

Customizable No-Code Collaborative Immersive Authoring Tool for Innovative Learning

Arman Hovhannisyan
National Polytechnic University of
Armenia
Yerevan, Armenia
e-mail: a.hovhannisyan@polytechnic.am

Artak Khemchyan
National Polytechnic University of
Armenia
Yerevan, Armenia
e-mail: a.khemchyan@polytechnic.am

Abstract—Recent advances in virtual reality technology increased interactivity and dropped prices, making it appealing for educators to consider an innovative teaching method of conducting classes in a virtual environment. Since educators aren't necessarily VR application developers and don't have programming skills, they will need a tool to rapidly create learning content or optimize an existing one. This paper proposes a method for developing a customizable, collaborative authoring tool for building virtual laboratory stands.

Keywords—Authoring tool, collaborative, no-code, innovative learning, virtual reality.

I. INTRODUCTION

Virtual Reality (VR) will change how we teach and learn. It has the perspective of innovating higher education by providing a purely digital ecosystem where teaching and learning are very similar to in-person interaction [1]. VR is gaining popularity in many directions, including education [2, 3, 4], training [5, 6], healthcare [7, 8], entertainment, and gaming [9]. According to a market analysis by Grand View Research, the virtual reality market size will hit USD 435.36 billion by 2030 [10]. Recent developments in VR technology have boosted interactivity and reduced prices, making it more appealing to academics. As mentioned by ELearning Inside, the price of VR devices is dropping, and VR-powered computers now cost under USD 1000 [11]. These developments make it cost-effective for higher education institutions (HEI) to apply VR technology in the education process. Another reason for incorporating VR in higher education is the novelty of the technology. Innovation is essential for HEIs to be successful and prepare qualified specialists. It is also engaging for the students as it helps them to be in touch with the new technologies and get better learning outcomes.

Many published studies report that VR increased students' learning interest and engagement. Allcoat and Mühlénen conducted a study where 99 students were assigned into three groups with different learning methods: traditional textbook learning, VR, and video. The results indicated that the students in the VR group had better knowledge acquisition and reported higher engagement [12]. In another research,

Hewawalpita et al. explored the effect of online learning courses with VR support against standard video-based support. The comparative analysis showcased much better learning outcomes from the VR setup [13]. Overall, the bibliometric analysis of VR in education indicates that the VR-based learning process may replace or supplement conventional teaching techniques, making it a helpful tool for educators. It enables full replication of real-life scenarios, still providing users with a high level of immersion and presence. Moreover, it has the advantage of simulating dangerous or costly experiments that otherwise won't be conducted in reality [14]. These specificities of VR make it a convenient technology to apply in laboratories.

Design and development of VR software is a complex task. Apparently, HEIs need well-designed and adapted applications to deploy VR technology in the teaching-learning process. Educators using these applications aren't necessarily VR application developers, nor are they required to have programming skills and knowledge. This means that they are limited to the learning content that the application provides. Any modification or optimization needed in the learning content must be done by the software engineer, who probably isn't as well-informed about the subject as the educator. Such kind of application modification process adds to both latency and costs. Authoring tools help fill this gap, allowing one to create VR content using a no-code approach. This usually means that the content creator is provided with a pre-defined set of tools and a user-friendly graphical user interface (GUI) to easily spawn, move, scale, manipulate and combine several objects. Eventually, educators may need to collaborate in the virtual environment (VE) to create learning content or optimize an existing one. Hence, the capacity to facilitate collaborative content creation is another requirement for authoring tools.

In this paper, we present a method to develop a customizable, collaborative authoring tool for building virtual laboratory stands. The tool can be adapted to any learning subject to enable diverse learning content creation.

II. RELATED WORK

There are a few works addressing the creation of VR authoring tools. L. Zhang and S. Oney introduced an immersive

authoring tool named FlowMatic [15], which allows developers to define objects and relationships between these objects using visual program representations. For each object, there is a list of attributes and methods listed, known as edges. Developers can specify the relationships between objects by joining edges. Although FlowMatic follows declarative programming concepts and makes it easy for programmers to create applications, it is still a developer-oriented solution and thus is not applicable to educators with no programming knowledge.

Another work proposed by J. Wang et al. is DIY World Builder [16]. It allows content creation from a first-person perspective using a hybrid setup of input devices. For user interaction, it makes use of both hand-held controllers and a tablet mounted to the forearm. Some actions, like selecting properties or objects, are performed on the tablet. This affects the immersive nature of the authoring tool, as the completeness of spatial information is compromised when the user interacts through a 2D screen.

