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ABSTRACT

Multi-User VR Assembly and Manufacture Design: Multimodal Object Modeling and High-Fidelity Gesture Interaction with WebGL Integration

JEONGHYEON KIM, Kumoh National Institute of Technology, Gumi, Kyongsangbuk-do, South Korea

JEMIN LEE, Kumoh National Institute of Technology, Gumi, Kyongsangbuk-do, South Korea

JUNGSIK KOO

JIYONG PARK

BYUNGWOO CHO

YOUNGHWA YUN, National Information Society Agency, Korea, Seoul, Jung-Gu, South Korea

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Jeonghyeon Kim
Kumoh National Institute of Technology
Gumi-si, Republic of Korea
3575253@naver.com

Jemin Lee
Kumoh National Institute of Technology
Gumi-si, Republic of Korea
char3941@gmail.com

Jungsik Koo
Gumi Electronics and Information Technology Research Institute (GERI)
Gumi-si, Republic of Korea
jskoo@geri.re.kr

Jiyong Park
Gumi Electronics and Information Technology Research Institute (GERI)
Gumi-si, Republic of Korea
jiyong@geri.re.kr

Byungwoo Cho
Gumi Electronics and Information Technology Research Institute (GERI)
Gumi-si, Republic of Korea
bwcho@geri.re.kr

YoungHwa Yun
National Information Society Agency
Daegu, Republic of Korea
yhyuun@nia.or.kr

Bumki Kim
KAI Inc.
Daejeon, Republic of Korea
bk.kim@kaistudio.co.kr

Daeun Kim
KAI Inc.
Daejeon, Republic of Korea
de.kim@kaistudio.co.kr

Hyeongjun Kang
Kumoh National Institute of Technology
Gumi-si, Republic of Korea
joh0816@gmail.com

Taewan Kim
Kumoh National Institute of Technology
Gumi-si, Republic of Korea
kimtaeyan21@naver.com

Youngwon Kim*
Kumoh National Institute of Technology
Gumi-si, Republic of Korea
kim01.xr@gmail.com

Abstract

Effective collaborative design in manufacturing is often hindered by complex software interfaces and limited intuitive remote interaction capabilities. We present a multi-user VR platform for assembly design that addresses these challenges by enabling rapid prototyping through multimodal (voice and text) modeling and intuitive manipulation using high-fidelity, finger-tracked gestures. Our system architecture incorporates WebGL integration, allowing remote experts to join and guide sessions from standard web browsers. We demonstrate a live scenario showcasing this seamless and accessible workflow for industrial collaboration, from declarative part generation to remote-assisted virtual assembly.

*Corresponding author

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CCS Concepts

• **Human-centered computing** → **Mixed / augmented reality**; **Collaborative interaction**; *Interaction techniques*; • **Computing methodologies** → *Modeling and simulation.*

Keywords

Collaborative VR, Assembly Design, Multimodal Interaction, Hand Tracking, Remote Collaboration, Declarative Modeling

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1 Introduction

Recent advancements in Extended Reality (XR) technologies are rapidly enabling environments that support multiple users interacting within shared virtual spaces [1, 5]. In industrial domains such as manufacturing and assembly, these collaborative XR platforms hold immense potential to revolutionize processes including design review, remote maintenance, and worker training. However, existing collaborative systems are often limited to interactions

through simple controllers or basic pinch gestures, are restricted to VR-only participants, and lack the high-fidelity feedback necessary for complex assembly tasks.

Grasping and manipulating virtual objects represents a fundamental interaction modality critical to both task success and user experience [7]. Modern VR systems present a fundamental trade-off: controller-based interaction offers high precision and reliability (pragmatic quality), but requiring users to hold physical and often cumbersome devices can detract from immersion [6]. Conversely, hand-tracking provides intuitive and natural interaction that enhances the sense of presence (hedonic quality) [3]. This naturalness, which mimics real-world object grasping, is particularly crucial in assembly simulations where understanding part affordances is key to successful task completion [4].

