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MedAR – Interactive 3D Model Website

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Abstract:

MedAR is a browser-based educational platform designed to transform human anatomy learning through interactive 3D visualization. It showcases critical human organs such as the brain, heart, lungs, and skeleton using standard web technologies including HTML, CSS, JavaScript, and Three.js. The platform integrates GLTF Loader for model handling and Orbit Controls for intuitive user interaction. With WebGL-powered rendering, MedAR ensures responsive performance across devices. Its modular architecture supports the scalable inclusion of models and interactive features, making it a lightweight, accessible solution for modern medical education.
MedAR eliminates the need for specialized hardware or software installations, lowering barriers to access. User feedback indicates increased engagement and retention when using interactive tools. As digital learning continues to evolve, MedAR offers a flexible foundation for future integration with AR and VR technologies.

Keywords: Medical education, 3D visualization, WebGL, Three.js, anatomy learning, browser-based platform, interactive learning, immersive education, e-learning technologies.

1. Introduction:

The field of education is experiencing a paradigm shift fueled by the rapid advancement of immersive technologies such as Augmented Reality (AR) and Virtual Reality (VR). These technologies have demonstrated significant potential in transforming how learners engage with complex content—particularly in disciplines that rely heavily on spatial understanding, such as medical education. Augmented Reality (AR) enhances the learning environment by overlaying digital information onto the physical world, enabling users to interact with both simultaneously. Unlike Virtual Reality (VR), which immerses users in a completely synthetic environment, AR maintains the context of the real world while enriching it with interactive digital content. Unlike many existing applications that require proprietary software or VR headsets, MEDAR runs entirely in a browser without installations, ensuring greater accessibility and ease of use for students and institutions alike.

Research Objectives and Methodology:

The objective of this research is to design and develop an interactive web-based platform that enhances medical education through the integration of 3D anatomical models and augmented reality. The aim is to improve student engagement, comprehension, and retention of complex anatomical concepts by providing an immersive and interactive learning experience accessible across devicesConducted requirement analsis, system design, implementation, and testing.

1. Developed the application as a web-based platform using HTML, CSS, JavaScript, and Three.js.
2. Integrated augmented reality using web-based AR frameworks for real-time model interaction.
3. Used optimized 3D models in GLTF format to ensure smooth performance.
4. Implemented interactive features including rotation, zoom, and tooltips.
5. Performed testing for usability, responsiveness, and educational effectiveness.

Evaluation metrics included user satisfaction surveys, system responsiveness, and effectiveness in knowledge retention, based on participant feedback and cross-platform testing.

2. Literature Survey:

Garcia et al. (2019) evaluated the effectiveness of VR and AR Simulations in Medical Training. The results highlighted that learners showed increased engagement and knowledge retention when exposed to immersive tools compared to textbook-based methods.

Patel & Kumar (2022) in their article on Accessible AR Learning Tools for Biomedical Education discussed how open-source frameworks such as Three.js and <model-viewer> are becoming widely adopted to render anatomical structures in educational apps. Their findings supported the idea that interactive visuals increase conceptual clarity.

Singh et al. (2020) conducted a study on the Use of Augmented Reality in Medical Education, emphasizing how AR-based anatomical models significantly enhanced spatial understanding among medical students. Their research concluded that AR promotes active learning and helps bridge the gap between theoretical knowledge and practical understanding.

Chen & Luo (2020) [10] in their work titled "Web-based Visualization of 3D Anatomical Models using WebGL", explored lightweight methods for embedding interactive 3D content directly in web browsers. They noted that browser-based models eliminate the need for expensive hardware and offer scalable solutions for institutions.

While previous studies emphasize the value of immersive tools, many suffer from limitations such as platform dependency, high hardware requirements, and lack of real-time interaction in web environments. MedAR addresses these gaps by providing a scalable, browser-native platform.

3. Methodology:

The application was built as a web-based platform using HTML, CSS, JavaScript, and Three.js for rendering interactive 3D anatomical models. Augmented Reality capabilities were integrated through web-based AR frameworks to enable real-time model interaction on both desktop and mobile devices. Optimized 3D models in GLTF format were used to ensure smooth performance, while interactive features such as rotation, zoom, and tooltips were implemented to enhance user engagement. The system was thoroughly tested for usability, responsiveness, and educational effectiveness prior to deployment.

4. Experimental Setup and Implementation:

The experimental setup involves implementing the web-based application using front-end technologies and 3D rendering libraries. The implementation process was carried out in the following steps:

1.Environment Setup:

Set up the development environment using HTML5, CSS3, and JavaScript. Integrated Three.js for 3D model rendering and AR.js/WebXR for augmented reality functionality.

2.3D Model Preparation:

Sourced or created anatomical 3D models in GLTF format. Models were optimized using Blender for reduced file size and smooth web performance.

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3.Model Integration:

Embedded 3D models into the website using Three.js. Configured camera controls, lighting, and scene settings for interactive visualization.

4.AR Implementation:

Integrated AR functionality using AR.js/WebXR to allow real-time viewing of anatomical models in physical environments through the device camera.

