ICELab Demo: an industrial digital-twin and simulator in VR

Deborah Pintani
deborah.pintani@univr.it
University of Verona
Verona, Italy

Marco Emporio
marco.emporio@univr.it
University of Verona
Verona, Italy

Ariel Caputo
ariel.caputo@univr.it
University of Verona
Verona, Italy

Dong Seon Cheng
dongseon.cheng@univr.it
University of Verona
Verona, Italy

Lorenzo Genghini
lorenzo.genghini@studenti.univr.it
University of Verona
Verona, Italy

Nicola Tomasoni
nicola.tomasoni@studenti.univr.it
University of Verona
Verona, Italy

Andrea Giachetti
andrea.giachetti@univr.it
University of Verona
Verona, Italy

ABSTRACT

In this demo we present an application featuring the integration of Virtual Reality (VR) technologies with the demonstration laboratory (ICELab) built around Industry 4.0/5.0 concepts. In particular, we showcase a digital twin of the real laboratory that allows the user to explore its environment in VR and interact with the different machinery to obtain several data and information.

CCS CONCEPTS

• **Human-centered computing → Mixed / augmented reality**; **Virtual reality**; • **Applied computing → Service-oriented architectures**; **Enterprise applications**.

KEYWORDS

Cyber-Physical Factory, Digital Twin, Computer Graphics

ACM Reference Format:

Deborah Pintani, Marco Emporio, Ariel Caputo, Dong Seon Cheng, Lorenzo Genghini, Nicola Tomasoni, and Andrea Giachetti. 2024. ICELab Demo: an industrial digital-twin and simulator in VR. In *30th ACM Symposium on Virtual Reality Software and Technology (VRST '24), October 09–11, 2024, Trier, Germany.* ACM, New York, NY, USA, 2 pages. https://doi.org/10.1145/3641825.3689946

1 INTRODUCTION

Virtual Reality is one of the core technologies for Industry 4.0 and even more so for Industry 5.0, focused on Human-centric design. In fact, the goal is to enhance the interaction between humans and machinery, allowing the workers to operate in a more comfortable and safe environment while, at the same time, improving the efficiency of their tasks [6] [5]. In an industrial context, a Digital Twin is a digital representation of the actual production facility. In our case, this representation is obtained with a highly detailed 3D model reproducing the original facility and integrating such model in an immersive VR environment. This allows the user to freely explore the virtual replica as well as obtain different information and data from the different machines.

VRST '24, October 09–11, 2024, Trier, Germany

ACM ISBN 979-8-4007-0535-9/24/10
https://doi.org/10.1145/3641825.3689946

Figure 1: Render of the LabICE 3D representation from Blender. Materials and models are reproduced with high fidelity to replicate real machines and devices accurately.

2 THE ICELAB VR DEMO

2.1 The ICELab

The Industrial Computer Engineering Laboratory (ICELab) is a complete industry 4.0/5.0 technology demonstrator within the University of Verona. It features an exhaustive set of industrial machines and devices that accurately replicate a production line, which can be reconfigurable at any moment. The laboratory is equipped with various manufacturing cells: robotic assembly, quality control, autonomous storage and logistics, functional testing, and additive/subtractive manufacturing. The facility provides additional environmental IoT sensors and cameras (RGB, RGB-D, fisheye, PTZ) to monitor workers and analyze surrounding variables. Figure 2 shows a simple top view of the layout of the laboratory.

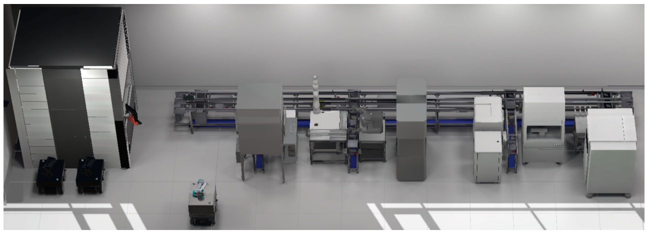

Figure 2: Top view of the ICELab using simple materials.

