Using Virtual Reality on Software Engineering and Education

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Abstract. Software systems are growing increasingly complex, needing new approaches to understanding and visualising them. Simultaneously, the nature of software engineering teams is changing, with employees playing more fluid roles and requiring seamless and contextual intelligence to make better decisions faster. Furthermore, the next generation of software developers will all be post-millennials, who may have very different expectations from their employment. As a result, we feel it is critical to reconsider how we usually perform software engineering, and immersive technologies offer enormous potential to assist with such difficulties. For this reason, the use of virtual reality in software engineering is examined in this article. Not only the current practices but also the studies in the academy are mentioned.

Keywords: VR · Software Engineering · Education.

1 Introduction

Virtual reality (VR) is a term, which denotes a simulation to experience desired things outside of the real world. There are different types of definitions about VR, but all of them point to the same spot. The best definition which merges all of them is Zeltzer's definition as in Figure 1: VR is an interactive and immersive (with the feeling of presence) experience in a simulated (autonomous) world and this measure we will use to determine the level of the advance of VR systems [1].

In popular culture, VR is used mainly for the entertainment industry. But this term is more comprehensive than that. Today nearly everything can be modelled in virtual reality. Also, virtual realities can be interconnected. Because of that, multiple universes can be built.

Even though, it might be thought that VR is a high tech product for modern days, the very first attempts can be dated back 17th and 18th centuries. This era can be called Victorian Virtual Reality [2]. There have been many early attempts at reproducing reality in such a way that it can be perceived as real by the user or observer. Charles Wheatstone [3] designed a stereoscope in the 1830s as in Figure 2.

However, these first attempts are far from fulfilling today's VR expectations since they essentially are luminous effects. In today's sense, VRs environments,

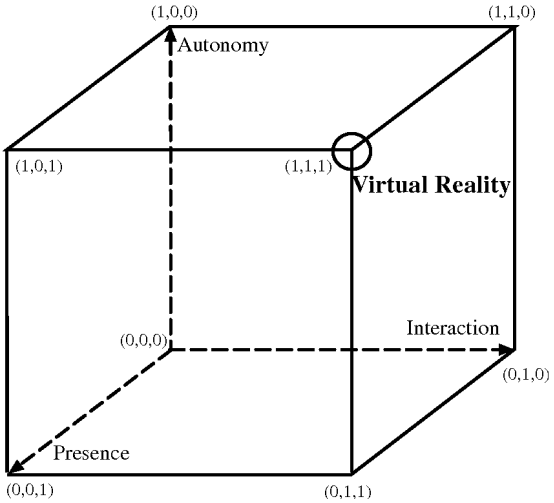

Fig. 1. Zeltzer's cube for VR definition [1]

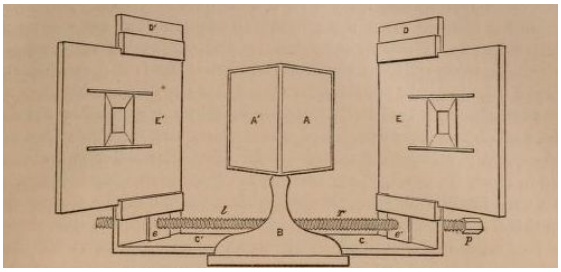

Fig. 2. Wheatstone's stereoscope

Fig. 3. Oculus Rift VR system

in which a virtual world is accessed with specially designed devices as in Figure 3, were encountered for the first time in the 60s [4–7].

The term "augmented reality" (AR) was coined by researchers Caudell and Mizell [8] in 1990 to describe how the head-mounted displays that electricians used when assembling complicated wiring harness worked [9]. AR is a registration or correction of the alignment of the virtual world with the real one [10]. However, in this particular paper, the main concern is VR technologies.

The benefits of the non-real world are drawn the attention of almost all the international high-profit companies. High-technology companies such as Facebook, Samsung, Microsoft, and Google started to increase their investments in such technologies and even some startup companies were acquired by these leading companies. For instance, Facebook acquired Oculus VR on March 25, 2014, for $2 billion [11].

Using VR in education can be considered a natural evolution in using technology to support learning [29]. In this paper, the effect of virtual reality environments on education, in general, will be discussed. Then, the contribution of virtual reality, which is our main topic, to software engineering and education will be mentioned.

