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WEB VIRTUAL REALITY FOR PRODUCT CUSTOMIZATON

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Abstract: *The main goal of our work is to present and discuss an approach to provide direct customers' participation in the design process in form of a pre-sale service, based on use of the Web Virtual Reality. Core element of implementation such a service is the 3D-product model web configurator. This configurator provides as feedback in the customer's web-browser not only the appropriate graphical representation of newly developed product, but information about product installation and operational area, animation of product action and dynamical change of assembly model and its components parameters such as dimensions of form, dimensions of dispositions and etc.*

Key Words: ***Product Customization & Individualization, VR-Modelling, 3D Web Configurator, Virtual Product Family, Product Design***

1. INTRODUCTION

The ability to create, transfer, assemble, integrate, protect and exploit knowledge assets is a main factor for the existence and successful work of the industrial companies. The knowledge base of the firm includes its technological competences, its knowledge of customer needs and supplier capabilities. The approach for the direct customers' participation in the design process by expressing their preferences allows customers to be actively involved in the product definition process rather than passively receive the end product designed by the producer. Presently the proposed approach is applied successfully to continue and maintain development of a "virtual product family" of modular positioning and handling systems called *DriveSets* [1].

In recent years, technological developments have made it possible to build interactive 3D models of objects and 3D Virtual Environments (VE) that can be experienced through the Web, using common, low-cost personal computers. As a result, 3D content is increasingly employed in different Web application areas, such as education and training, e-commerce, virtual communities etc. Application of such 3D Web Sites is still not so popular for solving real world engineering and des problems.

The main goal of presented work is to propose use of a configurator to build a 3D product models and a correspondent virtual environment for the needs of Design-by-the-Customer process of modular handling and assembly systems called *DriveSets* representing an extension of early developed eXtensible Markup Language (XML) based CAx knowledge structuring environment. Constructing such a virtual product configurator shall enable the accurate assessments of the customer acceptance, better informed development of "tailored products", a sort of "binding" the customer to the designed system.

2. CUSTOMER PRODUCT CO-DESIGN FACILITATED BY INTERNET

Customer Co-Design, which term we adopted for the well known "Design-by-the-Customer" approach of development of new products, refers to a process in which customers are allowed to express their product requirements and carry out the mapping process to the physical domain of the product. If implemented as a pre-sale service it will bring a lot of benefits for both the producer and the customer which could be summarized extending the presented by Piller in [2] as (i) providing a better starting product configuration through direct use of customer needs, (ii) supporting the product design through fostering joint creativity problem solving capability of the stakeholders (iii) reducing cost and efforts, (iv) changing the customer attitude toward new developed product through trust building trust relation and reducing the risk perception.

According to [3] the nowadays computer-mediated global economy will accelerate the process of customization through its technologies. The Internet provides new channels for promoting products and making sales in B2B market segment and so becomes an extremely important factor for the business in a wide range of industrial branches. Considerable research in using the Internet for supporting the design and production process is already done [4]. The Internet enables customer to improve his involvement in the early stages of product development through use of interactive web-based platform customization as an extensions of product family design.

One of the most promising approaches to facilitate design and customization and to improve customer involvement within product development is use of so called Virtual Manufacturing (VM) environments that goes far beyond the scope of traditional modeling and simulation in CAD/CIM [5]. Different scenarios for the use of Web-based VR in the small and medium-scale companies are reasonable, such as Component catalogues, Digital procurements, Electronic bids, Partner selection, Customization etc [6]. Recently a trend for developing of so-called Virtual Products is established. Here the concept of "the virtual product" concerns not only the conventional computer aided planning and simulation of the developed products. According to the adopted definition "the virtual product" is a technical system, which allows instant and direct access and management from every PC, everywhere and on every stage and level of its life-cycle in order to increase the competitiveness and to guarantee the market share of the vendor through high diversity of the covered technical parameter ranges and possibility for promptly development and "materialization" of pre-engineered "custom-tailored" solutions according to the individual clients needs. Here "access" is referred to a full duplex data flow performed by appropriate transfer protocol (usually TCP/IP) which can be configured and optimized on-line and independently of the place and time.

One of the possible ways for direct involvement of the Customer within virtual product development process is the use of 3D Web Sites. A common idea behind this is that the 3D model of the product over Internet could enhance communication and collaboration between customers and the product developer, located in geographically dispersed places and enabling full product customization. The customers could select some of the product features and their correspondent parameters using the product VR-model and standard web controls.