Finally, D. Checa et al. proposed an application for computer hardware assembly with the primary goal of evaluating learning outcomes [17]. The system allows students to combine different components and connect them in a reasonable order to accomplish the task of assembling a computer. However, the application is intended for use by a single user and doesn't support collaborative work between students.

III. MATERIALS AND METHODS

We start with a system requirements analysis to determine the primary services provided by the system and the quality constraints that must be satisfied. There are two main categories of requirements: functional and non-functional. The functional requirements are as follows: the system must support authorization and authentication functions to distinguish between different educators and students; include a set of tools agreed with the educators, which may be

combined together to assemble various laboratory stands; support an intuitive interface to manipulate, move and scale the objects easily; allow educators to combine objects with a drag-and-drop technique easily; enable educators to create new projects and load existing ones; allow for collaborative work and render the actions performed by other educators in real-time; support a revision system for the educators to be able to view the changes applied to the project over time and rollback to a specific version. For the non-functional requirements, we defined the following constraints: the authoring tool should work properly on all VR devices available on the market that conform to the OpenXR standard; handle the situations in collaborative work properly when an educator is trying to interact with an object which has been already interacted by another educator but not rendered properly due to connection latency.

A. Educator Tools

Educators need a set of tools to create learning content while immersed in VR. These tools are defined in the product design stage in cooperation with the educator. Real laboratory stands are disassembled into elementary components, and virtual representations for these components are created in 3D modeling software. We used SketchUp to build 3D models in the development process, but it may be any convenient CAD software. Afterward, the 3D models are imported into the Unity software, and corresponding functional behaviors are applied to these models by writing scripts in C# language. The general system development pipeline is illustrated in Fig. 1.

B. Object manipulation

To select and manipulate the objects, we utilize the XR Interaction Toolkit, a framework to make 3D and UI interactions [18]. It introduces a concept of interactor and interactable components. These components have to be applied to whatever object we want to have the ability to be manipulated. E.g., an XR Ray Interactor component may be applied to the input controllers to define the ray casting

