Chen, W. et al. (Eds.) (2016). Proceedings of the 24th International Conference on Computers in Education. India: Asia-Pacific Society for Computers in Education

Towards an Architecture for Educational Virtual Reality Spaces

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Abstract: In recent years, hardware for the production and consumption of virtual reality content has reached level of prices that make it affordable to everyone. Accordingly, schools and universities are showing increased interest in implementations of virtual reality technologies for supporting their innovative educational activities. Hence, this paper presents a flexible architecture for supporting the development of virtual reality learning scenarios conveniently deployed for educational purposes. We also suggest an example of such educational scenario for medical purposes deployable with the suggested architecture. In addition, we developed and used a questionnaire answered by 17 medical students in order to derive additional requirements for refining such scenarios. Then, we present these efforts while aiming at deployments usable also for additional domains. Finally, we summarize and mention aspects we will address in our coming efforts while deploying such activities.

Keywords: TEL, Virtual Reality, Educational scenarios, Medicine

1. Introduction

Over the past decade, pioneering teachers started to seek for new technological implementations that could potentially make educational activities to become more meaningful and appealing. In recent years, teachers used Information and Communication Technologies (ICT) to enrich educational experiences with interactive media experiences beyond the boundaries of the traditional classroom (Cohen, 2015; Giemza et al., 2011). Occasionally, such educational implementations require coordinated efforts exercised along a process that includes design, development, and deployment practiced by various stakeholders including teachers, students and developers (Kohen-Vacs et al., 2016(. In such cases, stakeholders focus their efforts on ICT systems and tools used to support educational interactions elected while considering its availability and adaptability across different settings and conditions (Zbick et al., 2014).

Recently, teachers and developers began to examine technologies that could support educational approaches combining innovative forms of rich media. They started to consider the advantages of implementations including 360-degrees pictures and videos combined in their educational strategies (Ramachandrappa, 2015). Accordingly, developers are required to cooperate and adapt architectures and environments for these new forms of educational implementations. In other cases, researchers and teachers began to seek new ways to combine advanced forms of rich media in forms of Virtual reality (VR) implemented for educational activities (Merchant et al., 2014). They exercise these efforts while developers could offer them a facilitated deployment process for innovative VR applications through new and available Software Development Kits (SDK) as well as development libraries (Weise et al., 2015). Consequently, various sectors including education rediscover and deploy activities based on VR technologies. Wickens (1992) mentions this rediscovery while emphasizing that VR implementations for education are not new and already exist for more than two decades. However, and despite of several decades of evolvements in the field of VR for education, there exists no architectural strategy yet for the incorporation of VR resources supporting pedagogical practices (Stouffs et al., 2013). In this paper, we describe the initiation of our efforts towards an architectural approach incorporating VR technologies that offers support for a variety of educational experiences.

In the next section, we present various cases dealing with VR deployments while focusing on implementations for educational purposes. Thereafter, we present our future efforts towards the establishment of an architectural approach adapted to support a pedagogical process practiced for educational medicine. In addition, we propose this approach for supporting additional domains and levels. Then, we present an educational scenario offering a meaningful and appealing experience for students attending an anatomy course. We continue and offer an analysis practiced and used in order to refine an educational scenario practiced for an anatomy course and supported by the mentioned architecture. Finally, we summarize the mentioned aspects of architectural requirements followed by our future research and deployment efforts.

2. Survey of VR Implementations Aimed for Training and Education

As already mentioned, the ideas behind the foundations for VR technologies have existed for more than half a century. Back in the early 60's Sutherland postulated the use of head-mounted and stereoscopic hardware equipment (Sutherland, 1968). Two decades after these concepts were introduced they developed into mature technologies that still were limited and available for a few elite research labs (Cruz-Beira et al., 2015). Nowadays, there is a new renaissance in terms of hardware and software used for VR purposes available for researchers, developers and end-users. Consequently, new sectors with less economical resources can afford to own and explore these innovations and offer them to their users. As mentioned, the educational field represents one of the sectors that rediscovered the potentials of VR technologies. This sector including universities and training departments in corporate companies have nowadays the opportunity to adopt and adapt VR technologies offered to its mass amount of researchers, employees, educators and students (Ong & Nee, 2013). In this section, we presented an overview of recent research efforts addressing various cases dealing with educational deployments supported by VR technologies practiced in the recent years.

