Digital Mock-up database simplification with the help of view and application dependent criteria for industrial Virtual Reality application

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Abstract:
Aircraft cockpits are advanced interfaces dedicated to the interaction and exchange of observations and commands between the pilot and the flying system. The design process of cockpits is benefiting from the use of Virtual Reality technologies: early ergonomics and layout analysis through the exploration of numerous alternatives, availability all along the cockpit life cycle of a virtual product ready for experimentation, reduced usage of costly physical mock-ups.

Nevertheless, the construction of a virtual cockpit with the adequate performances is very complex. Due to the fact that the CAD based digital mock-up used for setting up the virtual cockpit is very large, one challenge is to achieve interactivity while maintaining the quality of rendering. The reduction of the information contained in the CAD database shall achieve a sufficient frame rate without degradation of the geometrical visual quality of the virtual cockpit which would alleviate the relevance of ergonomics and layout studies.

This paper proposes to control the simplification process by using objective criteria based on considerations about the cockpit application and the visual performances of human beings. First, it presents the results of studies on the characteristics of the Human Visual System linked to virtual reality and visualization applications. Illustrated by first results, it establishes how to control simplifications in a rational and automatic way.

Categories:

1. Introduction

A cockpit is a confined environment where a pilot interacts with a flying system.
The efficiency of this interface is linked to its quality (understanding of messages, accessibility to functionalities, visibility and readability, audibility, knowledge of the user...), and to its comfort (confined environment, vibrations).
The use of virtual reality improves the development process and the takeover of cockpits, traditionally based on physical mock-ups : on the one hand, it will support communications between different disciplines, and on the other hand, it will help saving time and money, by using digital mock-ups instead of physical mock-ups. It is important to notice that the goal of the Virtual Cockpit application is not to conceive a whole cockpit but to give support to the design and analysis of ergonomics issues.
The study of the ergonomics through virtual reality requires a digital mock-up (DMU) of the cockpit, real-time interaction and immersion. Due to the very high level of details of the DMU in industry, the real-time

constraint means often preparing and adapting the DMU database. But in the case of ergonomics study, this stage of adaptation must be done carefully, in order to keep the application useful for ergonomics, visibility and readability studies, by keeping a sufficient level of details of the database. The human user, the application, and the hardware used, must be then taken into account, in the development process of the database for the Virtual Cockpit application.

In this paper, in a first part, the Virtual Cockpit application will be presented through its goal and actual state. In a second part, vision criteria will be established through the study of the Human Visual System, and the needs of the ergonomics application in cockpits. In a last part, a short presentation of an advised method of reduction of the database for ergonomics and observation studies will be done.

2. The Virtual Cockpit Application

2.1. Context and goal

The Virtual Cockpit concept begins with technical specifications that allow the construction of the cockpit. The use of virtual reality is just an innovating tool that will improve the concept of ergonomics.
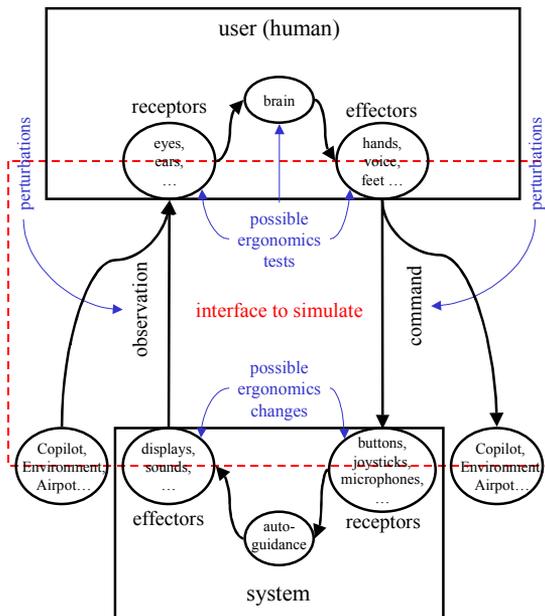

Figure 1: *The cockpit : an interface between the user and the flying system*

As mentioned in the introduction of this paper, a cockpit is a user/system interface. But the development and the takeover of this interface are complex and are supported by an organization of work between engineering specialists. Through this organization, the three main categories are mechanical engineering (CAD/CAM tools

and methods and physical mock-ups), system engineering (CASE/CAI tools and methods), and ergonomic engineering.

