Maroon VR: A Room-scale Physics Laboratory Experience

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***Abstract*—Understanding physical phenomena is still a challenging task. Three-dimensional interactive simulations are a valuable tool to support understanding. We implemented different physical simulations designed so that students can interact and learn with them. However, student engagement is crucial to support the learning process. Virtual reality applications offer a promising way to engage and immerse students in three-dimensional environments and to keep them focused on the learning task. In this paper, we explore interactive virtual reality experiences implemented with HTC Vive as an alternative form of learning tool supporting engagement and to support the ability to concentrate better on the learning tasks. We ran a two-fold user study in which 19 students evaluated the experience looking at engagement, motivation, usability, and learning. First results indicate that such experiences are well suited as a supplement to traditional in-class learning and that they support realistic laboratory setups and simulations in an engaging, interesting, and immersive way and help students to focus more on the learning task compared to traditional applications.**

***Keywords*-virtual reality; physics education; virtual laboratory**

I. Introduction

Students often describe natural science education is often as a boring and non-intuitive field. STEM (science, technology, engineering, and mathematics) classes are even described as ineffective and uninspiring, and many students still indicate that they have little interest in studying such subjects[1] and often have issues focusing on the learning tasks. In particular in physics education, the use of interactive simulations has been proven to be a valuable tool for active learning scenarios. They provide a powerful environment to let students experiment with concepts and understand underlying physical phenomena and processes [2]. Digital simulations and virtual laboratories allow students to experiment with the physical phenomena in a safe environment. The simulations allow them to see concepts which are not visible in real life (e.g. field lines) to better understand the underlying concept and link it to the theoretical formulas [3]. In addition, virtually simulated laboratory experiments or remote laboratories can facilitate expensive, dangerous, complicated, or even impossible experiments [4]. In a large-scale study, Corter et al. [5] found that learning outcomes after performing assignments in remote or simulated laboratories are as high or higher compared to traditional hands-on laboratories.

However, it still poses a challenge to keep students engaged and concentrated in both, classroom, but also self-regulated learning settings and missing engagement is often an outcome of missing active and meaningful participation in activities [6]. Immersion and engagement are often described as being important factors for creating interesting and involving experiences. Immersion describes an experience of being part of the digital experience [7]. Flow is a targeted feeling in many domains (games, learning, training) for creating engaging experiences. It is described as full involvement in an activity. This state is achieved by balancing skill level and challenge and describing clear goals [7], [8]. One way to enhance immersion and engagement is the use of virtual reality (VR) technologies. The current state of available VR devices, such as Oculus Rift or HTC Vive, offers a sufficient level of maturity to be considered a serious tool for education or training scenarios.

In this paper, we want to introduce new forms of immersive and engaging active learning tools using VR technologies for the classroom to make interacting with physics simulations even more realistic and engaging. We introduce Maroon VR, a physics laboratory implemented for an interactive VR experience with the HTC Vive. Maroon VR aims to teach different physical phenomena, promoting immersive and explorative experiences in a virtual reality setup to increase student interest, engagement, and concentration. By performing a user study, we demonstrate the capabilities enabled by this immersive environment and show first evidence that such experiences support engaging and immersive in-class learning and can be used to visualize laboratory setups in a realistic and engaging way. The contributions of this paper can be summarized as follows: (1) integration of a virtual physics lab *(Maroon)* in an interactive virtual reality setup (HTC Vive), (2) demonstration that users are engaged and immersed by such a setup by means of a user study (questionnaires and quotes while conducting the experiment), and (3) description of setup as valuable learning asset for classroom scenarios.

II. Maroon and Maroon VR

Maroon is designed as a three-dimensional extensible virtual laboratory developed in Unity3D, in which various physics experiments can be integrated to illustrate and simulate physical phenomena. In the first prototype two main experiments and two interactions were integrated. The environment is designed as a open laboratory room with different stations, which represent experiments or activities. The two experiments in the current prototype are two electromagnetic experiments. The first one demonstrates the electric field (including field lines) between a Van de Graaff Generator and a grounder. Users can change the distance between the grounder and the generator to see how the frequency of the discharges changes. The second experiment simulates the behaviour of a balloon, which is placed between grounder and Van de Graaff Generator. The two activities are an interactive whiteboard and a multiple-choice quiz. The controls are designed similar to computer games controls for an interaction with the keyboard and a mouse. For *Maroon VR*, Maroon formed the basis and was extended with room-scale VR support for the HTC Vive. Different VR setups provide different levels of interactivity and support different scenarios [9]. Compared to other devices, HTC Vive provides the possibility to additionally integrate haptic cues and interact with the lab using two controllers tracked by base stations. Users would move in the environment by moving within the roomscale setup and can additionally teleport themselves to other positions with the controller.

