Guest Editors' Introduction

Virtual and Augmented Reality Applications in Science and Engineering

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WE ARE IN the midst of an explosive growth in visually augmenting the spaces around us by creating environments where visual, aural, and kinesthetic immersive experiences afforded by virtual and augmented reality (AR) powerfully engage us in a way no other medium can. Virtual reality (VR) recreates the sensory world around us entirely through computer-generated signals of sight, sound, touch (and in some cases smell and taste). AR overlays the computer-generated sensory signals on the real world allowing the user to experience a rich juxtaposition of the virtual and the real worlds simultaneously. Together, these technologies are transforming the way people from all walks of life—scientists, engineers, educators, industrial workers, health care professionals, artists, and everyday people—see and use the information that matters most to them, in an intuitive embodied way. Just as mobile technology has revolutionized how we communicate with each other and with our digital worlds, ubiquitous VR and AR will fundamentally alter how our society creates, inspires, engages, and learns from the information-rich and enriched cyberspaces around us. While affordable consumer-quality VR and AR hardware is becoming available, significant work is needed to adopt VR and AR for important and difficult scientific and societal applications. At our home institutions of NASA Goddard Space Flight Center and the University of Maryland, we have been fortunate to be a part of this exciting journey to the new frontiers of immersive science and engineering.

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VR and AR applications enable scientists and engineers to interpret and visualize science data in new ways and experience environments that are otherwise hard, impossible, or too costly to visit in person. For instance, researchers at the NASA Goddard Space Flight Center (GSFC) have developed immersive tools for exploring regions at the depths of our oceans to distant stars and galaxies. NASA GSFC's PointCloudsVR application[1] supports particle visualization across various science disciplines. GSFC scientists have used this software to visualize positions and velocities of 4 million Gaia stars,[2] Solar wind hitting Mars' magnetosphere, phytoplankton flow, terrestrial lava flows and tubes, and revisit "real-world" sites captured by LIDAR.[3–5] Tools developed for these applications in partnership with NASA scientists also facilitate scientific measurements and groupings in the VR environment for various structures and features in science data. As another example, consider the OnSight application[6] developed through a collaboration between NASA JPL's Ops[7] Lab and Microsoft. This application creates an immersive 3-D terrain model of the sites that Curiosity rover visited and allows scientists to collaboratively study the geology of Mars as they virtually meet at those sites. All these applications provide scientists and engineers an immersive experience of virtual presence in the field.

NASA GSFC has also developed engineering VR and AR applications for design, construction, and operations of spacecraft. One such application is a 3-D simulation of GSFC's thermal-vacuum chamber in order for engineers to ensure all spacecraft components would fit inside the facility before testing starts. Another GSFC engineering AR application combines camera views and telemetry data within the field of view of technicians who operate robotic arms such as the one on the International Space Station. JPL in collaboration with Google has also developed the AR Spacecraft Mobile App[8] that brings 3-D models of NASA's various robotic spacecrafts such as Curiosity Mars rover, Juno, Cassini, and Voyager to users.

At the University of Maryland, professors, researchers, and students have developed a number of VR and AR environments. These include: working with the Newseum on their virtual Berlin Wall exhibit; creating immersive medical anatomy educational modules with the School of Medicine at the University of Maryland Baltimore; developing an AR extraventricular drainage procedure with the neurosurgeons at the Baltimore R Adams Cowley Shock Trauma Center;[4] devising VR training modules for diversity and inclusion for the Prince George's County Police Department; capturing live performances, including a solo concert violinist as well as an opera performance, for evaluation of VR for pain mitigation with the School of Nursing at the University of Maryland, Baltimore;[5] creating a tool for immersive evaluation of weather data with NOAA;[6] an immersive social media platform[7] and collaborating with Microsoft and Google on real-time cinematic quality multiview reconstruction of people from arrays of cameras and depth sensors for telepresence applications.[8] Each of these environments was meticulously crafted with careful attention to detail on the driving application and the user experience. University of Maryland researchers have also conducted one of the first in-depth analyses on whether people learn better through virtual, immersive environments as opposed to more traditional platforms like a 2-D desktop computer or hand-held tablet; results showed an 8.8% improvement overall in recall accuracy using VR headsets.[9]

IN THIS ISSUE

It was quite gratifying to witness the breadth and depth of the papers on VR and AR applications and research submitted for this special issue. Selecting a small set of papers that could be accommodated within the space constraints of this special issue became a daunting challenge! After a rigorous, multiround process of reviews, we are pleased to present this special issue of CiSE that highlights VR and AR projects in medicine, assisting people with disabilities, and data analysis for science and engineering.

