Virtual Reality Automotive Lab Development

Subjects: Others

Submitted by: Diego Adrián Fabila Bustos

Definition

A Virtual Reality application was developed to be used as an immersive virtual learning strategy for Oculus Rift S Virtual Reality glasses and through Leap Motion Controller™ infrared sensors, focused on students of the Automotive Systems Engineering academic program, as a practical teaching-learning tool in the context of Education 4.0 and the pandemic caused by COVID-19 that has kept schools closed since March 2020. The technological pillars of Industry 4.0 were used to profile students so that they can meet the demands of their professional performance at the industrial level. Virtual Reality (VR) plays a very important role for the production-engineering sector in areas such as design and autonomous cars, as well as in training and driving courses. The VR application provides the student with a more immersive and interactive experience, supported by 3D models of both the main parts that make up the four-stroke combustion engine and the mechanical workshop scenario; it allows the student to manipulate the main parts of the four-stroke combustion engine through the Oculus Rift S controls and the Leap Motion Controller™ infrared sensors, and relate them to the operation of the engine, through the animation of its operation and the additional information shown for each part that makes it up in the application.

1. Introduction

Virtual Reality (VR) is a computer-generated environment that allows immersion in a virtual world through computational graphics applications [1]. The aim purpose of this graphics implementation is that the virtual world has a real aspect (virtual realism), real sound (auditive realism), and the user feels like part of that environment (haptic realism) [2]. Therefore, these aspects could be carried out through optic devices, electronics, and computational implementations to have a visual representation and a hand simulation to realize different tasks inside the virtual environment such as pick up, place, alter and order objects taking into consideration their hand position and movements [3].

Virtual worlds could be created through the implementation of software; however, the development of digital human models requires hardware capable of functioning as an interface between the computer system and the user. Optical devices such as deep vision cameras (Leap Motion Controller™, Leap Motion Inc., San Francisco, CA, USA, Kinect™, Microsoft, WA, USA, Oculus Rift™, Oculus VR LLC, San Francisco, CA, USA), infrared cameras, pressure sensors, motion sensors, joysticks, and accelerometers, among others, complement the perception of the simulated environment. Because of this, Virtual Reality application has grown, making this technology a useful tool to satisfy current needs in several areas of knowledge such as education [4][5][6][7], industry [2][8], music [9], medicine [10][11], architecture [12], and Virtual Laboratories [13][14], where it is possible to reproduce the conditions of a real environment with visual, tactile, and auditive stimulus [15][16].

Virtual Reality application areas are different and to a certain extent are owing to Industry 4.0 emergence, but the principal approach of these technologies is based on learning [17][18][19][20][21][22] and training [14][23][24][25][26][27] stages. In the case of automotive Virtual Reality immersive applications, some examples include: driving simulators [28][29][30][31], automotive design [32][33][34], and virtual automotive ergonomics [35][36]. Hence, this work aims towards the development of a virtual laboratory that complements the Automotive Systems Engineering formation with the use of a virtual environment; this environment enables the students to have an immersive experience to visualize and have an auditive description of different pieces that are part of a combustion engine. It allows the interaction and manipulation of pieces through hand controls, and principally, allows users to participate in the process of a combustion engine's assembly using Unity3D Game Engine® Software (Unity Software Inc., San Francisco, CA, USA) and the Virtual Reality headset Oculus Rift S. Moreover, there is a previous work from this research group where an augmented reality portable application in Android™ OS was developed. This application, in conjunction with a device that has a camera, allows the user a visualization of 3D models of four-stroke engine principal parts, besides obtaining additional information about their operation through the Otto thermodynamic cycle [37].

Concerning the field of education, a Virtual Laboratory implementation has some advantages compared to real laboratory installations, because the latter could have available material restrictions to practice, and occasionally, the teacher is the one who is working, and students are limited to observing and do not interact with the tools and the equipment. Additionally, depending on the risks of laboratory practice, feedback is required, which is not necessary for a Virtual Laboratory. For that reason, the Virtual Laboratory could be considered as a cost-effective and fully controllable educational tool that allows practice repetitively and in an easier form, leading to the student self-learning, becoming capable of understanding real-life challenges, and developing engineering skills; as such, Virtual Laboratories become interesting and attract students' attention and participation [27][38][39][40].

