

## THE COMBINATION OF COMPUTER AIDED DESIGN SOFTWARE AND X3D TECHNOLOGY IN THE CREATION OF VIRTUAL ASSEMBLY CLASSROOM

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### ABSTRACT

*Interactive simulations, virtual environments and 3D interfaces can significantly contribute to the learning process, through collaboration and interaction with distant participants, as well as through simulation of real environments and real life situations. Depending on the needs and subject matter, different technologies, software, and their combinations are used. This paper presents a comparative study based on the use of different CAD software in combination with X3D technology, in order to support students' needs at Department of Engineering Management, Singidunum University, in Belgrade. Considering the specificity of a given students' profile, selection of CAD software is confined to Solidworks, Inventor, CATIA, Pro/E and AutoCAD. The main criteria to us were communication between X3D and CAD in terms of format and file size, node types and material properties. The paper gives concrete results, advantages and disadvantages of software, technologies and solutions, as well as predictions about the future developments.*

**Keywords:** CAD (Computer Aided Design), X3D (eXtensible 3D), Virtual Assembly

### 1. INTRODUCTION

Computer laboratory exercises are essential part of engineering education. It improves students' understanding of fundamental concepts about data analysis, problem solving, and scientific interpretation. Mostly, such laboratories either are inaccessible or unable to meet the users' requirements entirely. The solution to the problem relies in creating virtual laboratories, which then can be used as a supplement or exchange of certain courses, enabling virtualization of real exercises or overcoming the limitations of real environments [1].

Very important part of such laboratories is assembly function. Assembly parts are geometric constraints, such as tangency, colinearity, parallelism, perpendicularity, coincidence, symmetry, etc. They impose a relationship between geometric features. Mentioned constraints can be applied on faces (circular or rectangular), lines and points as parts of work geometry.

Although most CAD programs have modules for collaboration, there is no simple exchange between them. Our idea is to use X3D as the suitable standard for the exchange. Using X3D we created virtual laboratory aimed for practical exercises in industrial design. The lab is used as a universally designed environment for collaborative design enabling involvement of various software packages in creating parts, but using only one space to assembly them.

The rest of the work is organized as follows: section two presents related work; section three gives a review of CAD software; section four explains the creation of virtual laboratory; and finally section five concludes and presents the future work.

## **2. RELATED WORK**

There are certain difficulties in sharing 3D models, because they are either too complex or heavyweight to be shared for distributed collaboration. For that reason, lightweight formats exist and an excellent survey of technologies that actually enable the presentation of 3D data in the Internet is presented in [2]. The most commonly used 3D Web technologies are X3D and WebGL (Web-based Graphics Library), both designed for creation of interactive Web-based and broadcast-based 3D content, suitable to integrate with multimedia. However, there is a significant difference between them and their use largely depends on the specific need. For example, WebGL as much progressive brings hardware-accelerated 3D graphics. It works without installing additional software, but only within compatible Web browsers. Regardless of the fact that X3D works at much lower level and needs installation of an appropriate plug-in, it enables displaying within any Web browser, and as scene-graph system and with XML encoding, it's a much better choice for beginning students.

The interesting solutions that utilize X3D for creating virtual laboratory, are presented in [3], [4], [5] and [6]. All describe great courses for engineering students. Majority of them are with integrated virtual assembly techniques, but with limited collaboration, communication or integration with more than two CAD software. Mentioned systems combine SolidWorks with X3D technology.

Virtual Manufacturing system for enterprises with limited resources is presented in [7]. The system performs collaborative tasks, including product design, manufacturing and resources. The manufacturing lab uses X3D in combination with Pro/E, AutoCAD, and similar CAD software, as well as a knowledge-based expert system for product assessments. Paper [8] describes a system combined of CATIA and VRML, which enables participants to share their design capabilities in order to complete a common product design. The system in its simulation part enables user to carry on analysis based on help of CAE software.

In respect to all previously mentioned systems, our system combines various CAD software and enables the use of the virtual classroom as universal format for parts assembling.

## **3. REVIEW OF CAD SOFTWARE**

It should be obvious that there is no one best 3D modeling program for all model-building applications. For some tasks, there are programs that are more suitable among other, and each of programs we evaluated handled different sets of tasks. In fact, inertia is actually the most compelling factor in choosing modeling programs. The remainder of this paper presents a detailed analysis for five selected CAD packages.

With respect to the specificity of the profile of students undergoing training, the selection of CAD packages is reduced to the five most commonly used in this field: SolidWorks, Inventor, CATIA, Pro/ENGINEER and AutoCAD. During research, we found that Inventor and AutoCAD do not export VRML/X3D file types. However, X3D combining with AutoCAD is described due to the existence of a number of plug-ins, as well as exporters and working groups working on CAD-X3D development.

When addressing the previously mentioned combinations, most of them come as integration of SolidWorks and X3D. This is because SolidWorks exports models with the least number of polygons, in addition to the fact that it is the easiest to master amongst the mentioned packages. Unfortunately,

SolidWorks has a considerable drawback – there is no direct export into X3D, and in order to do so it has to be done via VRML or Collada exporter. CATIA has the best communication with X3D. A lot of effort is invested into their integration (CAD3D Work Group). CATIA has the option to import complete assemblies into X3D (assemblies from other programs are exported into VRML/X3D as complete models). In this case, it is obvious that the disadvantage of AutoCAD not being able to export into STEP seems negligible. As for Pro/E, although there is a basis for integration of the X3D, no efforts are made in this direction. Probably because Pro/E relies on the U3D format, as well as on native formats of other CAD packages.

