

Editing complex industrial scenarios with human and autonomous agents from an immersive digital twin using authoring-by-doing

Alexandre Courallet
CESI LINEACT
Saint-Etienne-Du-Rouvray, France
acourallet@cesi.fr

David Baudry
CESI LINEACT
Saint-Etienne-Du-Rouvray, France
dbaudry@cesi.fr

Vincent Havard
CESI LINEACT
Saint-Etienne-Du-Rouvray, France
vhavard@cesi.fr

Florian Maillard
CESI LINEACT
Saint-Etienne-Du-Rouvray, France
florian.maillard@viacesi.fr

Abstract—XR-interfaced digital twin showed its usages and relevancy in both training and business activities. However, the concept of scenario in training and authoring of said scenarios in a virtual reality training context or as a guide in augmented reality still brings new challenges. This paper will show the first steps taken to tackle some of these challenges, including the addition of cobotic arms and autonomous agents and making the scenario editor as simple as possible for non-technical individuals.

Keywords—*Digital twin, mixed reality, virtual reality, augmented reality, scenario authoring, Human System Interaction, Industry 5.0, training, data modeling*

I. INTRODUCTION

With the growth of Industry 4.0 came the development of Digital Twins (DTs) [1]. When XR-interfaced, they can be used for designing industrial systems, training or guiding trainees in business operations [2], [3]. With Industry 5.0 [4], people are once again at the center of both intelligence and action. Meanwhile, universities and engineering schools are developing their learning factory and need to combine it with their own immersive Digital Twins [5], [6]. However, they encounter three difficulties: first, the creation and authoring of scenarios depend on the technical and business expertise of the trainer. Second, not all virtual environments are tailored for such use, with data models and procedures far too complicated. Finally, there is a lack of tools allowing the creation of scenarios [7]. Our previous proposed approach, called INTERVALES [8], allows to formally define a XR scenario, and a first authoring tool was proposed. The objective of the following proposed approach is to create a data and interaction model allowing the authoring of training scenarios or assisted guides with an XR-interfaced Digital Twin while allowing one or multiple human or autonomous agents to work together, according to scenario parameters. This paper thus focus on the remaining challenges of the proposed INTERVALES framework [8], then it proposes a novel approach called NEURONES (No code scEnario aUthoRing fOr exteNded rEality), based on data model and XR interactions associated, to author XR scenario. Finally it illustrates the approach by defining a simple use-case.

II. FOCUS ON REMAINING CHALLENGES OF THE INTERVALES FRAMEWORK

The first challenge is to make INTERVALES framework evolve to integrate the notion of « agent », linked to every Actions and Tasks to perform. It should also allow agents to simultaneously act on one or different tasks. Evolution of the formalism should include information about the object (e.g the weight of the object) and the agent (e.g the weight a robotic arm can lift). This information should add context to author the scenario, for instance to limit the actions a particular agent can perform.

The second challenge is about the method to naturally edit the scenario, using an agent-based authoring-by-doing approach while associating this method to a 2D editor for more complex use cases.

Third challenge, even if this framework allows the edition of scenario in immersive environments through a set of interactions and authoring rules that facilitate the creation of procedural scenarios for non-technical individuals, it still has some weaknesses. First, linking tasks in a scenario is possible, but done in two different ways that will hinder the scalability of the framework. Moreover it lacks various Doors to compose more complex scenarios.

III. SCENARIO EDITION AND AUTHORING WITH NEURONES MODULE

This paper focuses on the NEURONES module integrated to the INTERVALES framework which adds feature to homogenize the edition process and clarify the work of future users (i.e. developpers or job experts). First, Fig. 1 shows the new architecture of the Scenario authoring components of the framework. The **ScenarioObject** lost its parameters “InputsIDs” and “OutputsIDs”, used to store the references to the previous and next ScenarioObjects in the current Scenario, as the “Edge” class is used instead, each instance representing the connection between two ScenarioObjects. It replaces the previous “Connexion” class to be more in line with the naming conventions of graphs.

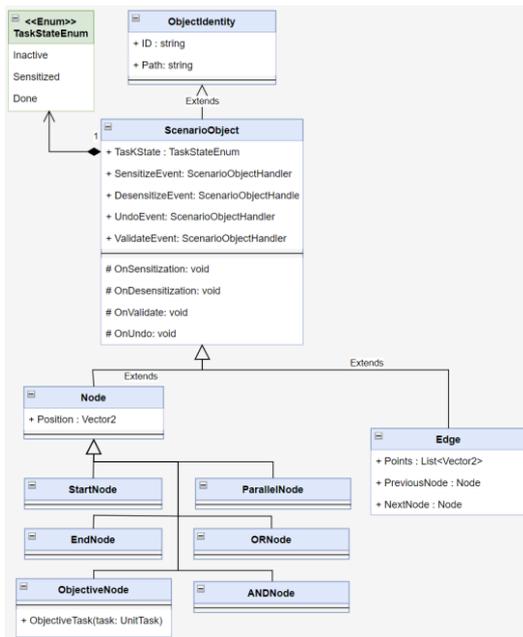


Fig. 1 INTERVALES.Core.Scenario class diagram

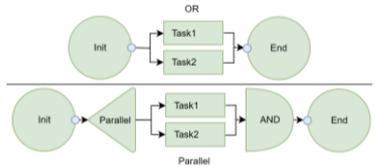


Fig. 2 OR and Parallel Node

Next, in order to give more freedom to scenario authors, some new types of nodes were added, working as logic door from Grafchart [9]: the “OR” node allows to choose a path between two paths in a scenario (Fig. 2 - top). The “Parallel” node creates two paths in the scenario that should both be done before merging in a same “AND” node, as seen in the bottom of Fig. 2. The “Init” and “End” nodes serves to start the scenario and end it.

