Original Article

No-Code Approach for Creating Virtual Stands for Professional Research

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Abstract - *Virtual reality (VR) is the computer-generated simulation of an environment that can be explored and manipulated in 360 degrees using special VR equipment. It is of great interest in educational institutions because of the possibilities it enables and the novelty of the technology. However, there are still obstacles to large-scale deployment of this technology, such as a lack of customization and flexibility. This paper presents a new approach to enhancing the use of virtual reality technology in education and research. The main goal is to help specialists with no programming knowledge construct new laboratory stands. The approach considers that real-life laboratory stands are decomposed into atomic components, and programmers create analogs for these components in the virtual environment. Later on, an intuitive and user-friendly virtual environment is provided, where no programming knowledge is needed to combine the virtual components into a laboratory stand. Using this approach, new virtual components can be continuously developed to cover more and more education fields.*

Keywords - *Immersive learning, No-code platform, Virtual laboratory, Virtual reality, Software.*

1. Introduction

A virtual reality (VR) environment is a 3D simulation that allows users to explore and interact with a virtual world in a fashion that simulates reality as experienced by the user's senses. Currently, standard virtual reality systems produce accurate images, audio, and other signals that mimic a user's actual presence in a virtual world. This effect is achieved via virtual reality headsets or multi-projected environments (such as CAVE installations using up to 6 rear-projection screens and projectors [1]). An individual utilizing virtual reality technology may gaze around the made-up environment, walk around, and interact with virtual elements or objects. In engineering, VR has proved very useful for both engineering educators and students. The most important component is the capacity to engage with 3D models that appropriately react depending on real-world possibilities. Using visual, aural, and occasionally sensory output devices enables students to interact with the virtual environment as if they were actually a part of it [2].

In recent years, the advance of virtual reality technologies raised the idea of transferring actual experiments to virtual environments. Particularly, the virtual laboratory stands, which are less hazardous and demanding not as strict working ethics as the real laboratory stands, are of great interest in educational institutions. Virtual reality technologies can be used as educational tools with the advantages of being safe, cost-effective, and fully controllable. Also, virtual reality environments significantly enhance the learning experience, providing the learner with realism and interactivity [3].

The recent developments in game-based VR educational laboratories have been studied by M. Zhang et al. [4]. As mentioned by the authors, several disadvantages prevent the broad deployment of VR technologies in higher education. These disadvantages include financial feasibility, lack of customizability, and flexibility. In another research, G. Makransky et al. conducted two experiments to examine the advantages of employing VR laboratory simulations in scientific teaching. In the first study, 99 students in the seventh (49) and eighth (50) grades, aged 13 to 16, participated in an IVR lab safety simulation. The findings showed a general rise in self-efficacy and scientific curiosity. The second research employed an experimental design to examine the benefits of utilizing a VR simulation as compared to a video of the simulation. The evaluation was based on participation results of 131 second and third-year high school students aged 17 to 20. The findings of the two studies indicate that IVR simulations that have been properly built and deployed can alleviate some of the problems that science education is now facing [5]. Amongst others evaluating the effectiveness of VR simulations, some studies focus on nursing education. A VR application named PILL-VR developed for learning medical administration techniques is the subject of an experiment in [6]. The experiment participants were nursing students, 82 of whom learned the medical administration techniques with the PILL-VR application, and 47 learned on a lecture-based curriculum. The results synthesized from quantitative analysis and questionnaires indicate significantly higher learning gains from the VR application compared to the lecture-based curriculum. All these findings emphasize the importance of

increasing engagement with VR applications in higher education.

Currently, some of the most commonly used virtual laboratory software packages are LearnSci LabSims, PraxiLabs, and Labster. Learnsci LabSims offers sophisticated digital worksheets and interactive, problem-solving lab simulations that support self-directed learning and development. Thanks to the system's digital resources, students may practice, use feedback, and learn the advanced abilities required for solid scientific literacy [7]. Labster is a virtual laboratory software offering simulations within the areas of biology, chemistry, and physics. The system enhances their learning results by encouraging students to investigate science through game-based aspects. Students then use their knowledge to resolve a real-world problem. Students learn curriculum-aligned theory, engage with cutting-edge equipment, develop methodologies, and conduct experiments inside a 3D simulation [8]. Praxilabs provides educational institutions and schools with a product that makes virtual scientific labs available, practical, and inexpensive. PraxiLabs delivers students an entirely realistic virtual lab experience and expanded information to increase their comprehension and expertise [9].

