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Post-doc Position Proposal
Virtual Maintenance Companion through Personalized Augmented Reality

1 - Context

The proposed post-doc position has for context the assistance to industrial maintenance by augmented reality. It is part of the VIMACO project, labeled by the ANR through the call for collaborative research projects with company in 2021 (project duration of 4 years). The VIMACO project (for Virtual Maintenance Companion) aims to promote the transmission of knowledge and skills between expert and novice operators through a set of technologies combining operator observation, artificial intelligence and augmented reality.

The VIMACO project aims to develop methods and tools for personalized augmented reality for industrial maintenance assistance. It is a collaborative research project (PRCE) involving the LISPEN (engineering sciences in virtual immersion and artificial intelligence) and CAPS (cognitive sciences) laboratories and the companies DIOTA (SME in augmented reality technologies for the industry) and SAFRAN (a major group in the aeronautics industry). Industrial maintenance is a field where human skills are precious and operations are complex. The scientific literature in the field of maintenance assistance by augmented reality reports works on the added value of augmented reality, the capture and analysis of human gestures as well as the analysis of maintenance procedures based on the system. Few works focus on the operator, his level of expertise and the information adapted to the strategy he chooses to perform the task. The VIMACO project aims to provide personalized assistance to the maintenance operator. The scientific issues identified are related to the analysis of the experts' behavior in order to extract a skeleton of the maintenance procedure, the knowledge of the level of expertise and the motor singularities of the operator, and the interactive guidance techniques in augmented reality. Three research questions are addressed in the framework of this project: how to extract a maintenance procedure by analyzing the movements of an expert operator? How to extract the level of expertise and the motor singularities of the operator in order to better guide him? What is the timely/appropriate sensory feedback needed by the operator based on the missing information and his level of expertise/knowledge?

2 - Issue

Within the VIMACO project, the proposed post-doc position will focus on issues related to the evaluation of information feedbacks as well as sensory feedbacks provided to the operator by augmented reality technologies in order to guide her/him during her/his task.

3 - State of the art

Immersion through virtual and augmented reality technologies is in essence highly dependent on the subject's perception. Indeed, there are many virtual immersion experiences for which differences in perception between subjects are observed (cybersickness, motion sickness, behavior). Many factors [Ijs00] can explain this (age, experience, cognitive-motor skills...). Also, the personalized adaptation of interaction modalities is the subject of research work mainly concerning driving simulation (to avoid simulator sickness) [Cle19] and interaction in virtual reality [Mic20] [Plo18]. However, few works exist on the personalized adaptation of interactions in augmented reality. It is also observed that multisensoriality can improve virtual immersion when adjusted to the subject [Tri19].

Maintenance is an important area for improvement in Industry 4.0 due to the complexity and diversity of tasks, and the transfer of skills between experts and novices [Dam18] [Gat20] [Scu18]. [Cha17] proposes methods and tools for disassembly through AR in two steps: detection of a sequence of states and actions from an analysis of possible interactions between parts, and AR to provide guidance. The operator's expertise is not taken into account (system-centric approach). [Syb16] proposes dynamic instructions for maintenance operations given to the operator depending on a rule-based expert system, where the rules are added manually and offline by an expert. [Mom24] developed a methodology describing the principle of adaptive assistance as well as standard characteristics and criteria to design Augmented Reality-based Adaptive Assistance Systems. Artificial intelligence (AI) is a promising technology to improve operations in the industry [Fah20]. Recent research on AI use for maintenance is mostly conducted to make situation recognition on equipment [Mou20] [Buk20].

The analysis of human movement is the subject of many works [Adi20] [Ben17]. Some are applied in the field of functional rehabilitation in particular, but also in the industrial field for workstation ergonomics studies. A lot of work has been done on the capture and analysis of gestures using sophisticated classification or artificial intelligence techniques [Kow21] [Yan19] [Adi20]. [Mal21] studied the digital twin of a human-robot couple to detect potential conflicts when programming the robot movement. For that, a virtual manikin is used, controlled by the expert's motion capture. Recently, [Num20] developed a work aiming at creating a knowledge database of hand gestures in maintenance tasks. The European project WEKIT developed a framework for registering an expert movement and restoring it to an apprentice. An interesting state of the art has been done related to sensor-based AR systems [Lim18], showing bottlenecks in cognitive process modeling, emotional state measurement of the operator, as well as expert performance capture. Some works are beginning to appear on the personalized analysis of human movement [Hil16]. In the literature, very few works concern the analysis of the operator and his level of expertise.