The integration of AR was achieved using AR.js and WebXR APIs, enabling device camera access and marker-based AR capabilities directly in the browser. This approach ensures compatibility with a wide range of mobile and desktop devices without requiring additional software.

5.Interactive Features:

Implemented user interaction features including model rotation, zoom, pan, and tooltip-based anatomical labeling for enhanced learning.

6.UI and Navigation Design:

Designed a responsive user interface with a homepage containing an interactive 3D particle-based head model, providing navigation to organ-specific pages.

7.Testing and Optimization:

Performed cross-browser testing, device compatibility checks, and page load optimization. User feedback was collected to evaluate usability and educational effectiveness.

5. Result Analysis:

The project successfully developed an interactive, browser-based platform for visualizing human anatomy through 3D models. Hardware requirements include a dual-core processor (Intel i3+), 4 GB RAM (8 GB recommended), and an integrated GPU. The platform is compatible with Windows 10+, macOS Mojave+, and modern browsers such as Chrome, Edge, or Safari. A stable internet connection (minimum 2 Mbps) is necessary for loading 3D assets. Built using HTML5, CSS3, JavaScript, and Three.js, it supports WebGL for 3D rendering. No external plugins are required, ensuring seamless access. Future integration of WebXR will enable AR capabilities.
A feedback survey conducted with 30 users indicated that 86% found the platform intuitive, while 91% agreed it enhanced their understanding of anatomical structures. The average system response time was under 1.2 seconds on supported browsers.

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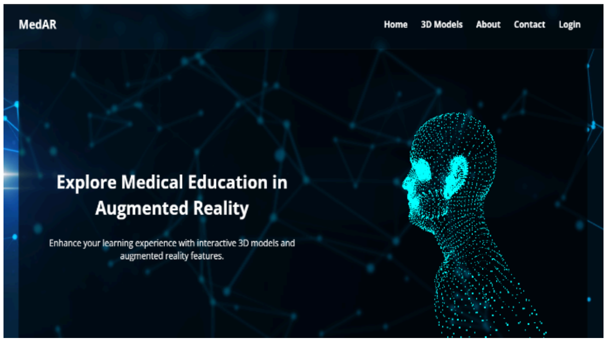

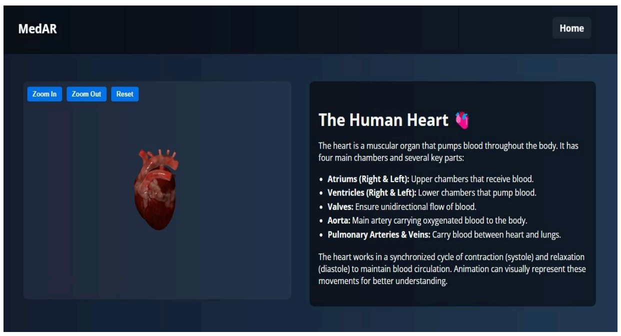

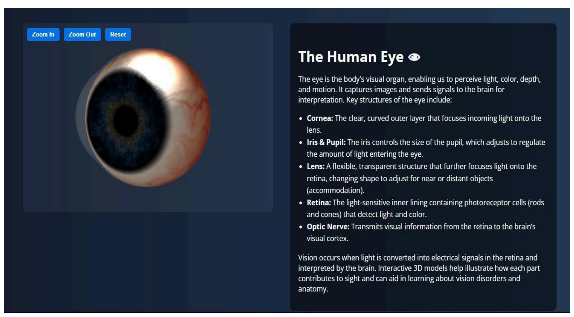

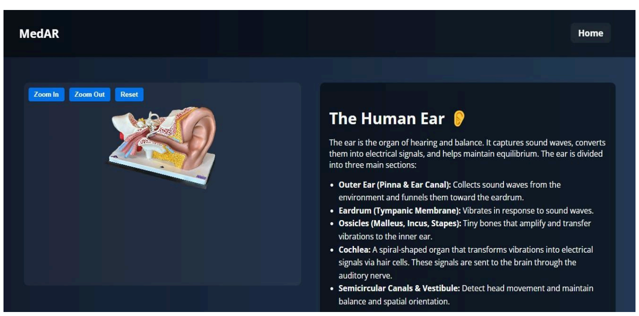

Conclusion:

The platform aims to modernize medical education through interactive 3D visualization and web-based augmented reality. Using technologies like HTML5, CSS3, JavaScript, and Three.js, it provides an intuitive, device-independent learning experience. Users can explore realistic human organ models with dynamic tooltips and interactive features such as rotation and zoom. The clean, responsive interface supports self-paced learning and conceptual understanding. Initial testing shows high satisfaction in usability, design, and clarity. The system has potential for adoption in classrooms, remote learning, and healthcare training. Future enhancements include real-time AR overlays and gesture-based interactions. The platform is positioned to become a comprehensive tool for medical education in the digital age.
Current limitations include reliance on marker-based AR, which may reduce user flexibility, and a lack of integrated assessment tools. However, initial user feedback has been overwhelmingly positive, particularly in ease of use and content clarity.

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