When you think of VR and AR, the first things that spring to mind are probably not people with intellectual and developmental disabilities. Yet, in the article "Design of a Virtual Reality Tour System for People With Intellectual and Developmental Disabilities: A Case Study," researchers from Kent State University present a case study on how they went about designing an immersive virtual tour to relieve social anxiety in people with such disabilities by enhancing their familiarity with places in VR before they actually visit them.

AR and VR are transforming medicine as we know it. The article "Augmented and Virtual Reality in Surgery" presents a survey on the promises and challenges of using AR and VR in surgery and healthcare authored by an interdisciplinary team of professors, researchers, and healthcare professionals from Queensland University of Technology and The University of Queensland. This article surveys the current state of the art in how immersive technologies can provide significant benefits to healthcare practitioners and patients alike.

One of the most amazing affordances of VR and AR is the sense of presence. Humans have evolved to solve some very challenging tasks using spatial perception and cognition. In "Virtual and Augmented Reality Applications to Support Data Analysis and Assessment of Science and Engineering," researchers from the U.S. Army Research Laboratory have explored how VR and AR can mediate interactions with big data analytics to leverage our spatial reasoning skills to answer several demanding data analytics and reasoning problems independently as well as in teams.

In "Pain Marker Evaluation Application in Augmented Reality and Mobile Platforms," researchers at the Case Western University of Cleveland, Cleveland, OH, USA, designed and developed an anatomy AR and VR application for users to interact with 3-D anatomy systems using Microsoft's HoloLens. In addition to its educational purposes, this application can help patients identify the location and level of pain they are experiencing in their body. Clinicians can then view dermatome maps that indicate which spinal nerve(s) user pain corresponds to. This consistent way of reporting pain can help with diagnosis, treatment, and recording methods through time among different clinicians for different types of injuries.

We hope that you will find the papers in this special issue as intellectually stimulating as we did. We are currently in the early stages of a visual computing technology revolution that is being driven by three significant trends: a) advances in commodity lightweight sensors; b) unprecedented computational power, enabled by multicore processors in relatively small form-factor devices; and c) increasing availability of consumer wearable VR and AR displays. This special issue gives us tantalizing glimpses into the future where rich digital cyberspaces will blend with the real world.

APPENDIX RELATED WORKS

1. NASA GSFC's PointCloudsVR application. [Online]. Available: https://github.com/nasa/PointCloudsVR
2. Gaia. [Online]. Available: https://sci.esa.int/web/gaia
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7. JPL Ops Lab. [Online]. Available: https://opslab.jpl.nasa.gov
8. Spacecraft Mobile App. [Online]. Available: https://www.jpl.nasa.gov/news/news.php?feature=7082
9. E. Honzel *et al.*, "Virtual reality, music, and pain: Developing the premise for an interdisciplinary approach to pain management," *Pain*, vol. 160, no. 9, pp. 1909–1919, Sep. 2019. [Online]. Available: https://doi.org/10.1097/j.pain.0000000000001539
10. P. C. Meyers *et al.*, "Examining an atmospheric river in virtual reality," in *Proc. 100th Amer. Meteorol. Soc. Annu. Meeting*, Jan. 2020. [Online]. Available: https://ams.confex.com/ams/2020Annual/meetingapp.cgi/Paper/365076
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14. E. Krokos, C. Plaisant, and A. Varshney, "Virtual memory palaces: Immersion aids recall," *Virtual Reality*, vol. 23, pp. 1–15, 2019. doi: 10.1007/s10055-018-0346-3

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