All of the interface functionalities (displays, auditive and visual signals, buttons...) are at sight or at hand for the user. In order to support ergonomic studies (i.e. readability, visibility and accessibility studies, lighting tests, tests of different configurations...), an interesting solution consists in simulating the pilot/real cockpit relation, which corresponds to the immersion, by using the avatar/virtual cockpit relation and the exchange of observation and command (see figure 1). The studies are then centered on this avatar/virtual cockpit relation, and will consequently conditioned different choices, like hardware choices (see section 2.3). The use of the avatar is very useful and adapted for the Virtual Cockpit application : in an ergonomic application, it helps to show which functionalities are accessible, which displays are in the field of view of the user by displaying around the avatar dynamic zones of accessibility and visibility.

The Virtual Cockpit will help to simulate and to provide model and information for ergonomics, but it is also a performing communication tool between different specialists working on the cockpit. It will then support concurrent engineering, work organization, marketing…

The goal of the Virtual Cockpit is to bring support on particular functions of the development process, which means simulate only particular parts of the cockpit and of the perturbations, in order to bring useful information to the different professions (see figure 2).
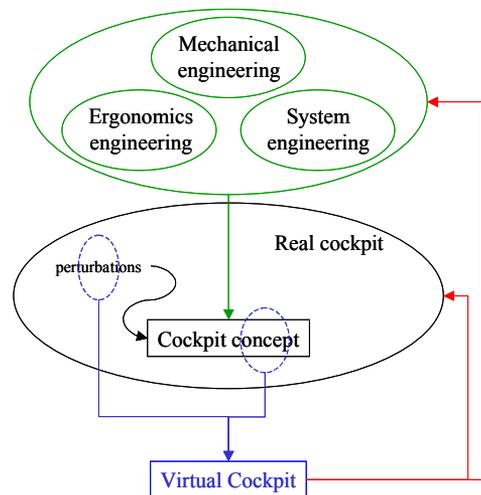

Figure 2: *The Place of the Virtual Cockpit in conception*

One advantage of the Virtual Cockpit is to reduce the number of physical mock-ups, which cost a lot of money. The Virtual Cockpit is also a modular interface that can be adapted to particular tests of ergonomics or first learning.

Its development, like any simulation problem, has a number of issues linked to it : the difference between the

real cockpit and the virtual mock-up (calibration problem), performances of the system (hardware and software problem), size of the DMU (design problem).

2.2. Hardware and software in the Virtual Cockpit

In this part, the application is presented in a more concrete way, with the help of descriptions of the hardware and software that lay behind the Virtual Cockpit.

As the application is centered on the avatar/virtual cockpit relation, the user has to be totally immerged in the virtual environment and perceptually substitute the avatar to himself. That is why CAVE-like systems or glasses are rejected and a Head-Mounted Display (HMD) solution has been chosen. The movements of the head, the hands, and the chest of the user are captured with an electromagnetic tracking system. It helps on the one hand, to generate images in relation with his head movement, and on the other hand, to animate an avatar of himself. The movements of the fingers of the right hand are captured with the help of a glove.

Figure 3: *The Virtual Cockpit application*

A simple wooden and plastic physical mock-up with real dimensions of the cockpit is used for many reasons : first, it enhances the immersion and interaction feelings when the hand hits the physical mock-up and the virtual hand hits the virtual mock-up at the same time ; moreover, it is very helpful for communication around this application to virtual reality novices. This mock-up doesn't have any details, only the shape of the interior of a cockpit.

2.3. Discussion

In the previous parts, the theory and the experimental aspects of the Virtual Cockpit application have been presented. In this one, the practical side of the implementation is discussed. Although two main characteristics for ergonomic study (observation and command, see figure 1) have been identified, only the first part will be discussed in this paper.

One of the main need for ergonomic studies for cockpits is the visual quality of the virtual mock-up. It shall have: a high "spatial and geometrical" visual quality, which means that the user must be able to read characters or to recognize functionalities for instance ; and a high "temporal" visual quality, which means a sufficient frame rate for the application. These two aspects of the visual quality are directly linked to the immersion of the user in the virtual environment, but also to the needs of the ergonomics studies.
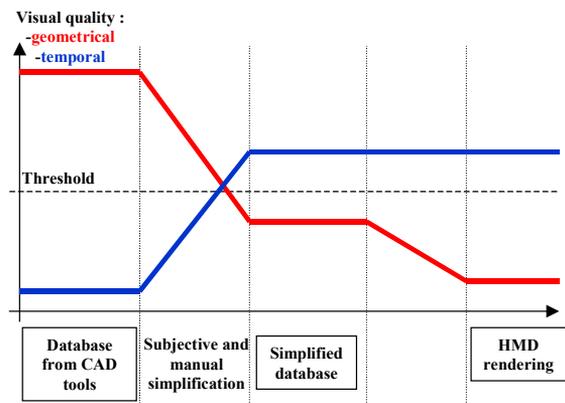

Figure 4: *Influence of subjective and manual simplification of the database on the visual quality*

But, in the industrial context, database to be tested are coming from the CAD/CAM tools and are highly detailed. Therefore, these databases are often unusable for real time application. However, it is still possible, by keeping only data useful for the application, to reduce the details of the database, and to obtain a real time application.