VR technologies used for educational implementations could vary in terms of their objective, stakeholders and the nature of the used technologies. Furthermore, these implementations could vary in terms of the used hardware and software enabling different types of ways to experience VR scenes as well as to interact with them. For example, Cheng & Huang (2015) addressed in their efforts, VR technologies used to improve children's' joint attention associated with pervasive developmental disorder. For this aim, they developed a VR and educational scenario designed in the 3D MAX environment and programmed with Virtools. In this implementation, teachers used regular computers to support interactions performed from keyboards and data-gloves. The deployment of this scenario included 12 specific interactions designed to support the mentioned aim.

The field of medical education represents another sector that could benefit from the use of VR technologies. For example, Antoniou et al., (2014) presented a VR scenario offering to support training for undergraduate dental education. In this case, designers and developers deployed their efforts based on the Second-Life environment programmed with the LSL language. This deployment aimed to provide a more open architecture offering additional options for integrating and using information about virtual patients that is available on the web. Students interacted in a more natural manner while using a set of available actions including chat and voice. However, the advancements along this scenario were also possible through predefined and multiple-choice interactions.

Gao et al., (2015) carried another research effort involved VR for education that aimed to provide college students with an appealing opportunity to understand the complex atmospheric nucleation processes. In this implementation, developers utilized the Three.js library enabling to experience 3D representations for VR across browsers and platforms. In addition, they used widely available and affordable hardware including a PC, Anaglyph glasses, 3D monitor 3D graphic cards, Oculus Rift and a Leap-Motion Controller. In other research effort, Casu et al., (2015) designed an educational scenario supported by Three.js library. In their efforts, they offered students to experience an educational scenario supported by VR containing models rendered with WebGL. This scenario focuses on the mentioned subject domain and therefore the adoption of such scenario for other purposed may be challenging.

In the next section, we present the design, development and deployment of architectures for future VR-based educational environments. We base these efforts on previous research and deployment experiences as described in this section. Furthermore, we consider previous efforts while focusing on their use-cases as well as software and hardware implementation utilized to support them (Cheng & Huang, 2012; Antoniou et al., 2014). Specifically, the aspects described in these cases cover educational and technological interrelated consideration while aiming to provide VR experiences used for supporting medical education. A close examination of the mentioned cases presented in this section reveal the complexities of such VR deployments in terms of their various aspects. In the following section, we present our initial efforts related to the design of an architecture for such educational purposes.

3. Architecture Design

Our deployment efforts addressed the development of an architecture that allows on the one hand integrating different input devices, while at the same time it provides an abstraction for different user interface technologies. As mentioned in the previous section, we propose this architecture while considering past deployments of VR technologies used for education including their various requirements as mentioned in past research efforts. As for the user interface layer, different technologies including typical 3D JavaScript libraries, e.g., ThreeJS could be used to better integrate to mobile devices. Unity3D offers an alternative for addressing the user interface level while offering a well-known development infrastructure known from the Oculus Rift. Additionally, our suggested architecture is flexible enough in order to integrate other user interface technologies, e.g., for an even better integration on mobile devices, or for the development for other technologies, e.g., 3D cages. In order to provide a flexible architecture for different scenarios that make use of 360-degree images and videos, we developed an initial one as shown in Figure 1 and later elaborated in this section.