The systems mentioned above provide powerful tools enough to enhance the learning process and to be treated as educational software. However, a new software development cycle would be required to build new laboratory stands or do modifications to the existing ones. This adds to both the budget and time required to deliver the end product. As summarized by Nan and Harter, excessive budget compression results in rapidly increasing software development cycle time and costs [17]. Based on the mentioned facts, many educational institutions would still prefer real-life laboratory stands over their virtual counterparts. To overcome this limitation and enhance the deployment of virtual reality technology in education and research, this paper presents a new approach to help specialists with no programming knowledge construct new laboratory stands, thus eliminating the need for a new software development cycle.

2. Related Work

There are several works addressing the composition of virtual scenes. J. De Leon et al. proposed a VR application named Genesys that allows users to create 3-dimensional scenes in virtual reality. The objective is to create an application where people with limited experiences in VR and game design can create, share, and play Virtual Reality scenes. During the scene creation process, users are immersed in a VR workspace using a VR head-mounted display. The immersion provided by the VR headset and motion controllers allows users to spawn, move, rotate, and scale these assets, enabling them to create scenes from a first-person perspective [11].

O. Pietikäinen et al. introduced a novel virtual reality tool for modeling molecules and experimenting with its application to teaching organic chemistry. Utilizing a head-mounted virtual reality device, the open-source program named VRChem was created primarily for creating, viewing, and manipulating organic molecules. The VRChem software's design objective was to produce an enjoyable and straightforward user experience for chemical modeling in virtual reality [12].

Finally, P. Trentsios et al. considered combining remote laboratories and virtual reality. In their work, the authors considered two distinct methods for building a virtual world with an eye toward varying levels of immersion. The first strategy is to use Street View-style 360° photos to provide the portrayal of the actual laboratory. The second strategy uses a fully rebuilt virtual 3D representation of the real physical laboratory [18].

This work aims toward helping specialists with no programming knowledge construct new laboratory stands. It also describes the processes needed to enrich the software scope and include more components that can be used during the stand composition.

3. Materials and Methods

This approach suggests that the user composing new laboratory stands must be provided with a pre-defined set of tools. Tools can be referred to as a set of basic elements related to a specific field of science, which can be used to compose new stands. The system must give the ability to select, customize and attach the selected tool to another one, thus composing a new stand (Figure 1). The system must be designed taking into account the fact that the user can utilize each of the tools as many times as it's needed in the new stand configuration. Thus, this approach not only simulates the real-world laboratory stands but also gives an advantage in that the elements are infinite in effect and can be used to experiment and create new configurations. The user must be able to customize the selected elements, e.g., resize, rotate, etc. The tools are developed and added to the system by programmers, after which no programming knowledge is necessary to compose new stands.

The approach considers a system of modular structure. The modular design stresses breaking down a program's functionality into separate, swappable modules, each with all the components needed to carry out just one particular element of the intended capability. Thus, the system is designed to consist of 2 main parts: Core and Toolset (Figure 2). A toolset can be referred to as a module containing all the necessary components to compose laboratory stands for a specific field of education (e.g., Mechanics). The core module itself contains all the essential functions needed in the system. Still, it comes with an empty toolset: the user is actually able to inspect and navigate the scene, but there are

no tools available to build a stand. To get a minimum viable product (MVP), the Core module and a minimum of one toolset are needed. Other toolsets may be developed and integrated over time.
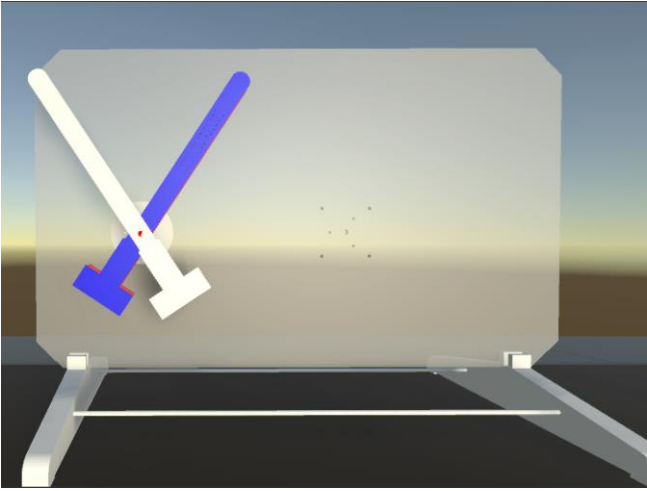
Fig. 1 Composition of a new stand, hovering components over each other to combine

3.1. Environment

The user's first contact with a virtual world is what the user sees after wearing the HMD. When developing a VR application, there is no single object in the virtual world. There is just a directional light (a light that is infinitely far and exclusively produces light in that direction) and the origin of the Cartesian coordinate system on which the user stands. Speaking of the user standing on the origin of the Cartesian coordinate system, it should be noted that there is no necessarily ground in there: it can be just an empty space. The ground is itself a plain object, with its' y-axis coordinate set to 0, which needs to be rendered.

