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HMI-HUFLAB – A BRAZILIAN - SWEDISH INITIATIVE IN HUMAN FACTORS FOR AERONAUTICS

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Abstract

The HMI-HUFLab project is a joint Brazilian Swedish initiative in the area of human factors and design of human machine interfaces for future military concepts in Aeronautics. This paper gives a short introduction to this Brazilian Swedish collaboration. It describes the main challenges for setting up the bilateral collaboration and how challenges were tackled. We present the first projects results, which includes the definition of relevant context and scenarios for the future air domain, a review of literature and implementation of complementary simulation environments in both countries.

Keywords: human-machine interface (HMI), human factors, bilateral projects.

1. Introduction

In 2013, Brazil and Sweden closed an agreement to incorporate the Swedish fighter Gripen E/F, developed by SAAB in cooperation with Brazilian industrial partners, into the Brazilian Air Force fleet. This agreement, intended as the start of a long-term relationship extended over decades, created a bilateral interest to go beyond the commercial contract and establish research collaboration and development that could benefit both countries. Starting in 2013, a number of initiatives have been carried out to strengthen joint research, involving different actors from government, universities and industry, following the triple helix model for fostering innovation. In 2015, a High-Level Group on Aeronautics (HLG) was established between the two countries as part of the commitment of the Swedish and Brazilian governments. In October 2016, the HLG approved a Long-term Strategic Plan for the Brazilian-Swedish Cooperation in Aeronautics.

As a consequence, a number of joint activities and initiatives were established approaching the area of human performance, such as:

- HumAer: This project is aimed at designing and commissioning a human factors laboratory in aeronautics (HumAer), supporting industrial and academic demands and providing an ideal environment to identify and model human behaviour in simulated operations. The proposal was based upon surveys and technical meetings with Swedish and Brazilian partners and included the implementation of laboratory facilities both at Linköping University and ITA. The project was funded by CISB, SAAB and CNPq. Some results of this project are presented in [1] and [2].
- IVHM-HFA: The project acronym stands for “Integrated Vehicle Health Management (IVHM) and Human Factors (HF) Analysis based on Big Data”. It was a joint Brazilian-Swedish project funded by FINEP from the Brazilian side and VINNOVA from the Swedish side. The Brazilian partners were ITA and Konatus, while the Swedish partners were Linköping University and SAAB. The project aims at developing systematic and integrated approaches for fault diagnosis and analysing pilot-aircraft interaction, based on offline flight data [3],[4] and [5].

- Air Study Domain (ADS): It is an on-going initiative that encompass a number of projects. It aims at identifying future scenarios and operational needs supporting both countries. Out of jointly identified future capability needs, coordinated research projects have been established.

As a result of the above-mentioned initiatives, the HMI-HUFLab project was set up in 2019, under the ADS umbrella. The project aims to build up the knowledge regarding human machine interface for future military concepts, manned as well as unmanned. Three research questions are investigated in the project:

1) *How do new human-machine interface (HMI) solutions contribute to improve performance and/or safety in different scenarios?*
2) *What are appropriate models and tools to measure the impact of HMI in different scenarios?*
3) *To what extent can we use flight simulators to investigate the pilot/aircraft interface?*

This paper is organized as follows. We start presenting the main challenges faced during the HMI-HUfLab project setup. The purpose is to provide guidelines and lessons learned for future initiatives. We then proceed to describe the results obtained from the first work packages of the HMI-HUFLab project, including the definition of scenarios and implementation of simulation environments. Finally, we draw some conclusions and discuss future steps.

2. Project setup - challenges and lessons learned

The HMI-HUFLab project proposal was the result of a process involving several steps. From the first manifestations of interest to the signature of the project agreement, a number of meetings, both virtual and face-to-face, were carried out between the two countries in order to find solutions to the main challenges. These challenges are discussed and included in this paper in order to serve as guidelines for future bilateral initiatives between both countries, in Aeronautics or other research areas. They are organized in categories:

- Challenges related to funding: in this item we discuss the main differences related to the kind of expenses usually included in the project budget, the nature of counterpart contributions required from industry, and advantages/limitations of being (or not) proposed under a joint funding call.
- Challenges related to intellectual property and other agreement clauses: in this item we include the main differences between the way each country treats intellectual property issues and confidentiality in R&D projects that follows the triple helix model.
- Challenges related to the integration of project teams: in this item we discuss the strategy adopted in the HMI-HUFLab project proposal to assure integration and knowledge sharing between the teams of each country.