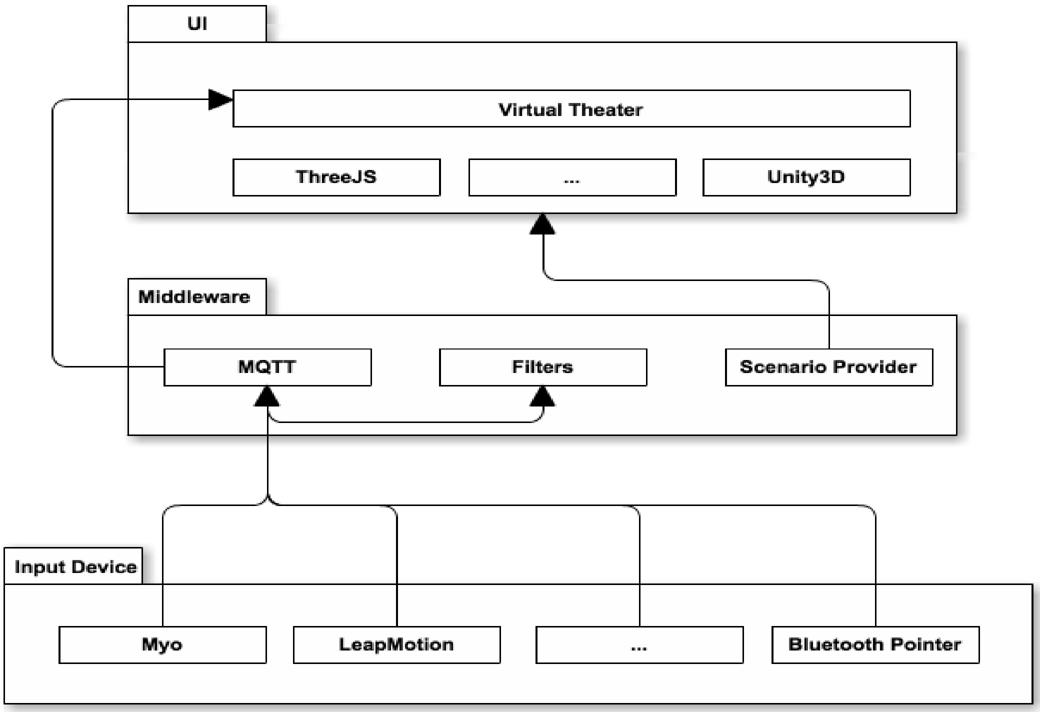

Figure 1. A flexible Architecture for the deployment of scenarios using 360 degree technology

The input device layer includes a number of input devices we aim to integrate in a virtual environment for allowing typical user interactions based on a keyboard or usual pointer device. In this case, we already integrated examples using Myo and the LeapMotion input devices, as typical low-cost examples for gesture recognition. Based on past deployments cases mentioned in previous section, we consider such suggested architecture as flexible enough in order to integrate other devices possibly emerging in the future. The flexibility for both directions, towards the user interface and towards the input devices is achieved by an abstraction in the middleware layer. The necessary abstraction was achieved by the integration of a standard messaging protocol, in our case an MQTT (http://mqtt.org) messaging system. On the one hand, the implementations for the different input devices are sending gathered events, e.g., certain gestures, via the messaging protocol to the middleware. Possible filters on the middleware layer can than do a first interpretation of the events. After passing the filters, the events are send via the messaging protocol to the user interface layer where they could be interpreted accordingly. By this, we achieved the necessary abstraction, that on the one hand allows for an easy integration of different input devices while at the same time is flexible enough to exchange the user interface technology according to the needs of the scenario in question. In the following section, we describe a scenario relying on the architecture presented here.

4. Scenario Description

In the previous section, we presented an architecture capable to support various educational activities supported by VR environments including those described in the literature review presented in presented section. Accordingly, we introduce an architecture including various software and hardware technological solutions to support various aspects the current scenario. We use these technologies to provide capabilities for authoring and using VR scenes deployed as educational scenario that are represented in 3D models. In addition, these technologies include UI means enabling the users to interact with the scenario. In this section, we demonstrate the potentials of this architecture to support an educational activity focusing on the study of the human anatomy. We present a scenario supported by the mentioned technology offering an educational process enriched with media presented in a VR space. Furthermore, it aligns to previous research efforts conducted by our group and by the community that deal with cases that include 3D visualizations and VR used to support educational processes for medical purposes (Merchant et al., 2014). Here, we propose an education Scenarios Augmented by Virtual Objects (SAViO) consisting of 4 phases:

The SaViO starts with a first phase conducted by the lecturer in a regular meeting in the classroom. In this meeting, the lecturer introduces and presents rich media content related to human anatomy. In the next phase, the lecturer requests from his/her students to access the presentation from the previous phase and further inquire the topics there. In addition, he assigns to each of the student with a specific sub-topic in anatomy including a 3D model followed by a description of the object of the studied body. The lecturer requires each of the students to author an educational label describing the anatomical object as well as single or multiple-choice types of interactions that relates to the addressed object. In the following phase, students are required to visit a VR environment enabling them to experience various virtual objects representing a structure of a human part as addressed in the previous phase. The 3D objects located in the virtual space enabling students to freely browse, and experience them. When arriving to such object, the student may examine it as well as to experience the interactions previously assigned to it. Consequently, labels or interactions assigned to virtual objects enable students with interactive opportunities to familiarize themselves with these virtual objects. The fourth and final phase of this activity takes place during a debriefing session conducted at classroom in which the lecturer illustrates and reviews key aspects of the learned material. In this debriefing, the teacher addresses the type and temporal sequence of the interactions practiced by his students along previous phases of the scenario.