4 - Scientific issues

In the context of this post-doc position, 3 main issues have been identified relatively to:

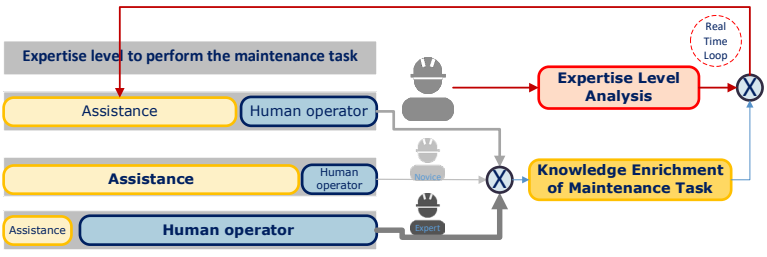
- Mental and physiological state and level of expertise of the operator
- Adapted information relatively to the needs of the operator
- Information feedbacks and sensory feedbacks bring to the operator through AR system

Scientific issue 1: Concatenation of information on level of expertise and mental and physiological state of the operator.

The level of expertise of the operator is being studied by the PhD student. His result will be used for this work. The post-doc will have to concatenate the information in order to guide the feedbacks to the operator. We also want to explore the effect of mental and physiological state of the operator on the work and the way a virtual companion can bring an help. For mental state, the stress level will be measured (by some bracelet device, from heart rate and/or sudation measurements). For physiological state, the fatigue of the operator will be studied (from duration of the task, movement analysis or other ways to propose).

Scientific issue 2: Adapted information relatively to the needs of the operator.

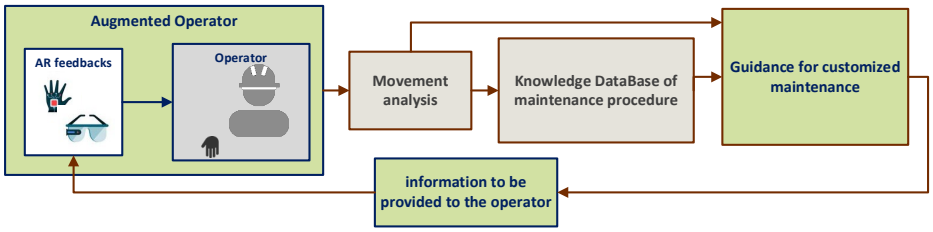
The issue is related to the selection of information in order to guide the operator in function of her/his requirements (depending of her/his level of expertise). The goal is to give her/him the just needed information as illustrated by the following figure.



The choice of the needed information will be guided by the knowledge of the level of expertise of the operator mainly. If possible, we want also to explore the how the mental and physiological state of the operator (stress, fatigue) can also be taken into account to adapt the information given to the operator.

Scientific issue 3: Information feedbacks and sensory feedbacks bring to the operator through AR system.

This issue is relative to the best ways to give information to the operator. Following the process (as illustrated by the scheme), the work will study firstly the most appropriate information to deliver to the operator (informative, symbolic, image, 3D…) and secondly the best feedbacks through AR technologies to the operator.



Sensory feedbacks will be studied in order to optimize the guidance. The contribution of visual, haptic as well as sound feedbacks will be studied.

If we have the opportunity, we want also explore the personalization of the guidance technology in studying and proposing the relevant information for the personalized guidance of the operator according to his level of expertise and his strategic profile (gradation between a visual approach and a proprioceptive one). This information will consist of a level of guidance and a type of sensory feedback (visuo-haptic coupling and relative weights of the modalities).

5 - Proposed approach

The proposed approach will follow the following steps:

- State of the art related to the issues
- Study of the scientific issues and formulation of the research questions
- Proposals for experiments (protocols, set-up)
- Experimentation and data analysis for validation of the proposals
- Publications

This work will be performed in the framework of the project VIMACO. The post-doc person will work in collaboration with a PhD student (working on the evaluation of level of expertise of the operator) as well as an engineer (who will help for the development of technological solutions and experimental set-up).

A technological demonstrator is fully operational to make the first proofs of concept (using virtual reality). A second technological demonstrator in augmented reality is under development in the research team. These two technological demonstrator will be used for this work.

6 - Expected results

The expected results of this research work are as follows:

- Technological demonstrators for proof of concept
- Evaluations in laboratory context
- Publications in international conferences and peer-reviewed journals
- Communications in internal seminars, internal meetings
- Scientific and technical reports

7 - Location of the work

The work will be carried out on the site of the LISPEN laboratory in Chalon-sur-Saône, France.

8 - Profile of the candidature

The profile of the expected candidature should correspond to some of these keywords:

- Human-machine interaction (design, evaluation)
- Virtual and augmented reality
- Multi-sensory feedbacks in mixt reality immersion
- Ergonomics
- Experimental Neuroscience
- Artificial Intelligence

The candidature has to be expressed to the contact people by email.

9 - Contacts

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