In general, a VR model contains data that are used to render a 3D digital world in which the customer could navigate in real-time and interact with its objects. The user could examine the digital product in 3D space from different angles and with different resolutions. The user could also interact with the digital product to trigger animations showing the dynamic behavior of the product such as the assembly or disassembly sequence, operational movement, and so on.

VR-model is good suited for customer-company interaction purpose for following reasons. VR-model has strong support in multi-media integration and interactive behavior specification, which are two important functions for developing product catalog and showing the dynamic behavior of the product. Further VR model could be dynamically generated on the fly to let the customer immediately see a proposed product customization in 3D space.

3. WEB VIRTUAL REALITY

The composing elements of a VR model are organized into three types of data structures: nodes, scene graph, and animation circuits (Fig.1). Nodes are the building blocks of a VR model. They contain data and methods to define the composing elements of a virtual environment. Nodes composing a virtual environment could be further classified into eight categories: (i) shape, (ii) appearance, (iii) grouping, (iv) environment, (v) viewing, (vi) animation, (vii) interaction, and (viii) miscellaneous [7]. In the VR model of a product, the shape or geometry nodes describe the 3D shape information of the product. The polyhedral approximations rather than geometric models are stored in the shape nodes. The appearance nodes provide detailed control over the color, texture, and transparency of the product. The grouping nodes simply serve as the parent node in the scene graph to manage a list of children nodes. The environment nodes define the show room of the product. The viewing nodes control the viewing camera. The animation nodes are used to show the dynamic behavior of the product, such as assembly or disassembly sequence or the operations. The interaction nodes are used to sense the users and then trigger the animation. At last, the miscellaneous nodes contain extra data that could not be classified by previous categories such as scripts. Nodes in a VR model are organized into a tree-like structure called a scene graph. The third type of data structure used to organize data in a VR model is a process diagram called animation circuit, which specifies the execution sequence and logics of the animation and interaction nodes in the scene graph. The animation circuit is composed of nodes wired together. Each node has inputs and outputs. Messages are passed among the nodes to change the status of the nodes and correspondingly cause changes in the virtual environment. The VR model of a product contains all data necessary to generate the 3D representation of the product.

The web sites containing 3D data can be divided into two basic groups: (i) sites that display interactive 3D models of objects embedded into Web pages, and (ii) sites that are mainly based on a 3D virtual environment which is displayed inside the Web browser.

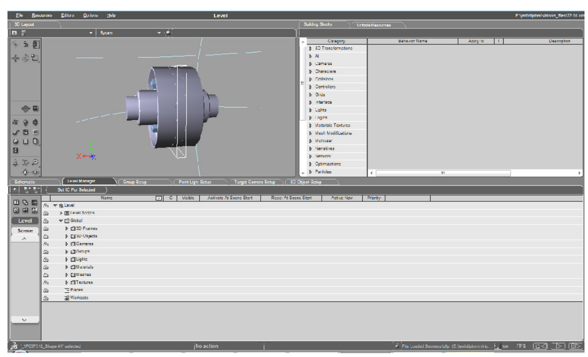

Fig. 1. Product VR model implementation

In the first case, the primary information structure and user's interaction methods are still based on the hypermedia model, with the additional possibility of inspecting 3D objects. In the second case, the primary information structure is a 3D space, within which users move and perform various actions.

Technologies for implementation of 3D Web sites are based on the common used technical and architectural solutions typical for the "conventional" web. The content, represented in a proper format, is stored on a server, requested by a client, through HTTP, and displayed by a browser, or, by a plug-in for a Web browser. 3D content can be integrated with other kinds of Web content such as images, sounds, videos inside a 3D VE accessible through the Web.

Beside the possibility for immersive 3D experience of the content in case of use of special hardware, 3D Web content normally is experienced with the common I/O – devices (CRT or LCD monitors, keyboard and mouse) allowing more realistic representations in comparison to the classical web content and enabling customers to inspect, manipulate and customize products before purchasing, as they are accustomed to do in the real world [8].

