

# A framework for tele-immersive design review of 3D CAD models

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*Abstract:* - The goal of this paper is to present an approach of using virtual reality technology to create a collaborative framework with the purpose to allow several people who are physically apart to inspect virtual prototypes. The method presented in this paper can be used by one or more design teams, who can collaborate remotely in a tele-immersive environment based on networked CAVE's systems and other stereoscopic desktop displays such as Reachin® Display or classical desktop monitors with stereo facilities. Design engineers can inspect and manipulate 3D virtual prototypes using 6DOF tracking devices and can have also a visual contact between them, using audio-video conference technologies embedded in immersive virtual reality scene. This paper makes a wider description of the framework, specifying the main modules and characteristics of the developed architecture. Finally, it is described in an experiment the process carried out for tele-immersive design review of a car engine.

*Key-Words:* - Virtual Reality, Tele-Immersive, Product Review, Computer Aided Design, Data Exchange

## 1 Introduction

As the computer technology is providing a crucial advantage on the industrial world competition more than ever, the complexity of the products increases dramatically. For this reason development of new multi-modal interfaces that will facilitate virtual prototyping of products is one of the topics of great interest. Virtual Reality (VR) can be used as an effective visualization tool for various applications [3] being a high-end human-computer interface that allows interaction of user with simulated environments. As VR technology has reached a very mature level in the last years, it is well suitable for industrial applications.

An important goal of the moment is to extend simulation of mechanical system based on the available virtual technology to collaborative virtual environments (CVE). This supposes the definition of a distributed virtual environment allowing multiple users from different geographical locations to interact over a network in real time. The important added value is that the collaborators no longer sit around at the same table, the CVE system allowing distance cooperation between them.

Tele-immersion systems represent the creation of persistent virtual environments enabling multiple, globally situated participants to collaborate over high-speed and high-bandwidth networks connected to heterogeneous supercomputing resources and large data stores [6].

The integration of the VR technologies in a CAD system is a complex task. Researches in VR-based CAD

systems have been carried out already by many academic and industrial research groups and led to development of systems that can be classified into two categories: VR-based integrated CAD systems that enable edition of CAD models using VR technologies [2] and VR-based CAD systems in which VR technologies are used only for high fidelity visualization of the CAD models generated earlier in the legacy CAD systems [5]. In our research work we focused the attention on this second type of VR-based CAD systems. In case of these systems, the CAD system outputs geometric data into the VR system which is used as a separated visualization tool [5]. These systems lack on the support for teamwork and which makes it difficult for people geographically apart to share information. Nevertheless, some of them give good solutions to specific problems.

The objective of this research is to present a generic framework based on the VR technologies that allow design review of the 3D models generated using a legacy CAD system. In the next sections the hardware and software architecture and some experiments will be described.

## 2 Framework architecture

The main network topologies of a collaborative virtual environment system are as follows [4]:

- Peer-To-Peer – Each client sends a separate message to all other clients collaborating in the same world.

- Client/Server – Each client transmits messages to a central server, which distributes messages to all the clients in the same world.
- Multicast – Each client transmits a message to a multicast address, to which all clients in the same world are connected.

In a networked virtual reality environment peer-to-peer is a common topology of communication system, but it has two disadvantages: the same network packet has to be sent many times to all connected participants and each participant requires a list with the IP address of all connected participants (these addresses have to be known at all time). Multicast protocol can send UDP datagrams to multiple computers in different networks with IP addresses class D, passing through routers. Whenever one of the participants sends any message to the group, it will be automatically forwarded to all the members of that group. The disadvantage of this protocol is the reliability of the UDP datagrams.

To overcome these disadvantages the client/server protocol was used. There are two category of messages exchanged between users: state change message (join or leave the group) and geometrical changes message (used for update the position or orientation of virtual objects when changed). Additionally, an audio-video facility was added to the system, to provide a communication means between participants.

