

An Overview of the 1st International Workshop on eXtended Reality for Industrial and Occupational Supports (XRIOS)

Heejin Jeong*^{id}
University of Illinois at Chicago

Isaac Cho[†]^{id}
Utah State University

Kangsoo Kim[‡]^{id}
University of Calgary

Hyungil Kim[§]^{id}
Oakland University

Myoungsoon Jeon[¶]^{id}
Virginia Tech

ABSTRACT

This workshop, the eXtended Reality for Industrial and Occupational Supports (XRIOS), aims to identify the current state of XR research and the gaps in the scope of human factors and ergonomics, mainly related to industrial and occupational tasks, and discuss potential future research directions. XRIOS will build a community that bridges XR developers/practitioners and human factors and ergonomics researchers interested in industrial and occupational applications.

Keywords: Extended reality, mixed reality, virtual reality, augmented reality, industrial support, occupational support, human factors, ergonomics.

Index Terms: Human-centered computing [Human computer interaction (HCI)]; Interaction paradigms—Mixed/augmented reality; Human-centered computing [Human computer interaction (HCI)]; Interaction paradigms—Collaborative interaction; Human-centered computing [Collaborative and social Computing]; Collaborative and social computing theory, concept and paradigms—Computer supported cooperative work

1 OVERVIEW

Over the past decades, eXtended Reality (XR) technologies have been applied to a wide range of industries and occupational areas [11, 13]; for example, for training and education [3, 8], quality control [4], maintenance [5], safety [2], job-aid [15, 16], remote collaboration [12], transportation [10], etc. The industries can benefit from XR by providing their employees with timely and efficient instructions [7]. The users (e.g., occupational workers) can improve their work performance while reducing mental and physical workload through effective XR systems [13]. Recent COVID-19 pandemic has changed the nature of work and work environments by shifting most in-person work to remote online modality, e.g., work-from-home [1]. In this era, the use of XR technologies has gained more and more attention not only from researchers and practitioners, but the actual end-users. As the workplace conditions become diverse, the XR applications should be adaptive and innovative to meet the new industrial and occupational needs. Furthermore, as such XR applications for industrial and occupational tasks include the users/workers' physical movements and activities in dynamic environments, it is necessary to perform a variety of assessments from human factors and ergonomics perspectives [6, 9, 14].

*e-mail: heejinj@uic.edu

[†]e-mail: isaac.cho@usu.edu

[‡]e-mail: kangsoo.kim@ucalgary.ca

[§]e-mail: hyungilkim@oakland.edu

[¶]e-mail: myoungsoonjeon@vt.edu

XRIOS e-mail: xrios.workshop@gmail.com

With an emphasis on the needs and potential implications of XR technologies, we organize this workshop on the eXtended Reality for Industrial and Occupational Supports (XRIOS). While broadly covering various XR application domains, XRIOS aims to identify the current state of XR research and the gaps in the scope of the industrial and occupational applications, and empower potential future research collaborations. We also aim to build and nurture a new community that bridges XR developers/practitioners and human factors and ergonomics researchers.

2 CALL FOR PAPERS

XRIOS 2022¹ is held at IEEE International Conference on Virtual Reality and 3D User Interfaces (IEEE VR) 2022, which is the largest, leading academic venue in the field of XR. We planned to have multiple research paper presentations, invited talks, and discussion sessions. Here, we describe our approach to promote paper submissions with the details of paper topics and types.

