A Human-Machine Interface for Aircraft Cockpit Design in Virtual Reality

Dr. Francesca De Crescenzio / Francesca Flamigni / Prof. Franco Persiani
DIEM – Mechanical Nuclear and Aerospace Engineering Department
University of Bologna
Via Fontanelle 40, Forlì (FC) 47100
ITALY

Email: francesca.decrescenzio@mail.ing.unibo.it / fflamigni@mail.ingfo.unibo.it / persiani@mail.ingfo.unibo.it

ABSTRACT

A full 3D Virtual Reality-based hardware and software environment for aircraft cockpit design is presented.

Virtual Reality immersive and interactive features are now widely used in many engineering tasks in order to preview and simulate a lot of expensive and time-consuming activities. For instance, in cockpit design a Virtual Reality based environment can be used for designing the instrument layout.

*In this work a physical mock-up of the seat and the cabin (“**Seating Buck**” [1]) is provided, where all the instruments are replaced by projected and software generated 3D models transforming the aircraft cockpit into a full digital Human Centred Virtual Environment. This is useful both for designing and customizing the flight instrumentation. The “Glass Cockpit” [2] evolves into a Virtual Cockpit equipped with stereoscopic vision and instrument manipulation features.*

Keywords: Glass Cockpit, Human Centred Design, Virtual Prototyping

1.0 INTRODUCTION

The development of computerization and automation in the aircraft cockpits allowed a wide amount of benefits to be achieved. In particular, a big saving in fuel and maintenance, a more reliable equipment and also a greater flexibility for instrumentations upgrades can be obtained.

Recent researches, on the other hand, showed that the novel cockpit technology and automation cause some problems, especially with regard to the role of the pilot and pilot-machine interfaces. The advanced automation of such interfaces are leading to a raising cognitive workload [3]. Hence, human factors have become an integral part of design analysis, and the research focuses on how to realize the optimum level of the pilot’s workload through an ergonomic design process [4].

One of the main tasks for cockpit designers is the positioning of all the commands and displays onto the panels. The designers have to face the increasing complexity of cockpit visualization environments, aiming at the optimisation of pilot’s performance. Indeed, pilots must maintain a high level of situation awareness during all phases of the flight in order to increase the safety level. A systematic approach consists on the accomplishment of two tasks: a fast cockpit layout definition and the reliable validation of its usability.

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In this paper the attainment of the above mentioned goals by means of a 3D Virtual Reality based environment is proposed. This 3D environment has been already used in many engineering applications [5, 6], aiming at a significant time and money saving.

The Virtual Cockpit, shown in Fig.1, is based on the active involvement of the final users (the pilot) in the design process. His participation allows the ergonomic requirements to be satisfied by means of a human-centred approach [7].

Figure 1: The Virtual Cockpit.

A Virtual Prototyping tool interfaces the cockpit with a CAD(Computer Aided Design) modelling environment. It provides essential and simple commands for the configuration of panels.

Moreover, usability tests in flight conditions are required to optimise the results in terms of performance. Flight operations, indeed, can be simulated to verify the visibility and the reachability of all meaningful commands and displays.

This practical testing permits the pilots to provide the evaluation about different cockpit configurations and their usability. The aim is to estimate the best visual display as the optimal way for conveying functional information to pilots.

In the next chapters the human-machine interface for Virtual Prototyping followed by the Flight Simulation Virtual Environment are described.

2.0 INTERACTIVE INTERFACE

In order to build an interactive interface a set of virtual devices are implemented.

A pair of virtual gloves are used in order to manipulate objects in a virtual environment. Such device enables the user to touch and grab 3D models of instruments in a very natural way. Since they are equipped with a magnetic tracking receiver, human movements are simulated in the virtual space. A virtual pointer represents the right hand position.

In addition, the use of virtual gloves allows traditional input devices, such as the keyboard and the mouse, to be eliminated. Indeed, input signals can be activated by means of electrical contacts on fingertips.

A pair of StereoGraphic Crystal Eyes provides the 3D perception of the visualized objects. It is synchronised with the software by an infra-red emitter. Stereoscopic visualization, as known, increases the system reliability enabling the user to make safe ergonomics tests.