2.2 Virtual Reality Application

The VR application runs on Meta Quest 3 standalone Head Mounted Display (HMD) and is developed using Unity [3]. The 3D replica of the laboratory is created first by obtaining the CAD files from manufacturers and using Autodesk Fusion 360 [1] to convert them into surface meshes. We then used Blender [2] to craft and optimize the 3D replica of the laboratory, by adding custom materials to represent the real scene accurately. Moreover, the meshes are processed to manage them better on low-end hardware: the simplification is specialized for each 3D model by removing internal parts, remeshing the external surface and overall mesh tidying. A render is shown in Figure 1.

The application features a working and animated reproduction of industrial machines. They reflect actual real-time movements by remotely receiving up-to-date information about their positions and states, effectively copying real motions. An MQTT (Message Queuing Telemetry Transport) broker exposes all the real-time data, communicating with our VR application through an MQTT module. This system features bidirectional communication, effectively enabling the possibility, through the application, to remotely control real devices and machinery counterparts such as robotic arms. These remote actions can be enabled or disabled from the user's UI, based on which operations workers can consider safe to perform remotely.

In particular, the following devices are animated:

- Kuka LBR iiwa 14 R820
- Minipallet Conveyor Line Bosch-Rexroth
- Collaborative mobile manipulator Robots Robotnik RB-KAIROS 5
- Cobot UR5e

The information and data received by the real production line can also be displayed through the use of floating panels, featuring a description of the machine and, if available, their real live status (e.g., the current or last job, the machine state, etc.). To do so, users may perform a pinch gesture on the 3D model to visualize this information. The panels can be anchored or, alternatively, follow the user. Figure 3 depicts a screenshot of the VR application showcasing a UI's floating panel. The application lets users freely navigate the laboratory environment using a point teleport technique, similar to the implementation of [4]. By pointing the main hand towards the floor and performing a pinch gesture (i.e., with the hand closed and the index and thumb extended, touching each other's tip), a ray is projected on the floor from the hand, and, by releasing the pinch gesture, the user is teleported to the chosen position.

The application can also perform on-demand simulation of the machines by reading artificially created data that simulates the data coming from the original production line. This option is useful for showing laboratory capabilities even when the machines are not functioning and performing tests on potentially interesting scenarios.

Another feature implemented to further improve the simulation capabilities allows users to view the laboratory from 7 different perspectives provided by the cameras, which replicate the views of the actual RGB cameras. This can be used to simulate scenarios in which the monitoring of the line is only possible through a remote position.

Figure 3: A screenshot of the VR application. The panel describing the machine and its live status is floating in the center.

3 FUTURE WORKS

The demo we presented offers an advanced platform that can be used for different studies. In fact, the importance of this technology in Industry 5.0 requires further investigation. In particular, we plan to design different user studies focused on human-machine interaction using this platform, in particular to evaluate the workers' user experience using the aid of VR technology. Moreover, we plan to further extend the functionality of the machinery to provide the basis for a complete simulation environment in which we will test the production line under different conditions and evaluate potential risks during malfunctions and/or unsafe human behaviors.

REFERENCES

[1] [n. d.]. Autodesk Fusion 360 web page. https://www.autodesk.com/products/fusion-360/personal. Accessed: 2033-09-30.
[2] [n. d.]. Blender web page. https://www.blender.org/. Accessed: 2033-09-30.
[3] [n. d.]. Unity web page. https://unity.com/. Accessed: 2033-09-30.
[4] Evren Bozgeyikli, Andrew Raij, Srinivas Katkoori, and Rajiv Dubey. 2016. Point & teleport locomotion technique for virtual reality. In *Proceedings of the 2016 annual symposium on computer-human interaction in play*. 205–216.
[5] Yuqian Lu, Juvenal Sastre Adrados, Saahil Shivneel Chand, and Lihui Wang. 2021. Humans Are Not Machines—Anthropocentric Human–Machine Symbiosis for Ultra-Flexible Smart Manufacturing. *Engineering* 7, 6 (2021), 734–737. https://doi.org/10.1016/j.eng.2020.09.018
[6] Julian Müller. 2020. Enabling technologies for Industry 5.0. *Independent Expert Report* (2020), 8–10.