2.1 Topics

To cover the wide range of XR applications in the context of industrial and occupational supports, we tried to include various XR-related topics, which embrace different disciplines and perspectives. Some of highlighted topic areas include, but are not restricted to:

- Industrial and occupational applications in XR
- Occupational safety and health training in XR
- XR for laborers in workplaces (e.g., construction, healthcare)
- XR in dynamic environments (e.g., transportation, emergency care support workers)
- XR for industrial job training
- XR for industrial hygiene
- Exoskeletons with XR for rehabilitation
- Human-robot interaction/collaboration with XR
- Physical and musculoskeletal assessment in XR
- Physiological and fatigue assessment in XR
- Physical and cognitive workload in XR
- Ergonomic considerations for wearable XR devices
- Working from home with XR in post COVID-19
- Remote collaboration and learning in XR
- Office/workplace ergonomics in XR
- Measures and human-performance modeling in XR

2.2 Paper Types and Advertisement

While inviting world-leading researchers in the field, we sought various types of paper submissions (1–4 pages, excluding references), which include:

- **Position Papers** that identify and share insightful opinions and ideas.
- **Survey Papers** that capture the current states of research and present potential research gaps and future directions.

¹XRIOS webpage: <https://sites.google.com/view/xrios2022>



Figure 1: The Workshop Digital Poster “Call for Papers”.

- **Project Papers** that give an overview of an ongoing/planning project by describing the approach and goals of the project.
- **Research Papers** that contribute state-of-the-art advances and provide results as evidence, which can include industrial/occupational XR applications and systems.

For effective communication and visibility, we designed a digital call-for-paper (CfP) poster (Figure 1). The CfP flyer was shared in the relevant research communities via multiple online resources (e.g., IEEE VR mailing list², 3DUI mailing list³, Human Factors and Ergonomics Society’s Connect⁴, ACM CHI mailing list⁵), and social media (e.g., Slack, Twitter and LinkedIn).

3 ORGANIZATION AND SCHEDULE

XRIOS 2022 is organized as a 4-hour half-day *online* workshop at IEEE VR 2022. The tentative schedule with two invited talks, paper presentations, and a discussion is shown in Table 1.

3.1 Invited Talks

(1) Innovating with Immersive Technologies at GM

- Speaker: **Jess Bradmon** (jess.bradmon@gm.com), Manager – Business Strategy & Innovation at General Motors
- Short bio: Jess Bradmon has worked in the product and automotive visualization industry for over 13 years. Starting as a consultant at 3D Excite (formerly RTT) and the last decade holding various creative technology positions at General Motors. Jess contributed to establishing GM’s Immersive Technologies strategic initiative and dedicated enterprise group. He manages a team of domain experts covering R&D, Design, Engineering, Manufacturing, Sales, Service, Marketing and

²IEEE VR mailing list: ieeevr-group@uncc.edu

³3DUI mailing list: 3dui-g@vt.edu

⁴Human Factors and Ergonomics Society’s Connect: <https://connect.hfes.org/>

⁵ACM CHI mailing list: CHI-ANNOUNCEMENTS@listserv.acm.org

Table 1: Tentative workshop schedule.

Opening	10 min
Invited Talk 1	40 min
Paper Session 1	48 min
Break	5 min
Paper Session 2	64 min
Discussion: Topic Breakrooms	35 min
Break	5 min
Invited Talk 2	30 min
Closing	3 min
Total	240 min

Customer Experience. This team is focused on developing immersive business strategy and delivering innovative solutions. Jess lives in south-east Michigan and holds a BFA in Industrial Design from the College for Creative Studies.

- Abstract: General Motors’ vision of zero crashes, zero emissions, and zero congestion has driven the need to accelerate the development of battery electric and autonomous vehicles. Designers and engineers require faster decision making tools and less physical prototyping. Sales and marketing teams need to develop a visual online presence that properly represents the innovation of the vehicle and brand. Meanwhile, the global COVID pandemic has resulted in more remote work and virtual collaboration. Join us for this session to review where immersive technologies (XR, VR, AR, MR) are being successfully utilized at GM, and areas where your work may help fill current gaps in the technology’s capability and application.