2. Virtual Reality Automotive Lab for Students

In this section we present the Virtual Reality Laboratory for engineering students' training which has been developed. When the application starts, it shows in the main scene the worktable with all the parts of the four-stroke engine, as we can see in **Figure 1**.

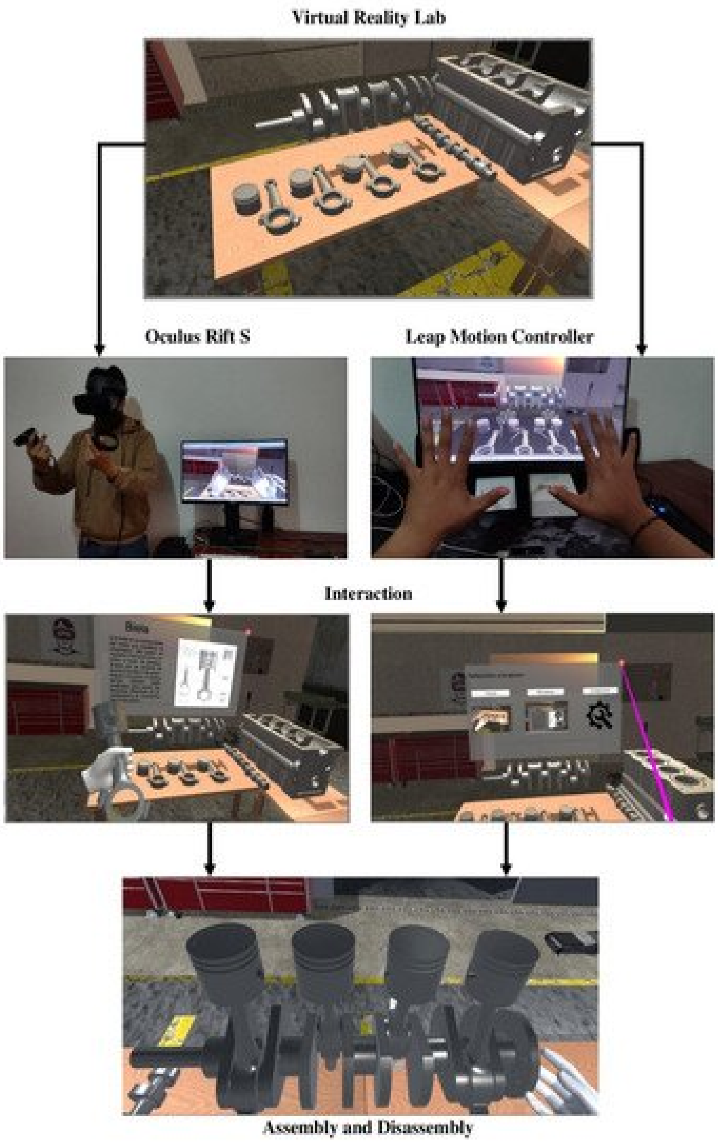

Figure 1. Flowchart of the operation of the VR application.

Here, the student can interact with each piece analyzing its operation and the correct position inside the engine. As we mentioned previously, this interaction can be fully immersive using the Oculus Rift S or partially immersive using the Leap Motion Controller™. A test with six different items was designed and applied to 20 students (n = 20) who evaluated the use of the Virtual Laboratory for assembling the main parts of a four-stroke engine using both the Oculus Rift S and Leap Motion Controller™. However, what is interesting is to the classification of the students participating in the evaluation into three groups: students without prior knowledge about the operation of the four-stroke combustion engine (neither practical nor theoretical), students with prior theoretical knowledge, and students with previous studies as technicians in automotive systems. **Figure 2** shows the distribution graphic of students' profiles who participated in the test.

