frontiers | Frontiers in Virtual Reality

Editorial: Virtual reality in industry: spotlight on women

Kay M. Stanney[1]*, Dioselin Gonzalez[2], Amela Sadagic[3] and Carolina Cruz-Neira[4]

[1]Design Interactive, Inc., Orlando, FL, United States, [2]Independent Researcher, Seattle, WA, United States, [3]Computer Science Department, Naval Postgraduate School, Monterey, CA, United States, [4]Department of Computer Science, University of Central Florida, Orlando, FL, United States

KEYWORDS

virtual reality, remote work, distributed collaboration, human-robot teaming, virtual reality training, mines rescue training, privacy threats, identity detection

Editorial on the Research Topic
Virtual reality in industry: spotlight on women

1 Introduction

The Frontiers in Virtual Reality Research Topic, *Virtual Reality in Industry: Spotlight on Women*, showcases an impressive collection of cutting-edge research led by women innovators. This collection highlights the growing role of virtual reality (VR) in transforming traditional industrial processes, pushing the boundaries of productivity, training, healthcare, and privacy. As industries and other domains of human activity continue to embrace digital transformation, the adoption of VR is becoming increasingly essential for improving human performance, operational efficiency, safety, and overall user experiences. Some VR solutions even allow operators to acquire skills and perform tasks that would otherwise be impossible.

The papers in this collection emphasize the practical applications of VR and confront critical challenges, such as ethical data use, privacy risks, and inclusivity in training and healthcare solutions. Furthermore, these works exemplify how VR can be adapted to address specific needs in high-risk environments and specialized medical conditions, offering forward-thinking solutions that blend a human-centered design paradigm and an array of advanced technologies that, when integrated, contribute to the compelling VR user experience.

Each paper reflects women's expertise, creativity, talent, and leadership in shaping the future of VR, proving that gender diversity is critical for innovation and impact within industrial and technological research. Women's active engagement offers unique perspectives, enriches the work of interdisciplinary teams, and maximizes talent and productivity. Below is an overview of each contribution, illustrating both their technical contributions and how they highlight the role of women in VR research.

2 Paper summaries

"*Virtual Reality and Productivity in Knowledge Workers,*" by Aufegger and Elliott-Deflo, investigates the role of VR in enhancing productivity among knowledge workers who operate in increasingly virtual work environments. Through two studies, the authors develop a framework that connects productivity with physical, cognitive, and behavioral needs within VR contexts. Their findings show that VR can improve team collaboration and individual efficiency in remote working setups, making it a vital tool for the future of the workplace. This work provides a foundation for understanding how immersive VR technologies can optimize both individual and organizational productivity in evolving digital workplaces, offering new solutions to the challenges of virtual and remote working environments. Furthermore, the paper highlights how VR can create more engaging virtual environments that enhance focus and reduce distractions, improving the overall work quality. The framework also offers insights into the design of virtual workspaces that cater to diverse working styles, ensuring that VR is a flexible and adaptable tool for a wide range of professional needs.

"*Influence of Age and Industry Experience on Learning Experiences and Outcomes in Virtual Reality Mines Rescue Training,*" by Pedram et al., focuses on the impact of age and industry experience on learning outcomes in VR training for mine rescue operations. Despite initial stress among older trainees, the study concludes that both older and younger participants benefit from VR-based training regardless of their prior experience. Additionally, the research points out the flexibility of VR in overcoming traditional training barriers, offering a scalable solution for industries where real-world training is often dangerous, costly, or impractical. The findings highlight VR's potential to make high-risk industry training accessible and effective for a wide range of workers, demonstrating that age is not a limiting factor in adopting new technologies for industrial training. By showing that VR training can be equally effective for older and less experienced workers, the paper advocates for the widespread adoption of VR technologies, emphasizing the importance of diversity in workforce training. Moreover, the study underscores VR's capacity to enhance safety by enabling trainees to practice in realistic, simulated environments without exposure to actual hazards, providing an invaluable tool for preparing workers in high-risk industries.

"*Designing Virtual Reality Exposure Scenarios to Treat Anxiety in People with Epilepsy,*" by Lewis-Fung et al., explored how to design tailored VR exposure therapy scenarios to treat anxiety in people with epilepsy (PwE). Using 360-degree video technology, the study creates a minimum viable product to simulate real-life anxiety-inducing scenarios for PwE. This research demonstrates how 360 videos can be safely and effectively applied to specialized medical conditions, expanding the role of immersive solutions in therapeutic settings, particularly for individuals with unique neurological conditions. The study is a testament to the potential of addressing complex medical challenges through the creative use of compelling experiences offered with the help of 360 videos. Furthermore, the approach emphasizes the importance of a user-centered design paradigm by involving individuals with epilepsy in the creation and testing process, ensuring that the therapy is both practical and tailored to real patient experiences. This patient involvement enhances the treatment's effectiveness and highlights the versatility of 360 videos as a tool for addressing personalized medical needs.