But today, most of the time, these simplifications of the digital mock-up are subjective and manual. Objects are deleted and reduction is imposed by technicians until the desired frame rate is reached. Consequently, the application becomes real time, but the spatial and geometrical visual quality is severely damaged.

Moreover, the visualization system will increase this loss of visual quality, because of its poor resolution and field of view.

There are two important consequences from the industrial point of view, due to this method of simplification : the first one is the loss of geometrical quality, and the second one, a very long time of reduction of a database.

Figure 4 sums up the stages of the preparation and rendering of the DMU database : temporal visual quality should exceed the threshold (30Hz) to allow a real-time application ; and spatial visual quality should exceed the threshold to reach a good visual quality of the environment.

Moreover to reduce such a database as a cockpit DMU, necessitates weeks when it is done by specialists. As digital mock-ups in industry are evolving everyday,

time to update the virtual cockpit must be as short as possible.

This analysis helps to determine two problems : the need of reducing the database in an objective (based on human and application considerations and needs) and automatic way, but also, the need of an adapted visualization system hardware. Figure 5 shows the ideal preparation of the database.
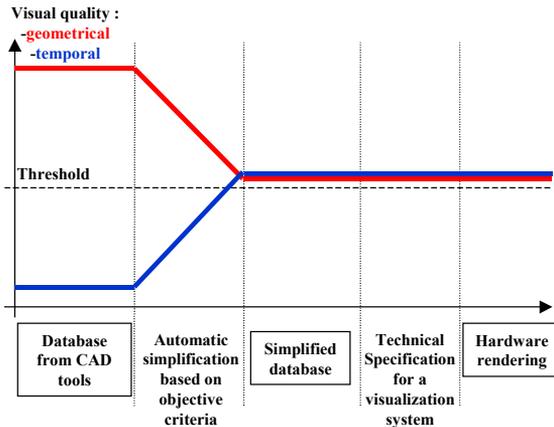
Figure 5: *Preparation of the digital mock-up database with objective and automatic criteria*

3. Vision criteria

This part presents our study of the Human Visual System characteristics linked to cockpit ergonomics, and virtual reality. Therefore, it is not the clinical point of view of human vision, but the ergonomics one that is taken into account.

First, the main characteristics of the Human Visual System are described and modeled. Then, the model obtained is modified with the Virtual Cockpit application considerations ; at last, a discussion on the limits imposed by the visualization hardware and the results is proposed.

3.1. Vision criteria linked to the human user

Field of view and visual acuity are the two main characteristics for our virtual reality application.

The field of view represents the part of space visible by the eyes. The human field of view is around 200 degrees horizontally, and 135 degrees vertically [Art00].

Visual acuity is our ability to perceive details, and therefore is responsible for spatial and geometrical visual quality appreciation. It is very dependent on several factors, like the field of view, the luminance, the contrast, or the movements. The repartition of the receptors (cones and rods) in the retina are the major cause of these dependences. Cones are receptors placed in the fovea (part of the retina which corresponds to the line of sight). They allow a precise visual acuity and color vision, are sensitive at mid and high luminances

(indoor lighting or daylight). Rods are found more in the periphery of the retina. They are less precise and do not allow color vision, but are far more sensitive to contrast, luminance and movements than cones [KL03] [Sch99].

The contrast is very linked to visual acuity. Figure 6 represents the Campbell-Robson test for Contrast Sensitivity. It shows a sinusoidal pattern of white and black lines, with an increase of the frequency when going from left to right, and an increase of the contrast when going from up to down. As frequency is related to the size of the smallest detail perceivable, it is possible to determine the limit of visual acuity with the contrast, by identifying when the pattern is perceivable or not. Moreover, it has to be known that the periphery of the field of view is more sensitive to contrast changes (and then movements), due to the presence of rods [Sch99].
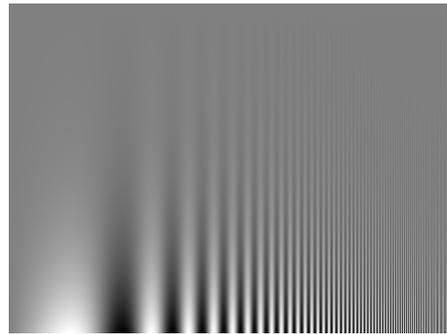
Figure 6: *Campbell-Robson test for Contrast Sensitivity*

For luminance under 0,005 cd/m² , human vision is in scotopic vision which corresponds to the night vision, where visual acuity is very low, because only the rods are active. The periphery of field of view is more sensitive at this low luminance than the fovea vision, for the same reason.