2 Non-Real Environments in Education

Bell and Fogler proved that when interactive teaching methods are applied, students learn much better [12]. Every single student can respond to each different method differently and therefore; different methods can create a good

atmosphere for a large student group. Based on the average retention rates of different learning and teaching methods, we can list the methods from best to the worst as follows: teaching others or immediate use of learning, learning by doing, discussion group, demonstration, audio-visual, reading, and lecture [13]. According to the constructivist learning view, the student learns by interacting with the environment and they must be actively engaged in this process [14].

As a result, the use of virtual reality technology in education has increased dramatically. For engineering, Chou et al. [15] designed a virtual environment to teach students how to make structural analyses. Hashemipour et al. [18] designed a laboratory for mechanical and manufacturing engineering students. Likewise, for chemical engineering students Ouyang et al. [21] designed a laboratory. Besides Karkoub et al. [19] designed a pipeline inspection environment for oil companies to help train their personnel.

As it is nearly impossible to interact with intergalactic objects, Guimarães and Gnecco [16] used VR to teach astronomy and celestial mechanics. In addition, for helping physics learners, Ayse designed a mechanical physics laboratory in a virtual world [28].

In the field of medicine, Harrington et al. [17] designed an environment for developing the decision-making skills of experts for critically injured virtual patients. Laparoscopy is a method used by specialists when they avoid making large incisions on the skin. Due to its sensitive nature, before being an expert, practitioners must be trained well. To fulfil this need Matzke et al.[20] designed a simulation environment. Except for training medical doctors, other medical staff must also be trained. In order to meet this need Padilha et al. [22] designed a VR for nurses. On the other hand, to observe other VR applications in the field of medicine, there are some surveys. While Pfandled et al. [23] are investigating spine surgeries, Roy et al. [24] prepared and comprehensive analysis for dental applications.

Differently, some of the universities in Australia also work on wearable technologies in education. The University of Canberra and Macquarie University have been organizing some workshops called wearable technologies in education since 2015. Also, the University of SouthWales applied VR in engineering education [25].

Other studies on VR explore the effects of wearable technologies on education. There are several recent studies on the use of wearable technologies for education [26, 27].

3 Non-Real Environments in Software Engineering Education

As in other fields, VR is used by the original creators of VR, computer engineers and scientists. When we consider the issue in terms of software engineering (SE), there are two mainstream approaches. While one side increases the quality of the software development process by using VR, the other side organizes didactic sessions for those new to the software world, thanks to the blessings of VR.

3.1 VR in Software Engineering

To begin with, virtual reality allows software programmers to be entirely immersed in a three-dimensional work environment rather than being restricted to a few 2D monitors in front of them. Second, virtual reality allows for interaction that is both more familiar to users and more flexible than standard mouse and keyboard interaction. Interactions with a virtual world take full advantage of the human body's capabilities, potentially resulting in better productivity, shorter learning curves, and higher user happiness.

We could say three benefits that are more important than others: depth, plasticity, and body movement. The sense of depth has a special place in the human brain. With the help of this sense, the decision-making and creativity mechanisms in the human brain are more advanced than other life forms. However, the coding process is run in 2D environments usually. VR tools can better engage our brain's spatial processing system by rendering with depth. Higher brain spatial involvement should lead to increased productivity. As a result, some attempts have realised to create a product that helps coders to write their scripts in a 3D world.

Outside the academia, a study was conducted by Microsoft Research named Data Mountain [30] that showed that storage times, retrieval times, and retrieval failures were all reduced because of this aspect of spatial memory's influence. This study can be considered as a pioneer in this field. It is essentially a 3D document management system. There is no need for any hardware to reach the environment as in Figure 4.

Fig. 4. Data Mountain with 100 web pages

Considering the computer graphics of 1998, it is an advanced system for the terms of the period. However, it is an illusion that makes users feel that they are working on a 3D desktop.