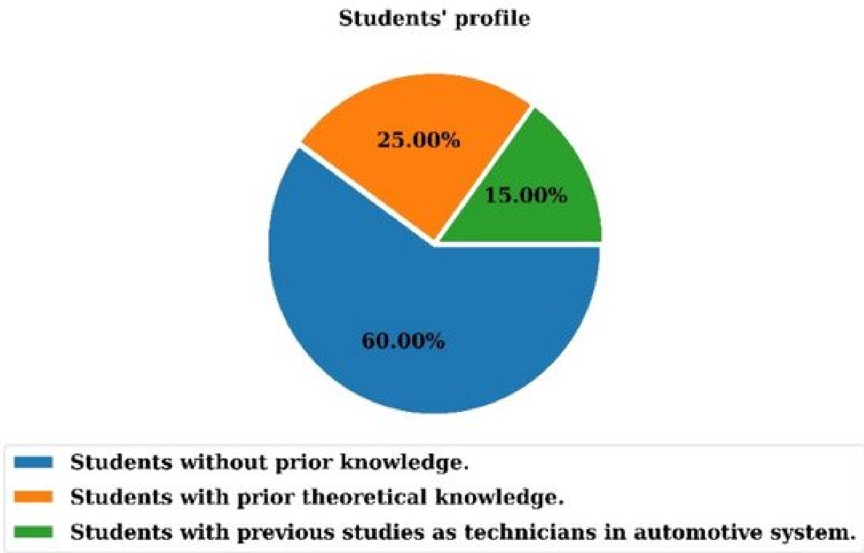

Figure 2. Students' profiles distribution.

Test results applied to participants are shown in **Figure 3**, **Figure 4**, **Figure 5**, **Figure 6**, **Figure 7**, **Figure 8**. Students (n = 20) evaluated the usability of immersive learning virtual applications to understand the main parts, the assembly, animation, and operation of a four-stroke engine, as well as the additional information of each element. The participants evaluated were chosen between "Very High", "High", "Average", "Low", and "Very Low" options.

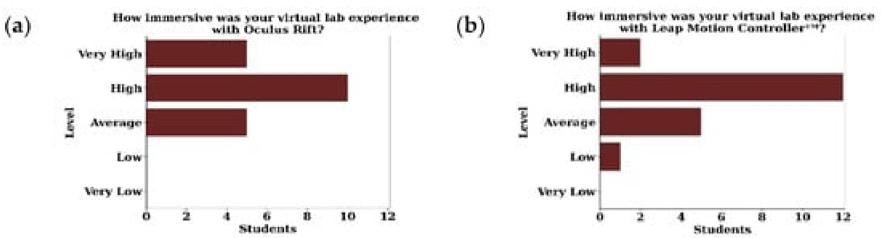

Figure 3. Results about the immersive experience of the Virtual Laboratory in the: (**a**) Oculus Rift S and (**b**) Leap Motion Controller™.

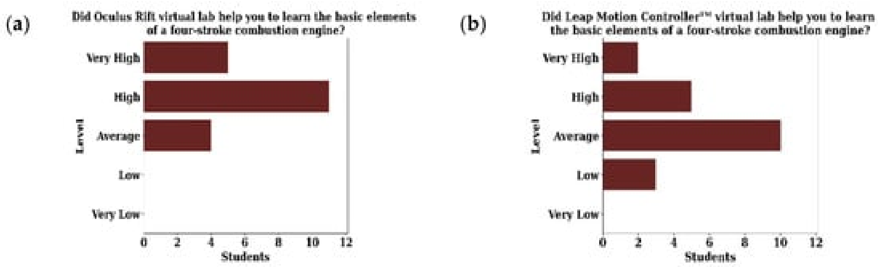

Figure 4. Results about the Virtual Laboratory as a learning tool in the: (**a**) Oculus Rift S and (**b**) Leap Motion Controller™.

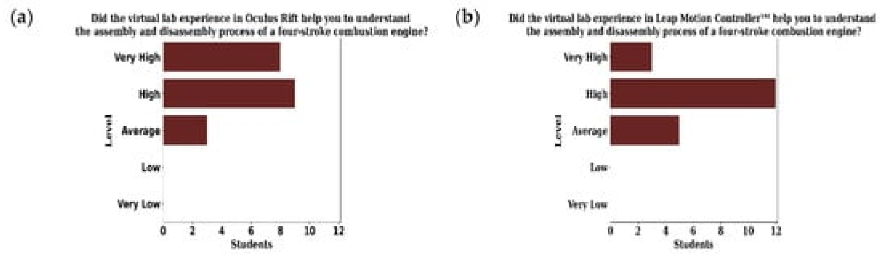

Figure 5. Results about the students' understanding of assembly and disassembly of the main ports of the four-stroke engine in the: (**a**) Oculus Rift S and (**b**) Leap Motion Controller™.

