# 3D modelling and synchronization of the Digital Twin in virtual and augmented reality for the factory of the future

**Location:** Institut Arts et Métiers de Chalon-sur-Saône, France
**Doctoral school: ED 432 SMI**
**PhD supervision:**

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This PhD is part of the **GORAFI** project (**G**estion **O**ptimisée de la **R**éalité **A**ugmentée pour le **F**utur de l'**I**ndustrie), between Institut Arts et Métiers de Chalon-sur-Saône/LISPEN and IMT Atlantique/Lab-STICC, which aims to deploy and operate a collaborative augmented reality platform to develop the uses of digital twins in industry via a human-centered approach. This is part of the **RéCLasSIF** meta-project (**Ré**seau de **C**ampus **La**bélisé**s** **S**olutions pour l'**I**ndustrie du **F**utur) between Arts et Metiers Institute for Technology and IMT.
The project involves setting up a platform for asymmetrical, distributed collaboration between people using mixed reality environments (XR). A typical use case is: an operator manipulating a complex system in a factory (site "A") needs assistance from an expert who is located remotely (e.g., design department, … - site "B"). In the following description, the person on the site "B" will remotely assist the person on the site "A" by providing a solution on the problem on site A. The cooperation is based on:

1) **real-time capture of a working environment at site A, including its geometry and multi-sensorial data (sound, temperature, etc.),**
2) **reconstruction geometrically of the captured environment and segmentation into elementary 3D shape geometries,**
3) **virtual reconstruction of site A for the person on site B, enrichment of geometry by multi-sensorial data for creating multi-sensorial virtual scene, adapted to the skills and knowledge of the user on site B,**
4) use of the flexibility of the virtual environment on site B, to facilitate exploration of alternative problem-solving approaches,
5) projection of the solution in augmented reality back to site A,
6) adjustment by analysis of the real problem on site A, leading to adaptation of the virtual environment and the constraints taken into account on site B.

The collaboration concerns operations such as recommending gestures, pointing to key elements of a device, or guiding an operator through specific procedures. The aim of the project is to move away from the tutor/student paradigm, i.e., top-down instructions, to a bilateral interaction, and address that of collaborative problem-solving. The advantage of the virtual component is that it enables solutions to be tested in non-destructive mode, thus avoiding the dangers and impacts of untimely manipulations on critical systems. The (augmented) reality part allows us to complement a digital twin of a process and/or system and get real data and more detailed opinions. It also provides at least a partial solution to the problem of updating digital twins, which remains an open issue.
This approach is particularly relevant to the industry of the future and the handling of complex, risky or sensitive components. As an example, we can imagine the insertion of a 3D component into a precise slot, requiring a series of manipulations (successive 3D rotations, frictionless insertions, etc.).
The real environment of the onsite operator can be captured (location and 3D part) and reproduced for the expert on the remote site, with special adaptation to this expert's skills and knowledge. It is possible to envisage the environment reconstruction being adapted to the context of the collaboration with the expert on site B. This can be useful when the collaboration is between two people from different professions, or to adapt to the tasks to be carried out, the collaboration context, etc.
The person on site B can test possible solutions to the current problems virtually and foresee possible errors before communicating working solutions to the operator on site A. The correct manipulation sequence can be "communicated" in augmented reality to the operator at site A.
The operator at site A can then see that the gesture recommended by his teammate (site B) cannot be carried out, due to weight constraints (for example), and iterate on a solution to the problem. The expert could also suggest some rearrangements of the real environment, and similarly maybe they could not be applied as it and collaboration could be needed between users to determine the best real arrangement in the factory.
The study also concerns the comfort and well-being of mixed reality users. In particular, we are planning to use augmented reality equipment in "ecological" situations (standing, moving, etc.), in contrast to more usual controlled conditions. This aspect of the project will enable us to study phenomena such as fatigue, perceptual bias, cybersickness and so on. It will also enable the production of scientific models relating to perception in XR environments and the acceptability of these devices.
Technically, it has already been identified that designed solutions will have to involve synchronized tracking of remote users, and monitoring of their state (effort measurement, for example).

From a more general point of view, the project is in line with the dynamics and perspective of digital twins and Mixed Reality for Industry of the Future.

This PhD thesis would deal mainly on points 1), 2), and 3): the real-time capture and segmentation of the working environment on site A as well as multi-sensorial enrichment, and its 3D reconstruction of site A for the expert on site B, including additional arrangement on site B and real-time synchronization between sites A and B.

