INSIDES – A new Virtual Prototyping Platform of Human Machine Interactions Systems for Automotive and Aerospace Applications

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Abstract: Human Machine Interactions Systems are decisive for the acceptance and the safety of new cockpits in the automotive as well as in the aerospace industries. A new design and simulation platform called INSIDES will be presented where virtual cockpit prototypes are being built based on 3D CAD geometry e.g. from CATIA and integrated with logical interaction data derived from UML specifications. This new development platform enables the continuous validation and check of new interaction concepts by involving usability engineers in the very early stage of the development cycle. Since the simulation work is being done in the context of the entire aircraft cockpit/car interior with all instruments, control commands as well displays devices a better validation of the HMI systems can be achieved.

1. Motivation

Human and machine interact (HMI) via a so-called human machine interface, which is influenced by several factors like the operating environment, both natural and systems-produced; the characteristics of the machine; and the performance of the human operator in the operational situation.

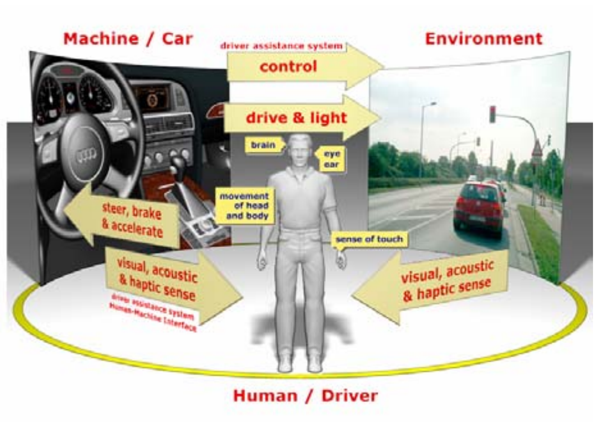

Figure 1: The tension field between human, machine and its environment

This circle of factors comprises a complex relationship involving plans, environmental quality, hardware technology, and human tolerance.

HMI in aerospace cockpits are essential to reduce pilot workload and to increase situational awareness in respect to the aircraft and its environment. In general aircraft cockpits systems represent a cluster of several HMI, which are linked together. Similar to the aerospace, HMI in car cockpits are becoming very important for traffic safety and the proper use of all kind of information offered trough telematic technologies.

This results in a complexity, which makes mandatory the use of virtual prototyping technologies to validate HMI systems in the very early stage of the product development cycle.

HMI developers in the aerospace as well as in the automotive industries recognise the need of design and simulation technologies, which take in account the global scope of the aircraft cockpit or of the car interior at a whole. It is not sufficient to simulate and to test single displays separately.

The current HMI tools on the market are only 2D based and cannot address these requirements. For the virtual design and simulation of complete cockpits concepts in a 3D environment based on UML logical data a new approach has to be developed.

Princess Interactive and the Chair of Information Technologies in Mechanical Engineering from the Otto-von-Guericke University Magdeburg (Germany) have conducted a study by using a new development platform for HMI design and simulation. For this project the A380 cockpit was rebuilt with CATIA version 5 to test the use of the new platform for aircrafts. The A6 car interior based on original CATIA geometry from AUDI was prototyped.

2. The Frontloading Process for the HMI Design

The early phases in the development of airplanes and automobiles are becoming more and more critical in achieving time and cost savings. The highest priority is however product quality and safety and the related processes. Cost savings and a concentration on “time-to-market” principles must still take a second rank versus to these main concerns. For this reason new development strategies are being used with more emphasis on concepts such as “frontloading”. In a very early phase of development, various virtualization technologies linked with full functionalities are used to test the physical properties in simulations. This process can partially replace the involvement of physical prototypes. Specially the implementation of nearly any kind of product functionalities scenarios will increase the use of the frontloading approach and amplify the degree of details and complexity for virtual prototypes [4], [5].