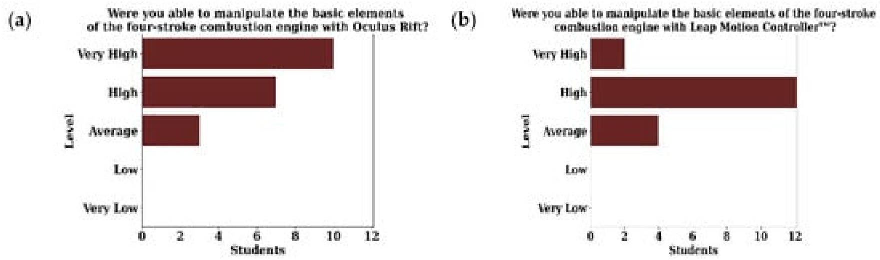

Figure 6. Results about the simplicity to manipulate the main parts of the four-stroke engine in the Virtual Laboratory using the: (**a**) Oculus Rift S and (**b**) Leap Motion Controller™.

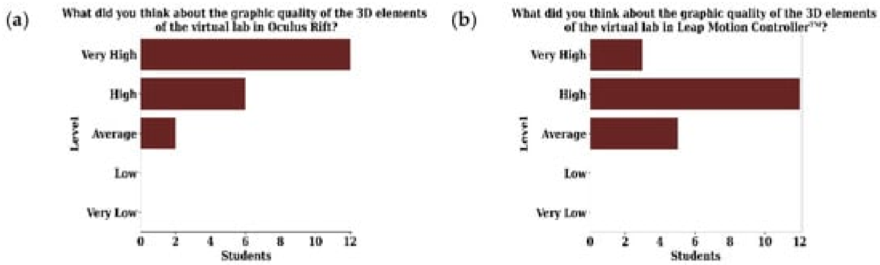

Figure 7. Graphic quality of the 3D elements of the Virtual Laboratory evaluation results using the: (**a**) Oculus Rift S and (**b**) Leap Motion Controller ™.

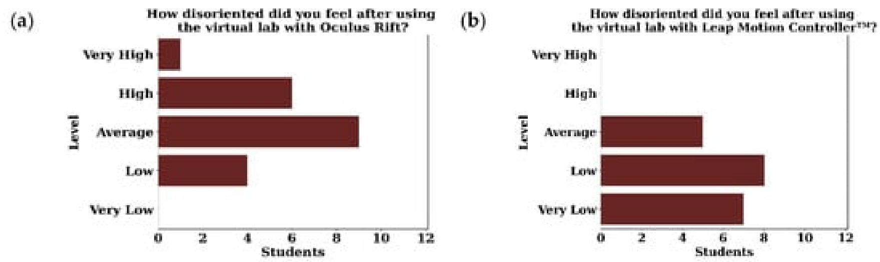

Figure 8. Motion sickness feeling evaluation results from students surveyed using the: (**a**) Oculus Rift S and (**b**) Leap Motion Controller ™.

In **Figure 3** the immersive experience of the Virtual Laboratory was evaluated, having 5 "Very High" ratings for the Oculus Rift S compared to 2 for the Leap Motion Controller™, having a higher frequency of "High" rating in both cases. However, it is noted that the Leap Motion Controller™ presented a "Low" rating, which means that the best and highest ratings were obtained by the Oculus Rift S, namely, students that participated in the test think that the immersive experience of the Virtual Laboratory is better through the Oculus Rift S.

Figure 4 evaluated the Virtual Laboratory as a learning tool of a four-stroke engine's basic elements. The highest qualifications (5 “Very High”, 11 “High”, and 4 “Average”) were for the Oculus Rift S, whilst the Leap Motion Controller™ had the “Average” qualification as the most selected answer, next to “Low”. In this case, the Oculus Rift S was evaluated as the best learning strategy in the Virtual Laboratory.