For luminance higher than 3 cd/m² , the vision is said photopic, which corresponds to indoor lighting to sunlight. In photopic vision the visual acuity is the best.

In test conditions, an increase of the luminance from 0,1 to 3000 cd/m² makes the visual acuity increases linearly from 5/10 to 20/10. After 3000 cd/m² , visual acuity remains approximately constant until 10^7 cd/m² where damages in the retina appears [KL03].

In our Virtual Cockpit application, we are simulating different lightning ambiances (day, night, spotlights…). As the best visual acuity is obtained for daylight, and as this kind of ambiance is part of the ones simulated, we can keep these values of luminance for criteria. Level of details, depending on luminance could be used, but they would not bring sufficient support to the application, because the highest level of detail with daylight will have to be generated as fast as the poorest level with nightlight.

As seen earlier, because of the repartition of cones and rods in the retina, the field of view has a strong influence on visual acuity; this last one is far better in the center of the line of sight (fovea vision) than in the periphery (just try to read this paper without moving the

eyes !). Rovamo and Virshu have determined an equation describing the influence of eccentricity in the field of view on visual acuity, based on clinical observations of the photoreceptors in the retina. Martin Reddy has given a correction after some experiments [Red97] :

$$M(e) = \begin{cases} 1 & \text{where } e \le 5{,}79° \\ \dfrac{7{,}49}{(0{,}3e+1)^2} & \text{where } e > 5{,}79° \end{cases}$$

where e is the eccentricity in any direction, expressed in degrees, and M the normalised factor of reduction of the visual acuity. This equation strongly decreases from 0° in any direction. Therefore the fovea vision is very small. These results are very interesting for virtual reality applications. As human beings perception is not equal on the whole field of view, virtual objects can have different level of details : the more detailed level would be presented in the line of sight, and, the more the object would go far away from it, the more its level of detail would be low. Such a solution will allow to save much time of calculation without influencing perception of the user.

Only few points have to be observed with attention. As seen earlier, rods are very sensitive to contrast changes [Sch99] and movements (which are local contrast changes). In consequences, a change of level of details in the periphery of the field of view will be noticed by the user. He will not be able to distinguish if the geometrical quality of the object is enhanced or not, but he will notice its change from a level to another. A solution of progressive mesh seems then more appropriate than pre-calculated levels of details.

The second point is the influence of shape or silhouette recognition. Human beings have abilities to recognize and memorize some characteristics very precisely. For instance, the memory of human face is very sensitive. The silhouette of an object is very important for human vision, and it has to be treated carefully, particularly when using levels of details or progressive meshes [Lue98].

Except for very slow movements, the more an object moves, the more visual acuity falls off. It can be a decrease locally on the object, or everywhere if the eyes are moving. Martin Reddy has proposed a formula to model visual acuity (in cycles per degree) in function of velocity (v) [Red97] :

$$G(v) = \begin{cases} 60.0 & \text{where } v \le 0.825 \deg/s \\ 57.69 - 27.78 \log_{10}(v) & \text{where } 118.3 \ge v > 0.825 \deg/s \\ 0.1 & \text{where } v > 118.3 \deg/s \end{cases}$$

By multiplying the functions $M(e)$ and $G(v)$, a model of visual acuity (in cycles per degree) is obtained, taking into account eccentricity and velocity in the visual field of view, at good conditions tests of luminance and contrast. Figure 7 represents this model for a very low

velocity, in comparison with the field of view. In this case, the peak at 100% corresponds to 60 cycles per degree, i.e. 20/10 on the European visual acuity chart, or the Snellen chart. In green, the part of the left eye field of view, and in red the part of the right one are represented. The yellow corresponds to the overlap (part of the field of view covered by the two eyes).
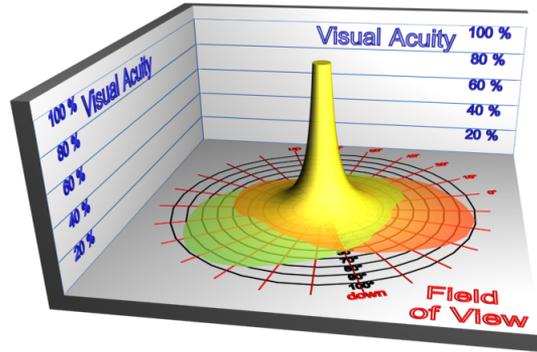