Secondly, from Aristotle, learning while doing a simple physical activity such as walking and standing is easier than learning while sitting. In addition, the

meaning of the name Peripatetic school, which is Aristotle's school, is of walking in ancient Greek [31]. Leeb and Perez-Marcos [32] experimented with this concept. Participants' brains were monitored while in a VR environment and encouraged to think about movement in the VR world in a lab experiment about brain-computer interfaces and VR. When the brain-computer interface recognised specific brain signals, it moved the participants' virtual legs. More than two out of every three subjects were able to walk down the virtual street completely only by thinking about it, according to the researchers. It was demonstrated that combining body movement into computer interaction allows users greater freedom and results in highly practical benefits such as enhanced productivity.

Finally, with the changeable nature of VR, it is possible to design the workspace that we want. The only two obstacles are the human imagination and technological competence. Therefore, the software development process can be made more efficient by creating virtual versions of environments where software developers feel comfortable. RiftSketch is a good example of this [33]. It is a live coding environment built for VR which allows users to describe a 3D scene using Three.js as seen in Figure 5.

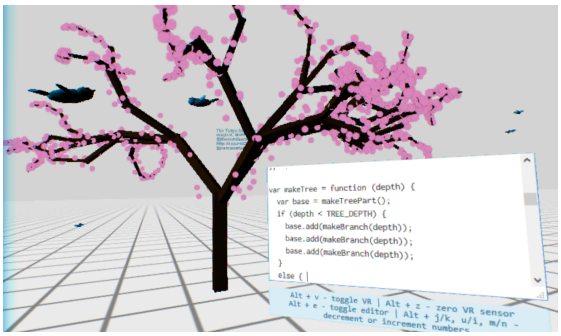

Fig. 5. RiftSketch screenshot

Live coding is a term used to describe an environment that allows a developer to make changes to a live application [34]. Edit, compile, link, and execute were the four stages in the classic programme development cycle. There is only one phase in live programming, at least in theory. During this phase, the programme is always running while numerous editing events take place.

Another application is Immersion [35] for code review. Immersion represents methods as code fragments similarly to Code Bubbles and displays groups of fragments as piles on the floor like BumpTop as in Figure 6.

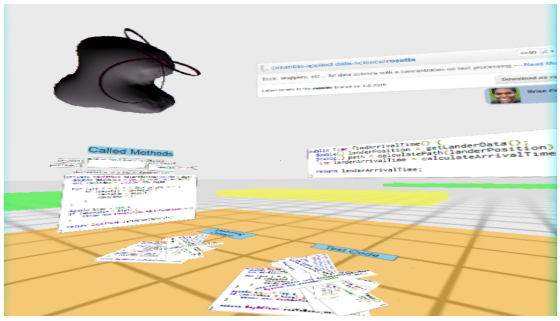

Fig. 6. Immersion screenshot

3.2 VR in Software Engineering Education

On the side of SE education, the studies are mostly done by academia itself. Although there is an enormous number of studies and surveys on the domain, we mentioned the most significant ones here.

In 2015, Elliott et al. [36] run a study. The "RiftSketch" and "Immersion" applications are described in the study. The first is an application that allows users to programme in a virtual reality environment, writing programmes and seeing real-time feedback on them. The other tries to provide code reviewers with an option by bringing codes into tables in a virtual reality environment as mentioned earlier.

In 2017, two different study groups designed VRs to show code structures like buildings by inspired by Vincur et al. [39] that described an application that presents software code structures as buildings in a VR environment. While Merino et al. [37] described an application that allows the user to see program code structures like buildings, Oberhauser and Lecon [38] abstracted software code structures as buildings in a virtual world. In addition, in the same year, Fittkau et al. [40] described the benefits of understanding the software system from different perspectives, including VR. They used software named ExplorViz in the research for mapping the system architecture and using HMD specific technologies to design the software architecture in VR environments.

In 2018, Akbulut et al. [41] designed a system, VRENITE, for learning sorting algorithms in which students experience the elements to be sorted.

In 2019, Ochoa and Babbit [42] designed a UML modelling application in VR to fulfil software requirements. Tanielu et al. [43] used VR to support the teaching of Object-Oriented Programming (OOP). To do that, the researchers took OOP concepts and abstracted them into constructions, which resulted in an application called OOPVR. On the other hand, Zhao et al. [44] designed a VR app to help students understand the manufacturing process. It comprises presenting to the user seven stations, in which he will need to assemble a manufactured product. At the first station, the user can analyze the requirements of the request, and at the second station, he can select which pieces he will need

to craft the product. The five subsequent stations were for the assembly of the vehicle.