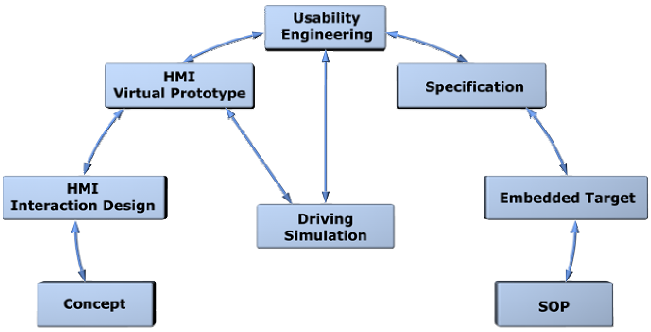

Figure 2: The HMI frontloading process in the automotive industry

The presented design and simulation platform for HMI is ideal for implementing the frontloading process. Since it has an open architecture and it can be linked with any high end technologies for visualization and simulation like VR/AR of driving and flight simulators. The new platform takes also advantage of the unified modelling language (UML) to describe logical behaviour. With its integrated code engine code is being generated for the targeted embedded systems. For further and in dept system validation the integration with the Rhapsody UML software has been developed.

3. The CAD modelling process

In the aerospace industry the mechanical design and CAD departments build the first model of new airplanes concepts in a digital manner by using a CAD system. Due the fact that no CAD data of the Airbus was made available to us we had no choice rather then to reconstruct the cockpit model entirely.

3.1 A380 cockpit geometry data collection

The goal of the study was to build 3D virtual prototypes based on CAD data in order to simulate the real workflow for creating HMI cockpit concepts in 3D. Because within the automotive and the aerospace industry the CAD software CATIA from Dassault is widely used, it was mandatory to have CATIA version 5 geometry. In the following it will be described how the CAD model of the Airbus A380 cockpit was generated.

The assembly of the A380 cockpit is based on several components (the armatures and the exterior surface cockpit, different switches and levers, seats etc.).These components contain a series of elements (features), which consist of different geometrical objects themselves, too. Since it was not possible to get original CAD data of the A380 from Dassault as mentioned before, the CAD laboratory of the Chair of Information Technologies in Mechanical Engineering from the Otto-von-Guericke University Magdeburg (Germany) had the challenging task to reconstruct this CAD geometry by using CATIA. The CAD-laboratory is well equipped with all the state-of-the art software and hardware technologies which are used in the industry today. To rebuild the A380 cockpit from scratch, one started by collecting information in paper and digital form which helped to produce the necessary basic drawings which represent the shape of the cockpit.

The input data like sketches and photos were found in various publications of several flight magazines (figure 3).

3.2 The modelling process

The so collected information was the starting point of the modelling process. For example pictures were scanned. Their contours were used to build the first forms of the cockpits components with the help of the tool “Sketch Tracer”. By using the scale function in this tool, the correct component proportions were defined.

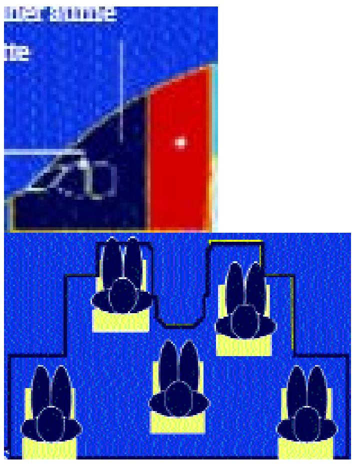

Figure 3: Illustrations of the A380 cockpit

The contour outlines from the pictures were generated and transformed into splines, which formed the base for the surface model (figure 4).

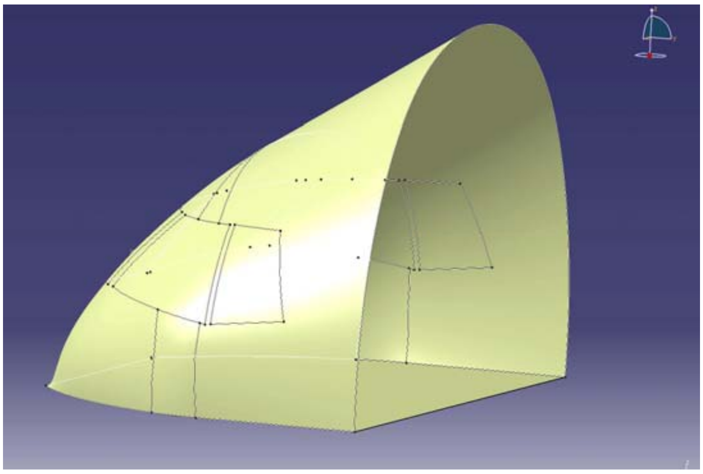

Figure 4: Generation of the surface model

Functions like e.g. filling surfaces, surfaces with multiple cuts, free forming junctions or free forming extrapolating were used for the creation of the surfaces. Finally, a solid body was created by setting an offset on top of the surfaces. The final result is the outer skin of the cockpit (figure 5).