2.1 Challenges related to funding

When setting up the project budget each side (Brazil and Sweden) has defined their own necessary requirements depending on the tasks to be performed and the parties involved.

The projects on each side have been coordinated as to the different activities but avoidance of too much dependence in deliveries cross borders. That way any issues of funding availability that could affect schedule have been avoided and each side can work independently upon the other. In hindsight, this approach has played out well not only for funding coordination reasons, but also as to the covid pandemic situation for the last two years, not being able to travel and only having to rely on virtual interaction.

In Sweden the academic institutions need to find funding for all project members who are employed (professors, PhD students, post doc etc) whereas in Brazil a professor is employed and do not need to apply for funding for paying his/her hours in a specific project.

Hourly cost is another thing that differs for employees in the two countries. If one would try to make a “one to one” equal situation just counting hours, those efforts would probably had let to that no project would have started. It would have been stuck in the bureaucracy. Both sides realize that we have more to gain being open to each other and that the exchange will benefit both. If we would have wanted to calculate efforts, we could in that case also put in the background each party brings to the table. It would have been like digging down in trenches on both sides.

In Sweden, when VINNOVA is partially funding a large company like Saab, the industry defines the research questions that they would like to be explored (industrial relevance). In general, the monetary means from the governmental agency are then distributed to the academy or institute. The company (if a large and not SME) generally need to contribute with the same amount of funding but it can be in-kind. In Brazil there are no such opportunity when the larger state funding organization like FINEP or EMBRAPII are involved. There, the company would need to contribute in cash with the equal amount of money as they receive and that the total amount would then go to an academic organization or an institute for doing the R&D. In the cases where the major result in the project would be building capability and risk reduction the knowledge would vest outside the company with the people involved since there are no in-kind part but only transfer of cash.

As a comparison, in EU-programs like Clean Sky, all parties are strictly adhering to a set of rules set out by the EU commission. In this case, it is all 28 member states that finance the EU total budget where each country has contributed and there are no specific national R&D for each industrial area that needs to be paid out in comparison with each country’s contribution.

2.2 Challenges related to intellectual property and other agreement clauses

The lower TRL (1-3) levels are easier to get by in the IPR discussions simply due to the fact that for those levels the expectations on IPR that is being generated for patent protection are quite scarce. For projects where there are new parties that are to work together for the first time it is a lot of trust that needs to be built while lower TRL is a good starting point, then gradually as you get to know each other, you build confidence, trust and knowledge of one another’s “eco system”. But as stated before we have avoided mixing to much of cross border deliveries so far but as we go on this will be more challenging, especially when moving higher up in TRL.

In Sweden the intellectual property that is generated by the academy or institutes when government funding is granted belongs to the researcher personally. This is by the Swedish law (it is normally referred to as the “teachers’ exception”) and has to be stated in the bilateral agreements set up between the parties. In order for the industry to capitalize on any individual IPR generated solely by the researcher from the academy/institute a clause would be written stating how this would be intended.

In Brazil the IPR generated with government funding should also get the government a kick-back. This is typically something between the Brazilian parties to set up in their individual agreement with their funding agency.

The agreements have been evolved during the last five years. It is important to have a core of main parties on each side to avoid too much of a set time, once new parties come on, to new projects.

Another area of contractual concern is indemnity and liability. This often requires legal advice to explain and clarify and it takes some experience on each side to comprehend in order to value and adequately mitigate the related risks. For a governmental party this could be seen differently than for an industrial party where this is more “day to day” business.