Finally, the notion of “Agent” in INTERVALES is taken into account in the NEURONES module. Each Task specified in scenario must define an Agent as the actor and will be validated only if this Agent accomplishes the task. Moreover, the proposition deals with the interaction to perform in XR in order to create the associated Tasks. We propose two concepts: Authoring-by-doing (AbDo) for human agent and Authoring-by-Demonstration (AbDe) for autonomous agents, such as a robot. For example, the author uses the VR controller to set the pose of the robot’s gripper to grab the targeted object.

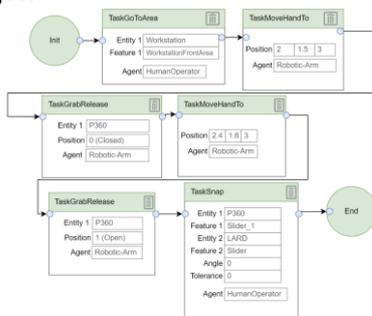


Fig. 3 Use case of collaborative work between human and autonomous agent

IV. USE-CASE

Before working on the modifications of the framework, multiple use-cases were defined. The Fig. 3 is an example of a straightforward use-case of collaborative work between two agents: a human operator and a robotic manipulator. The framework sends orders to the simulated autonomous agent or its physical twin. In such a case, it will call for an OPC-UA method, following the architecture presented in [5].

V. CONCLUSION AND PERSPECTIVES

These modifications to the INTERVALES framework should lead it nearer the objectives of facilitating the development of pedagogical scenario in an XR-interface immersive environment like a Digital Twin and allowing the creation of such scenarios in collaboration with other agents, humans or autonomous. But there is still a lot to do and challenges to tackle on: implementing the actions of the autonomous agents, adding more general actions like reading a panel or waiting in the AbD editor and integrating seamlessly the agents in the scenario edition are the three main priorities. Then other ideas are to be studied, like the creation of “sub-scenarios” with parameters, allowing to quickly set-up chains of repetitive tasks, collaborative edition via AbD, automation of the tasks of a human agent if one is missing.

ACKNOWLEDGEMENTS

This work was partially funded by the French program investment of the future under the project JENII - ANR21-DMES-0006.

- [1] J. Leng, D. Wang, W. Shen, X. Li, Q. Liu, and X. Chen, “Digital twins-based smart manufacturing system design in Industry 4.0: A review,” *J. Manuf. Syst.*, vol. 60, pp. 119–137, Jul. 2021, doi: 10.1016/j.jmsy.2021.05.011.
- [2] J. Radianti, T. A. Majchrzak, J. Fromm, and I. Wohlgenannt, “A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda,” *Comput. Educ.*, vol. 147, p. 103778, Apr. 2020, doi: 10.1016/j.compedu.2019.103778.
- [3] V. Havard, B. Jeanne, M. Lacomblez, and D. Baudry, “Digital twin and virtual reality: a co-simulation environment for design and assessment of industrial workstations,” *Prod. Manuf. Res.*, vol. 7, no. 1, pp. 472–489, Jan. 2019, doi: 10.1080/21693277.2019.1660283.
- [4] F. Longo, A. Padovano, and S. Umbrello, “Value-oriented and ethical technology engineering in industry 5.0: A human-centric perspective for the design of the factory of the future,” *Appl. Sci. Switz.*, vol. 10, no. 12, pp. 1–25, 2020, doi: 10.3390/APP10124182.
- [5] V. Havard, A. Courallet, D. Baudry, and H. Delalin, “Digital Twin, Virtual Reality and OPCUA-based architecture for pedagogical scenarios in Manufacturing and Computer Sciences curriculum,” in *SSRN Electronic Journal*, 2023, doi: 10.2139/ssrn.4457032.
- [6] P. K. R. Maddikunta *et al.*, “Industry 5.0: A survey on enabling technologies and potential applications,” *J. Ind. Inf. Integr.*, vol. 26, p. 100257, Mar. 2022, doi: 10.1016/j.jii.2021.100257.
- [7] M. Nebeling and M. Speicher, “The Trouble with Augmented Reality/Virtual Reality Authoring Tools,” in *2018 IEEE International Symposium on Mixed and Augmented Reality Adjunct (ISMAR-Adjunct)*, Munich, Germany: IEEE, Oct. 2018, pp. 333–337, doi: 10.1109/ISMAR-Adjunct.2018.00098.
- [8] K. Richard, V. Havard, J. His, and D. Baudry, “INTERVALES: INTERactive Virtual and Augmented framework for industrial Environment and Scenarios,” *Adv. Eng. Inform.*, vol. 50, p. 101425, Oct. 2021, doi: 10.1016/j.aei.2021.101425.
- [9] R. David and H. Alla, (1992) *Du grafcet aux reseaux de Petri*, Science Publications. 1992.