III. Experimental Study Design

A first study has been conducted to measure the potential of the setup to engage participants, with a focus on measuring experience, engagement (flow, absorption, immersion, and presence), and learning potential, and to compare Maroon with Maroon VR. We divided the study into a number of sub-questions we wanted to answer: (Q1) *Is the lab perceived as a **valuable learning tool**?* (Q2) *Would users suggest that the lab should be used in a **classroom setting or at home**?* (Q3) *Would users use it as a **mobile** virtual reality solution?* (Q4) *How **engaged** are users?* (Q5) *How **immersed** are users?* (Q6) *Advantages/disadvantages to stand-alone solutions?*

19 participants (5f) between 18 and 53 (AM=26.58, SD=7.96) took part in the study. 12 participants were students, 7 employed. On a Likert scale between 1 (fully disagree) and 5 (fully agree), 16 participants self-identified as computer experts (4.36; 1.15). Three considered themselves as experts in VR (2.11; 1.24), two in physics (2.68; 0.75). Only five participants had used the HTC Vive before. We used the HTC Vive as HMD for the VR scenarios and the shipped controllers for interactions. The room-scaled setup was used in a roughly 2mx2m setting. The laboratory was executed on a high-end PC designed for gaming and external speakers.

The experiment was set up in two iterations. First, eleven participants tested the environment without focus on interaction, in a second iteration the environment setup was extended with an additional tutorial zone, where participants were able to try out the controls and interact with in-world objects (picking-up, throwing). Before the experiment, the participants had been informed about the outline and process of the experimental session and filled out the background questionnaire (demographic data; experience with computers, games, virtual reality devices, and physics). As introduction, participants were informed about the main interaction possibilities with the controllers and how the VR experiment works. Then participants where asked to use Maroon VR (duration: 10-20 minutes). The participants constantly remained in contact with the study supervisor, who also consecutively introduced them to the different experimental tasks: (T1): Look around and familiarize yourself with the environment and the controls. (T2): Use the teleporting functionality to beam yourself to different locations. (T3): Start the experiment (Van de Graaff generator with grounder and balloon). (T4) (optional): Find the "Easter egg" (hidden room with Tesla coil).

The overall goal of this experiment was not only to showcase the possibilities of immersive interaction in VR, but also to evaluate the future potential of a fully implemented Maroon VR with several lab stations for understanding the concept of electromagnetism in Physics. After the VR-experience, they filled-out a post-questionnaire and were interviewed on their experience. The post-questionnaire was divided into three main parts: (1) open-ended questions about overall experience, what they liked/disliked, perception of the learning possibilities, experience with interactions, usability, controls, and controllers; (2) experience scale (21 items), rating of experience in terms of engagement, learning, and preferences on a Likert scale between 1 (fully disagree) and 7 (fully agree). (3) Game Engagement Questionnaire (GEQ) [7], to measure engagement based on immersion, presence, flow, and absorption.

IV. Findings

A. Engagement and Immersion Data

In this section we want to discuss the participants engagement with the interactive and immersive physics laboratory and answer the following questions (Q4,Q5): *How **engaged** are users? How **immersed** are users?*

The first part of the post-questionnaire, containing 11 questions, dealt with the overall user experience and impression. To find out about engagement, the participants were asked the following question: ***"Do you find it engaging and motivating?"***. Overall, participants found the experience interesting and motivating and would use it to learn concepts interactively, which are easier to understand when visualized or simulated. Selected responses are listed: *"It was interesting because it was my first time engaging with VR."; "Yes, and if you use it for learning, it would probably be the most interactive form there is after real-life learning."* On a Likert scale between 1 and 7, participants rated the learning experience as engaging (AM=5.58, SD=1,61) and more motivating than ordinary exercises (5.78; 1.26). Based on GEQ results, the overall engagement with the experience was rated as high. On a Likert scale between 1 and 5, in particular immersion (3.44; 1.1) and flow (3.41; 0.78) were rated as high. Presence was rated with an arithmetic mean of 3.39 (SD=0.06) and absorption with 3.41 (SD=0.24). (Comparative data can be found in [9], where the authors also used GEQ to evaluate different VR setups .) Participants highlighted the feeling of immersion: *"..it felt like I was really there."*.