Confidentiality is probably something more relevant to the commercial (industrial) actors which typically have more interest in protecting their information and commercializing new ideas whereas academic actors are more focusing on compensation and disclosing information (publish papers). Export licenses is a major issue to always recognize and consider. In Sweden there is a regulatory agency ISP (Institute for Strategic Products) that shall be notified when information including higher TRL or for military purposes is transferred to a foreign party.

2.3 Challenges related to the integration of project teams for the HMI-HUFLab project

The project teams are formed on broad multi-disciplinary knowledge as well as deep understanding of the domain, including technical capabilities, making the most out of collaboration between academia, institutes and industry. Both teams have used similar approaches to simulation and assessment which have been beneficial to the integration of the teams, and also visits for shorter and longer time has made the integration stronger. Also, the coordinated use of scenarios and use cases has contributed to the integration of project teams, sharing common and complementary aspects of a vision of a future air domain.

3. Project execution – definition of context and scenarios

This section describes the context and scenarios proposed by each country. Starting from a common set of research questions to be investigated in the project, these questions were unfolded into a set of related future air systems scenarios to be implemented, in different kinds of simulators, and analysed in each country. As a requirement, the scenarios were expected to have similarities and complementarities, in order that the knowledge developed by one team also contributes to the activities of the other team. The scenarios and corresponding use-cases were proposed based on interviews with pilots and potential stakeholders.

From the Brazilian side, the chosen scenario is related to the use of Mixed Reality in-flight for training purposes. The concepts of Augmented Reality (AR) and Mixed Reality (MR) are related to that of virtual reality (VR). VR aims at immersing the user in a completely synthetic, computer-generated environment that stimulates one or more user's senses, such as vision, hearing and haptics. On the other hand, AR does not completely suppress the real environment, but complements it with synthetic elements. Most of the recent applications of AR are visual and focus on anchoring virtual objects (text, 2D or 3D images) on the real-world environment, maintaining their position and orientation even when the user turns his/her head and moves around. While the distinction between AR and VR is well stablished and dates back from the 90's, the concept of MR has gained evidence more recently. It usually implies an application that not only anchors virtual objects but also allows the user and the environment to interact with the virtual objects. The term "mixed reality" was introduced by Milgram *et al* [6] as part of the concept of reality-virtuality continuum, as illustrated in Figure 1. In this case, both augmented reality and augmented virtuality are considered part of mixed reality.

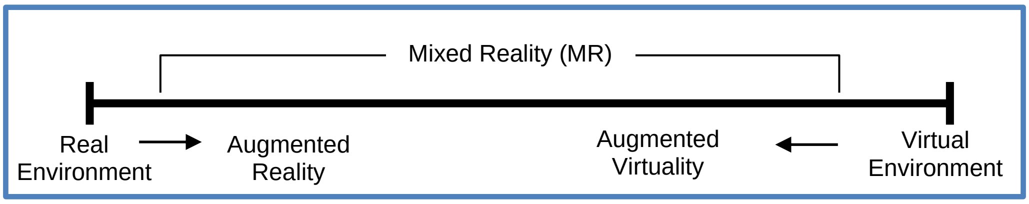

Figure 1. The reality virtuality continuum, as proposed by Milgram et al [6].

The Brazilian scenario consisted of training a wing pilot in a basic flight formation where the wing pilot is flying a real aircraft using MR glasses and the leader is a virtual aircraft projected through the glasses. In order to better illustrate the proposal, Figure 2 presents some of the available simulation options for training flight formation, including the one related to this use case. The first simulation environment is characterized by the use of virtual reality for representing both the wing and the leader. In the second environment, the wing is flying a high-fidelity flight simulator and the leader is projected through simulator visual system. The third option is the one proposed as a use case, where the wing pilot flies a real aircraft using MR glasses and sees the virtual leader through the glasses. Finally, the last one is the case where both wing and leader are real aircrafts.

