XL CILAMCE
IBERO-LATIN AMERICAN CONGRESS ON COMPUTATIONAL METHODS IN ENGINEERING
NOVEMBER 11-14, 2019
Praiamar Natal Hotel & Convention
Natal, RN-BRAZIL

DEVELOP0MENT OF 3D WEB PLATAFORM TO SUPPORT THE TEACHING-LEARNING PROCESS IN ENGINEERING

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Abstract. The University of the future, the theme of the Second Academic Congress of UNIFESP, had as its most defended ideals the need for innovation in higher education and the promotion of social inclusion and integration.The ”Knowledge Society” requires new skills and knowledge from its professionals, such as technical skills like: application of knowledge and learning continuous updating through research, openness to criticism, search for creative and innovation solutions and team management. Such demands directly affect universities, which automatically directs us to think of innovation in higher education. Studies have shown that the students' greatest difficulty relates to the ability to visualize and understand the analyzed problem as well as interpret the results. The exact interpretation of a phenomenon is the result of training and perfecting these skills. Virtual Reality is an advanced user interface technique with a computer, which allows simulating a real environment and allows the users to immerse, interact and navigate in a three-dimensional synthetic environment generated by a computer using multisensory channels. The potential of using Virtual Reality technology in education is widely recognized. Christine Youngblut in her work ”Educational Uses of Virtual Reality Technology” lists several experiences with the development, evaluation, and use of Virtual Reality in Teaching. Recently new technologies aimed at WEB development have caused a revolution in the construction of content of educational character. In particular, the JavaScript language and new paradigms of programming have become the basis for the proliferation of frameworks that make it possible to transform the WEB into a development platform for Virtual Reality, generating an effective environment for the simulation of the sensorial channels responsible for capturing the content and retention learning. This work aims to present a Platform developed for WEB 3D content in Virtual reality focused on the exploration of contents that require the understanding and interpretation of a phenomena and complex concepts in Mathematics, Physics, Biology and Chemistry disciplines seeking to help teachers and students in a journey in search of knowledge.

Keywords: Virtual Reality, WebVR, Teaching-Learning

1 Introduction

The University of the future, the theme of the Second Academic Congress of UNIFESP, had as its most defended ideals the need for innovation in higher education and the promotion of social inclusion and integration. The ”Knowledge Society” requires new skills and knowledge from its professionals, such as technical skills like: application of knowledge and learning continuous updating through research, openness to criticism, search for creative and innovative solutions and team management.

Mike Wadhera [1] in his article ”The Information age is dead. Welcome to the experiential age” shows us that the majority of the youth is online today, living live streaming experiences, playing on 3D multiplayer gaming platforms, sharing stories, pictures and videos of exciting daily occurrences, living a new age: ”The experiential age” .

The shift from the Information age, in which, access to and accumulation of information was the high priority, to the Experience age where sharing and experiencing new points of view, have led young people to become used to rich learning environments.

Such demands directly affect universities, which automatically leads us to think about innovation in higher education. Educators face this new reality having to abandon the old style of transmitting knowledge in a passive way and introduce new skills necessary to learn from experiences, where the student can exercise their creativity.

Inside this context we see the evolution of graphic hardware technologies, associated to the increase in data transmission velocity, allowing an increasingly invasion of multi-platform and multi-user games, which causes an expanded use of virtual reality technologies on the WEB.

As for the use of virtual reality in education and quoting Hu-Au [2] we can observe that it can lead to the increase in the engagement of the student; provide active and constructivist learning; increase the frequency of authentic learning experiences; allow for empathetic experiences; capacitate students in exercise creativity; and provide new experiences where abstract concepts can be concretely observed.

On this paper, the role of Virtual Reality in a synthetized form of education will be discussed, as well as the advances on WEB technology that allowed the reduction of the high costs involved in the use of Virtual Reality in education. Finally, we will present the platform implemented with the objective of supporting teaching and learning process in engineering.

2 Virtual Reality in Education

Neelakantam [3] explains in his work that Virtual Reality is basically a set of technologies and computer hardware that, when combined, are used to create an immersive simulation of a three-dimensional environment. The virtual environment is usually a replication of a real environment and is achieved using three-dimensional settings (such as depth perception), sounds, and instruments like consoles to allow users to interact with it. The movement of a user is tracked using either a head-mounted device or using motion detection sensors. Basically, Virtual Reality is an advanced user interface technique with a computer, which allows simulating a real environment and allows the users to immerse, interact and navigate in a three-dimensional synthetic environment generated by computer using multi-sensory channels.

This isn't a new concept, since 1990 the potential of this kind of technology has been explored, firstly in in the military and industrial environments trough the introduction of training simulators. As for the use of this technology for education, multiple studies have been done. Christine Youngblut [4] in her work ”Educational Uses of Virtual Reality Technology” lists several experiences with the development, evaluation and use of Virtual Reality in teaching.

