full spectrum of cognitive interaction challenges. Current implementations often focus on specific functionalities rather than providing holistic solutions for adaptive and intelligent user experiences. Furthermore, integrating AI with ARKit requires careful consideration of computational efficiency, real-time processing, and device constraints [10]. Training models to operate effectively on mobile devices without latency or excessive power consumption remains a major challenge. The development of unified frameworks that seamlessly combine AI algorithms with ARKit functionalities is essential to achieve fully interactive, context-aware, and personalized AR experiences. Such integration has the potential to revolutionize iOS AR applications by enabling intelligent, responsive, and immersive interactions.

User Experience and Engagement

User experience (UX) is a pivotal factor in the adoption and success of AR applications. AR environments that offer personalized, context-aware, and interactive experiences have been shown to significantly increase user engagement and satisfaction [11]. AI plays a critical role in enhancing UX by analyzing user data, predicting preferences, and adapting interactions in real-time. For instance, AI-driven recommendation systems can suggest content based on user behavior, while adaptive interfaces can respond dynamically to gestures or environmental changes. Studies indicate that users are more likely to remain engaged with AR applications that feel intuitive, responsive, and tailored to their needs [12]. However, implementing such personalization introduces challenges related to data privacy and ethical considerations. Collecting, storing, and processing user data must comply with privacy regulations, and AI models should avoid biases that may affect user experiences. Moreover, ensuring consistent performance across diverse devices and environments is crucial to maintaining engagement. To maximize UX, developers must balance personalization, responsiveness, and ethical considerations, integrating AI algorithms into AR frameworks like ARKit without compromising usability [13]. Enhancing cognitive interaction through AI-driven UX improvements remains a critical research area for creating highly engaging AR applications.

Literature gap

Although previous studies have examined different facets of integrating Artificial Intelligence (AI) with ARKit, there remains a notable deficiency in research that provides a comprehensive framework for enhancing cognitive interaction within AR applications. Existing work primarily focuses on isolated functionalities, such as gesture recognition, object detection, or basic user adaptation, without addressing the broader goal of creating fully intelligent, context-aware AR experiences. As a result, most AR applications offer limited personalization and fail to dynamically respond to users' behaviors, preferences, or environmental changes. Furthermore, there is insufficient exploration of combining multiple AI techniques such as machine learning, computer vision, and natural language processing within a single, cohesive AR framework to support adaptive, real-time interactions. This gap highlights the need for a unified approach that not only integrates AI into ARKit but also systematically enhances cognitive interaction, enabling immersive, responsive, and user-centric experiences that can advance the usability and effectiveness of AR applications across diverse domains.

III. METHODOLOGY

Fig 3: Methodology

This research employs a secondary qualitative data analysis method, utilizing existing literature to explore the integration of AI with ARKit for enhancing cognitive interaction in iOS applications [14]. Thematic analysis is the primary analytical approach, allowing for the identification of recurring themes and patterns across selected studies.

Data Collection

Data was collected from peer-reviewed journal articles, conference proceedings, and technical reports published in the last five years. The selection criteria included relevance to the research objectives, methodological rigor, and citation count. Studies were sourced from academic databases such as IEEE Xplore, ACM Digital Library, and Google Scholar.

Data Analysis

Thematic analysis is conducted in several phases:

1. Familiarization with Data: Initial reading of selected studies to gain an understanding of the content.
2. Generating Initial Codes: Identification of significant features and coding of relevant data segments.
3. Searching for Themes: Collating codes into potential themes based on patterns and relationships.
4. Reviewing Themes: Refining themes to ensure they accurately represent the data.
5. Defining and Naming Themes: Finalizing themes and providing clear definitions.

This iterative process ensured a comprehensive analysis of the data, leading to the identification of key themes related to AI integration and cognitive interaction in AR applications.

Ethical Considerations

Given the secondary nature of the data, ethical considerations primarily involved proper citation and acknowledgment of original authors [15]. No primary data collection was conducted, mitigating concerns related to participant consent and data privacy.

Limitations

The study's reliance on existing literature may introduce publication bias, as studies with significant findings are more likely to be published. Additionally, the rapidly evolving nature of AI and AR technologies means that some findings may become outdated [16]. Despite these limitations, the thematic analysis provides valuable insights into the integration of AI with ARKit for enhancing cognitive interaction.