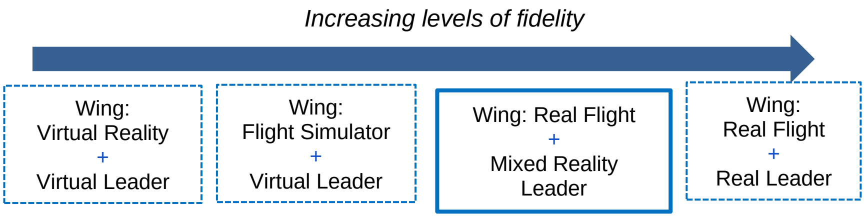

Figure 2. Training environments.

In a basic formation flight, the wing aircraft must maintain its relative position and orientation to the leader. During the mission, the leader can make requests to change the wings' position, change the formation type or change the distance between aircrafts. Also, at any time during the flight and specially in the case of emergency situations, the wingman may be commanded by the leader or other wings to leave the formation.

The main motivation for the proposed scenario is the possibility of reducing training costs and improving safety without losing fidelity. It is based on the hypotheses that training in simulators cannot completely replace training in real flights. This hypothesis is confirmed in a number of previous works that compared the human response in real and simulated flights. Among them, we highlight the work of Leino [7], which detected difference in the level of ANP hormone, indicating different psychological workload for real and simulated flights, Vellman [8] observed changes in the cortison level. Finally, McClernon [9], [10] observed the influence of the level of stress in the transfer of training. Assuming that real flights provide a better transfer of training, we want to investigate the impact of replacing a real external entity by a virtual one. We are interested in analysing how the pilot perceives the virtual projection of the leader, how it affects the pilot performance, workload and situational awareness, how its learning curves compares to that of other simulation environments and if it induces any aspect of negative training. Additionally, we also want to investigate what are the main aspects of the leader behaviour that must be modelled and embedded in the virtual leader in order to assure a realistic simulation environment and what are the limits of the current available MR technology when it comes to in-flight applications.

From the Swedish side, after evaluation and discussion of different scenarios with SMEs, we committed to pursue a future reconnaissance mission performed by a Manned-Unmanned Aircraft team with two use cases: Transfer of Control and Loss of Communication. The motivation behind these choices is the need for inter-personal coordination, but for different demands. In short, Transfer of Control can be described as a process of two or more authorized systems transferring control of UA (Unmanned Aircraft) and/or payload between each other [11]. In this, the demands are to establish common intentions between humans (e.g., manned aircraft pilots and GCS – Ground Control Station - operators) and unmanned aircraft in the scenario by communication. In contrast, Loss of Communication refers to situations where there are no means for establishing common intent via a data link, thus must rely much on the understanding of each other's situation, capabilities, and authority. The overarching scenario includes a set of important events in a plausible future in terms of agents, capabilities, artefacts, properties, and activities in a context.

The scenarios are highly relevant for future air domain, and also well suited for the study of HMI and Human Factors, including manned-unmanned aircraft teaming. Transfer of control is highly relevant for the future air domain, for instance for a manned aircraft to take over control of an unmanned aircraft when a ground control station is no longer able to control as well. Link loss could appear for a number of reasons, for example due to malfunction, large distance and/or weather conditions. Both in the case of transfer of control as well as for link loss, the user's situation awareness must be supported, and cooperation between manned and unmanned aircraft need to be supported.

Technology to support this include pilot modelling, for instance to represent pilot intent to an unmanned aircraft, and to guide future cockpit design and interaction. Additionally, pilot monitoring techniques, including psychophysiological assessments, support this by making assessments of the pilot mental state available to the system.

4. Project execution – state of art

In order to support the implementation phase, a review of the literature was carried out including published work related to the impact of different levels of autonomy and also existing methods to evaluate pilot mental workload and situational awareness that could be applied to the scenarios. The reason for focusing on autonomy is that there is an ongoing trend towards higher levels of autonomy within the aviation domain. The increased levels of autonomy are in itself challenging to develop, but even more challenging to develop with respect to teaming and interaction with human decision makers such as pilots in manned aircraft.

The review of literature on autonomy is organized in 4 topics: levels of automation/autonomy, command and control, human-machine interaction and simulation.

