HoloPC-Augmented Reality Platform for Interactive PC Hardware Learning

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Abstract: Visualization of internal computer hardware components is a fundamental requirement in technical education. However, traditional instructional methods rely heavily on textbooks, static diagrams, and limited laboratory sessions that do not adequately convey the spatial arrangement of system components. This paper presents Holo-PC, a web-based augmented reality framework developed to enable interactive exploration of internal computer hardware structures. The proposed system integrates optimized three-dimensional hardware models within a browser-accessible AR environment, allowing users to observe, manipulate, and understand hardware components without physical disassembly. The platform emphasizes accessibility, interactivity, and educational effectiveness by supporting real-time rendering and cross-device compatibility. Experimental validation demonstrates that AR-assisted visualization significantly enhances conceptual clarity and learner engagement compared to conventional methods. The proposed framework highlights the potential of immersive web technologies in modern technical education.

Keywords-Augmented Reality, Hardware Visualization, Interactive Learning Systems, Web-Based AR, Technical Education Technology.

I.INTRODUCTION

Computer hardware education plays a critical role in developing technical competency among students in computing and networking disciplines.

A comprehensive understanding of internal system architecture requires visualization of component placement, physical structure, and interconnections between modules such as processors, memory units, storage devices, and motherboards. Traditional learning environments present several challenges, including limited access to laboratory equipment, potential hardware damage during repeated demonstrations, and reliance on two-dimensional representations that fail to convey depth and spatial relationships. Advancements in immersive technologies have introduced augmented reality as a promising educational tool capable of overlaying digital information onto real-world environments. AR allows learners to interact with virtual objects while maintaining awareness of their physical surroundings, thereby bridging the gap between theoretical knowledge and practical visualization. This research introduces Holo-Pc, an interactive web-based AR framework that enhances hardware education through dynamic three-dimensional visualization.

II.SYSTEM DESIGN AND METHODOLOGY

2.1 DESIGN OBJECTIVES:

The development of the Holo-PC framework is guided by three primary objectives:

- •Deliver immersive visualization of internal hardware components
- •Enable intuitive interaction through gesture-based controls
- •Ensure accessibility through browser-based deployment

The system prioritizes educational usability while maintaining computational efficiency across multiple device platforms.

2.2 OVERALL SYSTEM ARCHITECTURE:

The architecture of Holo-PC consists of five major layers: user interaction layer, camera acquisition layer, AR processing engine, model rendering subsystem, and informational interface module. The structural organization and interconnection of the major functional modules in the proposed system are illustrated in Fig.2.1. These layers collectively manage environment sensing, virtual object placement, and interactive visualization.

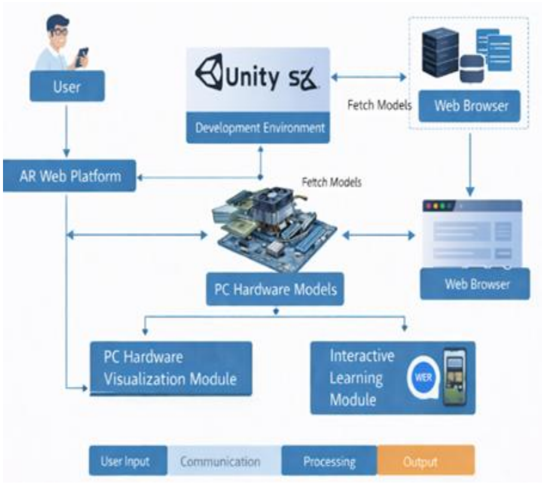

Fig.2.1 Overall System Architecture

The modular structure ensures scalability and allows seamless integration of additional hardware components and interactive features.

2.3 FUNCTIONAL BLOCK REPRESENTATION:

The functional block diagram illustrates the logical flow of data from user input to AR visualization. Camera input captures the real-world environment, which is processed by the AR engine to identify planar surfaces. The logical flow of data and processing stages within the system are represented in Fig.2.2.

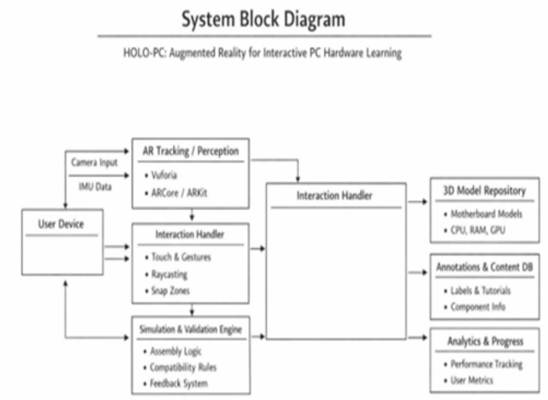

Fig.2.2 Functional Block Diagram of the Proposed System

AR engine to identify planar surfaces. The rendering engine then overlays optimized 3D hardware models within the detected spatial region.

2.4 USER-CENTRED WORKFLOW:

The operational workflow emphasizes simplicity and guided interaction. Users initiate the platform via a web interface, enable camera access, and select desired hardware components from the menu. The AR engine dynamically renders virtual objects in real-time, allowing users to explore components interactively. The workflow is designed to minimize technical complexity for non-expert users.

2.5 SYSTEM PROCESS FLOW:

The process flow diagram outlines sequential system operations including environment detection, model retrieval, rendering synchronization, and interactive manipulation Efficient coordination between modules ensures smooth real-time visualization. The sequential operational workflow followed by the system during augmented visualization is depicted in Fig. 2.3.