IV. DATA ANALYSIS

Theme 1: Enhancing Contextual Awareness through AI

Contextual awareness in augmented reality (AR) refers to the system’s capability to understand and interpret the environment in which it operates. AI algorithms, particularly those based on machine learning (ML) and computer vision, play a pivotal role in achieving this awareness. By analyzing data from device sensors, such as cameras, LiDAR, accelerometers, and gyroscopes, AI can construct a dynamic understanding of the user’s surroundings. For instance, computer vision algorithms can recognize objects, surfaces, and spatial layouts, while ML models can infer patterns in environmental changes over time [17]. This allows AR applications to adapt content dynamically, ensuring that digital objects interact seamlessly with the real-world environment. Furthermore, AI can detect and respond to changes in lighting, orientation, and motion, maintaining a consistent and immersive visual experience. Studies indicate that integrating contextual awareness improves user engagement and satisfaction by providing interactions that feel more natural and responsive. For example, an educational AR application could adjust its content based on the type of object detected in the user's environment, offering relevant information or instructions [18]. Despite these advantages, challenges remain in implementing contextual AI on mobile devices. Real-time processing requires efficient algorithms and optimized resource management to prevent latency or battery drain. Additionally, sensor inaccuracies and environmental variability can impact the system's ability to interpret context correctly. Addressing these issues is essential to deliver AR applications that are not only immersive but also adaptive, reliable, and capable of providing a personalized experience [19]. Overall, enhancing contextual awareness through AI represents a foundational step toward more intelligent and responsive AR applications.

Theme 2: Personalization of User Interactions

Personalization in AR applications focuses on tailoring experiences to the unique behaviors, preferences, and requirements of individual users. AI algorithms, particularly machine learning and recommendation systems, enable applications to analyze user interactions and adapt content accordingly. By examining patterns such as gaze direction, gesture inputs, navigation behavior, and past interactions, AI models can predict user intentions and deliver relevant responses [20]. For instance, in a shopping AR app, AI could recommend products or overlays based on the user's preferences and past selections. Personalization enhances user engagement by creating a sense of relevance and interactivity, as the application continuously adjusts to individual needs. Machine learning models, including clustering and predictive algorithms, can segment users and dynamically adjust content, offering tailored experiences without manual configuration. Moreover, personalization supports adaptive interfaces that modify their layout, difficulty, or feedback style to suit user proficiency and behavior. Research shows that applications incorporating personalization mechanisms achieve higher retention rates, increased satisfaction, and deeper engagement compared to static AR systems [21]. However, personalization must be balanced with privacy and ethical considerations. Collecting and processing user data responsibly is crucial to prevent misuse and ensure trust. Additionally, ensuring that personalization algorithms are unbiased and inclusive is necessary to provide equitable user experiences. Overall, AI-driven personalization transforms AR interactions from generic overlays into contextually rich, user-centered experiences, significantly enhancing the intuitive and engaging nature of AR applications.

Theme 3: Real-Time Adaptability and Feedback Mechanisms

Real-time adaptability in AR applications refers to the system's ability to respond instantly to user actions and environmental changes. AI algorithms enable these applications to provide continuous feedback, maintain immersion, and enhance the overall user experience. By analyzing sensor data, user interactions, and behavioral patterns, AI models can adjust virtual elements dynamically to align with user performance or environmental variations [22]. For example, in an AR-based training application, AI can modify the difficulty level of exercises according to the user's proficiency or provide hints when mistakes occur. Real-time feedback mechanisms also allow users to correct actions immediately, fostering learning, engagement, and improved task performance. Additionally, adaptive AR systems can modify visual cues, audio prompts, or interactive elements in response to changing contexts, such as lighting or spatial configuration, ensuring a consistent and effective user experience [23]. Studies indicate that AR applications incorporating real-time adaptability achieve higher engagement, reduced cognitive load, and enhanced satisfaction compared to static systems. Implementing real-time adaptability requires efficient algorithms and optimized processing to minimize latency while preserving accuracy. Challenges include computational resource constraints, sensor noise, and ensuring that feedback remains relevant and non-intrusive [24]. Despite these challenges, AI-powered adaptability represents a significant advancement in AR, bridging the gap between static content and interactive, intelligent experiences. By providing instantaneous adjustments and personalized feedback, AI enhances cognitive interaction, promotes user engagement, and ensures that AR applications remain immersive, responsive, and highly effective across diverse use cases.