(2) Applying Inclusive Design to Create Accessible MR Experiences

- Speaker: **Thomas M. Gable** (gabletm@gmail.com), Senior User Researcher, Mixed Reality Team at Microsoft
- Short bio: Thom Gable works as a Senior User Researcher on the Mixed Reality team at Microsoft. Prior to Microsoft, Thom completed his Ph.D. at Georgia Institute of Technology where he specialized in Engineering Psychology, with his research focusing on interaction with multimodal displays while multitasking. At Microsoft, Thom works across product areas in the MR space with a focus on input and interaction, hardware experience, and accessibility.
- Abstract: As mixed reality systems become more common, people are increasingly using these technologies in situations where there is a misalignment of the system’s capabilities and that of the user. Whether the user has a permanent disability, temporary impairment, or situational limitation, they should still be able to use the technology to accomplish their task. For example, if a mixed reality user on a factory floor is using both hands to hold tools, they may still need to interact with their device and be guided through their current task. By designing for someone who cannot use their hands, we can prevent these misalignments before they happen. In this talk, Thom will guide us through the persona spectrum of looking at disabilities and how to apply inclusive design in an effort to make XR devices usable for all.

3.2 Accepted Papers

All submissions were reviewed by the single-blind peer-review process. A total of 14 papers have been accepted. Table 2 shows the accepted papers categorized by topic, method, technology, and use case. Among these, two survey papers (Papers #3 and #10) discuss the current state-of-the-art, opportunities, and challenges, as well as future directions of enterprise XR. Topics presented in research and project papers include applications of XR technologies in various

industries such as construction, manufacturing, transportation, and healthcare. Researchers and practitioners share their experience in prototyping new XR applications as proofs-of-concept. Three papers go beyond this step by reporting the results of usability evaluations of the proposed XR systems. In terms of XR devices, most studies used AR head-worn devices that allow hands-free access to contextual information and may better fit industrial applications. The proposed XR systems support various use-cases but most of them are designed to be used in practice. This may reflect the emerging trends in instructional interventions [17]: shifting from “learn-and-apply (training)” to “learning-while-applying (job-aid)” that can be facilitated by XR technologies. Here we summarize the key contributions of the papers, which the authors provided.

Paper #1 (Tadeja et al.): This paper presents an augmented reality (AR) system for assembly process training enhanced with QR-tagging and 3D models. Moreover, we describe the system design using an engineering design methodology as well as present results of expert assessment of the system.

Paper #2 (Husinsky): Situated Visualization of IIoT data using AR head-mounted displays (HMDs) poses several challenges. We describe the steps necessary how machine data can be interfaced with the HoloLens 2 and compare indexical with iconic/symbolic visualizations to support workers in understanding the state of a plant.

Paper #3 (Perey & Bernstein): The AREA developed an objective, data-driven research agenda for enterprise AR. This paper describes an automated approach for gathering and organizing research about enterprise AR, a method for identifying research gaps and opportunities, and set of promising research topics.

Paper #4 (Choi et al.): This study proposes an XR approach to safe HRC by calculating the minimum distance between the human operator and robot. The virtual robot is synchronized with the real robot by ICP matching, which can provide more effective task assistance to the user.

Paper #5 (Park et al.): This study proposes a novel indirect robot interaction and manipulation method using eye gaze and head movement in mixed reality. Thus, the proposed approach can support hands-free interaction for the future of work in human-robot collaboration.

Paper #6 (Bayro et al.): This study compares HMD- and PC-based virtual reality (VR) solutions that enable interaction through immersive environments. The results showed that the HMD-based remote collaboration has a higher co-presence sense than the PC.

Paper #7 (Luksas et al.): Nurses completed the system-usability scale (SUS) to rate usability of a HoloLens application. Use of AR to support nurse decision making may reduce cognitive workload and focus attention on critical areas to recognize patient deterioration.

Paper #8 (Pomykała et al.): In this work-in-progress paper, we present the design process, the detailed production pipeline and the challenges we have met during the implementation of the WebXR interactive environment based on the 360 video of the mining technologies pipeline captured at the open pit mine.

Paper #9 (Smith et al.): Interviews, surveys, and site visits were utilized to understand the work domain of bridge inspection. A VR prototype of an AR bridge inspection assistance system was developed and tested with subject-matter experts (SMEs). Future integration of machine learning, computer vision, and unmanned aerial vehicles (UAVs) are discussed.

