Metaverse: Technologies for Virtual Worlds

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Virtual worlds can be a powerful tool for a variety of applications, including education, visualization, collaboration, or entertainment. Some of these virtual worlds utilize augmented reality (AR), virtual reality (VR), or extended reality (XR); others use Web 3.0 technologies. These virtual worlds can be isolated or interconnected within a metaverse and some can even use blockchain technologies to enforce permanent records of, for example, ownership of part of the virtual world. For this special issue, we solicited manuscripts focused on a variety of technologies for such virtual worlds, including AR, VR, and XR as well as Web 3.0 and blockchain technologies, running on different devices ranging from web browsers, hand-held devices or head-mounted displays to full-scale CAVE-type systems. Based on the formal *IEEE Computer Graphic and Applications* review process, we were able to accept five out of the nine submissions that were received.

In the first article,[A1] Bosnar et al. describe methods for creating virtual models for different types of manufacturing defects. Based on appropriate lighting methods, very realistic models can be created. These models can then be used to create virtual representatives of defective products. By creating a variety of such defective models, the resulting database can be used for visual inspection system training.

The second article[A2] expands the capabilities of a virtual environment by including flavors to cover an additional sense. Based on six to nine cartridges, the device can generate a variety of smells to deliver taste and retronasal smell. In a pilot study, participants were exposed to real and virtual samples of different flavors. The experiment showed that it is possible to provide the ability to enjoy a meal or drink in a virtual environment by analyzing the flavor components and then synthesize the sensation with the virtual flavor device.

To compare the efficacy of virtual reality serious games versus web video games, López-Fernández et al.[A3] performed a robust empirical study with 289 participants in their article. A serious game was developed to learn the software development framework Scrum that supports virtual reality through head-mounted displays and another version based on WebGL. The results show a statistically significant improvement in learning performance when using virtual reality over the web-based version.

In order to accelerate the process of creating virtual reality-based training software for the medical domain, Zikas et al.[A4] present a novel software development kit (SDK) in their article. This framework allows developers to create medical simulations in a low-code environment. It supports collaborative environments integrating both virtual and augmented reality. The SDK incorporates realistic simulation of organic tissues and highly realistic cutting and tearing algorithms. This framework was successfully deployed in a variety of virtual medical training scenarios.

As outlined by Patel et al. in their article,[A5] virtual training can be an effective tool to improve specific skills. These virtual scenarios present a participant with a realistic encounter of different types of patients. This provides a learning environment in which the trainee can improve their skills at their own time by just installing an application on their phone or other devices. This provides a safe learning environment. The empirical results show an improvement of compassion and empathy toward their patient after completing the learning experience.

After publishing the call for papers for this special issue, one of our guest editors, André Stork, was elected the new Editor-in-Chief (EIC) for *IEEE Computer Graphics and Applications*. He started this new role in January 2023. In accordance with the rules of IEEE, as EIC he was not involved in the decision making on the submissions. This process was run by the

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corresponding Associate EIC for special issues Pak Chung Wong.

We wish to thank Pak Chung Wong for his guidance in producing this special issue, and we also wish to thank the authors and reviewers for their hard work. We hope you enjoy reading these manuscripts and learn more about the various technologies for virtual worlds.

APPENDIX: RELATED ARTICLES

A1. L. Bosnar, H. Hagen, and P. Gospodnetic, "Procedural defect modeling for virtual surface inspection environments," *IEEE Comput. Graphics Appl.*, vol. 43, no. 2, pp. 13–22, Mar./Apr. 2023, doi: 10.1109/MCG.2023.3243276.

A2. A. Chalmers, D. Zholzhanova, T. Arun, and A. Asadipour, "Virtual flavor: High-fidelity simulation of real flavor experiences," *IEEE Comput. Graphics Appl.*, vol. 43, no. 2, pp. 23–31, Mar./Apr. 2023, doi: 10.1109/MCG.2023.3242316.

A3. D. López-Fernández, J. Mayor, M. García-Pérez, and A. Gordillo, "Are virtual reality serious video games more effective than web video games?," *IEEE Comput. Graphics Appl.*, vol. 43, no. 2, pp. 32–42, Mar./Apr. 2023, doi: 10.1109/MCG.2023.3244036.

A4. P. Zikas, et al., "MAGES 4.0: Accelerating the world's transition to VR training and democratizing the authoring of the medical metaverse," *IEEE Comput. Graphics Appl.*, vol. 43, no. 2, pp. 43–56, Mar./Apr. 2023, doi: 10.1109/MCG.2023.3242686.

A5. D. B. Patel, Y. Pei, M. Vasoya, and P. J. Hershberger, "Computer-supported experiential learning-based tool for healthcare skills," *IEEE Comput. Graphics Appl.*, vol. 43, no. 2, pp. 57–68, Mar./Apr. 2023, doi: 10.1109/MCG.2023.3242921.

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