For implementation of 3D Web following two main open ISO standards are used VRML and X3D. VRML (Virtual Reality Modeling Language) is most know and used technology for building and delivering 3D Web content. VRML documents are text files that describe 3D objects and 3D VEs using a hierarchical scene graph. VRML defines different node types, including geometry primitives, appearance properties, sound and video, and nodes for animation and interactivity [9]. Recently a new ISO standard, called eXtensible 3D Graphics (X3D), has been proposed as a successor of VRML. X3D inherits most of the features of VRML improving upon VRML mainly in adding new nodes and capabilities, mostly to support advances in 3D graphics techniques and hardware, such as shaders etc.

Besides open ISO standards, there are many other (non-standardized) technologies for 3D on the Web. The best known examples are probably Java3D <http://java.sun.com/products/java-media/3D/>, an extension of the Java language for building 3D applications and applets and Shockwave 3D <http://www.adobe.com/products/shockwaveplayer/> from Macromedia.

Access to VRML/X3D Web content is possible through one of the available Web browser plug-ins, such as Octaga Player, Parallelgraphics Cortona and Mediamachines Flux player.

4. VR WEB FOR SYSTEMATIC CUSTOMER PRODUCT CO-DESIGN

The systematic design provides an effective way to rationalize the development and production processes. Such design method is prerequisite for continuous computer support of the design by using stored data. Systematic processing makes possible consideration of cost and quality of the designed products on early stage, which enables better market chances. In our work we have combined the main principles of the systematic design [Pahl, 2000] with the 3D web technologies in order to provide the direct participation of the customers at very early stage of the modular product development in form of a pre-sale service for SMEs.

Our approach compromises four stages and includes following basic elements:

- a 3D Web configurator and an appropriate virtual environment assisting the identification, structuring and mapping the customer requirements and real-time graphical representation of the developed product enabling direct interaction with the customers;
- a product frame describing the significant parameters and features of the product (or product family member) derived on the ground of preliminary analysis of the customer needs and requirements;
- a functional structure and UML-model of the product (product family);
- a classification of the functional units performing the single sub-functions of the product (product family members) stored in a data base;
- a morphological matrix to compose the functional unit set of the single sub functions in overall product functional structure;
- an algorithm generating the possible variants of the product structures;
- a procedure for selection the optimal product variant for specific set of objectives;
- a validation procedure;
- an algorithm for automatic generation of the technical documentation and web-presentation of the newly created product variant.

The concise and simplified linear organization of the above mentioned elements within particular stages of the proposed approach for customer co-design approach within product development process can be described as follows (see Fig. 2):

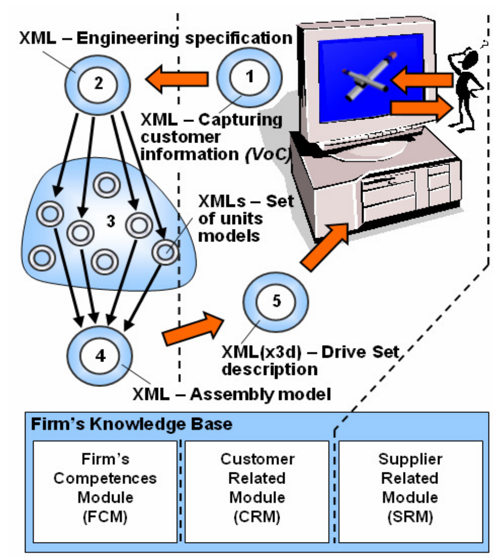

Fig. 2. Systematic processing of customer input through Customer Co-Design approach using 3D Web configurator

The core element of the proposed systematic approach for Customer Product Co-Design is the 3D Web Configurator. On higher level it represents one of the components of so called “Customer Related Module” (CRM), which stores and manages the information about customer’s needs, requests and advices of the producer. The 3D configurator is responsible for the 3D graphical representation within the configuration and development of the modular products, enabling the direct participation of the customers within system designing. Customers’ needs identification and structuring for the Customer Co-Design within early Product Design stages of the products allow interactively altering and improvement the products and direct participation within product definition. Customers are presented a wizard, in which a set of product attributes and their possible values are presented for selection and modification. The frame of the parametric range was built by systematic variation and full combination of some significant technical and structure product parameters. Beside that come the common for VR operations like turning, aligning, flying etc. enables customer to change some parameters of the designed system.

The 3D Web Configurator provides as feedback in the web-browser of the customer not only the appropriate graphical representation of the newly developed system, but the model of the systems installation and operational area, animation of the systems action and dynamical change of the model parameters such as dimensions of form, dimensions of dispositions etc.