Paper #10 (Brettschuh et al.): In this paper, we present a literature review of immersive VR experiences in SMEs. Our results show an increased interest in the usage of VR in SMEs. We describe different use cases and contribute a list with advantages and opportunities as well as limitations and challenges.

Paper #11 (Bowman et al.): As a proof-of-concept of intelligent AR, we present the design of the BuildAR prototype, which illustrates how a context-aware AR system might support an assembly

task conducted by steel workers.

Paper #12 (Roofigari-Esfahan et al.): The proposed approach is expected to significantly reduce worker-involved work zone accidents and as such generate far-reaching improvements in highway workers’ safety and health and contribute to economic benefits nationwide.

Paper #13 (Anton et al.): The aim of this pilot study was to assess experienced nurses’ perceptions on the usability of AR. Using the system-usability scale, experienced nurses rated usability of the HoloLens 2 as moderate, but emphasized the potential usefulness of AR for nurse education.

Paper #14 (Greatbatch et al.): A driving simulator study demonstrates the benefits of AR head-up displays in driver situation awareness and performance when the human driver needs to take over vehicle control from driving automation systems.

4 ORGANIZERS

We formed a group of five organizers who have intensive research expertise in XR and human factors for this workshop.

Heejin Jeong is an Assistant Professor in the Department of Mechanical and Industrial Engineering and an affiliated faculty member in the Department of Biomedical Engineering at the University of Illinois at Chicago. His research focuses on XR systems and assistive robotics for occupational safety enhancement and healthcare rehabilitation. He is directing the Human-in-Mind Engineering Research (HiMER) Lab, where develops human behavior models based on experimental/physiological data and cognitive processing theories. The lab also develops XR-based experimental prototypes and tools to evaluate the usability and effectiveness of human interactive systems. His research has been funded by government and research sponsors, such as NSF, NIOSH.

Isaac Cho is an Assistant Professor in the Computer Science Department at Utah State University. He is also an adjunct professor in the Computer Science Department at the University of North Carolina at Charlotte and an affiliated faculty member of the Ribarsky Center for Visual Analytics (the Charlotte Visualization Center). His main research interests are Spatial 3D User Interfaces, Multi-scale Virtual Environment, Interactive Visual Analytics, and Human-Computer Interactions. He has served as organizing and program committee member in several international conferences such as IEEE VR, IEEE Visualization, IEEE AIVR, and more.

Kangsoo Kim is an Assistant Professor in the Department of Electrical and Software Engineering at the University of Calgary. His research broadly covers pervasive context-aware XR systems and intelligent social interactions in XR. While focusing on user experience and perception/cognition in XR, he has published in top-tier conferences and journals, including IEEE TVCG, IEEE VR, IEEE ISMAR, and ACM IVA, achieving multiple Best Paper Awards.

Hyungil Kim is an Assistant Professor in the School of Engineering and Computer Science at Oakland University. He is a member of Oakland University’s Augmented Reality Center and leading the Human-Centered Engineering lab. His research explores new methods for the requirements analysis, design, prototyping, and evaluation of extended reality applications with an emphasis on human-technology partnerships at future workplaces. He has published over 20 papers on augmented reality in top conferences and journals including IEEE VR, IEEE ISMAR, and IEEE TVCG.

Myoungsoon Jeon is an Associate Professor of the Department of Industrial and Systems Engineering and the Department of Computer Science (by courtesy) at Virginia Tech. His Mind Music Machine Lab tries to integrate different levels of research on human-automation (vehicles, robots, and agents) interaction, including neurological, psychological, and computational approaches. He has published over 200 papers and organized over 30 workshops in international conferences.

5 CONCLUSION AND FUTURE WORK

We hope that this workshop will provide the state of the art of XR applications for industrial and occupational support. This overview of the case studies with diverse methods and approaches will significantly contribute to the design of XR technologies in industry settings and guide researchers to more impactful research directions. We plan to continue this workshop series in IEEE VR and other conferences (e.g., ACM CHI and IEEE ISMAR Conferences). Also, we will guest edit a special issue on the same topic in a journal (e.g., Presence: Virtual and Augmented Reality or Frontiers in Virtual Reality). We thank all the authors, reviewers, and workshop chairs for contributing to this exciting workshop.

