Exploring alternative problem-solving approaches using virtual and augmented reality for the factory of the future

Location: IMT Atlantique, Brest, France
Doctoral school: ED SPIN
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), which aims 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).
The project involves setting up a platform for asymmetrical, distributed cooperation between immersive environments (XR), located respectively at the Brest and Châlon-Sur-Saône sites. The cooperation is based on:

- real-time capture of a working environment at site A,
- segmentation of the captured environment into distinct objects and not simply a big mesh,
- 3D reconstruction in a virtual environment on site B,
- **use of the flexibility of the virtual environment on site B, to facilitate exploration of alternative problem-solving approaches,**
- **projection of the solution in augmented reality back to site A,**
- **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.**

These procedures concern operations such as recommending gestures, pointing to key elements of a device, or guiding an operator through procedures. The aim of the project is to move away from the single tutor/student paradigm 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 go beyond the limits of 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 can be captured (location and 3D part), reproduced on the remote site by an expert, and after trial and error, a manipulation sequence can be "communicated" in augmented reality to the operator at site A. The latter can then see that the gesture recommended by his teammate 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 is 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 laboratory conditions. This aspect of the project will enable us to study phenomena such as fatigue, perceptual bias, kinetosis 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 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 Metaverse (or the link between the Metaverse and the real world).

This PhD thesis would deal mainly on the exploration of alternative problem-solving approaches on site B, on projection of the solution in augmented reality back to site A, on 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.

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

- Study of the acceptability of remote XR collaboration (visual fatigue, cyberkinetosis)
- Design of interaction devices with shared repositories in remote XR
- Study of the role of avatars in remote XR collaboration
- 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 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 a mandatory

Provisional schedule:

- **Months 1-6**: Study of the state of the art, familiarization with development tools (Unity 3D, C#), definition with partners of the project of the system's collaborative requirements.
- **Months 7-10**: Definition of relevant guidance information to be highlighted to improve mutual understanding between system users (such as demonstrations of technical gestures by an expert to an operator).
- **Months 11-18**: Design and evaluation of asymmetrical immersive collaborative assistance metaphors in VR/AR enabling experts (in VR) to assist operators (in AR).
- **Months 19-22**: Definition of ways to explore alternative solving-problem approaches.
- **Months 23-30**: Design and evaluation in VR of some of those approaches.
- **Months 30-36**: Writing of thesis manuscript and preparation of defense

Related work:

- [Duval 2014] Improving Awareness for 3D Virtual Collaboration by Embedding the Features of Users' Physical Environments and by Augmenting Interaction Tools with Cognitive Feedback Cues. T. Duval , T. T. H. Nguyen, C. Fleury, A. Chauffaut, G. Dumont, V. Gouranton. in JMUI (Journal on Multimodal User Interfaces), Volume 8, Issue 2, pp 187-197, June 2014
- [Nguyen 2014] A Survey on Communication and Awareness in Collaborative Virtual Environments. T.T.H. Nguyen, T. Duval. in Proceedings of 3DCVE 2014 (IEEE VR 2014 International Workshop on 3D Collaborative Virtual Environments), p 1-8, IEEE, Minneapolis, USA, March 30, 2014
- [Le Chénéchal 2015-1] Toward an Enhanced Mutual Awareness in Asymmetric CVE. M. Le Chénéchal, S. Chalmé, T. Duval, J. Royan, V. Gouranton, B. Arnaldi. in Proceedings of CTS 2015, 233-240, Atlanta, USA, June 1-5, 2015
- [Le Chénéchal 2015-2] The Stretchable Arms for Collaborative Remote Guiding. M. Le Chénéchal, T. Duval, V. Gouranton, J. Royan, B. Arnaldi. in Proceedings of ICAT-EGVE 2015, Eurographics, p. 147-150, Kyoto, Japan, October 28-30, 2015
- [Le Chénéchal 2016-1] Vishnu: Virtual Immersive Support for HelpiNg Users - An Interaction Paradigm for Remote Collaborative Maintenance in Mixed Reality. M. le Chénéchal, T. Duval, J. Royan, V. Gouranton, B. Arnaldi. in Proceedings of 3DCVE 2016 (IEEE VR 2016 International Workshop on 3D Collaborative Virtual Environments), 5 pages, Greenville, South Carolina, USA, March 20, 2016
- [Le Chénéchal 2016-1] Vishnu: Virtual Immersive Support for HelpiNg Users - An Interaction Paradigm for Remote Collaborative Maintenance in Mixed Reality. M. le Chénéchal, T. Duval, J. Royan, V. Gouranton, B. Arnaldi. in Proceedings of 3DCVE 2016 (IEEE VR 2016 International Workshop on 3D Collaborative Virtual Environments), 5 pages, Greenville, South Carolina, USA, March 20, 2016
- [Nguyen 2017] VR-based Operating Modes and Metaphors for Collaborative Ergonomic Design of Industrial Workstations. T. T. H. Nguyen, C. Pontonnier, S. Hilt, T. Duval , G. Dumont. in JMUI (Journal on Multimodal User Interfaces), Volume 11, Issue 1, pp 97-111, March 2017
- [Le Chénéchal 2019] Help! I Need a Remote Guide in my Mixed Reality Collaborrative Environment. M. Le Chénéchal, T. Duval, V. Gouranton, J. Royan, B. Arnaldi. in the research topic Collaboration in Mixed-Reality of the Virtual Env. section of Frontiers in ICT journal and Frontiers in Robotics and AI journal, Oct. 2019
- [Fages 2022] Arthur Fages, Cédric Fleury, and Theophanis Tsandilas. 2022. Understanding Multi-View Collaboration between Augmented Reality and Remote Desktop Users. Proc. ACM Hum.-Comput. Interact. 6, CSCW2, Article 549 (November 2022), 27 pages.
- [Rinnert 2023] How Can One Share a User's Activity during VR Synchronous Augmentative Cooperation? T. Rinnert, J. Walsh, C. Fleury, G. Coppin, T. Duval, B. Thomas. Multimodal Technologies and Interaction, 2023.