A very important task is to replicate the cabin environment as real as possible. The cabin components are identified as two main object types, viz. reconfigurable parts and non reconfigurable parts. The reconfigurable parts are the front side deck and the lateral consoles, while the non reconfigurable parts are the cabin and the seat. The level of presence is increased by using a real mock-up of the cockpit.

While for the projection of the lateral panels two 21” flat screens are used, for the front cockpit a deck shaped panel is retro-projected by a BARCO CRT (Cathode Ray Tubes). An additional 21” screen is used to visualize the *Controller window* in which the CAD models of the instruments for the virtual prototype are displayed. The visualization architecture of the Virtual Cockpit is depicted in fig. 2.

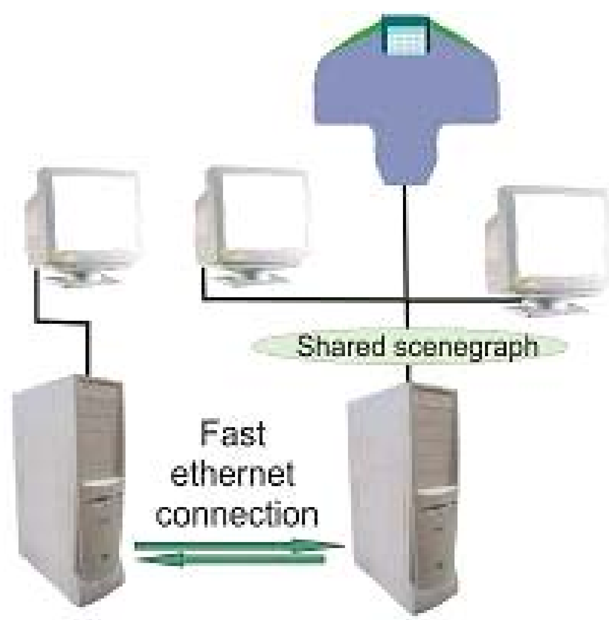

Figure 2: Visualization Architecture.

The Virtual cockpit interface is designed for two degrees of interaction. In the *Prototyping Mode* the user performs the positioning of the instruments in order to customize the aircraft cockpit. On the other hand, in the *Operating Simulation Mode* the user is enabled to interact with the instruments by the activation of commands. The symbology of instruments can be simulated allowing the functional aspects in the virtual cockpit to be evaluated. The passage from the *Prototyping* to the *Operating Simulation Mode* represents the evolution of the system from a Virtual Prototyping tool to a Virtual Operating Simulation environment.

The virtual pointer colour corresponds the activation of different events depending on the current mode according to the following scheme:

- Yellow: no event;
- Red: *Virtual prototyping* events;
- Green: *Operating* events.