Figure 7: *Human visual acuity and field of view in good test conditions*

This model is centred on the line of sight. Another solution consists in using the head direction as centre. In this case, the peak of the model is no more aligned with the line of sight. This representation is interesting because more appropriate to the vision modelling when using a Head-Mounted Display (like in the Virtual Cockpit application) or with any system using head tracking. They are different types of eye movements, with different speed and amplitude (up to 45° eccentricity in all directions) : saccades (quick movements of any amplitude in order to scan continuously the scene without taking care of it), fixation (keeping the eyes on a fixed target), and gaze movements. These last ones are the more natural movements and are the combination of head and eye movements. When a target appears in the field of view, human beings move first the eyes, and then the head to compensate [GvO97]. Actually, in the major Virtual Reality applications, head tracking are used, but not eye tracking. Then, if the model of the figure 7 is used for the definition of level of details, the user will often look in zones where objects are geometrically degraded. Using the assumption that in natural movements, the eyes direction compared to the head are rarely higher than 20° in any direction, a good solution consists in modifying the model by enlarging the peak of 20° in all directions (cf. Figure 8).

3.2. Vision criteria linked to the application

The model presented in the last part can bring support to the simplification of huge industrial digital mock-up database. But, the previous simplification might not be

enough, and moreover, the geometrical visual quality allowed, is still too high for most of applications.

Using the case of the Virtual Cockpit, we show how these criteria can be modified in order to be more restrictive.
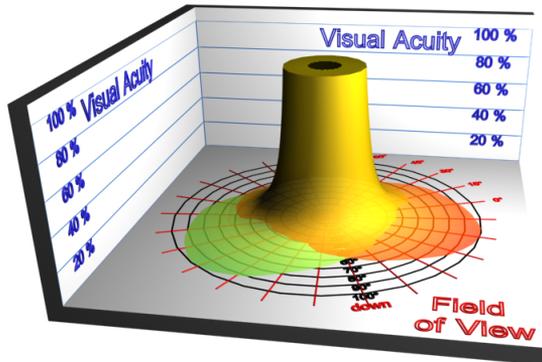

Figure 8: *Human vision model taking into account eye movements*

Firstly, the whole field of view is not often necessary for virtual reality application. Arthur has studied the influence of the field of view on user performance during different tasks [Art00]. He has noticed a decrease of performances for navigation tasks or search tasks. In the case of a Virtual Cockpit application, navigation tasks have a very low importance.

Related works on cockpit applications [Sch00] [KHS*97] reach all the same conclusions : there is an improvement of performances for all kind of cockpit tasks when the field of view increases until it reaches 80°; for a field of view higher than 80°, there is no improvement of performances but users prefer larger field of view for their own comfort. Authors of these papers all advise to use a field of view of 80° horizontally. This field of view is sufficient for a one pilot application, but becomes insufficient for a two pilots application.

Concerning visual acuity, the main vision constraint in a cockpit is linked to the size of characters to read on displays. Taking into account all characters from the pilot point of view, a visual acuity of 6/10 is sufficient for Virtual Cockpit application.

Knowing these application conditions we can determine a new model, less limiting than the human vision model established in the previous part. This model, represented in figure 9, represents the exact needs in vision for the Virtual Cockpit application, taking into account, the Human Visual System, and the application itself. The model established is centered on the head position and orientation.

Knowing exactly the application to realize, it is possible to define more criteria. In the case of the Virtual Cockpit application, like other command or driving applications, the user's head positions and movements are well known. They can be summarized with visualization

vectors [PMN*03], where the origin correspond to a given position of the eyes in the digital mock-up, and the direction to the line of sight. Figure 10 shows some visualization vectors for a person sitting on a chair. This knowledge will bring support during the preparation of the digital mock-up database.
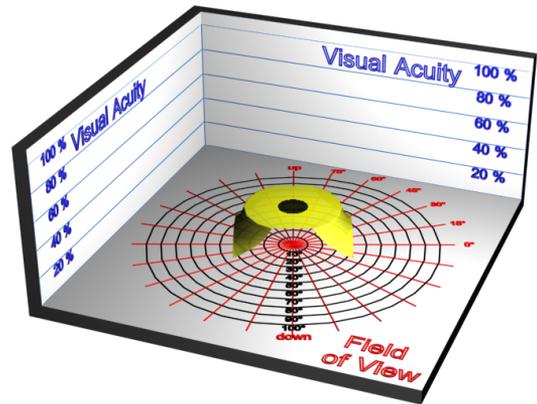

Figure 9: *Vision criteria for a Virtual Cockpit application taking into account human vision and the application itself*

3.3.   Discussion

In conclusion, we have seen in this part, different levels of criteria : a model based on the human vision, a second one on the application. With these criteria, we have defined another application influence represented by visualization vectors.