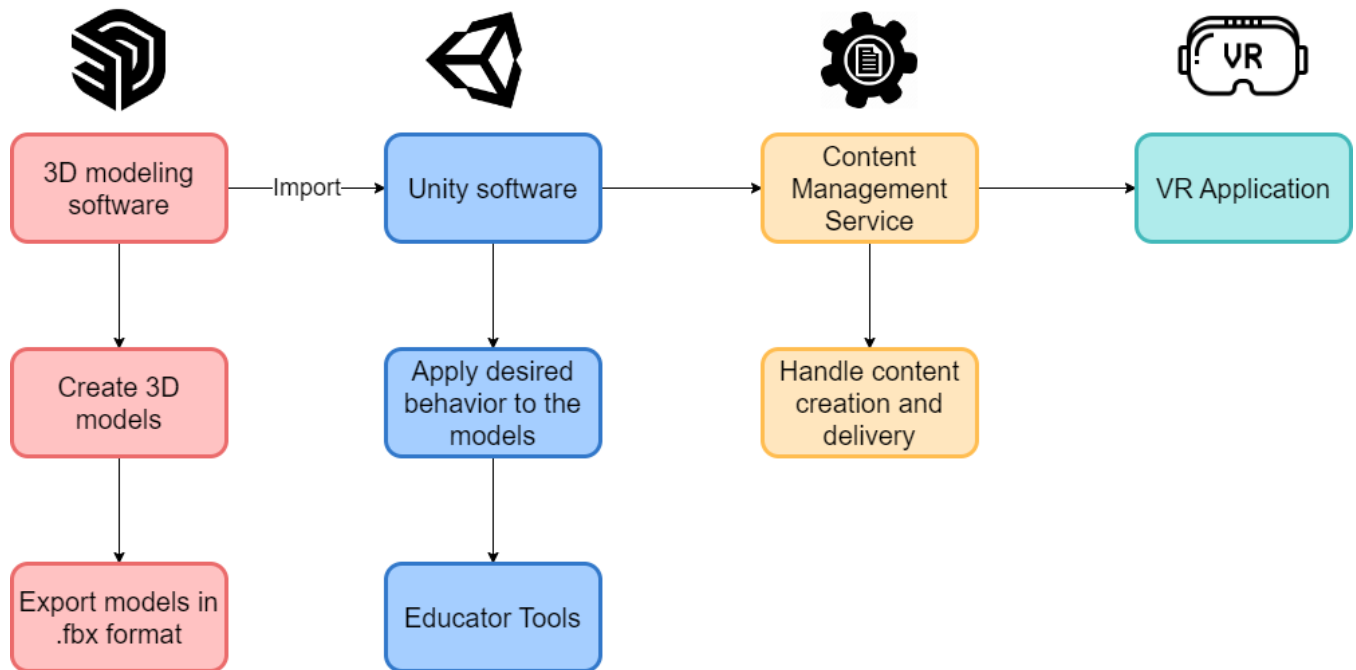


Fig. 1 System development pipeline

interaction method. Ray casting is a typical interaction method used in VR where objects are manipulated through rays radiated from the controllers. The XR Interaction Toolkit also conforms to the OpenXR standard, thus supporting cross-platform controller input. It meets one of our system's non-functional requirements: the ability to work correctly on all the VR devices conforming to the OpenXR standard.

C. Combining objects

To combine objects, the following steps must be accomplished: apply the XR Socket Interactor component provided by the XR Interaction Toolkit to one of the objects; identify the selection area, which, when hovered over, serves as a trigger for another object to be attached to the current one; add a sphere collider to the current object and adjust the radius so the sphere occupies the selection area; apply an XR Grab Interactable component to the other object. This way, we implement an easy-to-use drag-and-drop technique for the objects to be combined. An example of this process can be viewed in Fig. 2, where a crank component is being hovered over the stand mounting plate. When the crank enters the sphere collider area defined on the mounting plate, a blue outline shows up, indicating that when the user releases the grip button, the crank will be attached to the mounting plate. This mechanism provides educators with an easy-to-use

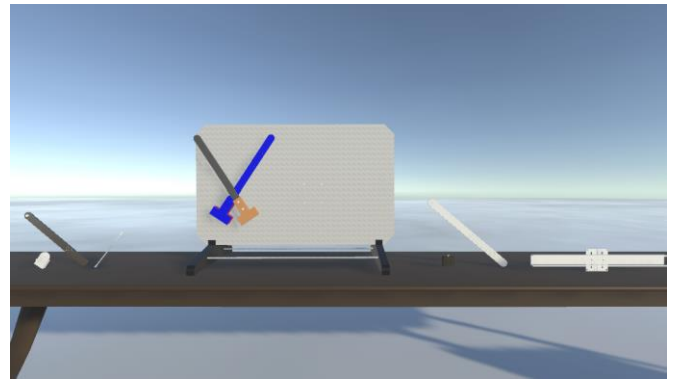


Fig. 2 A crank component being attached to the stand mounting plate using the drag-and-drop technique

interface where various stands can be assembled using the drag-and-drop technique.

D. Project repository

To save the learning content created by the educators, we use a centralized repository residing on a remote server. The communication with the remote server is performed via a REST API explicitly developed for this purpose. This decision complements the system's functional requirement to support collaborative work for multiple educators. Thus, one entry in