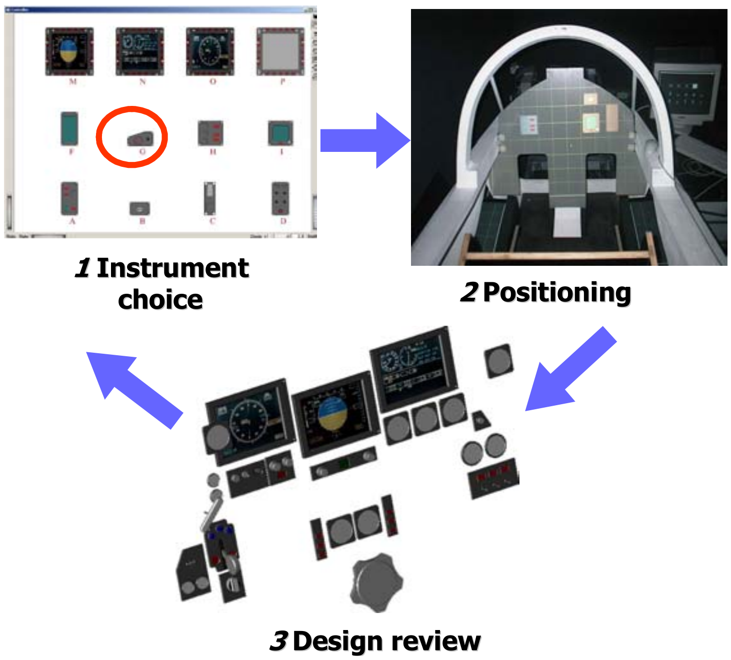

Figure 3: ***Virtual Prototyping Mode*.**

Table 1: Virtual Gloves Features

INPUT		Features
RIGHT HAND	Thumb/Forefinger	*Operating Simulation Mode*
	Thumb/Middle finger	*Prototyping mode*
	Thumb/Ring finger	Grid ON/OFF
	Thumb/Little finger	SNAP ON/OFF
LEFT HAND	Thumb/Forefinger	Select object
	Thumb/Middle finger	Delete selected object
	Thumb/Ring finger	Reset environment
	Thumb/Little finger	Save configuration

2.1 Virtual Prototyping

By means of the above devices, the user is asked to lay out his preferred cockpit configuration.

The Virtual prototyping tool starts with an empty cockpit. The first feature consists in the browsing a data-base of instruments. This data-base is composed by a set of instruments modelled singly in a CAD (Computer Aided Design) environment. The virtual model of each instrument is displayed in a VRML viewer and can be highlighted iteratively by pinching the thumb and the forefinger of the left hand.

Once the user has chosen the instrument from this selection panel, he can load it in the virtual panel and continue grabbing it until the release. This operation can be repeated as many times as the number of models one wants to load in the cockpit layout.

A previously released instrument can be selected again through a collision detection feature and grabbed to a new position. In order to assist the positioning of instruments, the software provides the use of some functions usually implemented in CAD systems. The first one is the GRID, which aids the user in the space-measurement correlation. Furthermore, a SNAP feature attracts the virtual pointer to the intersections of the grid. Instruments can be also deleted both one by one and by means of a total environment reset function. Once the user has defined an ergonomic layout, he can save the cockpit configuration.

2.2 Virtual Functional Simulation

The *Operating Simulation Mode* is the second degree of interaction. This mode is activated by means of the contact between the thumb and the forefinger of the right hand. In fig. 4 it is shown the passage from the *Stand-by Mode* (yellow) to the *Functional Simulation Mode* for the data input (green pointer). By means of a virtual interaction with the instruments their actual functionality can be verified. If a virtual button is picked by the pointer, the attendant action is simulated as it is in the real instrument. The selected instruments are consequently capable to perform the function for which they have been designed.

Figure 4: *Operating Simulation Mode* in Virtual UFCP.

For instance, the UFCP (Up Front Control Panel) operation logic in the virtual environment for testing the keyboard usability in the *Operating Simulation Mode* has been implemented.

Without the realization of real instrument prototypes, the pilot can evaluate the different sequences defined for the attainment of particular functions, suggesting new solutions for the achievement of the “optimum” procedure for data entry.

Indeed, the virtual instrument simulates in real time what happens when the pilot presses a button or which and how many buttons must be pressed to perform a task. In this way, once the UFCP is optimised via software in function of the usability tests results, a physical model can be realised.

Moreover, the pilot can return to the *Prototyping Mode* and configure the UFCP keys position on the keypad customizing the layout.

Another example of operation logic implementation is the modelling of the Multi Function Display MFD. Such completely analogical instrument conveys to the pilot a large and complex amount of data during the flight procedures. The requested data visualization is realized by means of different principal formats. The available formats are selectable by means of “soft keys” positioned around the MFD screen, as shown in fig. 5. In the Virtual Cockpit the pilot is enabled to construct and test the correlation between the keys and the formats.