The first model is based on the human vision (figures 7 and 8) and is then linked to the perception. It takes into account: contrast, luminance, field of view, visual acuity, eccentricity, velocity… A simplification using the criteria from this model would not change the perception of the user, which means that the environment before and after simplification would "look" exactly the same to the user. Only the "useless" (in terms of vision) polygons would have been changed or deleted. The first model can be used for every application.

The second model is based on a particular application (figure 9 in the case of the Virtual Cockpit). It takes into account the necessary conditions of visual acuity, field of view… It acts like a filter over the previous model. A simplification using this model would change the perception of the user, but would not degrade his performances or interfere with the application. It would keep the necessary precision and details for the application. Only the "useful" (in terms of vision) polygons would have been kept. These application criteria have to be defined for every application.

The two kinds of criteria presented above are centered in the head referential : they are valid for a given position and a given orientation. That is why we use

visualization vectors : they are records of certain position and line of sight of the user for a given application. But it is important to notice that images, after being generated by the computer graphics hardware, are displayed by the visualization system. Today, there are few or no display able to display images allowing a field of view of 80° horizontally, with a visual acuity of 6/10. The vision criteria must then be adapted to the display, because a deeper simplification can give the same result when displayed on a poor visualization system [CNM*03].
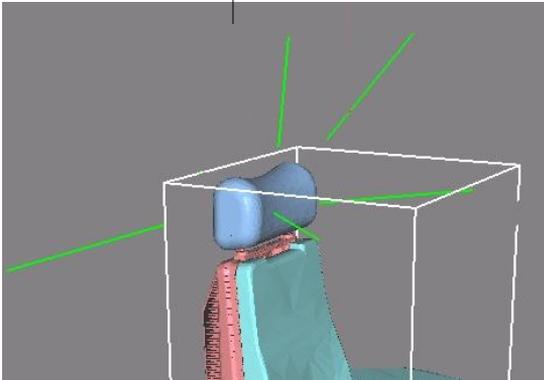

Figure 10: *Visualization vectors linked to the application*

But a more active approach consists in defining a Technical Specification for new displays with these vision criteria.

4. Database simplification method

As presented in the first part, in an industrial context, DMU databases are often huge, and non adapted to real-time applications. They are too big and/or too precisely defined. At EADS, this issue is well-known : for instance, an aircraft digital mock-up represents more than 15 millions of polygons. CAD databases are usually done by specialists with different methods and manually ; therefore, databases may be topologically different. They contain very large models of objects and very small ones, very large polygons and very small ones in complex and confined assemblies.

A simplification of the database has to be done. However, simplifications are very complex and difficult to control. Moreover, they are barely automated, and necessitate additional "manual" simplifications (like low polygonal re-modelisation). At last, they are not based on studies or criteria linked to the application, and therefore are not always adapted to it.

This part does not deal with simplification algorithm, but only with the method to establish in order to prepare an industrial digital mock-up database in a rational and automatic way, for ergonomics or project review application. As mentioned earlier, the proposed method concerns only geometrical characteristics of the database.

Our method proposes the use of levels of details of objects, and is made of two steps : the first one, called the "static simplification", is the definition of the more detailed level of each object, before the beginning of the application, with the help of the vision and application criteria ; the second one, called the "dynamic simplification", is the use of dynamic changes of the tessellation during the application controlled by the criteria.

4.1. Static simplification to prepare the application

Data come from CAD tools. The tessellation of these data induces a loss of geometrical quality. The first step is then to find the more appropriate tessellation for each object, or with other words, the highest level of details that will be used in the application for all objects. It is possible to separate it in two tasks : deletion of invisible parts, and the choice of the tessellation of the visible parts.

For this, the application must be taken into account : knowing the visualization vectors, parts that will never be seen by the user, can be found and deleted [PMN*03]. In the second task, the highest detailed level of the object can be determined by finding the maximum estimated visual acuity during the application (i.e. the shortest distance between the objects and the eye, and/or the shortest eccentricity…) with the help of the visualization vectors and the vision model. Then, knowing the maximum visual acuity on an object or part of an object, the tessellation can be adapted, by relating visual acuity and characteristics of the tessellation. We are currently testing which characteristics are best suited: for instance, distance between two vertices, screenspace error, geometrical error between two meshes…

As we can see, these parts are very dependent on the application and the use of the visualization vectors. These last ones are very useful, because after their generation, the deletion and the tessellation are automatic. The visualization vectors are defined knowing how the application is going to be used, or they can be defined dynamically by recording the user movements during the application. The vectors can then be updated every time the application is running and this static simplification updated for the next time the application will run.

It is important to notice that in industrial applications, there is a huge number of objects. It is better if these simplifications are done for grouped objects or even the whole scene, and in particular for static objects. For instance, in a cockpit, many objects are totally static. If the scene is simplified object by object, the number of parts deleted will be lower than if the scene is treated as a whole, because objects are hiding each other.