Results about the understanding of the assembly of the main parts of the four-stroke combustion engine are shown in **Figure 5**, where it can be seen that both devices obtained high marks; however, the Virtual Laboratory using the Oculus Rift S had a higher frequency in the qualification of “Very High” compared with the Leap Motion Controller™ which was rated more frequently as “High”. In this item, there was no evaluation in the “Low” rate, so it is considered an application that helps to understand the engine assembly process.

Figure 6 shows the results about the simplicity to manipulate the main parts of the four-stroke engine in the Virtual Laboratory, where the Oculus Rift S was evaluated as “Very High” having a frequency rate of 10. On the other hand, the Leap Motion Controller™ was evaluated as “High” with a frequency rate of 12. Therefore, in both cases, it is considered that the manipulation is easy and suitable for the surveyed students.

The graphic quality of the 3D elements of the Virtual Laboratory was evaluated as “Very High” with a frequency of 12 in the Oculus Rift S, and at the same frequency in the Leap Motion Controller™ but in the “High” rating. For both devices, this is a high rating in terms of graphic quality, and is best appreciated in the case of the Oculus Rift S. Results are shown in **Figure 7**.

Finally, the test assessed the feelings of motion sickness evaluate the grade of disorientation that the use of this kind of device could cause in some people after using the Virtual Laboratory. Results shown in **Figure 8**, and indicate that the frequency of “Low”, and “Very Low” rates are higher in the Leap Motion Controller™ comparing to the Oculus Rift S, where students evaluate with a “High” rating having a frequency of 6, and there is one case of rating as a “Very High”, which is remarkably common for users without previous experience with this device that is highly immersive.

3. Discussion

In fact, VR is good enough for different application areas but, in general, the principal idea is to have the opportunity to increase the necessary skills depending on the application area [14][23][24][25][26][27]. It is possible to observe that since the year 2010, VR implementation has increased, not only in industry but also in school laboratories, in order to involve students in the emergent technology and prepare them for the industry exigences; it shows a substantial improvement in learning productivity, which has allowed increases in creativity, innovation, communication and teamwork [39]. Owing to the fact that Automotive Industry is one of the principal areas where this technology is implemented [40], we have developed a VR application that allows the user to assemble and disassemble the principal pieces of a four-stroke engine in Virtual Reality, using as a sensor the Leap Motion Controller™ or the Oculus Rift S.

Most of the users subjected to several Virtual Reality experiences have positive opinions about VR’s importance in teaching due to it is easy to use, and the way it improves understanding and analysis of teaching materials [13][20][21][27][38]. Hence, this project allows students to achieve active learning and put into practice their knowledge about the design, assembly, and disassembly of a four-stroke engine, where interactivity, realism, and educational purposes were some of the most important features to highlight.

Similar labs for educational and training in the automotive field have been proposed for different workgroups, Makarova et al. [14] developed a laboratory focus on the process of balancing the wheels of a vehicle, where students must learn to balance the tires of a car correctly and accurately. In this case, HTC Vive headset (HTC Corp., New Taipei, Taiwan) and Unreal Engine 4 Software (Epic MegaGames, Cary, USA) were used. Quevedo et al. [41] developed an automotive workshop for identification and assembly of an engine, and also they used a HTC Vive headset and Unity3D Software for the environment. However, in both cases, successful results are described in terms of the time to make the activities, and evidence of the user's experience about the learning and VR environment was not reported.

In our research the evaluated items and the qualifications, obtained both in the Oculus Rift S and Leap Motion Controller™, were positive in all areas for didactic purposes of this Virtual Laboratory. For the evaluation and acceptance with the students as an immersive teaching-learning virtual didactic strategy, the Oculus Rift S is the platform that presents the best evaluation ("High") in terms of the graphic quality of the 3D elements, manipulability, immersion, and understanding about the assembly of the four-stroke engine and learning of the main elements thereof, as well as disorientation afterwards its use. These results coincide with earlier similar studies in which virtually trained participants improved their abilities for assembly of the vehicle center console [42]. In the case of the Leap Motion Controller™, it presents "High" qualifications more frequently in the areas of the graphic quality of the 3D elements, manipulability, immersion, and understanding about the assembly of the four-stroke engine and learning of its main elements, as well as ratings of "Low" for disorientation after use; this is attributed to the fact that the Leap Motion Controller™ device is semi-immersive, with the user being able to retain visualization of the real environment at all times. In general, the applications focused on automotive systems are limited to VR headset hardware and are not scalable for operation with hand-tracking systems such as the Leap Motion Controller™. Although VR headsets such as Oculus Rift S, HTC Vive, among others, allow a fully immersive experience, the Leap Motion Controller can represent a low-cost implementation of our VR environment. In fact, several studies in other fields have reported the development of applications using the Leap Motion Controller™ with favorable results at low cost [43][44].