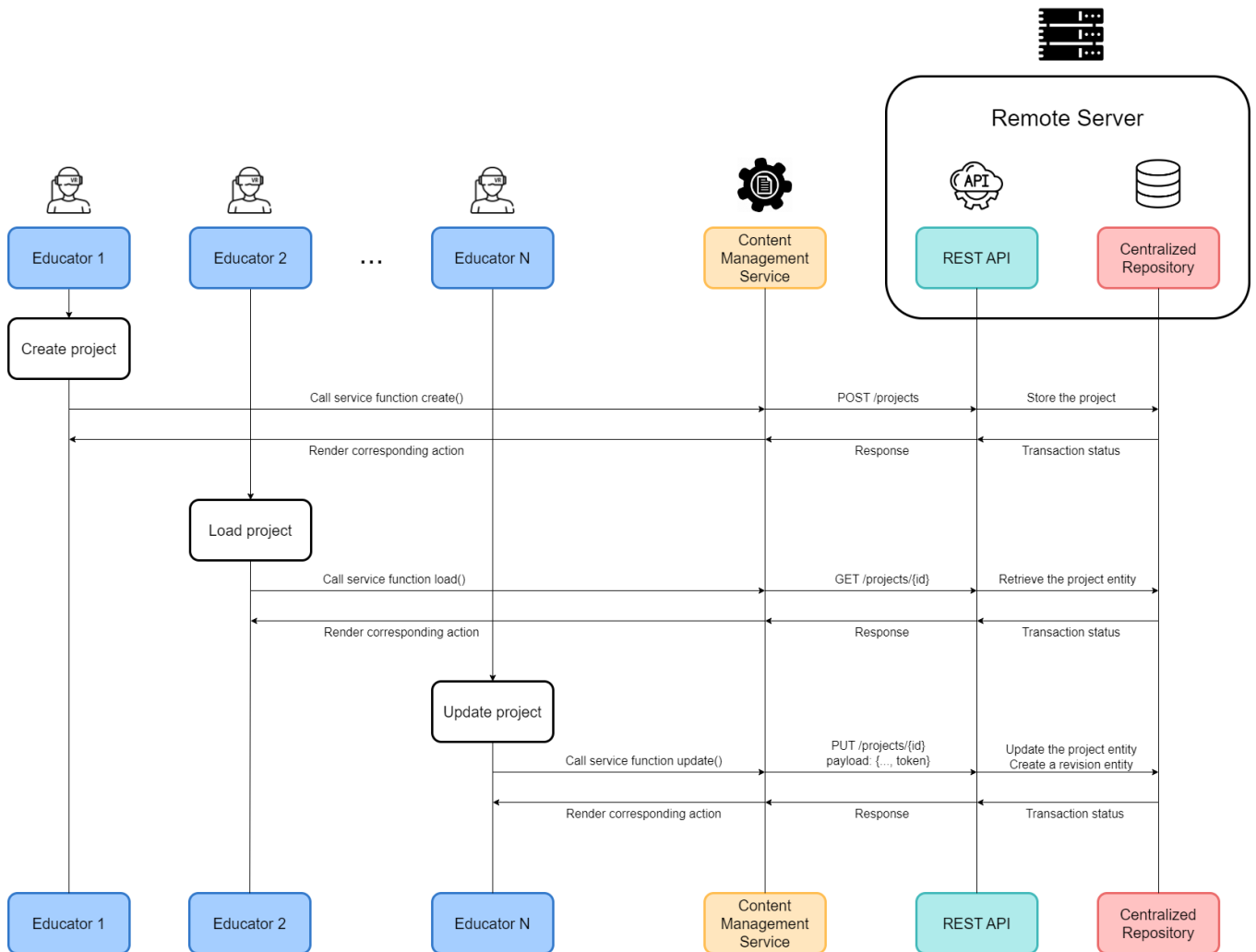


Fig. 3 Authoring tool architecture

the repository is created for every composed project, which can later be retrieved or updated on subsequent requests. The centralized repository can be located on the system architecture diagram in Fig. 3.

E. Revision system

Another requirement for the system is the ability for educators to view the modification history of the project and roll back to a specific version if needed. To meet this requirement, we propose creating a revision entity every time the server receives a request for creating or updating a project. The revision entity is a copy of the project entity containing all its metadata. Thus, when an educator presses the GUI element responsible for loading the project history, a REST API request can be triggered to retrieve all the revision entities related to the project id. This process is illustrated in Fig. 2 on the Update project action.

F. Real-time rendering

The educators working simultaneously on the same project must be able to see the actions performed by the other educators in real time. For this purpose, we make use of web sockets. Thus, a socket connection is established between each client and the server. Every action performed by a client is propagated to the server. After receiving the action event, the server broadcasts the event data to all the clients currently working on the project. This way, all the educators always see the up-to-date state of objects residing in the project.

There is still one issue inherent in this scenario. Because of the connection's real-time nature, some unanticipated actions may be performed due to connection latency. We may consider the following scenario for reference: Educator 1 starts moving some objects. Typically, this action would also trigger a web socket event, and the other users will immediately see the object changing position. But, Educator 2 may have connection issues and, therefore, may not see the changes performed by Educator 1. After Educator 2 starts editing the same object, this may lead to unexpected behavior of the system because the object is still being edited by Educator 1. To overcome this limitation, we refer to the work of Coelho et al. [19], where they use a locking mechanism similar to a semaphore operation in OS. Thus, with every socket event, a unique token is generated for the object being edited, which blocks the object until it is released.

IV. CONCLUSIONS

VR technology is rapidly emerging, thus being an attractive, appealing, and cost-effective technology to deploy in higher education. Specifically, it is convenient for moving real-life laboratory experiments to a virtual environment. The current pipeline of the VR application development process is inefficient, as the educators, who are in charge of learning content but don't have programming skills and knowledge, cannot create learning content themselves. To overcome this limitation, we propose a collaborative authoring tool to enable educators to create learning content with a no-code approach. The authoring tool provides educators with an intuitive graphical user interface, where laboratory stands can be assembled using the drag-and-drop technique. The authoring tool facilitates collaborative work between multiple educators, allowing them to optimize the learning content. The system is easy to be prototyped for various learning subjects, thus

allowing to create diverse learning content. Overall, the proposed system fills the gap between educators and developers and has the perspective of being broadly deployed in higher education institutions.

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