4.2. Dynamic simplification during the application

The studies about vision criteria have shown that a variation of level of details depending on several factors (distance, eccentricity, velocity, luminance...) seems well adapted to the need of simplification, without loss of perception quality.

In the second step, there are further possibilities : the use of discrete levels of details [LRC*03] (pre-calculated), the use of progressive meshes [Hop96] or vertex tree [Lue98] (both calculated in real-time with the help of an organization of the different vertices...), the use of normal maps [CMR*99] (textures where the coordinates of the normal of the faces are recorded in order to simulate details on a very simplified object).

In the following, we discuss these three possibilities, and then we explain which method we have chosen for the dynamic simplification during the application. The idea is to generate in an automatic way, levels of details depending on vision criteria, like distance, eccentricity [Red97], velocity, silhouettes [Lue98][WLC*03], illumination [XV96] [WLC*03].

In the first case, we propose to use a discrete number of levels of details. For instance, if an object lies in the visual field with an eccentricity lower than 25°, its highest level of details is used, lower than 35° the second level of details is used, lower than 60°, the third one etc... This method presents some disadvantages. As seen earlier, human beings are very sensitive to movements, and contrast changes : the switch between two levels of details can then be annoying. Moreover, very large objects (like terrain, or the envelop of the cockpit) are inadapted to this method : using for instance the criteria of the influence of the field of view on visual acuity (eccentricity), a very large object will always be in its highest level of details, because there will always be a part of it in the line of sight. Then, large objects have to be cut, which has often to be done manually and is not precise. Small objects (like screws) are going to have each their own levels of details, but it will be far more simple if they were grouped together or with larger objects. Discrete levels of details are not the good solution for industrial virtual reality applications.

The use of progressive meshes [Hop96] or vertex trees [[Lue98] can be a first solution for the issue of the switch between two discrete levels of details, and are very well adapted to the vision and application criteria. The influence of vision criteria would be continuous, by a reduction or an enhancement of the number of vertices of an object when it has to be more or less precise [Hop97][Lue98][EV99][LT00][DP02][ILG*03]. Vertex trees and progressive meshes are based on the vertex merging method where two (progressive mesh) or several (vertex tree) vertices are merged into a single vertex in order to reduce the number of vertices and triangles. The inverse transformation is possible too : one vertex can be split in two (progressive mesh) or more (vertex tree) vertices. The mesh or the tree is prepared before the running of the application. Using the vision and application criteria at each vertex, allows to consider not only the object but also part of objects. This

is very useful for big objects, which can therefore be simplified locally, depending on the line of sight of the user. It can also be used to keep details on the silhouette of the objects. With this approach, the scene can even be considered as one object. Figure 11 sums up the approach in the case of the Virtual Cockpit.
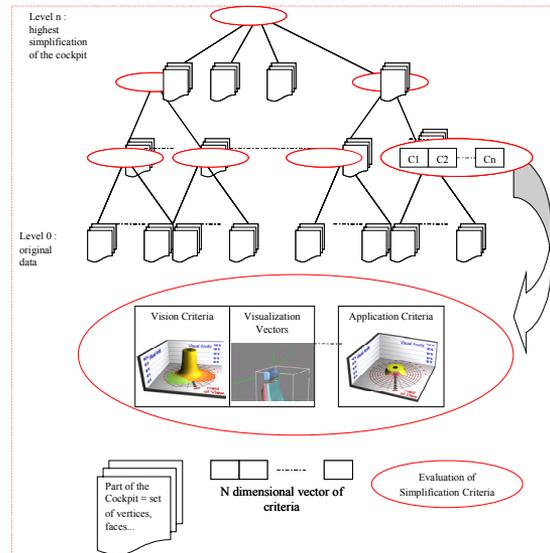

Figure 11: *Use of a vertex tree or progressive mesh approach for the dynamic simplification of the Virtual Cockpit*

The last solution consists in the use of normal maps in order to considerably reduce the number of polygons, by replacing the geometry with an enhanced texture, during the rendering of the objects [CMR*99][COM98]. A normal map is a texture calculated with a geometrically detailed object, where every texel encodes the normal of the point associated on the detailed surface of the object. Then, by applying the normal map on a very simplified version of the object, and using the information contained in the texture for the calculation of lights and shadows, we can give the impression of a detailed object. This solution has some disadvantages : for a given point of view, the extruded parts can never "go out" of the silhouette (remember the normal map is a texture !), which is an important vision artifact; the user can not turn around the object. Although these important disadvantages, this solution seems very interesting for industrial application and particularly for virtual cockpits. Actually, the user will look at the different functionalities and displays during the application. When he is sitting, he always sees objects with almost the same visualization vectors. He is not going to turn around objects. Moreover, the geometry of all the buttons is very complex and well defined, but usually, it is not much extruded : there are mostly buttons that have to be manipulated by fingers, and reparted on a rectangular plane (panels). Normal maps seems very appropriated for representing these functionalites : with

only two triangles (a plan) and a normal map, the user could see different buttons in three dimensions.