4. CASE STUDY *DRIVE SETS*

For our experimental implementation of the 3D Web configurator we have used virtual product model of the *DriveSets*-family brought to the market by Systec E+S GmbH, Germany <*http://www.drivesets.de*>.

The Drive Sets have been designed as a scalable frame based parametric range of modular linear positioning and handling systems with application in the industrial and laboratory automation, evolved through the integration of OEM-components (see Fig. 3).

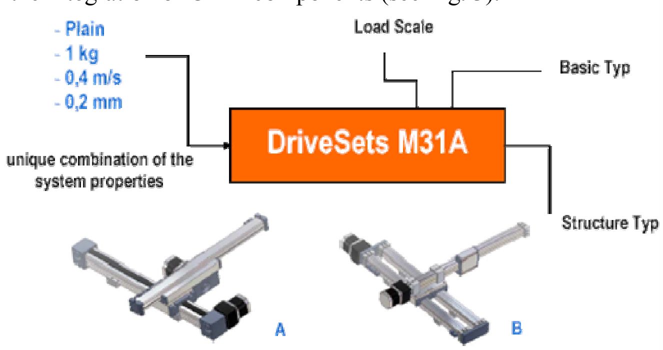

Fig. 3 An example for a ***DriveSet*** *positioning and handling system: significant system parameter set and its correspondent product family*

The particular *DriveSets* form a "virtual product family" in accordance with the predefined sets of systems properties (such as paying load, maximum speed, repeatability, operating area, design type, stroke) described in a form of a product platform. The specific value of the system parameters for each family member is determined at the design phase on the ground of the mapped customer requirement and constraints providing a sort of tailored customization. Every unique property value combination has a particular number identifying the correspondent representative of the family. In such a manner some 144 basic structures have been specified. The customer could select among these "virtual existing" pre-engineered basic structures and find the system most appropriate for his specific needs using a simple selection procedure in n-dimensional system feature space (online or supported by hard copy catalogue). Further he can choose the stroke for every single axis of the system. 10 standard stroke lengths are available for every system axis. Various additional properties of the system like as cable chains, control unit type, material etc. are optional for the customer and enable him to perform a sort of standardized customization.

In our work we have focused on the development of a prototype of an experimental 3D Web configurator providing "deeper" involvement of the customer within process of configuration new or existing DriveSets-structures using XML-technologies to ensure exchangeability and extensibility of data and models. The easy to understand XML description of the virtual product model could be obtained from Fig. 4. On the grounds of the XML description of the product a X3D file is generated, which can be visualized directly in the web browser of the customer. The flexibility and support of dynamical changes are provided trough the 3d Ajax technology. The experiments are carried out through the Document Object Model (DOM) - Scene Access Interface (SAI) connection. This connection is used to change dynamically the X3D scene.

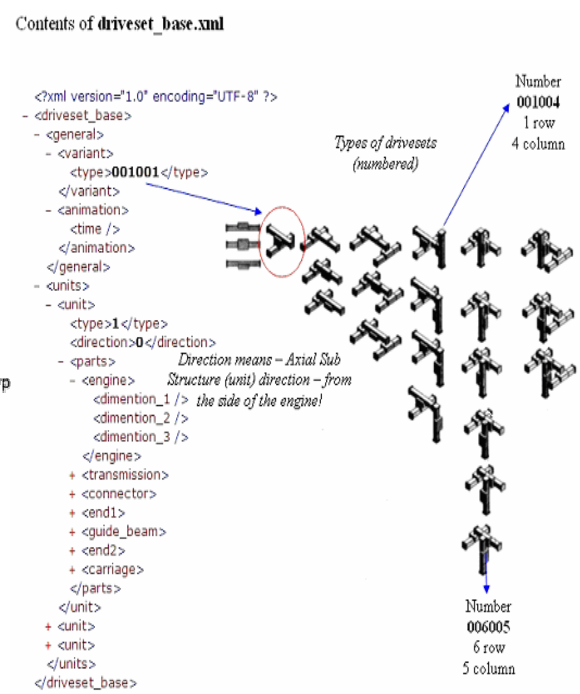

Fig. 4 XML-description of the ***DriveSets*** *product family*

For the needs of the X3D modeling of the *DriveSets*, they have been decomposed in single subassemblies (single axes), which have been denoted as unit1, unit2 and unit3 (see Fig. 5).