"*Privacy Threats of Behavior Identity Detection in VR,*" by Kumarapeli et al., highlights significant privacy concerns tied to the increasing use of behavioral data collected in VR environments. The study demonstrates how machine learning algorithms can accurately identify users based on their actions, even when they deliberately attempt to alter their behavior. This raises important questions about privacy, security, and the ethical use of sensitive personal data, particularly as behavioral biometrics become central to authentication and identity tracking. The research underscores the urgency for robust privacy protections to safeguard users in an era where VR technologies are becoming an integral part of everyday life. It also calls for a comprehensive discussion on the balance between technological advancement and user rights, positioning privacy as a crucial element in the future of digital environments.

"*Magic NeRF Lens: Interactive Fusion of Neural Radiance Fields for Virtual Facility Inspection,*" by Li et al., presents a VR framework that combines neural radiance fields (NeRF) with CAD models to deliver highly realistic visualizations for industrial facility inspections. This approach allows for immersive and interactive visual experiences, which are ideal for performing maintenance and safety inspections in environments that are difficult or dangerous to access physically. The Magic NeRF Lens significantly enhances the realism of virtual inspections, offering potential improvements in productivity and safety for industrial applications. This research paves the way for the broader adoption of VR technologies in industries that rely heavily on facility management and remote operations by providing more accurate visual representations of complex facilities and systems. Additionally, the fusion of NeRF and CAD models ensures that even highly detailed, intricate environments can be accurately visualized, helping industries achieve higher precision in both routine maintenance inspections and critical infrastructure management tasks. Integrating such immersive visualization tools could potentially revolutionize industries requiring remote or hazardous inspections, contributing to better safety standards and operational efficiency.

"*RealTHASC—A Cyber-Physical XR Testbed for AI-Supported Real-Time Human Autonomous Systems Collaborations,*" by Paradise et al., presents RealTHASC, a cutting-edge testbed that integrates real and virtual environments to enable real-time collaborations between humans and autonomous systems. Using extended reality (XR) technology, the platform allows for seamless interaction between robots and humans, tested through a variety of industrial scenarios. Specifically, this platform bridges the "simulation-to-reality gap" by offering realistic feedback loops and safe, cost-effective testing of AI systems in scenarios like search-and-rescue. By combining wearable sensors, motion capture, AI, and VR, RealTHASC enables real-time interaction between humans and robots, allowing for detailed experimentation in dynamic, high-risk environments such as defense, healthcare, and emergency response. The system's ability to simulate complex, hazardous situations without exposing participants to real danger manifested in the physical world makes it a highly valuable tool for advancing autonomous systems research while ensuring safety and practicality in testing.

Additionally, RealTHASC's versatility supports a broad range of applications, from AI-driven decision-making in high-pressure scenarios to refining human-autonomy teamwork in industries reliant on precision and safety.

3 Theory, measures, and applications

This Research Topic, *Virtual Reality in Industry: Spotlight on Women*, highlights VR's transformative potential across various industrial sectors. The papers presented here demonstrate how VR and associated technologies are reshaping industries by offering new solutions to long-standing challenges—ranging from improving productivity and workforce training to advancing healthcare interventions and addressing critical ethical concerns around privacy and data security.

VR's ability to create immersive, interactive environments enables industries to streamline processes and enhance outcomes in ways that were once thought impossible. In sectors like knowledge work and remote collaboration, VR provides solutions to the challenges an increasingly virtual and distributed workforce poses. As demonstrated in the paper on knowledge worker productivity by Aufegger and Elliott-Deflo, VR frameworks can optimize individual and team efficiency, creating virtual workspaces that are engaging, focused, and adaptable to the needs of diverse working styles. By enabling real-time collaboration across geographic boundaries, VR also fosters a new level of global connectivity, allowing companies to leverage talent from anywhere in the world while maintaining high levels of productivity and communication.

In high-risk industries such as mining, VR plays an equally transformative role by making training programs more effective and inclusive. The study on mine rescue training by Pedram et al. underscores how VR can provide a safe, scalable solution to train workers in hazardous environments without putting them at risk. This is particularly important in industries where traditional training methods are not only dangerous but also costly, time-consuming, and, in some cases, less effective. The ability to simulate real-world conditions with high fidelity allows workers to gain practical experience in a controlled, virtual setting, significantly reducing the potential for accidents and improving safety standards across the board. Moreover, VR's inclusivity ensures that workers of different ages and experience levels can benefit equally from such training programs, helping industries address diversity and inclusivity in workforce development.