Under the levels of autonomy topic, we compare different proposals for classifying the degree of autonomy. This review includes 3 classes of works: those derived or adapted from the first definition of levels of automation, proposed by Sheridan and Verplank in 1978; those derived from Control Engineering theory; and other independent proposals. The focus of Sheridan and Verplank [12] was on automation, rather than autonomy. They proposed a scale of "Levels of Automation" that applies to human-machine interaction when performing a given task. The classification reflects how much of the control effort is performed by the human operator or the computer, with the higher levels approaching autonomy, as it involves higher levels of cognitive capabilities and decision-making. Parasuraman et al [13] extend the ten levels of automation to functional dimensions defined based on human cognitive processes. In [14], the scale originally proposed in 1978 is revised with focus on human-machine interaction, covering topics like trust, adaptive automation, ecological interface design, and user acceptance or rejection of automation. Following, Cummings and Bruni [15] expand the initial classification of Parasuraman related to information processing model to focus on collaborative decision making. Among the works derived from Control Engineering theory, we presented the definition proposed by Antsaklis [16], which considers that any autonomous system is also a control system. Antsaklis defines autonomy as the system ability to achieve goals by itself, without the need of external intervention, under uncertainties. The first important point of this definition is that the system is autonomous considering a set of goals, it is not just generically autonomous. The second point is that the system operation is subject to uncertainties that affect the ability of the system to achieve its goals. If there was no uncertainty, we could pre-program the system. It is important to observe that the definition proposed by Antsaklis aims at being independent of context or area of application. It does not involve how goals are achieved or how the system interacts with external entities. Finally, as representative of the third class, Johnson et al [17] presented a design philosophy that views humans and automation (specifically robot agents) as interdependent teammates. Generalizing from this perspective, human-automation interaction can be viewed as a joint activity, with a human and automation (in some form) interacting and cooperating to perform a task, contrary to the traditional idea of human supervisory control of automated systems.

The second topic in autonomy approached in the review is about autonomy and command and control. The literature was reviewed beginning with efforts on describing characteristics of UAV flight, including challenges with formation flight. We then extend to more general civilian challenges such as how air traffic controllers could be affected by autonomous airborne systems and end with a study of the military command and control context, focusing on autonomy functions. Among the discussed works, Khan et al. [18] presented a guiding framework based on a literature survey. The Unmanned Aerial Vehicles (UAVs) is considered as one of the most dynamic and multi-dimensional emerging technologies of the modern era. The authors presented a universal guiding framework for ensuring a safe and efficient execution of a UAV-based study. It also explored the analysis steps that follow the execution of a drone flight. Woltjer *et al* [19] highlighted that recent military developments of increasing battle dynamics emphasize the increasing importance of smart technologies with autonomous functions. Discussions of autonomous systems have mostly addressed potential technology applications and interaction between operator and systems. Aspects of command and control and cooperation between human operators and autonomous systems in complex constellations have not been studied to the same extent. The report described an explorative interview study with Swedish Armed Forces personnel about a number of potential future automated or "autonomous" functions and capabilities that were described using "capability cards".

The third topic is about autonomy and interaction beginning with a short reflection on levels of autonomy, through challenges related to interaction with swarms and examples of human machine interaction challenges [20], extending to concerns related to workload and situation awareness and ending with challenges related to the study and design of future systems. Hocraffer and Nam [21] performed an analysis of human-system interfaces in UAV swarm interaction. An analysis was conducted to systematically evaluate the current state of research on human-system interfaces for users controlling semi-autonomous swarms composed of groups of drones or unmanned aerial vehicles (UAVs). Naghsh et al. [22] performed an analysis and design of human-robot swarm interaction in firefighting. Kolling et al. [23] reported an experimental study on human-swarm interaction. They presented the first study of human-swarm interaction comparing two fundamental types of interaction, coined intermittent and environmental. Simple autonomous swarms outperformed human operators in open environments, but operators adapted better to complex environments with obstacles. Human controlled swarms fell short of task-specific benchmarks under all conditions. The results reinforced the importance of understanding and choosing appropriate types of human-swarm interaction when designing swarm systems, in addition to choosing appropriate swarm behaviours.

