Progressive Education: Augmented Reality Visualization of Human Anatomy on HoloLens 2

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Abstract
The landscape of medical education is undergoing a transformative shift driven by rapid technological evolution. In the 21st century, innovative platforms, notably Augmented Reality (AR), play a crucial role in creating immersive and interactive learning environments, especially in medicine. The HoloLens headset, representing a leading AR platform, stands out in revolutionizing medical education by seamlessly merging the physical and digital realms. This article explores the development of an AR application for HoloLens 2, specifically focusing on visualizing human anatomy and highlighting intricate details of implants within the human system. The primary objective is to enrich the learning experience, providing a comprehensive understanding of anatomical structures through the lens of cutting-edge technology.

Keywords
Human anatomy, Augmented reality, Microsoft HoloLens 2

1. Introduction

The rapid evolution of technology has always been a driving force behind advancements in medical education. The immersion and interactive capabilities offered by Augmented Reality (AR) headsets like the HoloLens represent a revolutionary step in the direction of enhancing learning and research experiences in the medical field.

One significant area where AR can make a difference is in the visualization and understanding of human anatomy and physiology. Traditional methods, such as textbooks or even 3D models, provide a limited perspective. On the other hand, AR allows users to delve deep into the human body, inspecting organs, systems, and even implants in a comprehensive and interactive manner.

Furthermore, with the increasing use of implants in medical treatments and surgeries, there's a growing need for a detailed, immersive visualization tool that can aid in both educational and practical scenarios. Training healthcare professionals about the location, function, and intricacies of these implants becomes paramount.

1.1. Progressive education

Progressive education is an educational philosophy that prioritizes student-centered learning, hands-on engagement, collaboration, and project-based learning. This approach is crucial for equipping students with the skills necessary for success in the 21st century. By shifting the focus

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from traditional, teacher-centered methods to more interactive and participatory approaches, progressive education fosters the development of critical skills essential for navigating the challenges of the modern world. [1]

The developed AR application aligns with several principles of progressive education, fostering the development of 21st-century skills among users. Among these skills, we would like to emphasize:

- Critical thinking
- Creativity and innovation
- Self-direction and independence
- Using technology as a learning tool

To attain this goal, Progressive Education incorporates the following principles:

- Curriculum tailored to individual learning styles, developmental needs, and intellectual interests
- The student as an active partner in learning
- Arts, sciences, and humanities equally valued in an interdisciplinary curriculum
- Learning through direct experience and primary material
- A focus on multicultural and global perspectives
- The school as a model of democracy

The emphasis on critical thinking, creativity, and innovation is evident in the user-friendly design that encourages seamless interaction and exploration of the anatomical model. The application's accessibility promotes self-direction and independence in learning, allowing learners to take ownership of their educational journey. By leveraging AR technology as a learning tool, the application transforms the educational experience into an engaging and interactive journey. The principles of progressive education further guide the application's development, ensuring a tailored curriculum that accommodates different learning styles, encourages students to be active partners in their learning, values interdisciplinary perspectives, provides direct hands-on experiences, embraces multicultural perspectives, and reflects collaborative and democratic principles.

2. Objectives

To achieve the above aim we developed an educational application to visualize human anatomy for the HoloLens 2. The application's centerpiece is a realistic human model encompassing all body systems—skin, skeleton, muscles, organs, and many others. Our primary goal was to design an easily comprehensible and user-friendly application, promoting seamless interaction and exploration of the anatomical model.

During the design phase, we envisioned a layered representation of various body systems, allowing users to toggle between them. As development progressed, additional concepts emerged, such as organ search functionality and an enhanced preview of human organs.

Figure 1: Example of application start view.

At this moment, the application itself consists of a single expansive scene where the human model is positioned one meter away from the user. On the foreground is the main menu, incorporating all essential functions of the application, as depicted in Figure 1. It includes four tabs on the left side of the canvas, which user can click and change the display of the corresponding tab content:

- Body layer switching: This menu features a grid of toggling buttons with layer icon and name, that shows corresponding layers.
- Search: Includes an input box, where user can enter desired query and a list of found items. User can click on any item and open detailed object overview as illustrated in Figure 2.
- Popular organs or bones: Displays a list of the most popular organs (e.g, heart, brain, skull), that also opens detailed object overview.
- Settings: Includes utility buttons, for example, to move the model across the space and toggle animations.