References

1. Zeltzer, D.: Autonomy, Interaction, and Presence. Presence: Teleoperators and Virtual Environments **1**(1), 127–132 (1992)
2. Goldsborough, G.: Victorian virtual reality. Manitoba History **54**, 30 (2007)
3. Wade, N. J.: Charles Wheatstone (1802 – 1875). Perception **31**(3), 265–272 (2002)
4. Flores-Arrendondo, J. H., Assad-Kotner, C.: Virtual reality: a look into the past to fuel the future. Bulletin of The Royal College of Surgeons of England **97**(10), 424–426 (2015)
5. Heilig, M. L.: Sensorama Simulator (1962)
6. Prema, K. N., Roopa B. S.: Virtual reality : A survey. International Research Journal of Engineering and Technology **5**(7), 1567–1569 (2018)
7. Żmigrodzka, M.: Development of Virtual Reality Technology in the Aspect of Educational Applications. Marketing of Scientific and Research Organizations **26**(4), 117-133 (2017)
8. Caudell, T. P., Mizell, D. W.: Augmented reality: an application of heads-up display technology to manual manufacturing processes. In: Proceedings of the Twenty-Fifth Hawaii International Conference on System Sciences, pp. 659–669 (1992)
9. Elmqaddem N.: Augmented Reality and Virtual Reality in Education. Myth or Reality?. International Journal of Emerging Technologies in Learning **14**(3), 234–242 (2019)
10. Azuma, R., Behringer, R., Feiner, S., Julier, S., Macintyre, B.: Recent advances in augmented reality. IEEE Computer Graphics and Applications 21, 1—27 (2001)
11. Williams, A.: Reality check [virtual reality technology]. Engineering and Technology **10**(2), 52–55 (2015)
12. Bell, J. T., Fogler, H. S.: The investigation and application of virtual reality as an educational tool. In: Proceedings of the american society for engineering education annual conference (D. Budny, R.Herrick, G Bjedov, and J. B. Perry, ed.), pp. 1718–1728. Anaheim, CA (1995)
13. Kizil, M.: Virtual reality applications in the Australian minerals industry. In: Conference proceedings of the 31st international symposium on application of computers and operations research in the minerals industries (I. F.A. Camisani-Calzolari, ed.), pp. 569–574. The South African Institute of Mining and Metallurgy, Johannesburg, (2003)
14. Harrod, J.: Enhancing mining education through the use of a scenario-based virtual reality simulation. MSc thesis, The University of Queensland (2016)
15. Chou, C., Hsu, H. L., Yao, Y. S.: Construction of a virtual reality learning environment for teaching structural analysis, Computer Applications in Engineering Education **5**, 223–230 (1997)
16. Guimarães, M. D. P., Gnecco, B. B.: Teaching astronomy and celestial mechanics through virtual reality, Computer Applications in Engineering Education **17**, 196–205 (2009)
17. Harrington, C. M., Kavanagh, D. O., Quinlan, J. F., Ryan, D., Dicker, P., O'Keeffe, D., Traynor, O., Tierney, S.: Development and evaluation of a trauma decision-making simulator in Oculus virtual reality, The American Journal of Surgery **215**(1), 42–47 (2018)