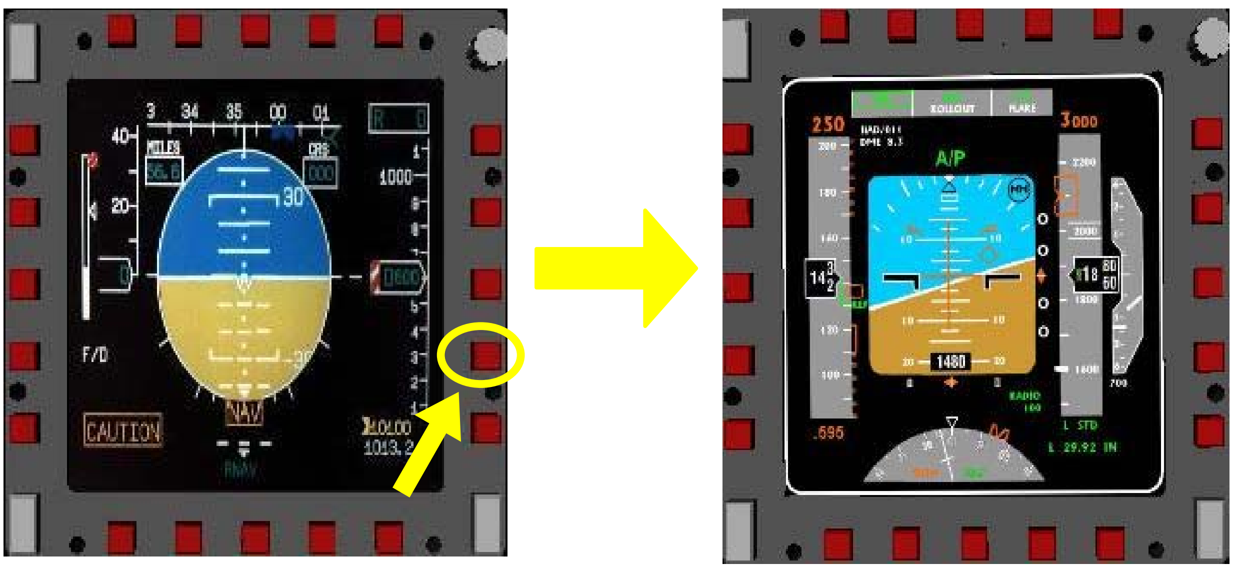

Figure 5: *Operating Mode* in Virtual MFD (Multi Function Display).

This system results to be a valid platform for ergonomic static tests reproducing not only the geometry of the aeronautic cockpit instrumentation, but also its functional behaviour. Indeed, the user estimates the clearness of displayed information on every single instrument or the overview of all the data managed from the system.

3.0 FLIGHT SIMULATION VIRTUAL ENVIRONMENT

The usability test is completed with the simulation of flight performed by means of a customized layout. The virtual cockpit has been thought to be integrated with large model visualization environment. Indeed, the cabin is positioned in the Virtual Immersive Room, as depicted in fig. 6, and connected to a simulation core.

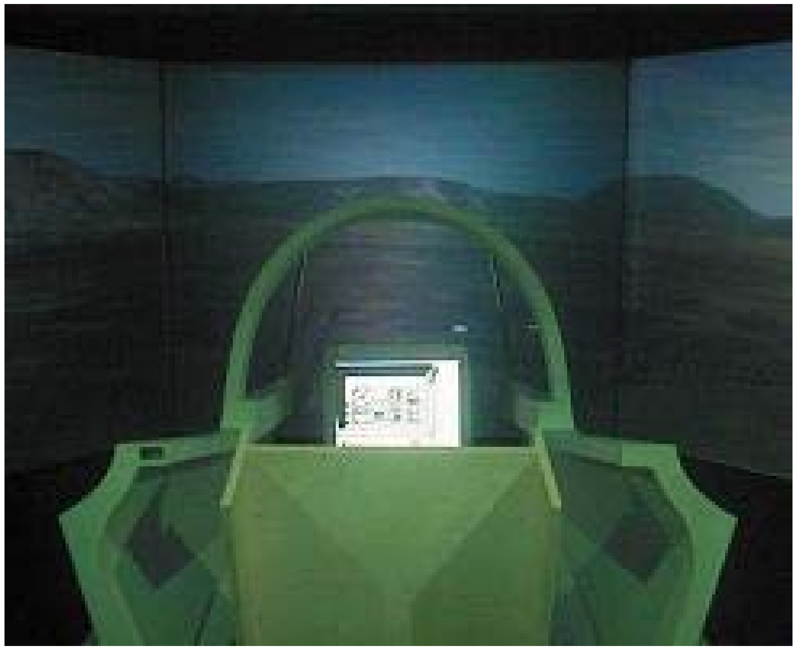

Figure 6: Flight Simulation Virtual Environment.