**4. VIRTUAL LABORATORY CREATION**

Defining geometry in X3D is accomplished using various nodes, but IndexedFaceSet is the most commonly used for creation of shapes, polygon by polygon (point by point), allowing a highly compact representation of the exported to a uniform format. Exporting X3D from mentioned CAD packages, considers objects creation of many IndexedFaceSet nodes. 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.

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. Generally in 3D, not only the amount of translation or angle of rotation must be specified, but also the axis of translation and rotation. 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. This node is essential for data exchange and it is only reference which can be used for further creation of mate references.

In order to enable visibility of all the screens in virtual laboratory (e.g., students working on specific part in specific CAD software), and work on individual parts from the lab, we use capability of X3D node called MovieTexture to support Flash movies. It defines a time dependent texture map, and the URL field defines the movie data support within the environment (Fig. 1).

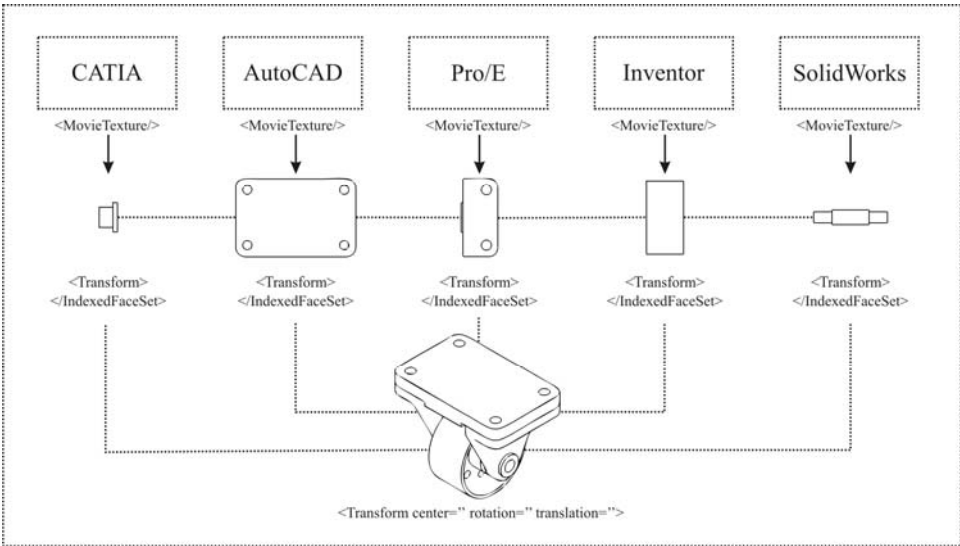


Figure 1. Organization of nodes and the final assembly work.

The basic steps in creating mate constraints in X3D include the following: objects detection, face selection, equaling values, mate constraints and additional adjustments. Face detecting is made by listing and grouping IndexedFaceSet values taking into account digits up to “-1”. If there are four digits prior to the first “-1” digit, the shape is a rectangular form. Circular surfaces (e.g. cylinder shape) are represented with 18 points. Selecting objects’ faces is a function which includes setting the coordinate system at selected place by finding the center of the object. This needs to be done for faces of both objects, depending on geometric constraint, especially in the case of classic mating (face to face). After setting and equalizing the coordinate systems of both objects, and by clicking on MATE button, objects are placed at the desired position, to the given coordinate systems ( $x_1=x_2$ ,  $y_1=y_2$ ,  $z_1=z_2$ ). Equalization means taking attribute values "rotation" and "translation" of the second selected object and assigning these values to the first selected object. Equating the coordinate systems solves the coincident case and based on the geometrical constraint equation used in computer graphics, defines the relationship between faces (distance and angle) as well as other constraints (parallel, tangent, concentric and perpendicular). In the case that the program did not recognized the designer's intent, it is necessary to allow additional adjustments which are possible through affecting "rotation" and "translation" attribute values.

## 5. CONCLUSION AND FUTURE WORK

In this paper we proposed a method for creating basic geometric constraints within the virtual laboratory. The proposed method combines various types of CAD programs and X3D technology for concurrent assembly work between distant students. The advantage of this method is in student's participation in simple projects without any extensive knowledge from relevant fields and they can also contribute to problem solving. In this way, students visually study and specialize, what is the reason for the use of simpler and less demanding projects. Besides, the proposed method has a faster generation of various models. The weakness is reflected in the use of simple constraints, but the idea is to introduce more complex constraints into the virtual environment as students gain certain knowledge. In addition to integrating as much CAD packages with X3D technology, our future work will be directed to exporting drawing files from the virtual assembly lab and link these with all previously created parts (associative feature in all CAD programs). Mentioned functions could be extended to haptic-enabled tools or CAVE system for sharing, learning, and testing.

## 6. ACKNOWLEDGMENT

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