For the purposes of the animation the elements of the X3D model have been "nested" as it is shown on Fig. 6. This is because every unit (it has its own movement) derives the movement from the preceding one. The parts of each unit are divided into two groups: fixed and dynamically altered (animated). The elements of the "offspring" unit must be included within the animated group of parts of its "parent".

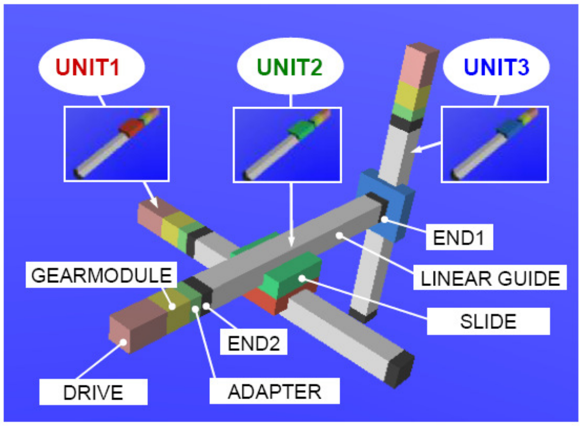

Fig. 5 Decomposition of the DriveSets for X3D-modelling

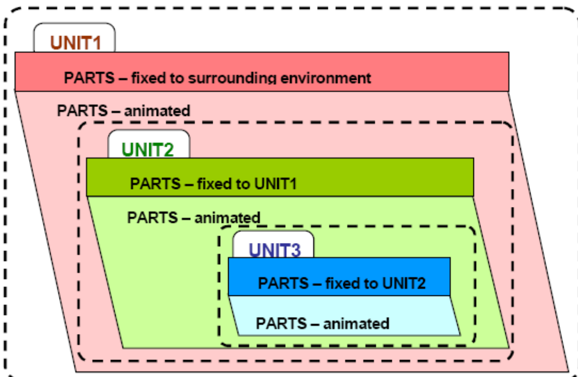

Fig. 6 Structure of X3D-representation of the DriveSets

There are two kinds of connection between units "slide - slide" or "slide - linear guide" and these relations are very important for the determination of which part within which group (fixed or animated) have to be included.

The experimental implementation of the 3D Web Configurator aims at providing an environment for 3D modeling and XML integration of the customer preferences, engineering calculations and reasoning and generating the product assembly model. It can work on two ways: (i) by the use the information from the other algorithms for engineering calculations working in background (the particular data are stored in the ASM.X3D file) and (ii) a) by the direct participation of the customer within design process or b) by conventional capturing the customers' requirements as already described (Fig. 7).

The system architecture of the framework for Customer Product Co-Design is presented on Fig. 8. The place of the 3D Web configurator is in the client's web browser. The calculation algorithm is implemented as a C++ application, which communicates from one site with the database and from other with a PHP-application using TCP/IP socket technology. The PHP-application generates HTML-pages based on predefined templates. The HTML-rages are served by the web browser to the single customers browsers.

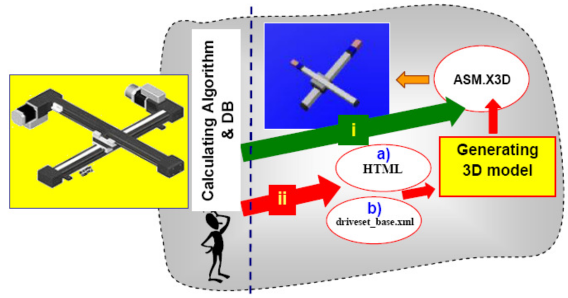

Fig. 7 2-way operation of the experimental software

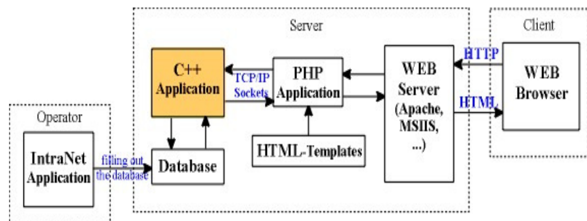

Fig. 8 System architecture of the web based Customer Product Co-Design framework

The following snapshots shows the graphical user interface and the 3D product model in the experimental implementation and the way of 3D model configuration of each of the single axis (Fig. 9) and their combination in a complex spatial structure (Fig. 10). As could be seen in the prototype the quality of the visualized 3D model is still rough (with low Level of Detail) and will be further enhanced. In particularly the proposed 3D configurator allows dimension modification and structure alteration (position of the elements within the system) for every single axis or the complete system. The operational and service areas of the designed system are visualized as well. Further it improves data transfer between geometrical model and other calculation modules and database running in background on the server.