In VR applications, the user is usually represented in first-person (any graphical perspective rendered from the viewpoint of the player's character). Thus, the user isn't actually a physical object but is represented as a camera view instead. Therefore, the user representation in a virtual world isn't subject to physics and does not obey the laws of physics. It can be concluded that the user representation in a virtual world doesn't need to be located on the ground to stand and provide an unchangeable point of view. Instead, it can be attached to an arbitrary point in space and inspect the world from that point of view. This doesn't meet the system requirement of providing a realistic environment, so the system is suggested to render a simple room on startup. Additionally, this choice is made to avoid users feeling like they are floating in space, making some feel queasy or uncomfortable [11]. Because laboratory experiments would naturally be held in a room containing a table, it is suggested that the rendered room also includes a table to perform the experiments (Figure 3).

For development purposes, the Unity cross-platform game engine is used. It works with several platforms, including virtual reality, desktop, mobile, and web. To make the development process platform-agnostic, the OpenXR standard is used. OpenXR offers portability between different VR devices. It enables developers to put content development ahead of porting. This ensures that the application works similarly on different VR headsets available in the market. For better accessibility, it is suggested that the application is distributed in 2 versions: desktop and web. Each of these two versions has its' own advantages: the desktop version can work without an active internet connection, and with the web version, there's no need to install any software on the user's computer. The desktop version can easily be delivered via the Unity engine. To render 3D graphics at high-performance levels within any compatible web browser, the Web Graphics Library (WebGL) Javascript API must be used. Currently, Unity doesn't support a VR input system for the WebGL platform. For this purpose, WebXR Device API (XRDA) is utilized. The XRDA exposes the underlying VR platform, offering a standard abstraction layer for real-time rendering and access to interaction devices on these platforms. Web developers are presented with a simple interface to a wide variety of interaction controllers and use WebGL to render 3D graphics using the device pose and timing information provided by WebXR [14].

3.2. Controllers

After getting into the virtual environment, the user can inspect the stereoscopic 3D environment, navigate it, and interact (such as grasping and moving an object). Interactions are held through the VR system controllers, handheld devices with several buttons, and sensors producing specific actions. These controllers have their representation in the virtual environment. They are shown as lasers pointing out of the left and right sides of the user (camera view), which move and change direction according to the position and orientation of the controller. This method can serve as an interaction tool, but it is not realistic and natural enough for the user to give the feeling of immersion and presence. Natural user interactions with the virtual environment are made possible using the character's hand as the main body component for interaction [19]. Considering the facts mentioned above, this approach considers the integration of immersive virtual hands as the basic method for user interactions [16]. In this study, it is suggested that when pressing the trigger button, only the index finger is open because this button is typically used to select particular objects, and the index finger would typically be open while the other fingers would be closed while performing such activity in real life.

Additionally, this choice is supported by the fact that the trigger button is touched by the index finger when holding the controller in its normal posture. On the trackpad, the

