

Defining a New Cross Reality

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Sixteen years ago, *IEEE Pervasive Computing* published a groundbreaking special issue on “Cross-Reality Environments,”¹ coedited by Joe Paradiso, who returns to the editorial team again for this issue, and James Landy. According to AI-driven web searches, this Special Issue first brought the term “Cross Reality” into our vernacular. The concept espoused then was based upon the fusion of ubiquitous sensor/actuator networks and immersive virtual worlds, envisioning a seamless electronic “nervous system” that connects physical and virtual realities to enable hybrid and scalable interaction across both domains. Inspired by classics of speculative fiction, such as Verner Vinge’s novella “True Names,”² the special issue back then envisioned “this environment as an extension of human perception and interaction, augmenting our five senses well beyond the canonical “here and now” and redefining the meaning of presence.”¹ At the time of the 2009 issue, cross reality systems tended to leverage data from specially designed sensor networks deployed in laboratories and other confined settings, and connected the data to custom AR systems and frameworks, sometimes exploiting nascent shared virtual world environments, like Second Life and Wonderland.

Since the original special issue came out in 2009, we have witnessed exponential growth in the deployment of pervasive computing, encompassing networked multimodal sensors everywhere along with wide penetration of low-cost platforms and shared frameworks for virtual, augmented, and mixed reality (VR/AR/MR). “Cross reality” has become a common phrase, and the term “digital twin,” essentially unknown in our field at the time of the 2009 issue, is now routinely adopted across domains. The denizens of mixed reality spaces now come in different shades, from

humans (fully or peripherally immersed/represented) to AI systems, and just as we saw at the dawn of Ubi-Comp, industries are working to brand dialects of it to suit their interests in a boom/bust digital gold rush.

This new era of Cross Reality still considers a unified space where VR/AR/MR in combination with wearable and ambient/pervasive technologies act as key connectors of distributed sensor data and physical experiences, but now they act together with AI. Despite significant progress and frequent breakthroughs in many related areas, key challenges remain in creating integrated systems that offer seamless interaction and rich user experiences. Similarly, realistic digital twin representations from individual human function and behavior to complete doppelworlds and their application are open scientific problems with groundbreaking potential. Accordingly, this special issue expands upon the original vision, exploring recent developments, current research, and future directions that impact cross-reality systems.

Attesting to the topical nature of the subject, this issue presents seven papers that provide complementary perspectives spanning from software frameworks to applications in medicine and space exploration.

The first two papers in this issue explore how advances in mixed and virtual reality technologies are reshaping human experience. The first paper, “*Ethical Considerations of Extended Reality in the Workplace*,”^{A1} offers a roadmap for responsible and inclusive XR deployment with a systematic review of 39 studies. The paper “*Cross-Reality Lifestyle: Integrating Physical and Virtual Lives through Multi-Platform Metaverse*”^{A2} introduces a technical framework spanning content design, platform infrastructure, and device infrastructure to guide the creation of integrated metaverse applications.

The next three papers present novel frameworks and approaches to advance cross-reality applications. The paper “*SurgiKIAR: An Augmented Reality Framework for Improved Surgical Training*”^{A3} introduces a mixed reality system that integrates preoperative 3D anatomical models with live laparoscopic video to enhance surgical precision, personalized guidance, and trainee education. The authors

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Digital Object Identifier 10.1109/MPRV.2025.3625006

Date of publication 14 November 2025; date of current version 26 December 2025.

of "Mixed-Reality System for Neurodegenerative Disorders: Design, Implementation, and User Evaluation"^{A4} investigate usability of a mixed reality system, including AR and sensors, to facilitate neurodegenerative disease assessment. A framework for networking Internet of Things devices to VR/AR systems is introduced in the paper "MetaGadget: An Accessible Framework for IoT Integration into Commercial Metaverse Platforms"^{A5} that leverages applications in prototyping and training.

The last two papers in this issue take a broader view as we progressively leave the planet. "Global-to-Local Decision Intelligence Using a Cross-Reality VR Platform and Satellite Earth Observation"^{A6} looks at integrating sensor data from satellite and terrestrial assets in mixed reality systems to form an "Earth Mission Control" for monitoring environmental and climate change at different scales. The following paper, "Creating Immersive Digital Twins of Terrestrial Planetary Analogs with Multimodal Sensing and Game Engines for Virtual Exploration,"^{A7} demonstrates techniques of integrating animated embedded sensor data with processed imagery for lunar and planetary exploration.

Technology revolutions, market dynamics, and public acceptance will rapidly forge cross reality into new forms across upcoming years. Concepts, such as this, which aim to define the future of human perception and interaction with the world, can determine the essence of who or what we will become. For this issue, we took inspiration from the first cross reality issue just over 16 years ago. Thinking of the topics that would be included in such a collection in another 16 years hence is, to say the least, a real mindbender. We definitely need to jack in and hold on for what promises to be a wild ride!

APPENDIX: RELATED ARTICLES

- A1. M. Constantinides and F. Liarokapis, "Ethical considerations of extended reality in the workplace," *IEEE Pervasive Comput.*, vol. 24, no. 4, pp. 10–18, Oct.–Dec. 2025, doi: [10.1109/MPRV.2025.3602230](https://doi.org/10.1109/MPRV.2025.3602230).
- A2. Y. Hiroi, Y. Hatada, and T. Hiraki, "Cross-reality lifestyle: Integrating physical and virtual lives through multi-platform metaverse," *IEEE Pervasive Comput.*, vol. 24, no. 4, pp. 19–28, Oct.–Dec. 2025, doi: [10.1109/MPRV.2025.3610749](https://doi.org/10.1109/MPRV.2025.3610749).

- A3. "SurgiKIAR: An augmented reality framework for improved surgical training," vol. 24, no. 4, pp. 29–39, Oct.–Dec. 2025.
- A4. D. Hemmerling et al., "Mixed-reality system for neurodegenerative disorders: Design, implementation, and user evaluation," vol. 24, no. 4, pp. 41–62, Oct.–Dec. 2025.
- A5. R. Kurai, H. Yanagawa, Y. Hiroi, and T. Hiraki, "MetaGadget: An accessible framework for IoT integration into commercial metaverse platforms," *IEEE Pervasive Comput.*, vol. 24, no. 4, pp. 63–73, Oct.–Dec. 2025, doi: [10.1109/MPRV.2025.3602289](https://doi.org/10.1109/MPRV.2025.3602289).
- A6. M. Rathnasabapathy, R. Connolly, L. De Bonet, and D. Newman, "Global-to-local decision intelligence using a cross-reality VR platform and satellite Earth observation," vol. 24, no. 4, pp. 74–84, Oct.–Dec. 2025.
- A7. L. Bensch et al., "Creating immersive digital twins of terrestrial planetary analogs with multimodal sensing and game engines for virtual exploration," vol. 24, no. 4, pp. 85–97, Oct.–Dec. 2025.

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- 2. V. Vinge, *True Names*. New York, NY, USA: Dell Books, 1981.

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