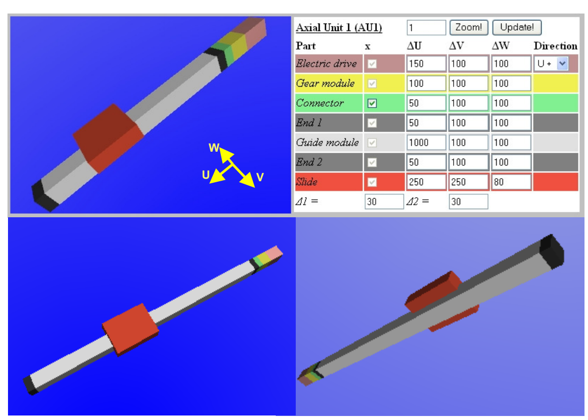

Fig. 9 Experimental 3D Axial Unit Configurator

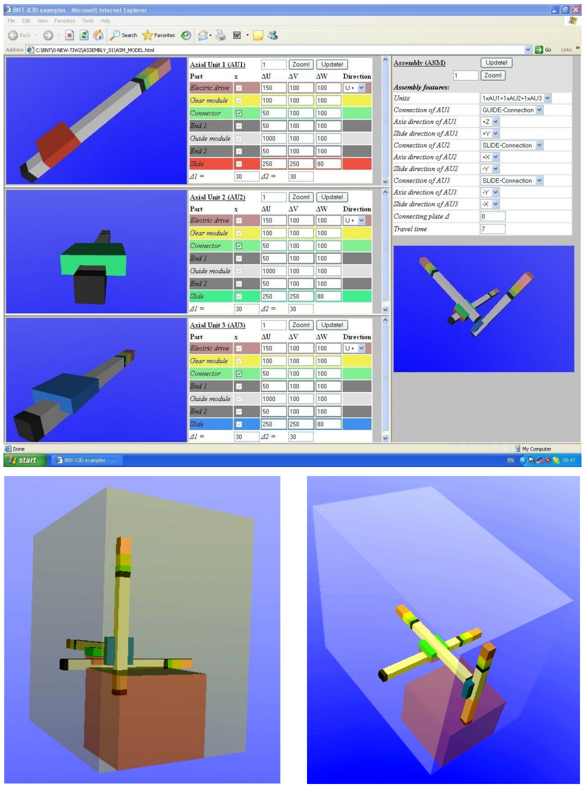

Fig. 10 Experimental 3D Web Product Configurator – graphical user interface and 3D model visualization from different view points

X3D provides unsurpassed interoperability for 3D data and significant flexibility in manipulating and displaying scenes interactively. By the represented experimental X3D Product Configurator the challenge of creating real-time 3D applications using a standard XML language for the Web has been realized.

5. CONCLUSIONS

It is obvious that a direct customer participation in the design process saves time and money, reduces the engineering efforts in respect to the solving of the design problem, improves the quality, changes the attitude of the customers towards the product and this way facilitates the product market realization. This involvement can be particularly “amplified” and leveraged using a 3D Web Configurator as a pre-sales service based on the X3D within XML CAx knowledge structuring environment. Here we conclude by pointing following obtained experimental results and outlook:

- The proposed approach ensures overcoming the negative effects of the communicational fragmentation: it is based on XML sets of applications;
- The customers’ knowledge and direct participation within the design process facilitates marketing and brings different customers’ attitudes towards buying decision making;
- As a consequence, the traditional cycle of “design – make – sell” is replaced by the new one: “design – sell – make”;
- Use of the X3D language enables the attractive, real-time, interactive and high quality graphic representation of the results obtained, as well as video and 3D data and allows components to be added to extend its functionality;
- By an additional attachment of functional information it is expected a X3D based model of the mechanical assembly to be developed for the needs of the more sophisticated VR immersive representation techniques.

The formalized description of DriveSets developed for the needs of this work can be observed as a basis for the development of neutral 3D Web Configurator of Products.

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