We have held back the two last methods for dynamic simplification. We then advise to use the vertex tree or progressive mesh approach, except for small objects not much extruded and placed on a plane, like a numeric keyboard for instance, where the use of normal maps is much more suited. The vision and application criteria will then be active at every vertex and in the definition of the normal maps.

4.3.   Review of the proposed method

Our method is made of two steps : the first one aims at preparing and keeping what is useful for the application, before it is running ; the second one aims at simplifying the scene at a given time for a given point of view of the user, during the application.

By using the visualization vectors linked to a particular application, the parts that will not be visible during the application are deleted, and so this simplification does not have any consequences on the user perception. In order to define the highest detailed models of objects, we use the visualization vectors, the vision criteria, and the application criteria : in the case of the vision criteria, the user will not see any change of the mock-up ; in the case of application criteria, the scene will be degraded, but it will not interfere with the user performances in this particular application. These simplifications are said "static" because the obtained mock-up will not change with user movements, and because they are done before the application runs.

In the second step of the simplification, the visualization vectors and the vision and application criteria are used once again in order to simplify in real time the scene, using the vertex tree approach and normal maps. The user will control these "dynamic" simplifications by moving his head, without taking care of it.

4.4.   Results

In this part, we present the first results of this method on the deletion of invisible parts. For this, we have used the works of Institut Image presented in [PMN*03]. Defining visualization vectors have necessitated less than thirty minutes for a novice, and less than twenty minutes for the application to delete 75% of the Virtual Cockpit database. When the user stays in the zone defined by the visualization vectors (i.e. around the pilot seat, see figure 10), he can not see any changes of the mock-up because there has been no changes of the geometry of the objects in his line of sight.

This method has two main advantages : first, it allows a very quick simplification without any loss of visual quality ; and it improves considerably the automated process of industrial digital mock-up database simplification for virtual reality applications. In figure 12, we can see front panels, in the first case, seen with a line of sight near of the visualization vectors, and the second case, very far of them.
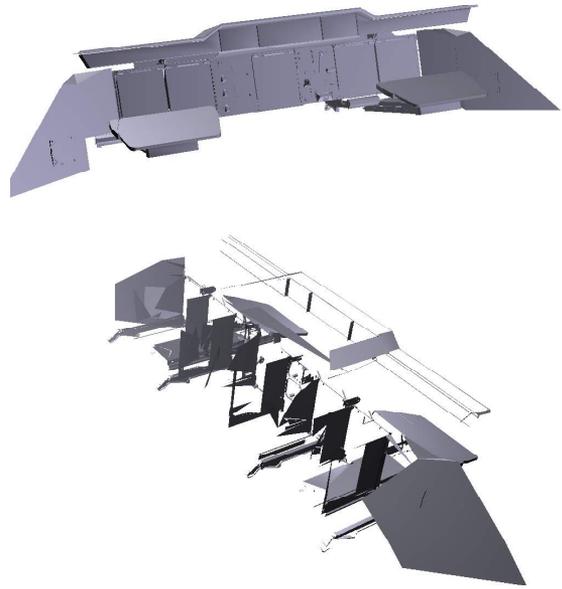

Figure 13: *Simplified objects of the Virtual Cockpit with the invisible parts deletion application with the method explained in 4.4. Up : the line of sight is near the visualization vectors ; down : the line of sight is very far the visualization vectors*

5.   Conclusion and future works

We have presented in this paper, the issue of the use of Virtual Reality in industry, for Virtual Cockpit application. But we have also seen that a lot of aspects inherent to the CAD industrial databases make the preparation and simplification of the digital mock-up data into virtual mock-up data difficult. We have proposed in this paper a rational and automated preparation and simplification process of the database. It is rational because it is based on the human visual performances (vision criteria in part 3.1) and the application needs and particularities (filter of the vision criteria and visualization vectors in part 3.2). The simplification process is proposed in two parts, and uses the defined cirteria : a static simplification, which prepare the more detailed definition of the mock-up before the application is running ; and a dynamic simplification which simplifies the scene during the application in real-time, based on the user line of sight. We have proved the efficiency of this method with first results (see part 4.4).

We are going to work on extensions of the method : multi user approach, functional considerations of objects for their simplification, interaction considerations.

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