The overview of the developed collaboration framework is presented in the figure 1. The proposed configuration software is capable to display in a synchronized way passive stereo 3D images on the multi-wall display environment, plug in different VR devices and facilitate the collaboration of remote engineering teams using natural and intuitive interaction methods. Each client holds the entire 3D scene, with

only positions and perspectives being different. It also provides methods by which objects in virtual environment can be manipulated, added, or removed. The software configuration (fig. 1) is designed as a distributed highly modular network, based on the strict separation of its VR system management into following layers:

- Multi User Server: performs the administration of the 3D model data and the users connected in the system.
- Virtual Environment Server: retrieving and interpreting the commands data from input devices, coordinates local projections and navigation in the virtual environment.
- CAD2VR module: automatically exports the necessary CAD model data to the virtual environment through a user selected option in the CAD system.
- Interaction manager module: get the position and rotation matrix of the user hand from a generic input device (for example an optical tracking system) and send in real time the new position to the user avatar or selected object.
- Audio-Video Conference module: provide a teleconference system embedded in the virtual reality environment to facilitate communication between engineering teams involved in project.

The collaborative virtual reality environment is described by a set of geometric objects that can be obtained from a Solidworks assembly of part CAD and automatically converted and stored in a VRML file. The user is able to be immersed in the virtual world and to interact with the virtual prototype by using several virtual reality devices.

The VR modules are implemented in C++ programming language. Microsoft Windows is the environment used for VR and CAD system.

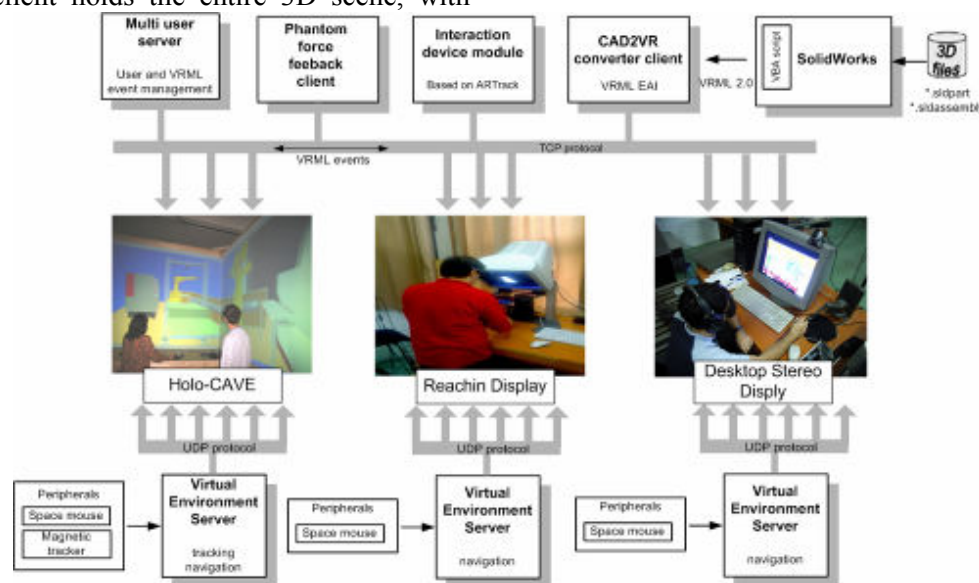


Fig.1 Architecture of the tele-immersive framework

The 3D representation is VRML2.0 (Virtual Reality Modeling Language) and the stereoscopic rendering of 3D models is done by BS Contact Stereo viewer. SolidWorks offers an API (Application Programming Interface) to create and access the CAD model data. For audio-video transmission over internet a server using MMS (Microsoft Media Server) protocol was used. Video signal is collected using video cameras placed in each working place, encoded, transmitted by the server to the internet and rendered directly on the VR environment. For working places with low bandwidth internet connection only an audio server was made.

### 3 Translation of CAD data to VR

The information of SolidWorks CAD models can't be used directly in the to VR environment because there is not a data exchange standard. In order to be accessible in the collaborative virtual environment by the participants, the 3D models have to be extracted from the Solidworks CAD database and automatically converted into an adequate format representation. The CAD system can export the CAD graphical models in other formats (for example STEP, VRML) by calling a feature available from a menu. Also external dedicated converters software can be used (for example Okino PolyTrans). But this technique not maintains all the data of the original model. Important features of the CAD model are not transmitted, such of identifiers of parts. Therefore it is necessary to develop a suitable model representation to support real-time visualization and interaction in a VE immersive environment.