other four fingers' open states are established clockwise as follows: thumb, middle finger, ring finger, and little finger make up the left quarter, top quarter, right quarter, and bottom quarter, respectively. Because the grip button is used to grasp objects, it is proposed that when pressing the grip button, all the fingers must be in the closed position to provide the user with a realistic sense of holding the object in their hands. The immersive virtual hands will also be used to implement the customization tools, which will be addressed in future work.
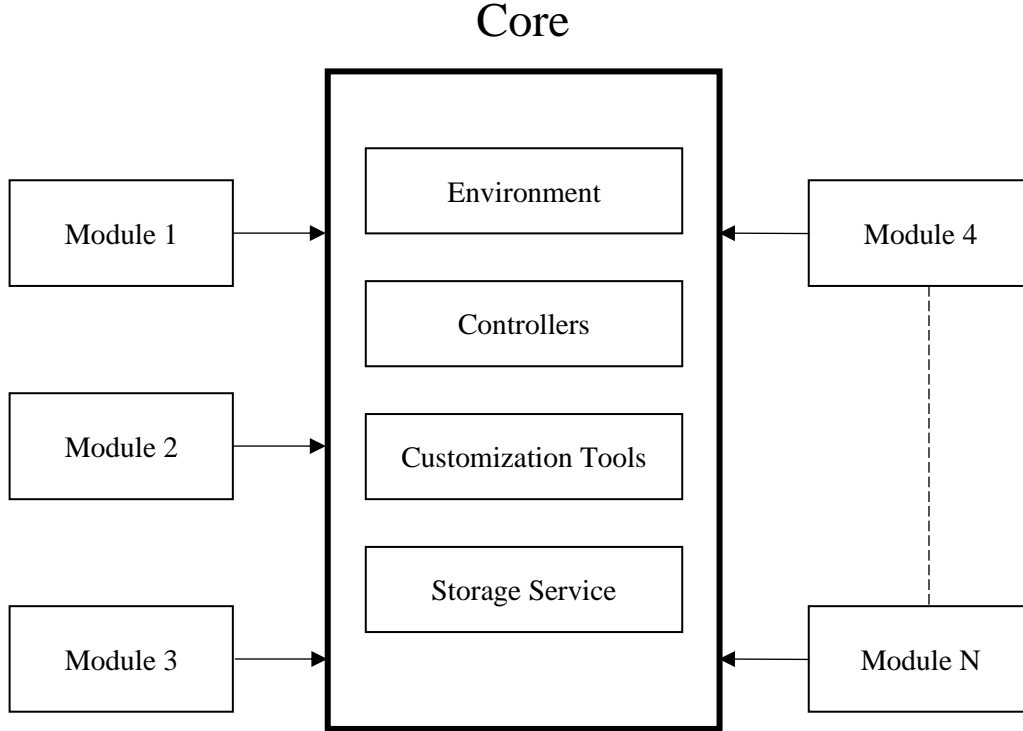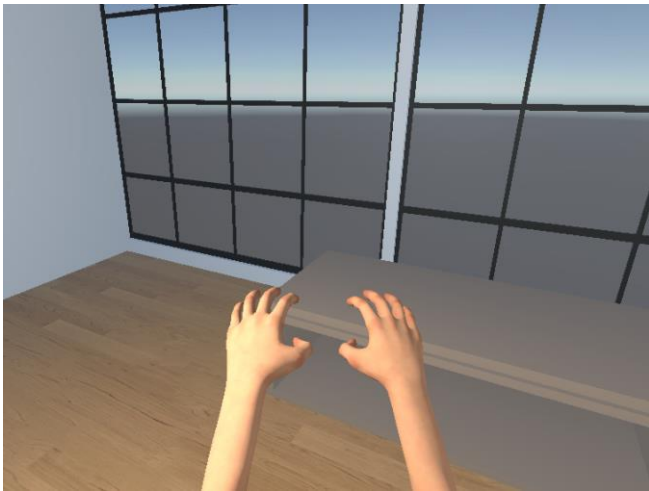

Fig. 2 The modular structure of the system

Fig. 3 The room, table, and hands from the first-person view

3.3. Storage Service

To provide the user with the ability to save the composed stand and share work with others, the system considers a storage service. There are two possible ways of storing data: locally and on a remote server. For this purpose, two domains are considered in the storage service.

The local domain is designed for storing data on the user's computer. The local file system is used to store files containing the work accomplished by the user.

A web application is developed to expose REST API to build up the remote domain. The application is located on a remote server, and the communication between the web application and the user is implemented through API endpoints. The web application is implemented in Node.js language and considers using a MySQL database.

4. Conclusion

This paper suggests a no-code approach for specialists with no programming knowledge to construct (modify) laboratory stands. In the proposed method, real-life laboratory stands are studied and decomposed to atomic elements, and programmers develop virtual components for these elements. After the elements have been developed and added to the system, there's no more need for a programmer to compose new laboratory stands: it can be done by specialists with no programming knowledge, using the tools provided by the system, customizing and attaching them in the corresponding position. As a result, the proposed

approach not only simulates the real-world laboratory stands but also gives an advantage in the fact that the elements are infinite in effect and can be used to experiment and create new configurations. Special attention was paid to providing the users with feelings of presence and immersion. A virtual environment was set up for that purpose, and immersive virtual hands were integrated.

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