ACKNOWLEDGMENTS

The authors thank Ann Hsieh at the University of Illinois at Chicago for the design of the workshop poster. We also thank the IEEE VR 2022 Workshop Chairs, Mashhudda Glencross, Lap-Fai (Craig) Yu, Bhuvaneshwari Sarupuri, and João Pereira.

REFERENCES

- [1] J. Cho, S. Beck, and S. Volda. Topophilia, Placemaking, and Boundary Work: Exploring the Psycho-Social Impact of the COVID-19 Work-From-Home Experience. *Proceedings of the ACM on Human-Computer Interaction*, 6(GROUP):24:1–33, 2022.
- [2] S. H. Choi, K.-B. Park, D. H. Roh, J. Y. Lee, M. Mohammed, Y. Ghasemi, and H. Jeong. An integrated mixed reality system for safety-aware human-robot collaboration using deep learning and digital twin generation. *Robotics and Computer-Integrated Manufacturing*, 73:102258, 2022.
- [3] S. Doolani, C. Wessels, V. Kanal, C. Sevastopoulos, A. Jaiswal, H. Nambiappan, and F. Makedon. A review of extended reality (XR) technologies for manufacturing training. *Technologies*, 8(4):77, 2020.
- [4] A. K. Etonam, G. Di Gravio, P. W. Kuloba, and J. G. Njiri. Augmented reality (ar) application in manufacturing encompassing quality control and maintenance. *International Journal of Engineering and Advanced Technology*, 9(1):197–204, 2019.
- [5] P. Fraga-Lamas, T. M. Fernandez-Carames, O. Blanco-Novoa, and M. A. Vilar-Montesinos. A review on industrial augmented reality systems for the industry 4.0 shipyard. *IEEE Access*, 6:13358–13375, 2018.
- [6] G. A. Garrett, C. R. Reid, M. Jenkins, T. Talbot, and S. Doherty. Effects of prolonged use of mixed reality systems in occupational settings discussion panel. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, vol. 62, pp. 2104–2106. SAGE Publications Sage CA: Los Angeles, CA, 2018.
- [7] J. Jetter, J. Eimecke, and A. Rese. Augmented reality tools for industrial applications: What are potential key performance indicators and who benefits? *Computers in Human Behavior*, 87:18–33, 2018.
- [8] A. D. Kaplan, J. Cruit, M. Endsley, S. M. Beers, B. D. Sawyer, and P. Hancock. The effects of virtual reality, augmented reality, and mixed reality as training enhancement methods: A meta-analysis. *Human Factors*, 63(4):706–726, 2021.
- [9] H. Kim and J. L. Gabbard. Assessing distraction potential of augmented reality head-up displays for vehicle drivers. *Human Factors*, p. 0018720819844845, 2019.
- [10] H. Kim, J. L. Gabbard, A. M. Anon, and T. Misu. Driver behavior and performance with augmented reality pedestrian collision warning: An outdoor user study. *IEEE Transactions on Visualization and Computer Graphics*, 24(4):1515–1524, 2018.
- [11] K. Kim, M. Billinghurst, G. Bruder, H. B.-L. Duh, and G. F. Welch. Revisiting trends in augmented reality research: A review of the 2nd decade of ismar (2008–2017). *IEEE Transactions on Visualization and Computer Graphics*, 24(11):2947–2962, 2018.
- [12] S. Kim, M. Billinghurst, and K. Kim. Multimodal interfaces and communication cues for remote collaboration. *Journal on Multimodal User Interfaces*, pp. 1–7, 2020.
- [13] S. Kim, M. A. Nussbaum, and J. L. Gabbard. Augmented reality “smart glasses” in the workplace: Industry perspectives and challenges for worker safety and health. *IIE Transactions on Occupational Ergonomics and Human Factors*, 4(4):253–258, 2016.
- [14] L. Lisle, K. Tanous, H. Kim, J. L. Gabbard, and D. A. Bowman. Effect of volumetric displays on depth perception in augmented reality. In *Proceedings of the 10th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, pp. 155–163, 2018.
- [15] K.-B. Park, S. H. Choi, J. Y. Lee, Y. Ghasemi, M. Mohammed, and H. Jeong. Hands-free human–robot interaction using multimodal gestures and deep learning in wearable mixed reality. *IEEE Access*, 9:55448–55464, 2021.
- [16] A. Singh, Y. Ghasemi, H. Jeong, M. Kim, and A. Johnson. A comparative evaluation of the wearable augmented reality-based data presentation interface and traditional methods for data entry tasks. *International Journal of Industrial Ergonomics*, 86:103190, 2021.
- [17] L. R. Winer, N. Rushby, and J. Vazquez-Abad. Emerging trends in instructional interventions. *Handbook of Human Performance Technology*, pp. 884–886, 1999.