In this context, our work introduces a novel collaborative VR platform designed to overcome these limitations. Existing workflows often (1) create bottlenecks in the design phase, hindering rapid prototyping for non-expert users, and (2) lack support for the precise, high-fidelity interactions required for realistic remote assembly tasks.

2 System and Interaction Model

In this demonstration, we present a real-time collaborative VR platform for manufacturing and assembly design. As shown in Figure 1, the system supports a complete workflow from declarative modeling of initial parts to collaborative assembly with high-fidelity gestures and remote observation via a web client.

The workflow begins with a declarative modeling interface where users create 3D geometries through simple voice or text commands. A Large Language Model (LLM) translates user intent into procedural models, producing 3D parts instantiated in the shared virtual environment as central artifacts for collaboration.

Once a model is generated, multiple users join the session using native VR clients to inspect and assemble parts. A key feature is high-fidelity gesture interaction: the system tracks finger-level hand movements in real time, enabling intuitive manipulation according to object affordances [4].

The platform also extends to non-VR users through a WebGL client, which streams sessions for remote experts to observe and provide guidance. Using 3D pointers and highlights, experts support asymmetric collaboration, aligning with findings that multimodal integration enhances shared understanding [2, 8]. All interactions, including object states and avatar data, are synchronized via a central server.

3 Demonstration Scenario

At the VRST conference, our demonstration will showcase a live, interactive workflow involving two VR participants and a third participant viewing remotely via a web browser. The scenario begins with an attendee generating an assembly part using simple voice or text commands. The system instantly parses the command and renders the 3D object in the shared virtual space. Next, two VR users collaboratively handle the newly created object, demonstrating how their realistic hand gestures down to individual finger movements are tracked and synchronized in real-time for precise and intuitive manipulation. Finally, the entire collaborative session is streamed in real-time to a standard web browser, showcasing how remote participants can observe VR users' actions for supervision, training, or design review purposes. This walkthrough provides attendees with direct experience of a seamless workflow, from rapid object conception to collaborative, high-fidelity review and remote observation. The entire process is demonstrated in the accompanying supplementary video.

4 Conclusion

In this paper, a multi-user VR platform designed to address key challenges in collaborative manufacturing and assembly design. By integrating declarative modeling via natural language, high-fidelity gestural interaction with real-time finger-level synchronization, and a web-based client for remote assistance, our system provides a seamless and intuitive workflow. Our demonstration showcases a viable and accessible solution that lowers barriers to rapid prototyping and enhances communication between co-located VR users and remote experts. We believe this multi-faceted approach contributes to more effective, efficient, and immersive collaborative design processes in industrial XR applications.

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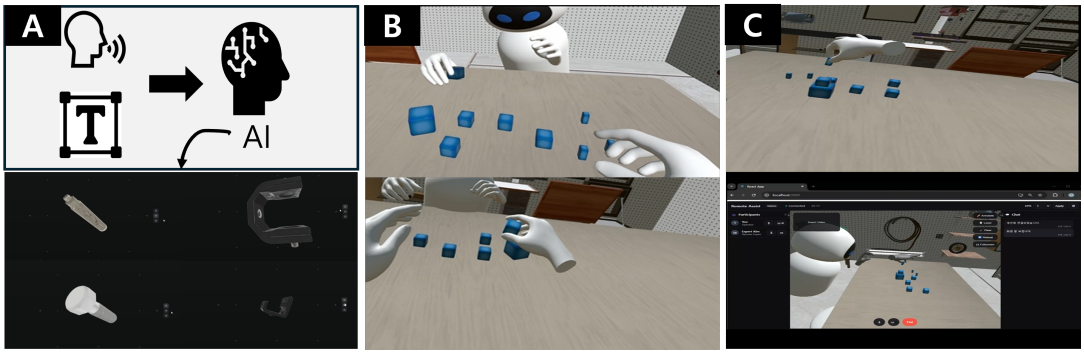

Figure 1: System architecture. (A) A 3D part is generated via declarative modeling (voice/text). (B) Multiple VR users collaboratively manipulate it with high-fidelity gestures. (C) A remote expert observes and provides guidance via a WebGL client.