HOW TO USE CAD TOOLS FOR MODELLING VIRTUAL ENGINEERING ENVIRONMENTS?[1]

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ABSTRACT
Working on distance has become a necessity. Especially this problem exists within the educational institutions where the need for practical teaching (on distance) is increasing. This paper describes how to use almost any Computer-Aided Design tool for the virtual environment creation, usable for remote modelling and assembling. The basic functions are created using CAD tool and the environment is exported and shown using the X3D technology. The comparative study of commonly used CAD software in engineering, 3D Web technologies and the best combination of the mentioned components has been described in the paper. Based on the experience, authors drawn the directions related to the future development of engineering virtual environments.

1. INTRODUCTION
Industrial design refers to those activities involved in creating the look of the product, deciding on the product's mechanical architecture, selecting materials and processes, and engineering the various components. Using Virtual Reality (VR) technology industrial design can be performed within Virtual Environment (VE), which shortens design and development time. Thus, industrial design shares the characteristics of VEs (e.g. collaboration) and in the form of Virtual Design, becomes applicable in engineering courses. It aims to enhance the validation of product concepts via advanced simulations, to increase the efficiency of component and material reuse in different life cycle phases, and to reduce simulation costs.

CAD software has been around a long, but the size of the 3D model, compatibility issues in cross-platform environments, and limited flow over Internet still present a problem in terms of their exchange and sharing. Development of standards for exchange of 3D objects over Internet helped in developing specific applications for designing, planning, and education. 3D Web technologies promise many applications in simulation and training, making users directly participate in and explore the virtual environment, making them sharing objects easily.

This paper describes how easy it is to create and use virtual environment that allows collaborative work of many distant clients. The environment aimed to support practical exercises of mutually distant participants is intended for fast, accurate creation of simple models. It can be designed in any CAD software. This paper at first detects CAD software and 3D Web technologies in order to make the best choice of these two. After that, creation methods are described through using concrete tool to export

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environment design, and proper technology to show and share the exported environment between participants.

Section 1 introduced the concept of virtual environments; Section 2 gives a survey of the most used CAD platforms in engineering; Section 3 gives a review of main 3D Web technologies; Section 4 describes virtual environments modelling process; Section 5 ends with conclusion and further directions.

2. CAD SOFTWARE REVIEW

In recent research [1][2], we have published a review of mostly used CAD tools. The selected packages were SolidWorks [3], Inventor [4], CATIA [5], Pro/ENGINEER (PTC Creo, Pro/E) [6], and AutoCAD [7]. Packages were chosen by specific engineering student profile and by presence in the market. We ranked the packages with respect to a few criteria: Learning curve rate or Ease of use, Export capabilities, Availability of plug-ins as a substitute for direct export, Method of export, Texture map or material properties. The criterion was also focused on whether models can be exported to VRML (Virtual Reality Modelling Language, direct predecessor of X3D) or X3D. In mentioned paper [1] we stated that Inventor and AutoCAD do not export to VRML/X3D. By recent research, we have found a converter for AutoCAD and Inventor whereby our research with the five mentioned tools is complete. We will briefly summarize our conclusions according to these criteria.

Most of the students involved in our research have evaluated SolidWorks to be the easiest for use. They were able to produce useful drawings within two weeks, and they easily mastered 3D CAD. One of the most important capabilities of this tool that helped students in their study is associatively. Associatively implies changes in drawing, which are immediately reflected in assemblies and parts, and vice versa. Mastering this tool within 2 weeks is the most important advantage. Very complex modelling and assembly creation is accomplished with Pro/E and Creo. An application that truly has a vast array of functionality takes time to learn, but students managed to master intermediate and some advanced 3D modelling skills within 30 hours, designing assemblies within 4 hours, and development of drawings within another 4 hours. The parametric connectivity and associatively are the main advantages of this CAD tool. Unlike SolidWorks and Pro/E, AutoCAD is significantly more complex and it is necessary 40 hours to master 2D drawing, and 30 hours to complete 3D drawing. This implies that 50 hours of training were necessary; having in mind that it is not possible to start 3D modelling without training in 2D. Working in CATIA is very similar to working in Pro/E. Students have also shown capability to do serious tasks in CATIA just after two weeks of training. These tasks include preparation of technical documentation besides modelling individual parts and complex assemblies. In addition, there is interconnectivity between CATIA and SolidWorks, since they are products of the same vendor. Regarding the environment, Inventor has a very simple interface. As such, usually 30 hours is sufficient to master the program at an intermediate level, and around 60 hours for advanced techniques.

The capability for exporting was the condition of this research for compatibility with X3D technology. All of the above tools can export VRML/X3D with or without the use of plug-ins, converters or translators. Pro/E (PTC Creo) has the best VRML export (direct export) of assemblies as a set of files. This feature can be used in a case of an individual to work within the Pro/E and subsequent splitting and a further modification of the far-off participants in the X3D environment. Material or material properties, shininess, and transparency can be also exported from all CAD programs.

3. WEB 3D TECHNOLOGIES, PLATFORMS AND SOLUTION REVIEW

Web technologies promise many 3D applications in simulation and training, making users directly participate in and explore environment. The most commonly used are X3D and WebGL (Web-based Graphics Library), both designed for the creation of interactive Web-based and broadcast-based 3D content. WebGL works without installing additional software, but only within a compatible Web browser. Regardless of the fact that X3D works at much lower level and needs installation of an appropriate plug-in, it works within any Web browser, employs a scene-graph, specifies a declarative geometry definition language, a run-time engine, and an application programming interface which provides an interactive, animated, real-time environment.