Suggestions and comments were recorded for the Virtual Laboratory in both devices, highlighting the comments on the immersion and graphic quality of the application in the case of the Oculus Rift S and for the case of the Leap Motion Controller™. Comments about its portability and ease of use were highlighted for the Leap Motion Controller™, as a more affordable option. The expressions of the students when putting on the Oculus Rift S are encompassed in amazement in terms of the similarity of the stage concerning the real laboratory and in terms of the immersion and freedom of movement within the virtual stage; this last aspect is the limitation with respect to the Leap Motion Controller™, since the field of action of the virtual hands is limited to the location of the infrared sensors of the Leap Motion Controller™. The case of students who became disoriented when putting on the Virtual Reality glasses was also presented; they commented that they had never had an experience with this type of glasses before, but gradually they became used to the virtual environment and had no problem using the application. With the Leap Motion Controller™, only one student did not tolerate the immersive experience of the virtual environment using the glasses and preferred to use the Leap Motion Controller™, with which he felt more comfortable. In the case of students who already had some experience with Virtual Reality glasses, their use was more natural from the beginning. About this situation, Homen Pavlin, M., and Sužnjević, M. also think that this could be probably due to the fact that only a fraction of students are familiar with VR devices [38]. In this sense, a deep analysis in the field of spatial cognition could help to learn more about the dependence between the virtual environments and the user's cognitive processing [45][46].

4. Conclusions

This paper shows the development and evaluation of the Virtual Reality application that presents in an interactive and immersive way, with the help of the lenses and controls of the Oculus Rift S and Leap Motion Controller™, to learn about the operation of the four-stroke engine through animation and the assembly and disassembly of its main pieces. Test results, reflected in the questionnaires applied to the students who used the Virtual Laboratory, were favorable, and the comments made when using both devices were very positive, demonstrating that the purpose for which the immersive Virtual Reality application was developed fulfills its target. Therefore, we can conclude that this application provides users with a more immersive experience, especially in the case of virtual interaction with the help of the Oculus Rift S, which allows the user to move with greater freedom within the virtual stage and the physical space, in which the way that virtual hands of the student interact through the controls of the Virtual Reality glasses with the 3D virtual models is not limited, as it is in the case of the Leap Motion Controller™, which is limited by the field of vision of the infrared sensors. This virtual application aims to familiarize the student with what the main parts of a four-stroke engine are, how they work, and how they are assembled and disassembled; it is also interactive, since, if the student wants to learn more about each engine part, they can display additional information for the selected part. This application has an interactive tutorial and allows the student to have an immersive practice in a virtual setting similar to the automotive workshop, where the practice is usually carried out in person. In the case of schools that do not have equipped workshops for each student to carry out the practice, this application allows them to experiment in a more immersive way and also allows them to have practice prior to visiting the automotive workshop to carry out a face-to-face practice with a four-stroke engine. This application can be scaled to have more modules within the Virtual Laboratory.

The advance in the development of new technologies has enormous potential in the field of education and its links with Industry 4.0. We learn more from hands-on experiences than from traditional classes and frequently referenced two-dimensional materials. Education must gradually adapt to the health conditions that we are experiencing due to the pandemic caused by COVID-19 to improve and facilitate student learning and ensure their adaptation to the work environment. The development and implementation of these virtual immersive teaching-learning tools in the academic training of automotive engineering students will allow them to be profiled towards what they will find in their professional performance at an industrial level, where Virtual Reality plays a very important role in design, autonomous cars, training, and driving.

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Keywords

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