3. Challenges and solutions

To implement our ideas effectively, we needed to carefully select a comprehensive human model that could meet our specific requirements. After exploring the market for available human models, we chose a suitable option and proceeded with it. This model, intricately designed in Blender, a powerful open-source 3D content creation tool, encompasses all human systems,
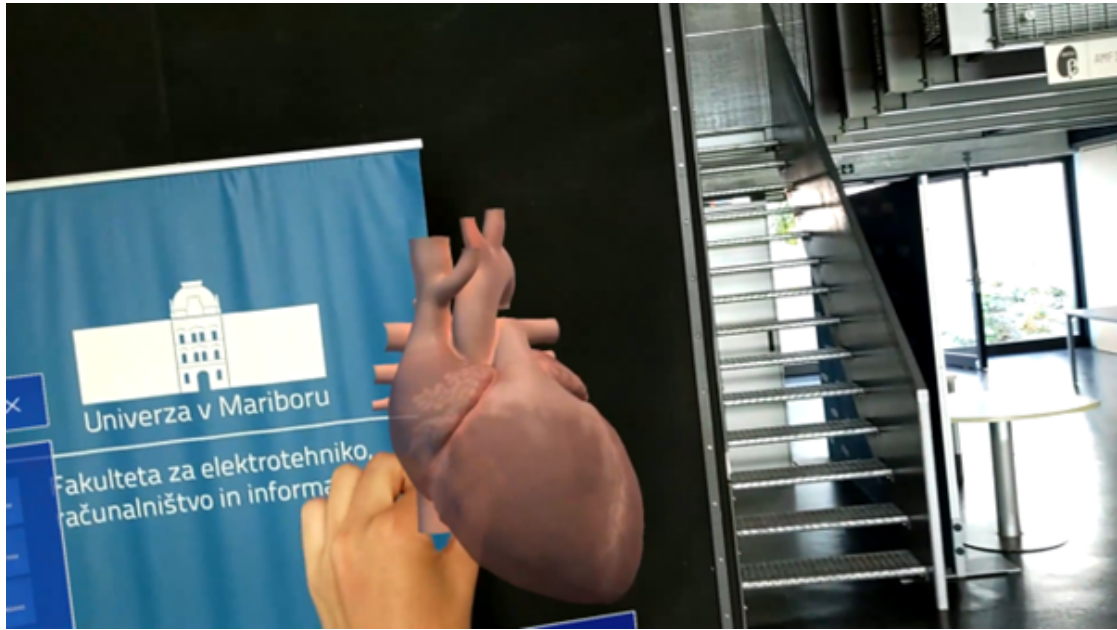
Figure 2: Detailed object overview.

including muscular, organ, lymphatic, skeletal, skin, and circulatory systems, see Figure 3. Additionally, it features an armature and a sample animation, providing a detailed and well-structured representation. This highly refined model presented an ideal foundation for our project. Our initial and crucial task involved seamlessly importing this detailed model into Unity, the chosen game engine for developing our HoloLens application.

Later in the development process, we expanded the model's capabilities by incorporating various implants, such as an electrode grid, infusion pump, neurostimulator, and electroencephalogram, as shown on middle object in Figure 3. These additions further enriched the application, allowing users to explore and understand the integration of these implants within the human body's intricate systems.

The general method for importing 3D models into Unity involves using the FBX extension. However, despite being a connecting element, challenges often arise due to the absence of certain functionalities during the import process, particularly in the development of our HoloLens application. In response, we prepared different solutions to overcome these obstacles.

The intricate material system of Blender posed difficulties during the conversion to Unity. The FBX extension faces compatibility issues with Blender's complex materials. To overcome this, our solution involved the strategic use of Python scripts within Blender. Python scripting in Blender is a powerful tool that allows users to program specific functions to suit their needs. In this instance, our scripts played a crucial role by baking textures, ensuring a smooth transition of materials into Unity.

Another significant obstacle revolved around the loss of object hierarchy during the import process. Blender organizes objects into collections, creating a hierarchical structure. However, Unity does not inherently support this hierarchy, resulting in a disorganized structure. Once

Figure 3: Different model body systems (https://goo.gl/VLCRBB).

again, Python scripts proved invaluable. We developed a script that renamed objects based on their collection, preserving a similar hierarchy in Unity.