5. Towards a Requirements Analysis

In order to initiate the design of the previously described scenario we commenced a process that included the identification of requirements with 17 participants attending an anatomy course at a medical school. In this case, we looked for specific aspects related to the learning practices supported by technology as reported by students at medical schools in anatomy courses. In order to proceed with this examination, we presented the students with a questionnaire including eight questions addressing several aspects of their learning practices as experienced during their anatomy lessons (α =0.65). The first group of questions addressed students' habits related to the learning materials and used the same Likert scale varying from 1 (does not apply at all) to 5 (does apply totally):

(Q1) Do you want to take compact learning materials to wherever you want?

(Q2) Do you think that questions or quizzes related to the learning materials help~~s~~ you learn the topics?

(Q3) Do you feel that you understand the learning materials better if they are explained to you?

(Q4) Do you learn new materials on your own?

(Q5) Do you ask questions if you have not understood major parts of the learning content?

We collected the answers from these questions and considered their topics and their relation to the Mobile Seamless Learning dimensions (MSLs) as suggested by Wong and Looi (2011). We consider these questions in the light of MSLs as part of our continuous efforts to examine requirements for rich media scenarios supported by mobile technologies (Kohen-Vacs et al., 2016). In Table 1, we summarize students' answers to the various questions (Q1-5) and propose their relations to various MSL dimension.

Table 1: description of answers to items (Q_n) and their relations to various MSLs

Questions	Q1	Q2	Q3	Q4	Q5
Average	4.33	4.27	3.87	4	3.40
Standard deviation	0.91	0.76	1.13	0	0.97
MSL-1: Encompassing formal and informal learning	✓			✓	
MSL-2: Encompassing personalized and social learning			✓	✓	✓
MSL-3: Learning Across time	✓			✓	
MSL-4: Learning Across locations	✓			✓	
MSL-5: Ubiquitous access to learning resources				✓	✓
MSL-6: Encompassing physical and digital worlds	✓			✓	✓
MSL-7: Combined use of multiple type of devices	✓			✓	
MSL-8: Seamless switching between learning tasks	✓	✓	✓	✓	
MSL-9: Knowledge synthesis		✓	✓	✓	✓
MSL-10: Encompassing multiple pedagogical models		✓	✓	✓	

The answers collected from the students indicated a high level of perceived applicability (average applicability is always greater than 4). In almost all of the cases, the standard deviation is smaller than 1 indicating on high level of agreement among the students. In addition to the mentioned questions, we also presented the students with some additional questions followed by with Likert scale including:

(Q6) Is it easier for you to study about an object by physically touching it or do you prefer images? (1- physical model 2-picture 3-both)

(Q7) Which degree of detail would be convenient for you in relation to an anatomy model? (1- overview 2-detailed 3-both)

(Q8) How important are features like pause, fast forward/backward or jumping to a particular point in time of a video?

(1-do not use videos for learning 2-regularly use videos for learning 3-do not control videos)

The answers for Q6 show that most of students preferred the physical model (52%) while only a minority preferred just the images (12%). Answers provided for Q7 revealed that most students (65%) felt that both degree of detail would be convenient. In addition, answers for Q6 and Q7 resulted with relative high levels of variances (0.79 and 0.6) indicating that students required varied types of means for visual representations to support their studding processes. The results provided for Q8 show that most (53%) of the students use regularly videos to support their learning. In addition, 41% of the students declare that they do not use videos for learning. Feedbacks gained from students revealed that most of them also use rich media (videos) possibly supported also by VR architecture. These answers for Q8 resulted with a variance of 0.3 indicating lower level of variance of the perceived important given by students using videos and controlling them.

6. Conclusions and Outlook

In this paper, we present and refined an educational scenario aimed for supporting anatomy studies with low cost virtual reality hardware. We also presented an architecture that allows flexible integration of either different frontend technologies and at the same time a large number of different interaction technologies. Here, we mainly focused on the usage of mobile technology, while at the same time, the architecture is scalable enough to support other kinds of virtual reality technologies, e.g., virtual reality caves enabling an improved and more realistic immersive experiences.