The cornerstone of the presented framework is the CAD2VR software module. This module solves the above mentioned CAD-VR integration problems by the direct automatic conversion of the data from the SolidWorks CAD runtime environment to VR system with no use of external conversion software. SolidWorks® use the Boundary Representation (BREP) model for the representation of the model in the database (figure 4). There are two data types used to represent the BREP model in the SolidWorks®: topology data (body, face, edge, co-edge, vertex, etc) used to manipulate the boundaries of all the geometry entities in the model and geometry data (surface, curve, point) used to manipulate the actual data that define the geometrical. SolidWorks API include function that allows traversing all the CAD model data. The result it is an VRML file with a scene graph structure which preserve all the geometry information of the entities of the CAD models detached into part name, triangle tessellations, visual characteristics of the parts (colors, materials etc.). In this way each tessellation corresponds to only one surface and each surface corresponds to only one part. In the

collaborative system the objects will be referenced by their names from the VRML scene file. The steps for the generation of VRML file from SolidWorks database are the following:

- Accessing the SolidWorks database.
- Determine the number of discrete points and triangles.
- Writing the header of the VRML file “# vrmf 2.0 utf8”
- Define the object PROTO interface.
- Get the identification information of every entity from the SolidWorks database using the SolidWorks API function `GetEntityName()`.
- Get the geometry information of every entity using the SolidWorks API functions `GetFirstSubFeature()`, `GetTessTriangles()`, `GetEdges()`, `GetCurve()`, `GetNextSubFeature()`. The information includes the number of discrete points, coordinate values, normal values, and material data.
- After all the entities are processed, the information is written in the VRML file.

### 4 Example application

In order to test the developed framework, an experiment for tele-immersive design review of a car engine was set up. For the experiment there were used two collaborative working places, but the number of working posts can be multiplied for how many are desired in a straightforward way. The central working place (fig. 2) was based on a multimodal interface that uses various VR devices: a large scale interactive multi wall projected virtual environment called Holo-CAVE [1] for the visualization system, a special interaction device with 6 DOF based on an optical tracker system and a CyberMouse used for spatial tracking of user position and orientation, a 6D SpaceMouse for navigation in the virtual environment and a microphone for voice recognition and audio communication.



Fig.2 Inspection of a CAD model in immersive CVE

The second working place was positioned in another building of our department and is based on a desktop VR system (fig. 3). This system is composed from a CRT monitor and shutter glasses for perception of active stereo 3-dimensional graphics, a Sensable PHANTOM Desktop device and a 6D SpaceMouse for 3D navigation. At this post only one person can manipulate objects from scene or can collaborate with other participants remotely.



Fig.3 Inspection of an immersive desktop VR system

In order to test the framework developed, an engine CAD model was generated in SolidWorks and has been directly transferred and displayed in both working places system using the CAD2VR module. All elements from the virtual scene are individual parts and can be independently manipulated, added or removed on the fly. In tele-immersive design inspection process, the participants have the possibility to manipulate components of the engine, communicate each other, measure the dimension of the virtual entities and navigate in the immersive environment.

The participants manipulate a virtual pointer with the CyberMouse/Phantom device that allows selection of the model surfaces by a raycasting collision detection algorithm. This algorithm check if a ray defined by two points hit the shape of an object and return the hitten object. When a component is selected, the colour is changed. After selection of a component, the user has the possibility to manipulate it, by moving the stylus of the haptic device or the CyberMouse. Only one participant can manipulate a part in the same moment of time. All the actions from the virtual environment can be perceived by all the users connected to the system.

When a manipulation task is issued, in a first step the user has to select two points of the model. Then the calculation of the distance it is performed by voice command "Distance", and the measured distance is displayed on the left corner of the screen. If a user wants to modify a part, first will select it and then remove it from the scene. Then will have to return to the Solidwork CAD system, modify the proprieties and then

directly reload the 3D model in the collaborative system by calling the VBA macro from a custom toolbar button.

## 5 Conclusion

In this paper was presented a tele-immersive system that offers a new way for handling of digital data in an immersive virtual 3D environment. A software module for directly conversion of CAD model to VR system was presented. The advantage is reduction of the time needed for integration of CAD model in the VR system. In the experiment conducted within this research, the CAD model data was translated accurately, so the interface developed proved to be an improved solution for translation of data between the CAD system and the CVE system. The users have also the possibility to interact in real time with the virtual model, the frameworks facilitating at the same time the collaboration of several users. The future research is focused on adding a mechanism for collaborative generation and modification of 3D CAD model inside the tele-immersive environment.

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