The integration of Artificial Intelligence (AI) with Apple's ARKit represents a major advancement in augmenting cognitive interaction within iOS applications. Thematic analysis of secondary data reveals three central dimensions that drive this enhancement: contextual **awareness**, **personalization of user interactions**, and **real-time adaptability**. Collectively, these dimensions redefine how users engage with augmented reality (AR) environments, transforming them into intelligent, adaptive, and highly immersive ecosystems. The results demonstrate that AI integration not only improves the interactivity of AR experiences but also aligns with the evolving expectations for more intuitive, responsive, and human-centered digital applications [25].

Contextual awareness serves as the foundation for cognitive interaction in AI-enhanced ARKit applications. By embedding AI-driven perception systems, applications can interpret user environments and dynamically adapt to real-world changes. Computer vision and deep learning models process live data streams from sensors such as LiDAR, accelerometers, gyroscopes, and device cameras [26]. These technologies allow applications to understand spatial configurations, identify physical objects, and track user movement with high precision. For instance, convolutional neural networks (CNNs) can detect and classify objects in real time, while ARKit's scene understanding capabilities translate this data into spatially coherent digital overlays [27].

Such integration allows AR environments to become contextually intelligent, capable of distinguishing between indoor and outdoor settings, detecting lighting variations, and adjusting digital content accordingly. An educational AR application, for example, could identify a specific object, such as a human organ model or a historical artifact, and project interactive annotations that provide real-time information [28]. In industrial contexts, contextual awareness could support maintenance workers by identifying machine parts and displaying relevant procedural guides.

The findings emphasize that applications incorporating contextual AI systems achieve higher levels of immersion and natural user engagement. Users perceive these systems as "intuitive," since responses appear aligned with environmental cues. However, limitations remain in terms of **sensor precision**, **processing latency**, and **environmental noise**, which can interfere with the accuracy of object detection and spatial mapping [29]. Research suggests that future iterations of ARKit, combined with optimized AI models such as MobileNet and TensorFlow Lite, can improve the accuracy and efficiency of contextual processing on mobile devices [30].

Personalization emerges as a transformative outcome of integrating AI into ARKit frameworks. AI-driven personalization allows applications to tailor content, visuals, and interactions based on user behavior, preferences, and engagement history [31]. By employing reinforcement learning and predictive analytics, applications can dynamically adjust their interfaces and functionalities to create individualized experiences.

For example, an AI-enabled AR shopping application can analyze a user's past browsing history, gesture patterns, and dwell time to suggest personalized products displayed within their real-world space. In education, ARKit applications can use learning analytics to adapt lesson difficulty levels according to a student's pace and comprehension. This capacity for personalization enhances motivation, retention, and satisfaction, as users feel the system "understands" and responds to their unique needs.

Machine learning algorithms such as decision trees, Bayesian networks, and collaborative filtering techniques facilitate such adaptive personalization by predicting user intent and refining recommendations over time. However, personalization introduces **ethical and technical challenges**, particularly concerning data privacy, algorithmic fairness, and transparency. Without careful governance, personalized systems risk reinforcing biases or overfitting user profiles [32]. Therefore, adopting privacy-preserving mechanisms, including federated learning and local data processing, becomes critical to balance personalization with user trust.

The thematic synthesis indicates that personalized AR environments significantly improve cognitive interaction by fostering emotional engagement and active participation. Users perceive these systems as intelligent partners rather than passive tools, deepening the cognitive bond between human and machine [33].

Real-time adaptability constitutes the third pillar of enhanced cognitive interaction. AI integration empowers ARKit applications to continuously monitor user inputs and environmental factors, adapting responses instantly to maintain engagement and immersion. Through continuous feedback loops, applications can adjust difficulty levels, modify object behavior, and provide immediate corrective feedback.

In training and simulation applications, such adaptability proves invaluable. For instance, in medical AR simulations, AI can assess a trainee's actions and offer immediate corrective guidance, ensuring both accuracy and confidence in skill development. Similarly, in gaming or fitness applications, AI models can track user performance and adapt challenges dynamically to sustain motivation and learning progression [34].