We observe that the literature review on autonomy and interaction is related to all of the scenarios and use cases, in the sense that all of them includes interaction between a human pilot and an autonomous system. Based on the literature related to autonomy and interaction we can implement prototype solutions related to interaction with relevance to all of the scenarios and use cases, in that all of them implies in the interaction between human pilot and an autonomous system. Finally, the last topic on autonomy discusses aspects related to the simulation of autonomous systems. It summarizes works that could contribute to the implementation of the proposed Brazilian and Swedish scenarios in a simulation environment.

The review of literature on evaluation methods covers techniques and approaches to assess mental workload and situation awareness. In the first group, we include subjective techniques, performance-based techniques as well as techniques based on use of neurophysiological sensors. Among the subjective techniques NASA-TLX [24] stands out as the most used one - it has been systematically used as a reference for evaluating other techniques [25]. Regarding neurophysiological data, we observed that their correlation with mental workload depends on the situation under analysis, but systematic trends have been observed for heartbeat [26],[27],[28] and [29], brain activity [30] and [31], respiration [32], eye activity [33] and [34] and electrodermal activity [35]. When it comes to the evaluation of situation awareness, most but not all of the methods are based on questionnaires and queries, such as the famous SAGAT (situation awareness global assessment technique) [36]. The use of neurophysiological sensors or performance measurements is not so common. Finally, we discuss some trends related to team situation awareness [37], particularly when the team includes one or more autonomous systems [38].

5. Project execution – implementation of complementary simulation environments

This section describes the simulation environments that were setup in each country in order to perform experiments and evaluate the proposed scenarios.

5.1 Brazilian research and development capabilities

From the Brazilian side, the simulation environment is built using as a starting point SIVOR, a high-fidelity robotic flight simulator available at ITA.

SIVOR is a motion-based flight simulator developed at the Aeronautics Institute of Technology (ITA), in partnership with the Brazilian aircraft manufacturer Embraer. This simulator uses a 6 Degree of Freedom (DoF) anthropomorphic robot arm, which rides a linear unit that provides an additional workspace and some redundancy for the robot movement. The SIVOR robot, a KUKA®KR-Titan, has a payload of 1000 kg, making it possible to carry a high-fidelity cabin of a small aircraft, as illustrated in Figure 3. Briefly, the SIVOR flight simulator is composed of the following systems: robotic platform; cockpit; visual system; and supervisory system.

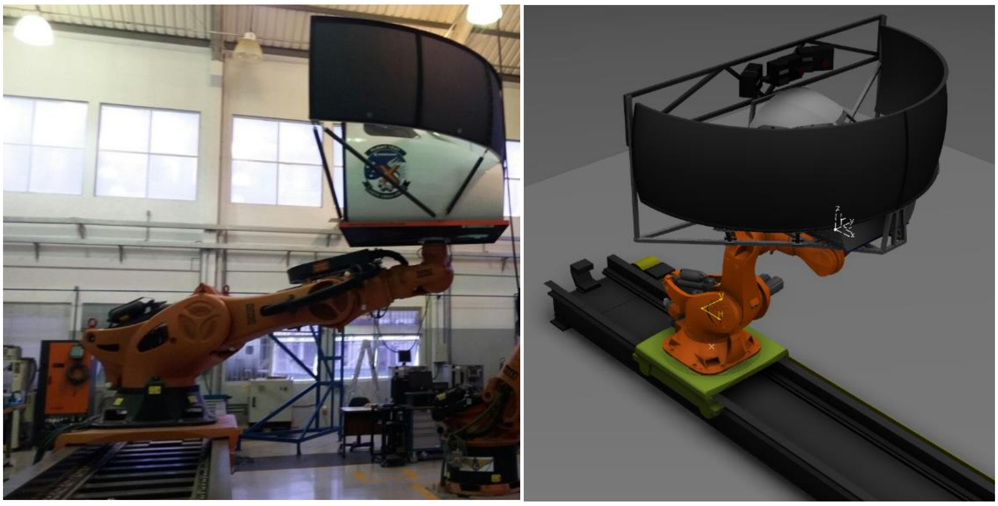

Figure 3. SIVOR flight simulator (cabin with embedded visual system on a robot arm).