According to these researches, we can conclude that only X3D has support for: CAD data, work on different platforms, for audio, video, interactive texturing, HTML5, mobile phone, and PDA devices. The mentioned criteria were a prerequisite for the creation of the laboratory described in this paper.

X3D is the XML-based file format for representing 3D computer graphics. Regardless of the fact that needs installation of an appropriate plug-in, X3D works within any Web browser, employs a scene-graph, specifies a run-time engine, and an application programming interface providing creation of the interactive, animated, and real-time environment. The plug-in can be eliminated by using X3DOM, but that would require different architecture from the one described in this paper. Scene-graph structure has proven for fast learning of these technologies, especially for users who are not familiar with using scripting or programming languages. Since it allows integration with most 3D modelling tools, this type of technology becomes convenient for CAD designers. Most 3D creation tools allow export to X3D or VRML file format, which enables understanding and creating virtual laboratory functionalities, as well as developing further implementations. In combination with an adequate player or viewer, HTML pages can be imported within the X3D environment.

Most CAD programs possess the modules for assembling and collaboration with other departments in the context of monitoring, development and product life cycle. Integration of VR system with CAD has been presented in [9]. Many solutions related to distributed and collaborative virtual prototyping, interactive design visualization systems, virtual design framework for product customization, and design and manufacturing simulation of mechanical products are presented in [10]. Also, there exist solutions using X3D for creating virtual assembly laboratory. The VIEW project [11] describes great course for engineering students using virtual assembly techniques, but without mating constraints, collaboration, text or video chat. From the same authors, an excellent educational environment is presented in [12], which combines X3D and SolidWorks in creating assembly, but lacks group-work support. Research in paper [13] is an excellent interface with many functions enabled, but also lacks group-work support and shared assembling functions.

4. PROCESS OF VIRTUAL ENVIRONMENTS MODELLING

Process of virtual environments modelling concerns choosing the right CAD tool and exporting VRML or X3D file. Later the environment can be placed on web using X3DOM technology. In this section the attention is on the CAD tools and how they export necessary format in order to make future virtual engineering environment.

SolidWorks exports only VRML 1.0, which is in this comparison a significant disadvantage. Besides, SolidWorks does not possess a plug-in for X3D. In this case, the conversion is realized by exporting into another file format that can be imported into the X3D environment. Parts from SolidWorks are exported into VRML as IndexFaceSet nodes, even when they are as simple as cubes, cylinders, sphere an alike, for which there are corresponding nodes in the X3D specification. Using add-on applications can enable Inventor to export to VRML, but they have proved to be insufficient as a solution. As for exporting to STEP format, there is no problem since Inventor release 2010 (in the remainder of this paper it will be explained in more detail why this format is so important). Files from CATIA can be exported by the CATIA VRML exporting API, and then converted into X3D by the VRML2X3D converter. Files are exported as VRML with IndexedFaceSet nodes, and like that are converted from VRML into X3D. Creo 2.0 exports VRML format in version of VRML 2.0 utf-8. There is no plug-ins available for X3D export from PTC Creo 2.0. Parts are exported into VRML as IndexedFaceSet nodes. AutoCAD cannot export into VRML and neither into X3D. Fortunately, this package works with a large group of exporters and translators. A special task group is working on integration of AutoCAD with X3D. Material is exported using the Collada exporter [14], but it is not possible with VRML 1.0. Both of these export attributes ambientColor, diffuseColor, emissiveColor, specularColor, shininess, and transparency.

The conversion process from CAD to X3D results with all parts grouped as IndexedFaceSet nodes with predefined Transform node and its "translation" and "rotation" attributes. IndexedFaceSet is the most commonly used node for creation of shapes, polygon by polygon (point by point), allowing a highly compact representation of the vertices. The specific attribute of this node is the "Coordinate"

field, which enables a vertex to be used many times. The "coordIndex" specifies a list of coordinate indexes defining the faces to be drawn. To separate the indexes a marker "-1" is used, which indicates that the current face has ended and the next one begins. This node has been used for the manipulation of 3D objects in scene.

For further functionality implementation, especially important is Transform node, with its "rotation", "center" and "translation" attributes. This grouping node defines a local or relative coordinate systems for the children nodes, defined in terms of transformations from ancestor coordinate systems. This is the most important part for organising objects as future interactive segments of the (virtual environment) scene.

5. CONCLUSION

In this paper, we proposed a possible combination of CAD software and X3D technology aimed for creating virtual laboratory for engineering students. The general conclusions regarding the technologies and platforms, as well as predictions concerned with the current working groups and support solutions to create a universal format for the exchange has been described. The capability for exporting was the condition of this research for compatibility with X3D technology. All of the above tools can export VRML/X3D with or without the use of plug-ins, converters or translators. Pro/E (PTC Creo) has the best VRML export (direct export) of assemblies as a set of files. This feature can be used in a case of an individual to work within the Pro/E and subsequent splitting and a further modification of the far-off participants in the X3D environment.

When it comes to virtual engineering environments, further integration and development of as many CAD functions as possible within the laboratory will be the main priority. Also, future actions will be directed towards exporting drawing files of the environment and link these with all previously created parts (associative attribute of all CAD programs). All mentioned functions it is possible to extend further using Cloud or Grid computing, as well as CAVE systems for sharing, learning, and testing.

6. REFERENCES

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