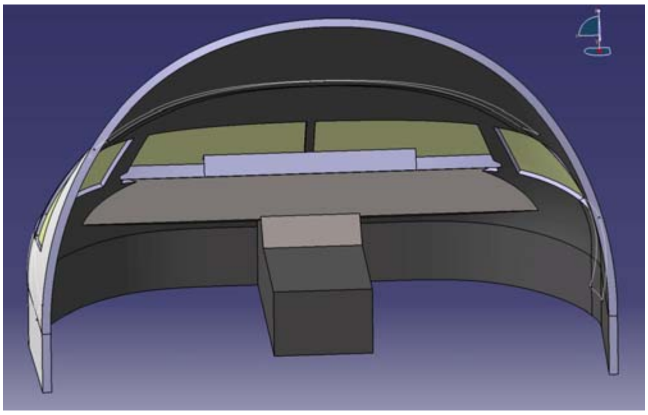

Figure 5: Solid body of the A380 cockpit

For building the cockpit interior photos were very helpful to understand the dash board and the instrument clustering. By using the extrusion tool the 3th dimension of the cockpit interior was generated.

Several iteration loops were necessary to reach the level of realism by letting new and recent pictures information converging with the final model. So at the end we were able to get the look and feel of the real A380 cockpit (figure 6).

The modelling task was fulfilled by using the CAD system CATIA version 5 to simulate the industrial design work, we wanted to present. The highlight of CATIA version 5 is its parametric capabilities.

With "parametric modelling" a design is developed from the beginning in such a way that isometric changes are accomplished later, simply by input of new parameter values [7]. The CAD solid model is for itself particularly suitably and thus supports the variants and change design. For example the different screen surfaces of the armatures were parameterised. If the position of a screen surface was changed, the other screen surfaces were adapted automatically. Moreover, it was meaningful to parameterise various switches and their positions. Thus fast different changes could be made.

During the parameterisation it should be paid attention that certain changes of the basic solid cannot be fulfilled, because different relations could be lost among themselves. Furthermore, CATIA version 5 is based on the "master model concept". That means that the base is always the CAD model. If design changes are made, then these are changed also in the assembly. Thereby, this saves the change effort in the assembly. This is very important within CATIA and helped to make changes and to optimise the final model which was the base in the following step for creating the HMI prototype.

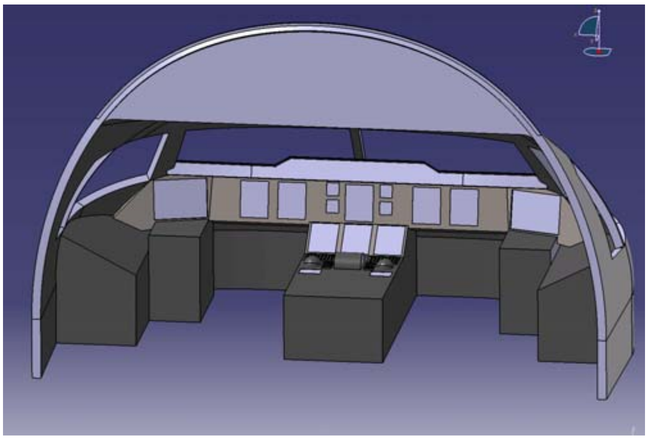

Figure 6: CAD model with the instruments locations

During the different iteration loops the HMI engineers from Princess Interactive were always involved. Weekly meetings took place with the CAD designers to discuss the cockpit model. This shows that a tight co-operation between these two groups is fundamental to build the appropriate model for the prototyping simulation. As a result the complete CAD model was generated as an assembly with all components and sub-components (figure 7).

Therefore the HMI design and simulation is a team work and cannot be seen as insulated process.

For this purpose the 3D functionality and the CAD compatibility of the new HMI platform INSIDES were absolutely necessary.