Optimizing complex systems, such as the skeleton or organs with numerous objects and polygons, presented a third challenge. Leveraging Blender's Decimate modifier, which reduces polygon counts, and a script that consolidated disconnected objects into a single structure proved instrumental in overcoming the optimization challenge on the HoloLens platform.

As a result, we have several scripts, that had the most influence on the process:

1. Bake Collections Objects: Iterates over all the collections and objects inside and bake diffuse and normal texture for every object separately.

2. Rename Collection Objects: Iterates over all the objects and appends the collection name to the object.

3. Collection Joiner: Selects all the objects of collection and joins them to a single object.

These scripts reference the Blender Python API, which provides extensive resources for developers.

With continuous refinement and testing of our scripts, we successfully imported the model into Unity, paving the way for subsequent stages of development. The result was a realistic human model seamlessly incorporating various body systems.

3.1. Unity Application Development and MRTK Library Features

For the development of augmented reality applications on the Unity platform, the powerful Mixed Reality Toolkit (MRTK) comes into play. This library significantly simplifies the development process by abstracting away low-level functions. It encompasses various UI components, user interaction functions, physics simulation, and more. [2]

At the time of creating our application, MRTK had already reached its third global version and was actively evolving. Our project was implemented using the second version of the library, where we discovered and utilized numerous useful functions. MRTK's documentation provides an excellent resource with an extensive set of examples and educational materials, serving as inspiration for developers.

In the scope of our application, we aimed to create a maximally intuitive user experience and interface. The educational materials of the library helped us master the controls, enabling us to work towards developing an optimal UI. An example of this approach is the main menu where clear controls contribute to a user experience that is easy to understand. Main application functions are easily discernible, and interaction with the primary model is straightforward.

In our project, we leveraged several MRTK functions and widgets to enhance the user experience:

1. Bake Collections Objects: Iterates over all the collections and objects inside and bake diffuse and normal texture for every object separately.

2. Rename Collection Objects: Iterates over all the objects and appends the collection name to the object.

3. Collection Joiner: Selects all the objects of collection and joins them to a single object.

4. Bounds Control and Object Manipulator: These were utilized to manipulate the human model, allowing users to interact with and explore anatomical structures seamlessly.

5. Directional Indicator and Solver Handler: These components were employed for UI/UX enhancements, providing clear directional cues, and handling problem-solving aspects.

6. Interaction and Manipulation Scripts for UI Components: These scripts facilitated the interaction and manipulation of various UI elements within the application.

7. Scrollable and Object Collection: Implemented to create scrollable lists and collections of objects, enhancing the organization and accessibility of information.

8. Voice Input: Integrated for hands-free interaction, allowing users to input commands or queries using voice commands.

9. By incorporating these MRTK functions and widgets, we aimed to create a dynamic and immersive learning experience within our augmented reality application.

4. MOS Celje Exhibition

In October 2023, we seized the opportunity to present our application at the MOS Exhibition in the city of Celje. This exhibition stands as the largest in Slovenia, making it crucial for us to gather feedback, assess the application's performance in real conditions, and refine any shortcomings. For a week, our booth welcomed visitors to experience our application firsthand. This provided us with valuable insights, allowing us to enhance the application based on real user interactions. Despite receiving overwhelmingly positive feedback, the initial days prompted us to identify a few areas for improvement in both the application and our presentation. During the exhibition we understood the importance of introducing the users, especially for unfamiliar with augmented reality, to the basic control concepts. Explaining how to interact with buttons, various available gestures, and navigating inside the virtual world proved crucial. These fundamental aspects, when explained correctly, make application usage experience better. We addressed these aspects, ensuring that our presentation was clear and compelling for visitors of various ages.

5. Conclusion

In conclusion, the development resulted in an application designed for the in-depth study of human anatomy, incorporating all planned features. In this work, various challenges were encountered, and therefore key solutions were prepared. The application underwent real user testing, yielding positive feedback and audience interest. As augmented reality technologies continue to evolve, ongoing refinement remains imperative for future advancements in the field.

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