This real-time responsiveness is enabled by predictive algorithms that process user input—such as gestures, gaze direction, or voice commands—within milliseconds. Reinforcement learning enables systems to optimize decisions based on feedback, ensuring continuous improvement. However, implementing real-time adaptability faces challenges related to **latency**, **energy consumption**, and **computational limitations** on mobile hardware. Edge computing and neural processing units (NPUs) within modern iPhones offer partial solutions, but further research into lightweight AI architectures is needed to fully realize seamless adaptability [35].

Moreover, the responsiveness of AI-enhanced ARKit applications not only enhances interactivity but also reduces cognitive load. By intuitively guiding users and simplifying complex tasks, these applications improve task efficiency, comprehension, and overall satisfaction. The incorporation of adaptive feedback systems ensures that users remain engaged without becoming overwhelmed, thus supporting a more natural human–computer interaction model.

Synthesizing the findings across the three thematic areas reveals that integrating AI with ARKit fundamentally elevates the cognitive dimension of user interaction [36]. Contextual awareness enables AR applications to perceive the environment; personalization allows them to understand and respond to users individually; and real-time adaptability ensures responsiveness that keeps interactions fluid and intuitive. Together, these elements transform AR applications from static overlays into intelligent systems capable of learning, reasoning, and adapting in real time.

The study also identifies emerging trends in **cross-domain applicability**. In healthcare, AI-powered ARKit applications can assist in surgery planning or remote diagnosis by overlaying patient data on 3D anatomical models [37]. In education, they can promote experiential learning through adaptive, immersive lessons. Retail, entertainment, and industrial maintenance sectors can also leverage such frameworks for improved user engagement and operational precision.

However, challenges remain significant. Technical constraints such as mobile processing power, limited battery life, and data bandwidth can restrict scalability. Moreover, ethical considerations, including informed consent, data ownership, and algorithmic transparency, must be prioritized to ensure responsible innovation. Addressing these issues requires collaboration between AI engineers, AR developers, ethicists, and policymakers.

Research Limitations:

- Reliance on secondary qualitative data may introduce publication bias and limit the evaluation of real-time AI-ARKit performance.
- Rapid evolution of AR and AI technologies may render some findings outdated or incomplete over time.

Implementation Considerations:

- Optimize AI algorithms for mobile ARKit applications to maintain real-time processing and energy efficiency.
- Incorporate privacy-preserving mechanisms and ethical guidelines to ensure responsible user data handling during personalization and adaptive interactions.

VI. FUTURE STUDY

Future research should emphasize the development of optimized AI algorithms specifically designed for mobile AR platforms to minimize latency, reduce computational overhead, and ensure real-time responsiveness. As AR applications operate in dynamic environments, integrating multimodal data such as visual, auditory, and motion-based inputs can significantly improve contextual understanding and cognitive responsiveness. Studies should also explore adaptive learning models that allow AR systems to evolve with user behavior over time, leading to continuous personalization. Ethical considerations, including privacy protection and transparent data handling, remain crucial for fostering user trust and regulatory compliance [38]. Therefore, future studies must focus on implementing privacy-preserving AI techniques, such as federated learning and on-device processing. Moreover, longitudinal research across different user demographics can provide deeper insights into engagement, satisfaction, and accessibility. Expanding AI-enhanced ARKit frameworks into domains like healthcare, education, and retail will further validate their real-world applicability and drive innovation in intelligent, user-centered AR experiences.

VII. CONCLUSION

The integration of Artificial Intelligence (AI) with Apple’s ARKit represents a transformative advancement in developing cognitively interactive AR applications. By combining contextual awareness, adaptive learning, and personalization, AI-enabled AR systems enhance engagement, interactivity, and user satisfaction across multiple domains. These intelligent systems can interpret user behavior, recognize environmental cues, and deliver real-time, responsive experiences that bridge the gap between digital and physical worlds. However, technical challenges such as energy consumption, latency, and mobile processing limitations continue to constrain seamless deployment. Ethical concerns related to data privacy, bias, and algorithmic transparency also require careful consideration. Despite these challenges, the study confirms that AI-ARKit integration has immense potential to redefine augmented reality by making it more intuitive, adaptive, and human-centered. Future advancements should focus on improving computational efficiency, securing user data, and customizing frameworks for domain-specific use cases, ultimately fostering the evolution of intelligent and responsible AR ecosystems.

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