

Support users' awareness with virtual reality and augmented reality in the factory of future

Location: IMT Atlantique, Brest, France

Doctoral school: ED SPIN (Brest area, France)

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This PhD is part of the 5GMetaverse project, which aims to prepare and promote 5G for the needs of the metaverse.

In this context, this PhD project addresses the representation of the state and activities of human workers in the factory of the future, to improve mutual understanding between these collaborators. This representation will be based on various visual metaphors, or more generally multimodal metaphors, which will be rendered using virtual reality and augmented reality. Collaborative interactions could then be set up to enable remote experts to assist operators present on the factory floor.

This work follows on from the PhD work of:

- Thi Thuong Huyen NGUYEN (defended November 2014)
 - Proposing new metaphors and techniques for 3D interaction and navigation that preserve immersion and facilitate collaboration between remote users
 - <https://hal.inria.fr/tel-01147673/>
- Morgan LE CHÉNÉCHAL (defended July 2016)
 - Awareness Model for Asymmetric Remote Collaboration in Mixed Reality
 - <https://theses.hal.science/tel-01392708>
- Thomas RINNERT (defense planned for late 2023)
 - Perceiving distant collaborative activity with Mixed Reality

As a first step, the objective of this PhD project will be to improve interpersonal communication between different operators present in a real factory and, possibly, other remote collaborators. All these users will be equipped with augmented reality or virtual reality devices, depending on the collaborative situation. Remote collaborators will be able to access a virtual reconstruction of the factory via the Digital Twin, which will be provided by the partners of the 5GMetaverse project. It will be necessary to choose the best way to represent the operators present in the factory in this virtual environment. Various solutions, such as 3D reconstructions, point clouds or animated avatars, could be considered.

In a second step, it will be necessary to define which information related to operators will be relevant to improve understanding between users ("awareness" mechanisms). This information will be selected from those that can be extracted from the Digital Twin and detected in the factory using AI algorithms provided by the partners of the 5GMetaverse project. For example, we can imagine using a classification of gestures, actions, and activities of operators in the factory. It will then be necessary to propose visual and multimodal representations of the state of operators to enable other users to better understand their activity, as well as their physical and psychological status. For example, this could enable managers to easily detect "suffering" operators at their workstations, and thus be able to help them.

Finally, in a third step, we would like to explore new remote assistance methods enabling an expert who is immersed in the factory's Digital Twin to guide an operator and act with him or her thanks to actuators (connected objects, cobots) also accessible via the Digital Twin (elements that will be provided by other partners of the 5GMetaverse project). This will be made possible by the bandwidth and low latency provided by the 5G platform. To this end, the collaborative interactions developed will be able to exploit and extend our previous results on asymmetrical collaboration in virtual and augmented environments.

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 5G Metaverse project of the system's collaborative requirements.
- **Months 7-10:** Definition of ways to capture and display operator status.
- **Months 11-18:** Design and evaluation of visual and multimodal representations of the state of operators in factories of the future.
- **Months 19-22:** 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 23-30:** Design and evaluation of an asymmetrical immersive collaborative prototype in VR/AR enabling experts (in VR) to assist operators (in AR).
- **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 Collaborative 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.