We used the answers to the questionnaire provided to 17 medicine students in order to refine requirements related to the proposed educational scenario. We provided those students with a questionnaire for identifying requirements that they would see for a virtual reality scenario related to their studies. After the evaluation of the results from the questionnaire, we combined these results with the former research conducted by Wong and Looi (2011) and applyied their different MSL dimensions to our scenario. We performed this as part of our evolving research efforts aiming refine educational scenarios enriched with new forms of media and supported by innovative technologies. Specifically, we exercise this as part of our efforts to support educational scenarios with VR technologies. The results from the questionnaire provided indications associating the questions to various aspects addressed in various types of MSL also applicable for different types of SaViOs. Accordingly, our future efforts will address several aspects of SaViOs including evaluation of usability addressing implementation of different types of scenarios. In addition, we also aim on developing scenarios for new educational topics.

In our coming efforts, we plan to integrate new VR hardware and devices that have the potential can to provide more realistic and better educational experiences. In these future efforts, we aim on providing deployments better adapted to scenarios refined according to feedbacks pointing over users' preferences. The ultimate goal will be to, design and develop new Interactive and efficient Learning Environments (ILE) that could be used by teachers for enhancing students' learning experiences as well as to support debriefing sessions to reflect on the content and subject matter that have been explored in these new kind of ILEs.

References

Antoniou, P. E., Athanasopoulou, C. A., Dafli, E., & Bamidis, P. D. (2014). Exploring design requirements for repurposing dental virtual patients from the web to second life: a focus group study. *Journal of medical Internet research*, 16(6), e151.

Cheng, Y., & Huang, R. (2012). Using virtual reality environment to improve joint attention associated with pervasive developmental disorder. *Research in developmental disabilities*, 33(6), 2141-2152.

Cohen, S. (2015). Creating Innovative Pedagogical Opportunities via "Treasure-HIT": Mobile Treasure Hunt Games Generator. Master thesis published at Linnéuniversitetet, Sweden.

Cruz-Neira, C., Dolinsky, M., Lanier, J., Azuma, R., Baron, E., & Cruz-Neira, C. (2015, August). The renaissance of VR: are we going to do it right this time?. In *ACM SIGGRAPH 2015* Panels (p. 1). ACM.

Giemza, A., Bollen, L., & Hoppe, H. U. (2011). LEMONADE: field-trip authoring and classroom reporting for integrated mobile learning scenarios with intelligent agent support. *International Journal of Mobile Learning and Organisation*, 5(1), 96-114.

Helsel, S. (1992). Virtual Reality and Education. Educational Technology, 32(5), 38-42.

Kohen-Vacs, D., Milrad, M., Ronen, M., & Jansen, M. (2016). Evaluation of enhanced educational experiences using interactive videos and web technologies: pedagogical and architectural considerations. *Smart Learning Environments*, 3(1), 1-19.

Merchant, Z., Goetz, E. T., Cifuentes, L., Keeney-Kennicutt, W., & Davis, T. J. (2014). Effectiveness of virtual reality-based instruction on students' learning outcomes in K-12 and higher education: A meta-analysis.*Computers & Education*, 70, 29-40.

Ong, S. K., & Nee, A. Y. C. (2013). Virtual and augmented reality applications in manufacturing. Springer Science & Business Media.

Ramachandrappa, A. (2015). Panoramic 360◦ videos in virtual reality using two lenses and a mobile phone.

Stouffs, R., Janssen, P., Roudavski, S., & Tunçer, B. (2013). What is happening to virtual and augemented L reality applied to architecture? In *Conference on Computer-Aided Architectural Design Research in Asia* (CAADRIA 2013) (Vol. 1, p. 10).

Sutherland, I. E. (1968, December). A head-mounted three dimensional display. In Proceedings of the December 9-11, 1968, fall joint computer conference, part I (pp. 757-764). ACM.

Weise, M., Zender, R., & Lucke, U. (2015, July). Systematic Fusion of Gesture Sensors for Practical Learning in Virtual Environments. In *Advanced Learning Technologies* (ICALT), 2015 IEEE 15th International Conference on(pp. 83-87). IEEE.

Wong, L. H., & Looi, C. K. (2011). What seams do we remove in mobile-assisted seamless learning? A critical review of the literature. *Computers & Education*, 57(4), 2364-2381.

Wickens, C. D. (1992, October). Virtual reality and education. In Systems, Man and Cybernetics, 1992., IEEE International Conference on systems (pp. 842-847). IEEE.

Zbick, Janosch, Maarten Jansen, and Marcelo Milrad. "Towards a web-based framework to support end-user programming of mobile learning activities." *Advanced Learning Technologies* (ICALT), 2014 IEEE 14th International Conference on. IEEE, 2014.