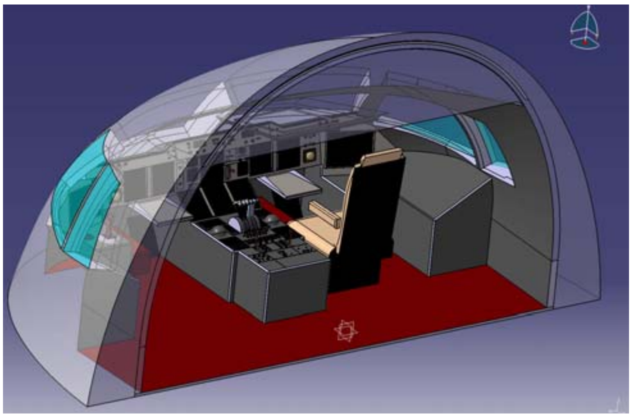

Figure 7: The complete CAD Model

3.3 The Audi A6 cockpit geometry

The geometry of the A6 cockpit was made available to Princess Interactive for demonstration purposes by the courtesy of Audi. This geometry data was delivered in CATIA 4 and 5 Format. This helped to validate the principles of the workflow, we are presenting in this paper as well

4. The HMI design process

HMI are essential for the safe operating of technical systems. Therefore the development of user friendly HMI is of great importance. The cockpit in modern transportation vehicles consists of several in- and output–components such as displays instruments, information systems, multifunction command devices, Head Up displays which are being integrated within a complex cluster. The design and simulation of this kind of system has to be applied on the entire aircraft or car interior to see the interaction and influence of all the components between each- other. Therefore a mixed 3D and 2D representation is necessary. Furthermore on the fully operational virtual prototype usability engineering will be concurrently conducted in the very early phase of the development process and not at its end. This is multidisciplinary task where executive managers, marketing and sales specialists, designers, electronic engineers like hard- and software programmers as well as psychologists and other partners or customers are involved. In this section the design process used in the study will be outlined.

4.1 CAD data preparation for virtual prototyping

For this purpose another tool, which is in the same time a CAD data acquisition tool as well as an optimisation tool, was used. With this software CATIA native geometry was imported and tessellated as well as level of details were generated. Also a very important feature of the tool called “Geometry filtering” was very helpful. This enables the elimination of all the internal parts, which are not relevant for the HMI simulation. The entire assembly of the geometry was structured in a logical scene graph. Material and textures were applied.

The so optimised geometrical model was then converted into the .PID format, which is the internal representation of the HMI design and simulation platform.

4.2 The HMI prototype

The optimised geometry is the first step for building a dynamic and fully operational HMI virtual prototype. It has to be well structured and must represent a systematic hierarchy, so single referenced objects as well as groups of objects can be handled separately. By using special tools within this new HMI simulation platform every single object or group of referenced objects will receive properties like movements (e.g. rotation or translation or a combination of them), appearance or textual information parameters. The assignment of this data will then be completed by setting boundary conditions to all parameters, which show, how they can be operated dynamically and specially interactively.

When all the reference objects are defined with their respective properties parameters their dynamic behaviour within the entire HMI cluster will be programmed. For this task, an hierarchical finite state machine will help by the definition and the deployment of all interaction scenarios which come from a detailed specification compiled by the system engineering people. The hierarchical finite state machine engine of the HMI design and simulation platform is completely graphically driven and is based on the principle of events, actions and transitions. The design of the HMI prototype is very modular. So each HMI display or HMI command device are represented by a single module, which carry on graphical and logical information and can be replaced, changed and enhanced or removed from the entire HMI cluster at any time. Also the separate modules can be designed concurrently at the same time by different people, which can work separately in different locations on the projects. The final HMI cluster can be assembled later on.

