View and Application Dependent Simplification Of Digital Mock-ups

Marc Chevaldonné (1, 2, 3)
marc.chevaldonne@eads.net

Marc Neveu (1)
marc.neveu@u-bourgogne.fr

Frédéric Mérienne (2)
frederic.merienne@cluny.ensam.fr

Nicolas Chevassus (3)
nicolas.chevassus @eads.net

François Guillaume (3)
francois.guillaume@eads.net

1 : Université de Bourgogne
UFR Sciences et Techniques
Aile de l'Ingénieur – BP 47870
21078 Dijon Cedex France

2 : Institut Image
2, rue Thomas Dumorey
71321 Chalon Sur Saône
France

3 : EADS-CCR
12, rue Pasteur, BP 76
92152 Suresnes Cedex
France

ABSTRACT

The use of virtual prototypes during the industrial design process of advanced human machine interfaces, like aircraft cockpits, brings competitive advantages: the development of virtual prototypes is cheaper and faster than the development of physical prototypes; virtual prototypes support early ergonomics studies and layout analysis and can be easily enhanced all along the design and development processes.

Nevertheless, the preparation of a virtual prototype is not so easy. In industry, digital mock-ups come from CAD/CAM environment, and thus, are highly detailed. The most important challenge is then to achieve interactivity while maintaining high visual quality and fidelity.

Through the example of the Virtual Cockpit application, we present how to reduce and simplify the geometrical information of the database, in order to achieve a sufficient frame rate without degrading the geometrical visual quality. These simplifications are controlled by objective criteria based on human and application considerations.

Keywords

Virtual Reality, Virtual Cockpit, Level Of Details, Progressive Meshes, Simplification.

1. INTRODUCTION

A cockpit is a complex interface between a pilot and a flying system. Its efficiency is linked to its quality to ergonomics and to its comfort.

In order to produce an efficient interface, it is necessary to test it soon and often during the design process. That is why prototypes are needed. But the traditionally used physical mock-ups (PMU) are costly and slow to prepare. Knowing that the design of a cockpit evolves every day, another less complicated approach consists in using Virtual Reality tools: a virtual mock-up (VMU) is created from the digital mock-up (DMU), and is faster to prepare, and far much cheaper.

But VMU are not simple to prepare: for instance, in order to test the cockpit through ergonomics studies, the VMU must be able to offer the user a good visual quality and interactivity. Unfortunately, in the case of the use of Virtual Reality tools, these two characteristics are opposite: the more the VMU is detailed, the slower the application is, and vice versa. As DMU, coming from CAD/CAM design, are highly detailed, a work of preparation and adaptation of the VMU must be done in order to achieve a sufficient frame rate to guarantee interactivity. If the simplification of the DMU is based on human (visual acuity, field of view...) [CHe04a] and application (line of sight during the application) [Pai03a] criteria, it seems possible to significantly reduce the geometrical information of the DMU, to achieve interactivity and to keep sufficient visual quality simultaneously. The motive of our work is to define

Conference proceedings ISBN 80-903100-7-9
WSCG'2005, January 31-February 4, 2005
Plzen, Czech Republic.

objective criteria to guide *automatic simplifications*. The objective criteria define the limits that must not be reached in order to guarantee good spatial (linked to readability and visibility of the geometry of the VMU) and temporal (linked to interactivity and fluidity of the application) visual qualities. Automatic simplifications allow to reduce the time of preparation of the database.

We will use the example of the Virtual Cockpit application: a user is immerged in the skin of the avatar, via Virtual Reality tools (a Head-Mounted Display, a tracking system to track the movements of the head, hands and chest, and a glove tracking the movements of the fingers of the right hand). The main goal of this application is to support ergonomics studies of the interface between the future user and the future cockpit in its earliest stages.

2. SIMPLIFICATIONS

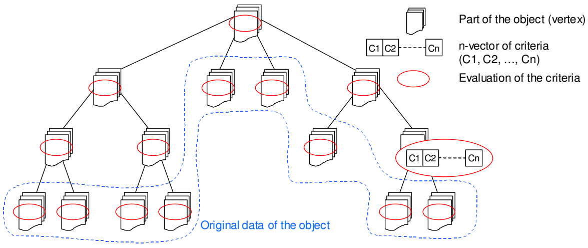

Figure 1. Use of a vertex tree structure in order to organize the objects to simplify

In order to link the geometrical characteristics and the details of the objects to the visual criteria, we structure the geometrical information in a Vertex Tree (see Fig.1) [Lue98a]. Each node of the tree represents a vertex. The leaves of the tree represent the original data of the object. If the node is a leaf, it corresponds to a vertex of the original data; otherwise it corresponds to a new vertex (into which all of its children are collapsed). For a particular state of the object, active vertices are those used in the mesh in order to represent it at this state: the higher the vertex is in the tree, the more simplified the object is. At each node of the tree, a set of criteria is tested (visual criteria, application criteria…). Our work consists in using this vertex tree introduced by Luebke [Lue98a] with our own criteria and choices of simplification [Che04a], in order to simplify the scene. We can distinguish two ways of using it: “Static simplifications” which are done before the running of the application, and “dynamic simplifications” which are performed when the application is running.

Static simplifications are preparing the geometry of the object, by keeping only the vertices that may be useful or visible by the user, by taking into account the behaviors of the user during the application. This means that a preparation must be led in order to indicate first the different possible points of view and lines of sight of the user.

Dynamic simplifications use a kind of Progressive Meshes: it changes the mesh of the object at each frame, to adapt it to the criteria. This method is well adapted to the real-time visualization because it will display details only where they are useful, and does not need any phase of preparation.

We can also use a composite simplification which consists in a static simplification, and then a dynamic simplification.

3. FIRST RESULTS

This section presents the performances of the different simplification possibilities, using a part of the Virtual Cockpit database. In order to do this, a simple OpenGL application has been programmed on a PC computer (Athlon 2200+ with 512 Mb of DDR RAM). The navigation in the database is the same in every case (61 views). The tests have been led on the original database and on simplified ones with the three methods presented (static, dynamic, composite. The results are schematically summed up in the tab below (see Tab.1).

	original cockpit	static cockpit	dynamic cockpit	composite cockpit
Preparation	No	Yes	No	Yes
Number of faces	100%	80%	≈35%	≈35%
Memory costs	100%	75%	765%	545%
Update and rendering time	100%	81%	≈49%	≈49%

Tab 1. Sum-up of the tests results of the simplification methods

4. CONCLUSION

The different methods of simplification are based on human and application criteria, which help to enhance the temporal visual quality (i.e. the frame rate), without degrading the spatial visual quality (i.e. the geometry), from the point of view of the human eyes during the application. The dynamic method seems interesting except for the memory costs. A reduction of this memory cost can be achieved by using a composite simplification.

5. REFERENCES

[Che04a] Chevaldonné M., Neveu M., Mérienne F., Dureigne M., Chevassus N., Guillaume F. Digital Mock-up database simplification with the help of view and application dependent criteria for industrial application. EGVE, 2004.

[Hop96a] Hoppe H. Progressive Meshes. Proceedings of ACM SIGGRAPH 1996.

[Lue98a] Luebke D.P. View-Dependent Simplification of Arbitrary Polygonal Environments. PhD dissertation, Chapel Hill, University of North Carolina. 1998.