Below we list some of the advantages observed in the use of this technology:

- Obtains more motivation;
- Presents a much more efficient power of illustration than any other form of media for some processes;
- Allows object/environment observation in either big or small scales;
- Allows the student to develop his work on his own rhythm;

- Allows for interaction, this way, stimulating active participation from the student;
- Allows for interaction with events where distance, time or security factors are a hindrance;
- Allows that disabled people realize activities otherwise impossible for them.

Studies have shown that learning starts by the observation of the phenomenon, experimentation, reflection, explanation and application in various situations. According to Felder [5] during this process the students show different styles of learning, some are visual, other verbal, some prefer to explore, other to deduce. According to Dede [6] the students better retain and generalize knowledge when they're actively involved in situations where they can build their knowledge trough the process of "learning while doing". We call this pedagogic philosophy constructivism.

Constructivism deals with the way that the students assimilate the knowledge alongside of a sequence of tasks that have as an objective the construction of an object. In the immersive virtual environments this construction can count with the collaboration of human or virtual agents. The students can grab objects, share them with other users and combine them as a way of building new objects and even using them to solve problems.

The objective of the constructivism in the virtual worlds is to promote the creativity and motivate first person learning trough active participation in knowledge building. These systems allow the development of group work, as the object of construction being consequence of the collaborative work, a lot of times from students that could be geographically distant.

3 WEB3D Technologies

Recently new technologies that aim at WEB development have caused a revolution in the construction of content of educational character. In particular, the JavaScript language with imperative programming paradigms characteristics, functional and object oriented has become the basis for the proliferation of frameworks that makes it possible to transform the WEB into a development platform for Virtual Reality, generating an effective environment for the simulation of the sensory channels responsible for content capturing and retention learning.[7]

The term "WEB3D" represents the language, protocol and software that makes Virtual Reality possible on the internet. This technology is based on the same principles of the WEB technology, where content is stored in servers and accessed by clients trough the HTTP protocol.

The Virtual Reality systems that were traditionally associated to high costs, especially when related to the acquisition of a specific hardware and the complexity of the development of applications, have become more accessible nowadays starting from the possibility of construction of virtual environments using WEB3D technologies. The WebVR is an open source JavaScript API for the use of Virtual Reality applications on the web. It was created in 2014 by the Mozilla community. The WebVR API provides input/output for VR Head Mounted Displays (HMDs), such as the Oculus Rift, HTC Vive, Sansung Gear VR, Daydream and cardboards and in a browser.

A-Frame is a WebVR framework for building rich 3D experiences on the web. It's built on top of ThreeJS as an abstraction layer. It is not just a 3D scene graph or a markup language; the core is a powerful entity-component framework that provides a declarative, extensible, and compound structure to ThreeJS. It provides an excellent HTML API for you to scaffold out the scene. You can work on the scene using HTML only, trough object manipulation using DOM. This feature allows the code to be implemented from modern frameworks: Angular, React and Vue.

The Scene component is the root node of an A-Frame app. It's what creates the stage for you to place 3D objects in, initializes the camera, the WebGL renderer and manages other entities. It should be the outermost element wrapping everything else inside it. You can think of Entity like an HTML . Entities are the basic building blocks of an A-Frame Scene. Every object inside the A-Frame scene is an Entity.

A-Frame [8] is built on the Entity-Component-System (ECS) architecture, a very common pattern utilized in 3D and game development most notably popularized by Unity, a powerful game engine.

What ECS means in the context of an A-Frame app is that we create a bunch of Entities that quite literally do nothing, and attach components to them to describe their behavior and appearance. Fig. 1 shows the elements involved in ECS:

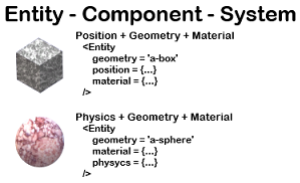

Figure 1. Entity - Component - System Diagram

- **Entities** are container objects into which components can be attached. Entities are the base of all objects in the scene. Entity by itself does not exhibit any behavior, appearance, or functionality. An entity, however, can contain several components, and these components can concede characteristics to entities.
- **Components** are reusable modules or data containers that can be attached to entities to provide appearance, behavior, and/or functionality. Components are like plug-and-play for objects.
- **Systems** provide global scope, management, and services for classes of components. Systems are often optional, but we can use them to separate logic and data; systems handle the logic, components act as data containers.

A-frame framework comes with a prepared set of components to use to order to create a 3D scene. You can develop from a plain HTML file without have to install any plugins. All you need is to include the library in the <script> tag and point to CDN (Content Delivery Network) distribution.