The advanced visualization system for the flight simulation is built on top of a master-slave architecture.

The master unit runs on the master computer, and has the following main functions:

- acquiring the joystick and/or virtual gloves input data, corresponding to pilot's actions;
- processing input data proceeding from the simulation core, in order to update the current flight data in real time;
- visualizing the instruments panel, updating the state or position of indicators;
- sending airplane position, attitude and other relevant data (such as "fog level" for instance) to the three slave units.

The three slave units have only visualization function. Each function generates the 3D images of the scenery in which the flight is taking place, as seen from the pilot's point of view. The position and orientation of the virtual camera are set according to the data coming from the master, which represents the six degrees of freedom of the aircraft. Nevertheless, each of the three slave units has to display a different portion of the surrounding world, in order to obtain both left, middle and right views. The overall system configuration is depicted in fig. 7.

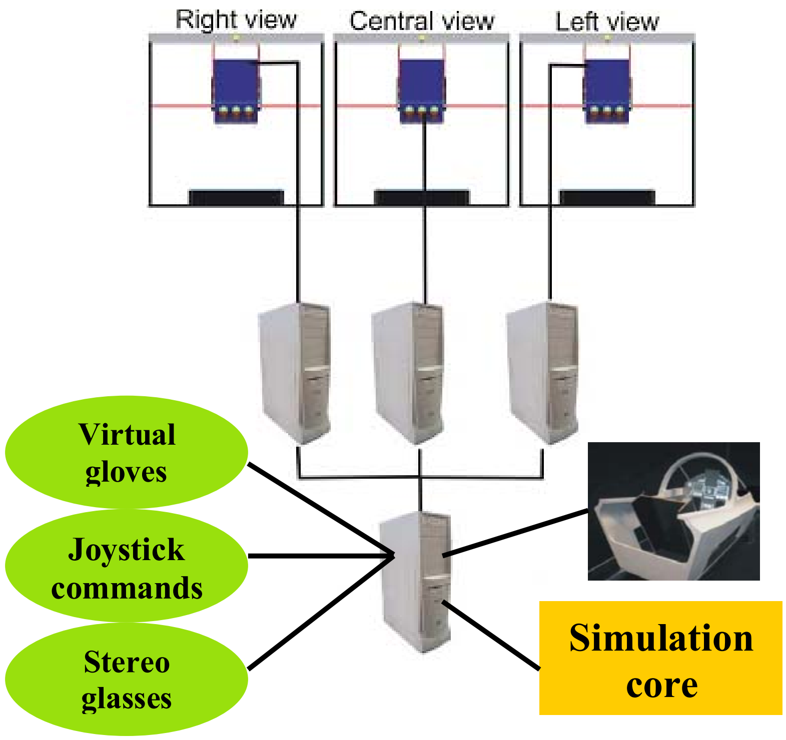

Figure 7: Hardware Configuration.

The *out-of-window* view provided by the integration of the Virtual Cockpit in the Immersive Room allows relevant results in terms of realism and reliability of simulation to be achieved. The efficiency of a layout can be measured during the flight simulation, by testing the accessibility of buttons and gouges or by checking the visibility of instruments. In the mean time the pilot is enabled to correlate the state of the flight displayed on the cockpit with the external visual. Hence, the evaluation of the ergonomics, the usability and the functionality of virtual panels takes into account his effective workload.

4.0 CONCLUSIONS

In this paper a user-driven interface for cockpit prototyping has been developed. The efficiency of this system depends on the integration between the prototyping and the simulation of a cockpit in a unique tool.

By means of this interface the pilot actively takes part in the design phase of the cockpit. In addition, a cockpit prototype is investigated from the human performance point of view.

High level graphics and interactive immersive virtual environments aid the pilot in the familiarization with novel concepts of aircraft cockpits. Furthermore, this system can be exploited for the evaluation of the effects of such formats of a cockpit display in terms of pilot workload, level of safety and situational awareness.

Acknowledgements

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