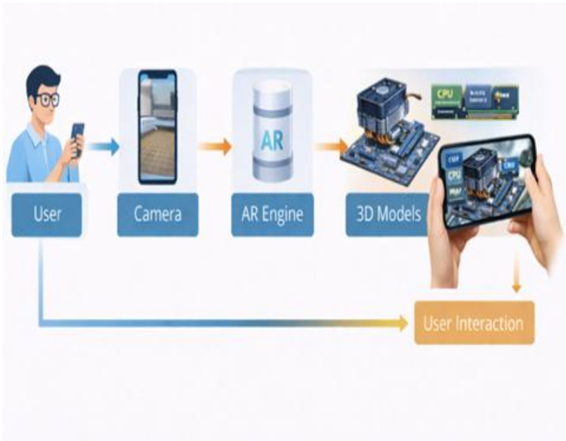

Fig.2.3 Operational Workflow of Holo-PC System

III.IMPLEMENTATION AND EXPERIMENTAL RESULTS

3.1 DEVELOPMENT ENVIRONMENT:

The Holo-PC framework is implemented using modern web technologies to ensure cross-platform compatibility. HTML and CSS provide structural layout and responsive interface design, while JavaScript manages system logic and interactive behaviour. Web-based augmented reality frameworks enable camera access, spatial tracking, and virtual object rendering within standard browsers. Visual Studio Code was utilized as the development environment due to its flexibility in handling integrated web resources.

3.2 INTEGRATION OF THREE-DIMENSIONAL HARDWARE MODELS:

Realistic three-dimensional models representing internal computer components were designed and optimized for real-time rendering. Performance considerations such as polygon reduction and texture

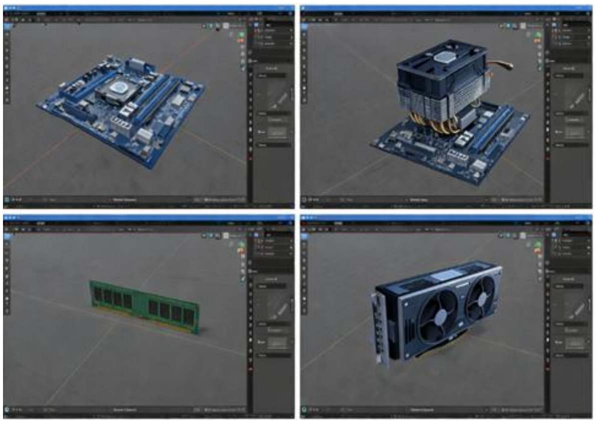

Fig.3.1 3D Hardware Component Models Used for Visualization

compression was applied to maintain smooth visualization across mobile and desktop platforms. Model optimization ensured efficient AR performance without compromising visual clarity. The optimized three-dimensional hardware component models integrated into the augmented environment are shown in Fig.3.1.

3.3 AUGMENTED REALITY ENVIRONMENT CONFIGURATION:

The AR subsystem processes live camera input to detect flat surfaces suitable for virtual object placement. Environmental mapping and motion tracking algorithms maintain positional accuracy of rendered objects during user movement. Stable surface detection ensures realistic alignment between virtual and physical environments.

3.4 INTERACTIVE VISUALIZATION FEATURES:

The platform incorporates multiple interaction mechanisms to enhance user engagement. Gesture-based controls allow rotation, scaling, and repositioning of virtual models. Interactive labels provide contextual information regarding component functionality. These features transform passive observation into active learning.

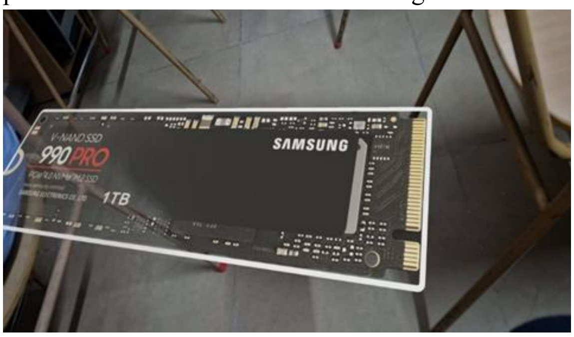

Fig.3.2 User Interaction with Augmented Hardware Visualization

User interaction with virtual hardware components through gesture-based controls is illustrated in Fig.3.2.

3.5 OPERATIONAL WORKFLOW VALIDATION:

System testing confirmed accurate coordination between AR processing modules, rendering pipelines, and interaction handlers. Results demonstrate consistent real-time visualization with minimal latency.

3.6 PERFORMANCE EVALUATION AND DISCUSSION:

Performance evaluation indicates that the platform operates reliably across multiple browser environments with stable rendering speed. User interaction remains responsive even under moderate device constraints. Comparative observation suggests improved spatial comprehension and engagement relative to traditional diagram-based instruction methods. The results validate AR-assisted visualization as an effective educational enhancement tool.

IV. CONCLUSION

This research presented Holo-PC, a web-based augmented reality framework designed to enhance interactive visualization of internal computer hardware systems. By integrating immersive AR technologies with optimized 3D models, the platform provides a realistic and accessible educational tool for technical learners. The framework demonstrates that web-based AR can effectively supplement laboratory-based learning while improving conceptual understanding and engagement.

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