B. Experience and Usability Data

In order to assess user experience and identify different issues (e.g. usability or controls), participants were also asked open questions such as: ***"How did you like the Immersive Physics Lab?"***, ***"What did you like?"*** and ***"What did you not like?"***. In particular, the controls as well as the immersive and interactive features were highlighted: *"The possibility to* *get into a huge world while standing in one place"; "The impressive fact that you could move around the physics lab freely"; "It does, however, take some getting used to as you can easily get sick if there's a lot of movement.."* While the overall experience was described as interesting and realistic, some users mentioned usability issues, such as the cable, cybersickness or dizziness. Also, the real room (2mx2m) was described as too small for the actual setup. The controls, the user interface, and the beaming functionality were received positively by 14 participants: *"The user interface was easy to learn and handle. The beaming function compensated the lack of physical space so it was actually possible to see the simulations from every side"*. Two participants had issues with learning to use the controls: *"although they were visible in VR there were buttons i could not touch/find."*. It was important to the participants to see the controller in VR.

C. Learning in VR

Furthermore, we were interested in the learning possibilities in the physics laboratory and aimed to answer the following questions: *Is the lab perceived as a* ***valuable learning tool****, Would users rather suggest that it be used in a* ***classroom setting*** *or at home?*, *Would users use it as a* ***mobile*** *virtual reality solution?* and what advantages and disadvantages they see in Maroon VR compared to the web/PC version of Maroon (Q1,Q2,Q3,Q6). Being asked if they would use it for learning, participants responded quite positively: *"Yes, it is for sure advantageous for visual learning types like me."; "Yes, with different contents: solar system, earth's rotation and orbit around the sun."; "Definitely, because you can try things multiple times without any drawbacks."* When being asked whether Maroon VR was good for learning: *"Yes; it would be practical to use for experiments that might require too elaborate or expensive of a setup IRL. Or for experiments that might be dangerous.."; "there are opportunities to learn a lot and it even makes fun"* On a Likert scale between 1 and 7, participants would like to learn with the lab (AM=5.33; SD=1,51). Most participants think it is a good supplement for regular learning (5.88;1,45). 12 fully agree that the physics lab makes learning more fun (6;1,64) and interesting (5.89;1,63). They would rather use it in the classroom (5.42;1.54) than at home (4.63; 1,74). Only a few would buy the VR glasses at the current price of the setup and download the physics lab at home (4.18; 1,28).

V. Discussion and Conclusion

In the present work, we have presented a first experimental design and evaluation of an interactive and immersive physics lab integrated with the VR device HTC Vive. We have explored the users experience with a focus on engagement, overall experience, and perceived learning value. The results indicate that participants would recommend this setup for learning about subjects which benefit from the use of simulations and visualizations, and that they see potential of such setups to create more engaging, focused, and interactive forms of learning. It was noted that this is particularly well suited for experiments, which are either too dangerous, expensive, or simply not visible. The participants would recommend using this form of learning in classroom scenarios and in addition to traditional lectures. Immersion and presence were rated as very high and mentioned as valuable tool to enhance the learners' concentration. Even though the design of the environment was described as not realistic in terms of graphics, the immersive experience was described as very realistic. Cybersickness and dizziness remain a problem, however, the number of participants reporting such issues was relatively low. Comparing Maroon and Maroon VR, they see more potential in Maroon VR for learning, because they relate immersion to full concentration on the learning tasks. In traditional digital learning environments, students can get distracted more easily. However, for short experiments Maroon is preferred, since the effort of setting up VR environments is quite high. Additionally, high costs and lack of portability were mentioned. As revealed by Corter et al. [5], students find not only the feeling of being present in a virtual laboratory important, but also discussing and collaborating with peers. While such environments still allow students to interact with the real world (e.g. discussing concepts with persons next to them), this might reduce immersion. For future work, a collaborative VR setup is planned, to allow two or more students to work together in the immersive laboratory. Additionally, we are developing and evaluating a mobile VR solution in parallel, which should address portable and cost-effective immersive learning solutions [10].

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