SIVOR is a flight simulator representative of an executive jet and is prepared to operate with both pilot and co-pilot. The cockpit reproduces the main panels and inceptors available in the aircraft (Figure 4). Additionally, it can be configured to operate with either yoke or sidestick. The pilot inputs provided through the SIVOR inceptors are sent to the aircraft aerodynamic model. The aircraft model calculates the aircraft aerodynamic variables (speed, attitude, altitude, etc.) and send it to both the visual system and the wash out filter. The wash-out filter transforms the aircraft movement into the corresponding robot movement and send it to the robot. The visual system projects the vision of the aircraft outside environment in a curved screen that wraps the cockpit.

Figure 4. Internal view of SIVOR cockpit.

Figure 5 presents a simplified vision of the SIVOR architecture. The aircraft aerodynamic model is implemented in a Dynamic-Link Library (DLL file) generated from a Matlab/Simulink model, and runs in a separated computer. The inceptors generate/receive data using dedicated embedded systems. The visual system uses X-Plane commercial tool to generate the image of the outside environment in another computer, which is connected to three projectors installed in the cockpit structure. The washout filter and the routines related to the robot interface are implemented in LabView and run in another computer. Communication among all these nodes is achieved using SECT, a real-time network developed by EMBRAER. Communication between the LabView computer and the robot controller is achieved using RSI, a proprietary serial protocol from KUKA, the robot manufacturer.

Efforts have been applied to integrate the AR/MR glasses with the infrastructure of SIVOR, in order to allow the evaluation of both Brazilian scenarios. For this purpose, two additional components related to the MR solution were integrated into the SIVOR infrastructure. The first one is the MR embedded unit, i.e., the MR glasses' embedded system. It is responsible to determine the relative position between the glasses and the cockpit and processes the image to be shown. The second component is the MR controller, which is developed in LabView and should determine the relative position between the wingman and leader aircraft, based on data received from the SIVOR aircraft model.

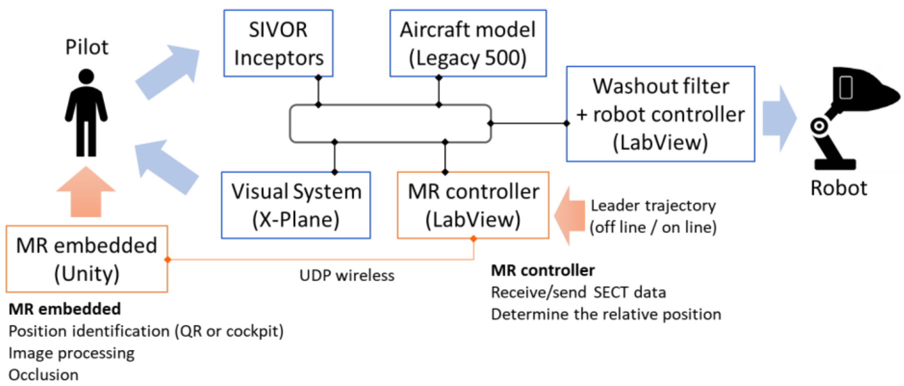

Figure 5. Simulation environment for Brazilian scenario.

A preliminary campaign of experiments has been performed comparing the situation of training with and without the use of AR/MR glasses. The evaluation considered factors such as workload, performance, stress and transfer of training. Results are still to be published.

5.2 Swedish research and development capabilities

From the Swedish side two simulator environments has been set up, one at Linköping University (LiU) and one at Saab. Both set-ups are based on the XPlane 11 software, making the different environments compatible with each other, as well as the Brazilian R&D capabilities. The set-up at LiU has been designed for controlled lab testing of pilot monitoring, while the Saab environment has a stronger focus on evaluating specific applications, such as new interfaces or various forms of automation. At LiU, there are two flight simulator set-ups available based on the same hardware configuration. Saab has one identical hardware set-up, making it possible to conduct joint studies where the experimental conditions can be kept constant. The initial LiU set-up was described in a previous publication [1]. Since then, the LiU set-up has been developed to include the ability to conduct studies utilizing either curved computer monitors with a 120-degree field of view, or fully immersed virtual reality using HTC Vive.