Table 2: A list of the accepted papers.

#	Title	Author(s)	Topic	Method	Technology	Use case
1	Design of ARQ: An Augmented Reality System for Assembly Training Enhanced with QR-Tagging and 3D Engineering Asset Model	Tadeja et al.	Construction/Assembly	Prototyping	AR head-worn	Training, assembly
2	Situated Visualization of IIoT Data on the HoloLens 2	Husinsky	Manufacturing / Industrial furnace	Prototyping	AR head-worn	Job-aid, operation and maintenance
3	A Research Agenda for Enterprise Augmented Reality	Perey & Bernstein	All/ Enterprise	Survey/Planning	AR	All
4	An XR-based Approach to Safe Human-Robot Collaboration	Choi et al.	Manufacturing/Robot	Prototyping	AR head-worn	Job-aid, operation
5	Indirect Robot Manipulation using Eye Gazing and Head Movement For Future of Work in Mixed Reality	Park et al.	Manufacturing/Robot	Prototyping	AR head-worn	Job-aid, operation
6	Subjective and Objective Analyses of Collaboration and Co-Presence in a Virtual Reality Remote Environment	Bayro et al.	All / Remote Collaboration	Evaluation	VR head-worn and computer	Job-aid, assembly
7	Search and Rescue AR Visualization Environment (SAVE): Designing an AR Application for Use with Search and Rescue Personnel	Luksas et al.	Rescue/Emergency	Prototyping	AR head-worn	Job-aid, search/inspection
8	"Put your feet in open pit" - a WebXR Unity application for learning about the technological processes in the open pit mine	Pomykala et al.	Construction/Mining	Prototyping	VR 360 Video, hand-held (smart phones)	Training, operation
9	Wearable Augmented Reality Interface Design for Bridge Inspection	Smith et al.	Construction	Prototyping	AR head-worn (simulated in VR)	Job-aid, search/inspection
10	Virtual Reality in Small and Medium-Sized Enterprises: A Systematic Literature Review	Brettschuh et al.	All / Small Enterprise	Survey	VR	All
11	BuildAR: A Proof-of-Concept Prototype of Intelligent Augmented Reality in Construction	Bowman et al.	Construction/Assembly	Prototyping	AR head-worn	Job-aid, assembly
12	Group-based VR Training to Improve Hazard Recognition, Evaluation, and Control for Highway Construction Workers	Roofgar-Esfahan et al.	Construction/Highway	Prototyping	VR CAVE	Training, search/inspection
13	Nurse Perceptions of the Usability of Augmented Reality to Support Clinical Decision Making: Results of a Pilot Study	Anton et al.	Healthcare/Nursing	Evaluation	AR head-worn	Job-aid
14	The Effects of Augmented Reality Head-Up Display Graphics on Driver Situation Awareness and Takeover Performance in Driving Automation Systems	Greatbatch et al.	Automotive/Driving	Prototyping and Evaluation (experiment)	AR head-up (simulated in VR)	Job-aid, driving