18. Hashemipour, M., Manesh, H. F., Bal, M.: A modular virtual reality system for engineering laboratory education, Computer Applications in Engineering Education **19**, 305–314 (2011)
19. Karkoub, M., Her, M. G., Chen, J. M.: Design of an interactive pipeline inspection VR system, Computer Applications in Engineering Education **19**, 814–825 (2011)
20. Matzke, J., Ziegler, C., Martin, K., Crawford, S., Sutton, E.: Usefulness of virtual reality in assessment of medical student laparoscopic skill. J Surg Res **211**, 191–195 (2017)
21. Ouyang, S-G, et al.: Unity3D-based interactive three-dimensional virtual practice platform for chemical engineering, Computer Applications in Engineering Education **26**, 91–100 (2018)
22. Padilha, J. M., et al.: Clinical virtual simulation in nursing education. Clin. Simul. Nurs **15**, 13–18 (2018)
23. Pfandler, M., et al.: Virtual reality-based simulators for spinesurgery: A systematic review. Spine. J. **17**, 1352–1363 (2017)
24. Roy, E., Bakr, M. M., George, R.: The need for virtual reality simulators in dental education: A review. Saudi. Dent. J. **29**, 41–47 (2017)
25. Alvarez, V., et al.: The use of wearable technologies in Australian universities: Examples from environmental science, cognitive and brain sciences and teacher training. In: Proceedings of the 15th World Conference on Mobile and Contextual Learning (W. Ng,ed.), pp. 25–32. University of Cyprus, Sydney, Australia (2016)
26. Bower, M., Sturman, D.: What are the educational affordances of wearable technologies? Comput. Educ. **88**, 343–353 (2015)
27. Sultan, N.: Reflective thoughts on the potential and challenges of wearable technology for healthcare provision and medical education. Int. J. Inf. Manage. **35**, 521–526 (2015)
28. Cengiz, A. B.: Solving and Visualizing the Mechanical Problems in Physics by Computer. MSc thesis, Dokuz Eylul University (2018)
29. Pantelidis, V. S.: Reasons to use virtual reality in education and training courses and a model to determine when to use virtual reality. Themes in Science and Technology Education **2**(1-2), 59–70 (2010)
30. Robertson, G., Czerwinski, M., Larson, K., Robbins, D. C., Thiel, D., van Dantzich, M.: Data mountain: using spatial memory for document management. In: Proceedings of the 11th annual ACM symposium on User interface software and technology, pp. 153–162. Association for Computing Machinery, New York (1998)
31. Online Etymology Dictionary. https://www.etymonline.com/search?q=Peripatetic, Last accessed 21 May 2022
32. Leeb, R., Pérez-Marcos, D.: Chapter 14 - Brain-computer interfaces and virtual reality for neurorehabilitation. In: Handbook of Clinical Neurology, pp. 183–197, Elsevier, (2020)
33. RiftSketch. https://brianpeiris.github.io/RiftSketch/. Last accessed 21 May 2022
34. Tanimoto, S. L.: A Perspective on the Evolution of Live Programming.
35. Immersion. https://immersionvr.co.uk/ Last accessed 21 May 2022
36. Elliott, A., Peiris, B., Parnin, C.: Virtual reality in software engineering: Affordances, applications, and challenges. 2015 IEEE/ACM 37th IEEE International Conference on Software Engineering **2**, 547-–550 (2015)
37. Merino, L., Ghafari, M., Anslow, C. Nierstrasz, O.: Cityvr: Gameful software visualization. In: 2017 IEEE International Conference on Software Maintenance and Evolution, pp. 633–637 (2017)

38. Oberhauser, R. Lecon, C.: Virtual reality flythrough of program code structures. In: Proceedings of the Virtual Reality International Conference-Laval Virtual 2017, pp. 1–4 (2017)
39. Vincur, J., Navrat, P. and Polasek, I.: Vr city: Software analysis in virtual reality environment. In: 2017 IEEE international conference on software quality, reliability and security companion (QRS-C), pp. 509–516 (2017)
40. Fittkau, F., Krause, A. Hasselbring, W.: Software landscape and application visualization for system comprehension with explorviz, Information and software technology **87**, 259–277 (2017)
41. Akbulut, A., Catal, C., Yildiz, B.: On the effectiveness of virtual reality in the education of software engineering. Computer Applications in Engineering Education **26**(4), 918–927 (2018)
42. Ochoa, O., Babbit, A.: Incorporating a virtual reality environment in the teaching of analysis of software requirements. In: 2019 IEEE Frontiers in Education Conference (FIE), IEEE, pp. 1—5 (2019)
43. Tanielu, T., 'Akau'ola, R., Varoy, E., Giacaman, N.: Combining analogies and virtual reality for active and visual object-oriented programming. In: Proceedings of the acm conference on global computing education, pp. 92—98 (2019)
44. Zhao, R., Aqlan, F., Elliott, L. J., Lum, H. C.: Developing a virtual reality game for manufacturing education. In: Proceedings of the 14th International Conference on the Foundations of Digital Games, pp. 1–4 (2019)