In healthcare, VR is driving innovative approaches to medical treatments, offering non-invasive, patient-centered solutions tailored to individual needs. The study on VR exposure therapy for people with epilepsy by Lewis-Fung et al. demonstrates how immersive technologies can be used to treat specialized medical conditions, providing patients with safe, controlled environments to confront their fears and anxieties. This application of VR goes beyond traditional therapeutic methods, offering patients a unique tool to improve their mental health and wellbeing without the need for pharmacological interventions. As more research explores the use of VR in therapeutic contexts, the potential to treat other conditions—such as PTSD, phobias, and even chronic pain—becomes increasingly apparent, pushing the boundaries of what healthcare can achieve through immersive technology.

At the same time, the growing use of VR in everyday life raises important questions about privacy and ethics, particularly around the collection and use of behavioral data. The paper on privacy threats in VR by Kumarapeli et al. highlights the critical need for stronger protections as machine learning algorithms and biometric data collection become more pervasive in VR environments. With the ability to track users' interactions, movements, behaviors, eye gaze, and even emotions, VR has the potential to infringe on personal privacy in unprecedented ways. The ethical implications of such technology must be addressed through robust regulations and safeguards that protect users from potential misuse of their data. As VR becomes more integrated into daily life and work, industries will need to adopt ethical frameworks that balance innovation with respect for privacy, ensuring that these technologies are used responsibly and inclusively.

The paper on Magic NeRF Lens by Li et al. further emphasizes the potential of VR in industrial applications, particularly in facility inspection and maintenance. The innovative combination of NeRF and CAD models creates highly realistic, immersive visualizations that allow workers to inspect complex facilities remotely in a detailed and interactive manner. This is especially valuable for industries with restricted or dangerous physical access, such as energy plants or high-security environments. The precision and realism offered by the Magic NeRF Lens can significantly improve the safety, accuracy, and efficiency of facility inspections, paving the way for broader VR adoption in industrial settings. By enhancing remote operations and improving worker safety, this research showcases how VR can become a key tool for managing infrastructure, reducing operational risks, and streamlining maintenance processes.

Similarly, the RealTHASC platform presented by Paradise et al. addresses the critical need for real-time collaboration between humans and autonomous systems in industrial scenarios. By bridging real and virtual environments, RealTHASC enables highly realistic simulations for testing AI-driven human-autonomy teams in complex, dynamic environments such as defense, healthcare, and emergency response. This platform provides a valuable tool for refining human-robot interactions in high-stakes situations, offering a safe, controlled space to experiment with AI decision-making and collaborative problem-solving. RealTHASC's ability to simulate hazardous or high-risk environments without endangering human lives makes it an essential resource for advancing the development of autonomous systems in industries that rely on precision, safety, and rapid decision-making. The platform's impact extends across multiple sectors, illustrating how VR can enhance not only productivity and training but also operational safety and human-AI collaboration.

Across all these applications, the role of women leaders in advancing VR research and innovation is both prominent and pivotal. The contributions from women researchers and practitioners in this research issue demonstrate not only their expertise but also their ability to drive meaningful change in industries that have historically been male-dominated. Their leadership in shaping the development and application of VR technologies highlights the importance of gender diversity in scientific and industrial research, as well as the critical role that women play in pushing the boundaries of innovation. By advancing VR in ways that enhance productivity, improve safety, and address ethical concerns, these women leaders are making an indelible mark on the future of VR and its applications across sectors. Their work serves as an inspiring example of how diversity in leadership can lead to more inclusive and impactful innovations. As VR continues

to evolve, women's active involvement and contributions will remain essential to ensuring that this transformative technology is developed and applied in ways that benefit society as a whole.

4 Conclusion

In conclusion, this Research Topic of Frontiers in Virtual Reality underscores the vast potential of VR to revolutionize industries, reshape the future of work, and improve the quality of life for individuals in ways previously unimaginable. The breadth of research presented here demonstrates VR's adaptability and versatility across different sectors while highlighting the critical role of ethical considerations in developing such transformative technologies. The contributions from women leaders further emphasize the importance of inclusivity and diversity in driving forward the next-generation of VR innovations, ensuring that the technology's impact is as wide-reaching and beneficial as possible.

Author contributions

KS: Conceptualization, Writing–original draft, Writing–review and editing. DG: Conceptualization, Writing–review and editing. AS: Conceptualization, Writing–review and editing. CC-N: Conceptualization, Writing–review and editing.

Conflict of interest

Author KS was employed by Design Interactive, Inc.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The author(s) declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

Generative AI statement

The author(s) declare that Generative AI was used in the creation of this manuscript in the following way: its use was limited to review, clean up, and streamlining of the draft text.

Publisher's note