Figure 6. One of the Linköping University flight simulator set-ups.

Pros and cons of these two using screens or VR are currently being evaluated, focusing on aspects such as immersion, usability, workload, and performance. Such knowledge is of importance to evaluate what kind of hardware that can be used for flight simulation in different types of studies. Virtual reality offers a more immersive environment, but also creates new challenges when it comes to interacting with hardware components such as flight controls and instrumentation. Computer screens are commonly use but restricts the field of view of the research participant. Another activity undertaken is the implementation of an interface that allows for connecting tactile interfaces to the flight simulator. This allows for experimentation with new ways of presenting feedback from aircraft systems or sensors to the pilot, such as different kinds of alarms, or directional information that can support navigation and situational awareness.

There are also other types of simulators in use in the LiU environment, such as C3Fire [39] and [40] and MATB-II [41] and [42]. Data streams from the two XPlane flight simulators at LiU were joined in the C3Fire simulator environment to create a share situational picture with blue-on-blue capability. Further, one of the sub-tasks in the MATB-II simulation has been implemented in the VR environment to allow for studies of mental workload [43]. Workload measures comprised both subjective ratings such as NASA-TLX [25], as well as psychophysiological measures of heart rate variability [44] and [45], electrodermal activity [44], eye movement [46], and blink rate [47]. The aim is to evaluate what measures of mental workload that provides both timely and reliable response, as well as to what degree the different measures are experienced as intrusive by the research participants. The latter is of particular interest when developing monitoring capabilities to be implemented in actual aircrafts, as these already have limited space and presents both tasks and systems that require the highest possible attention from the pilot [48].

Two visual tasks have been implemented in a virtual reality environment. The participants eyes, heart, and skin conductivity are used to monitor psychophysiological response. Technical testing have been performed and planning of the simulations and analyses has been performed. The simulation environment at Saab is designed to study pilot intent in the selected scenario. A tactical environment has been integrated and scenarios has been set up representing conditions and events in the scenario. Also, an interaction environment for the pilot to interact with the tactical environment through the displays and controls has been set up and tested.

6. Conclusions

This paper presents the first results obtained in the context of HMI-HUFLab project, a joint Swedish and Brazilian initiative that aims at developing knowledge in both countries regarding human machine interface and human factors for future military concepts of aircraft operation, manned as well as unmanned.

The project has pinpointed key human factors challenges for interacting with future unmanned aircraft and matured HMI technologies to meet these challenges. The project has studied how do new human-machine interface (HMI) solutions contribute to improve performance and/or safety in different scenarios, what are appropriate models and tools to measure the impact of HMI in different scenarios, and to what extent can we use flight simulators to investigate pilot/aircraft interface.

Human factors and pilot behaviour are of great importance for the development of future air forces. This project has built up the knowledge regarding the interface for both manned and unmanned systems. In this project, pilot environment for future military concepts, manned as well as unmanned has be studied, both regarding training, increasing situation awareness through augmented reality, and for a reconnaissance mission with a manned and unmanned aircraft. When a manned and unmanned aircraft is working together like this it is important for the pilot in the manned aircraft to be virtually present and been able to interact with high level control to be able to maintain situation awareness with fast and accurate decision making.

Also, techniques for pilot monitoring have been matured in the project, including psychophysiological assessment techniques based on eye-tracking, electrodermal activity (EDA) and heartrate. From this project, we now know how these techniques together gives a view of the pilot’s mental states for tasks of relevance of the selected scenarios.

Next steps after this project include interaction with multiple unmanned aircraft. Also, further maturation of HMI technologies for pilot monitoring and cognitive modelling, in advanced tactical simulations or even flight tests before bringing the technologies towards mature systems.

7. Acknowledgment

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9. Copyright Statement

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