To build a virtual environment, you just need to insert a tag <a-scene>, that should contain all the needed components to what you wish to create. In Fig. 2 below we can see the necessary code for the implementation of the virtual environment.

```
<!DOCTYPE html>
<html>
  <head>
    <meta charset="utf-8">
    <title>Hello, WebVR! • A-Frame</title>
    <meta name="description" content="Hello, WebVR! • A-Frame">
    <script src="https://aframe.io/releases/0.9.2/aframe.min.js"></script>
  </head>
  <body>
    <a-scene background="color: #FAFAFA">
      <a-box position="-1 0.5 -3" rotation="0 45 0" color="#4CC3D9" shadow></a-box>
      <a-sphere position="0 1.25 -5" radius="1.25" color="#EF2D5E" shadow></a-sphere>
      <a-cylinder position="1 0.75 -3" radius="0.5" height="1.5" color="#FFC65D" shadow></a-cylinder>
      <a-plane position="0 0 -4" rotation="-90 0 0" width="4" height="4" color="#7BC8A4" shadow></a-plane>
    </a-scene>
  </body>
</html>
```

Figure 2. Base code for VR - A-frame implementation [8]

The components included in the code are rendered in the scene showed on Fig. 3, where we can identify each component of the scene in an illustrative way.

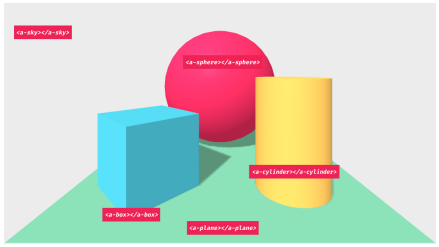

Figure 3. Rendered VR - A-frame scene

4 Platform to support the Teaching-Learning Process in Engineering

This aims to identify the benefits achieved by the use of the Virtual Reality technology coming from the development of a Platform to support the teaching-learning in engineering. The Fig. 4 below is a representation of the involved technologies.

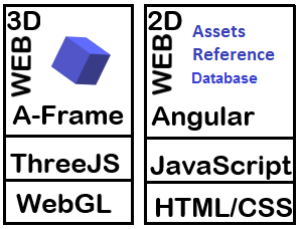

Figure 4. Platform to support the Teaching-Learning Process in Engineering

We developed models applied to the exploration of contents that need understanding and interpretation of complex phenomena linked to Mathematics, Physics, Biology and Chemistry, looking to help professors and students in their knowledge seeking journey.

Our purpose in the creation of this platform is to develop virtual environments that can be visited by multiple visualization platforms, such as: Desktop, mobile VR and HMD (Head Mounted Displays) or VR headsets with controllers. For each environment we need to adapt the way that we interact in the virtual world.

Fig. 5 presents one of the virtual worlds implemented on the platform. In this case, for an application involving concepts of physics, the environment simulates a free falling rock that hits a brick wall, with the consequent destruction of the latter by the impact. Parameters such as gravity's acceleration, friction and sliding coefficient, among others can be altered to allowing the analysis of the behaviour of the rigid bodies involved in the scene.

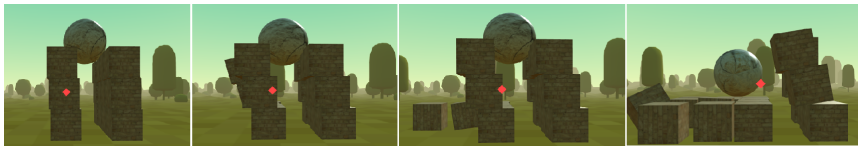

Figure 5. Physics VR environment

4.1 Conclusions and Future Research

The complexity that the construction, exploration and evaluation of the benefits that come from the use of the Virtual Reality technology involves, has been the reason for the involvement of multi-field teams (engineers, physicists, mathematicians, biologists, chemists, programmers, etc.), as well as the use of several resources for the construction of the tri-dimensional models and virtual environments.

Exploring and realizing the benefits evaluated by Christine Youngblut [4] makes the use and construction of these environments in an academic medium increasingly attractive, where complex and abstract concepts can be explored, allowing for a more efficient process of teaching and learning.

The use of the 3D WEB platform built with A-Frame technology allowed a reduction of the complexity of the code implementation, as well as the use of an environment where we can have access to content even while being distant from the classroom, utilizing multiple equipment such as mobile VR, VR Devices(Oculus, HTC Vive), Head Mounted Displays and the WEB Browser platform of a Desktop.

Research is being expanded, looking to integrate new devices that allow for project flexibility, construction and use of Virtual Reality in the process of teaching and learning in engineering. This synergy must create the ideal environment for the construction of 3D model libraries and database of simulations on collaborative and distributed environments.

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