## Scientific themes that may contribute to the realization of the project:

- Collaborative updating of digital twins in a remote augmented reality context
- Design of interaction devices with shared repositories in remote XR
- Augmented Reality "in the wild": study of the use of AR devices in natural conditions
- Mutual adjustment of problem and solution spaces: the digital twin for distributed and cooperative resolution of complex problems

## Expected skills of the PhD candidate:

- Skills in computational geometry required
- Skills in Mixed reality (Virtual Reality - Augmented Reality) required
- Skills in Software development required
- Skills in Unity 3D or Unreal Engine development would be highly appreciated
- Skills in human sciences, such as knowledge in cognitive ergonomics, user studies and statistical analysis of experimental results, would also be greatly appreciated
- Excellent writing skills in English are mandatory

## Provisional schedule:

- **Months 1-6**: Study of the state of the art, familiarization with development tools (Unity 3D, C#), discussion with project partners about the Digital Twin's reconstruction and authoring needs and the architectural requirements of the system.
- **Months 7-15**: Design and evaluation of interaction metaphors for a VR authoring tool for the Digital Twin of a factory based on 3D reconstruction of the real environment, including segmentation into several virtual objects, implementation of a first prototype of this tool and connection with a real Digital Twin model.
- **Months 16-18**: Extension of the system to collaborative authoring in VR and evaluation of this system on a collaborative situation.
- **Months 19-24**: Design of interaction in AR for authoring, adding the ability to modify the 3D model of the factory's Digital Twin also in AR.
- **Months 25-27**: Optimization of system architecture to enable dynamic 3D model transfers.
- **Months 28-30**: System evaluation on an asymmetrical collaborative authoring situation in VR-AR.
- **Months 30-36**: Writing of thesis manuscript and preparation of defense.

## Related work:


- [Bao 2025] Y. Bao *et al*., "3D Gaussian Splatting: Survey, Technologies, Challenges, and Opportunities," in *IEEE Transactions on Circuits and Systems for Video Technology*, doi: 10.1109/TCSVT.2025.3538684.
- [Bodenmuller 2007] Bodenmuller, Tim, et al. "Tackling multi-sensory 3d data acquisition and fusion." *2007 IEEE/RSJ International Conference on Intelligent Robots and Systems*. IEEE, 2007.
- [Fleury 2010] Architectures and Mechanisms to efficiently Maintain Consistency in Collaborative Virtual Environments. C. Fleury, T. Duval, V. Gouranton, B. Arnaldi. In Proceedings of SEARIS 2010 (IEEE VR 2010 Workshop on Software Engineering and Architectures for Realtime Interactive Systems), p. 87-94, Waltham, 125assachusetts, USA, March 21, 2010
- [Bégout 2020] WAAT: a Workstation AR Authoring Tool for Industry 4.0. P. Bégout, T. Duval, S. Kubicki, B. Charbonnier, E. Bricard. In proceedings of SALENTO AVR 2020, 7th International Conference on Augmented Reality, Virtual Reality and Computer Graphics, Lecce (online), Italy, September 7-10, 2020
- [Bégout 2022] Augmented Reality Authoring of Digital Twins: Design, Implementation and Evaluation in an Industry 4.0 Context. P. Bégout, S. Kubicki, E. Bricard, T. Duval. In in the "Exploring Synergies between the Digital Twin Paradigm and eXtended Reality" research topic of "Technologies for VR" section of Frontiers in Virtual Reality, June 2022
- [Lee 2005] Gun A. Lee, Gerard J. Kim, and Mark Billinghurst. 2005. Immersive authoring: What You eXperience Is What You Get (WYXIWYG). Commun. ACM 48, 7 (July 2005), 76–81.
- [Prouzeau 2020] Arnaud Prouzeau, Yuchen Wang, Barrett Ens, Wesley Willett, and Tim Dwyer. 2020. Corsican Twin: Authoring In Situ Augmented Reality Visualisations in Virtual Reality. In Proceedings of the International Conference on Advanced Visual Interfaces (AVI '20).

- [Chauvergne 2023] Edwige Chauvergne, Martin Hachet, and Arnaud Prouzeau. 2023. Authoring Interactive and Immersive Experiences Using Programming by Demonstration. In Proceedings of the 34th Conference on l'Interaction Humain-Machine (IHM '23).