Figure 8: The A380 cockpit built with INSIDES

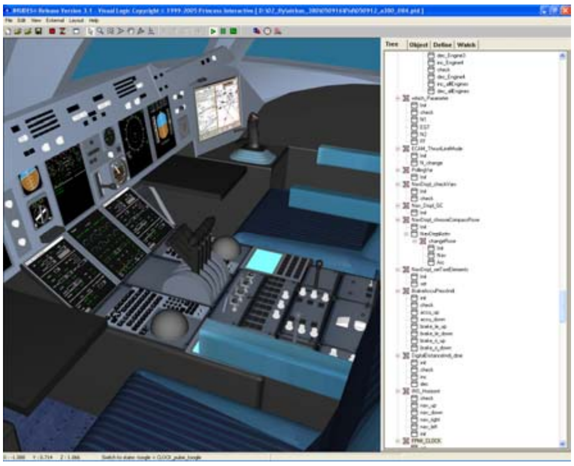

Figure 9: The A380 cockpit built with INSIDES

Figure 10: The A6 cockpit built with INSIDES

5. Simulation and Validation

After the first version of the entire prototype was finished, the simulation of the cockpit could be started. In this phase consistency checks of the HMI cluster as well usability studies were fulfilled.

Due the lack of time and financing only the tests were used based on the A6 cockpit. For this purpose several test benches were built.

The simulation in both benches runs under the Windows and Linux operating systems.

a) Desktop Test Bench

By using a graphical workstation and interfacing the the HMI Audi virtual prototype with a real steering wheel and the physical MMI haptic device one was able to conduct the first interaction checks. This was a very cost effective method to validate the HMI during the development cycle. It helps also to detect inconsistencies within HMI cluster.

b) Test Bench in conjunction with a virtual human model

The open architecture of this new design and simulation platform allowed the integration of the virtual human model "RAMSIS" which is widely used in the automotive industry. In this case two separate simulation environment were build and connected in real time together.

- *The real environment*

  This environment represents the test person, which is wearing the head mounted display and is being tracked by an optical tracking system. The test person is able to see and manipulate interactively with entire virtual cockpit.

- *The virtual environment*

  This environment describes virtually the entire 3D car interior of the A6 with all operational HMI devices and displays. Within this virtual environment the human model "RAMSIS" was put in place. It was completely synchronised with the real tester e.g. for hands actions and manipulations, which was possible by using data gloves.

This two environment are synchronised together in real time. Any action operated by the test person is being fulfilled by the human model RAMIS within the virtual environment. A series of interaction scenarios can be tested to validate new human machine interfaces in the car interior.

This test bench set up is very complex but allows to conduct usability studies when nothing real is available and can be used in the very beginning to back up the front loading process.

6. Code Generation

The new HMI design and simulation platform has a code generation engine, which generate separately graphical data as OpenGL or OpenGLES and logical information as C- or Java-code for embedded devices. For the study pure OpenGLES code combined with logical information has been generated and tested under a “Microsoft Windows” environment.

7. Future Development

The project has shown that 3D HMI prototypes are necessary to investigate complete HMI cluster within aircrafts or car cockpits. 2D based design and simulation are not enough. However the actual and new 3D based HMI software has to be extended with new features, which are already in development.

The following work is already in progress:

a) Integration of embedded systems from the beginning to test the performance of the HMI displays. For this case a flexible embedded environment will be worked out and proposed for users of the design and simulation platform INSIDES.
b) Integration of a specification methodology to allow the automatic generation of specification documents [1], [6].
c) Integration with well known UML Tools like Rhapsody [2].

8. Conclusion

The frontloading within the HMI design process is essential to reduce costs and time in respect to quality and safety. The actual 2D based HMI tools cannot fulfil the above requirements. Therefore a 2D and 3D combined approach is necessary. The new presented HMI design and simulation platform INSIDES could contribute to help the acceptance of this process. Also the study has shown that one can conduct interaction checks and usability engineering with very limited costs in the very beginning of the development cycle. This can have a very positive impact on the entire product development cycle in term of time and costs saving.

9. Acknowledgement

All the people involved in the success of this study have to be acknowledged for their contribution. It is important to mention the co-operation of Princess Interactive with the Chair of Information Technologies in Mechanical Engineering from the Otto-von-Guericke University Magdeburg (Germany), which helped to conduct this project at a very low cost budget.

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11. Glossary

HMI	Human Machine Interface
VR	Virtual Reality
AR	Augmented Reality
OpenGL	Graphical Standard initiated by SGI Inc.
OpenGL ES	Graphical Standard initiated by Khronos
RAMSIS	Human Model by Human Solutions Inc.
CATIA	CAD Software by Dassault Systems.
Rhapsody	Software by iLogix Inc.
INSIDES	HMI Design and Simulation Platform by Princess Interactive
SOP	Start of Production