A LITERATURE STUDY AND CONCEPTUAL FRAMEWORK FOR CONCEPTUAL KNOWLEDGE IN THREE-DIMENSIONAL COMPUTER-AIDED DESIGN (3D CAD) MODELING

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ABSTRACT

The development of methods and procedures to make it easier to acquire pertinent skills in virtual modeling has been prompted by the growth of computer technology and the widespread usage of 3D CAD modeling systems. A overview of the literature on knowledge representation in CAD is presented in this article, along with a novel paradigm for conceptual knowledge in 3D CAD modeling. According to the results of the research we analyzed, methods emphasizing the creation of a model within a single platform—rather than different modeling techniques and use patterns—have dominated conceptions of knowledge representation in 3D CAD modeling. It is suggested that a new knowledge representation in 3D CAD modeling be used to help students develop into competent engineers.

Keywords: 3D CAD, Conceptual Knowledge, Knowledge Representation in CAD

1. INTRODUCTION

Since the development of computer technology, it has been noted that the usage of 3D CAD systems in manufacturing sectors has grown in popularity (Choi et al., 2009). Published literature (Mi et al., 2006; Hwang et al., 2007; Choi et al., 2009) supports the significance of the system in the context of digital product modeling. The need of matching modeling system training to industry demands is confirmed by the realization of the value of modeling approaches (Duan, 2004).This article will give a review and synthesis of the important literature on the many categories of knowledge in virtual modeling. It is thematically organized around the idea of knowledge representation in 3D CAD modeling. Additionally, the conceptual knowledge framework in the modeling process will be covered. Condo et al. (2004) claim that 3D CAD is becoming more and more used as a technology for product modeling. In the age of globalization, the use of modeling systems has emerged as one of the most important competitive aspects. The more complicated modeling system we see today is the result of developments in computer technology over the last several decades. Due to current advancements and increasing computerized modeling methodologies, conceptual comprehension of the system's use is thus necessary. In general, the context in which it has been used in the manufacturing sectors must be addressed in order to address the interrelatedness of the characteristics and tasks in producing functional virtual models. This conceptual review's goal is to enlighten the community of researchers studying engineering education on the role that conceptual knowledge plays in modeling. Constructs of conceptual knowledge in 3D CAD modeling are created based on the fact that all commercial CAD systems' product modeling processes are comparable, drawing on literature in the field of digital product modeling (Yang et al., 2008). This article's main objective is to develop constructs based on the common features offered by the programmd and the typical tasks for which the user may utilize the modeling system. The suggested framework aims to expand on the significant contributions made by the recently published literature on the use of 3D CAD systems in the field of product modeling. The article specifically covers the context of knowledge representation in 3D CAD modeling methods in relation to the need to comprehend the sorts of knowledge in the production of a digital product model and the effects on maintaining complicated design models. Command, declarative, strategic, and procedural categories of knowledge dominated the area of knowledge representation in CAD modeling in the early stages of the modeling system's development (Lang et al., 1991; Banana, 2000). To construct a virtual model, similar aspects in the functional approach must be emphasized due to variances in modeling methodologies and the development of computer technology. It's because more people are beginning to understand the value of 3D CAD modeling, which now a common is modeling technique utilized in the creation of product models. The modeling system is used by manufacturing businesses to help their product development process. Several different forms of knowledge have previously been recognized in previous studies on the use of CAD systems in the creation of virtual models. When they were initially launched, several of them were based on the two-dimensional CAD system. As technology develops quickly, a review on knowledge representation in the use of the modeling system is designed to look at the problem of the kind of knowledge generation in the use of the modeling system. Understanding how information is represented in 3D CAD modeling procedures enables us to improve, hone, and create fresh approaches to teaching modeling systems in higher education. Because of this, recently graduated engineering students are more qualified for entry-level positions connected to the engineering product development process. Due to the technology's increased

complexity as a result of the availability of numerous modeling methodologies, each of which has a unique set of capabilities for performing distinct duties, it is necessary to acknowledge the presence of conceptual knowledge while using the modeling system. Because different vendor products utilize diverse types of technology, resulting in a wide range of software features, the strategies used vary. An awareness of the need to identify linked component of conceptual knowledge in 3D CAD modeling will be provided by a review on the subject of interest. The requirement to recognize the important features given by the vendor to produce virtual models from the complicated modeling system will be highlighted by discussing constructs common to all commercially available CAD modeling systems.

2. KNOWLEDGE REPRESENTATION IN CAD

Declarative and procedural knowledge were classified by Lang et al. (1991) as knowledge in CAD. Declarative knowledge, according to their definition, comprises of the situation's facts, which would include knowledge about the item being drawn and the specific instructions that may be utilized with a certain CAD system. They went on to explain that users should have access to information about the objects being designed, such as the mechanical properties of the object, sound engineering practices that can be applied to the object, and understanding of other designs for objects of a similar nature that can be used as a reference for the designed object. Additionally, users need declarative knowledge about the system in question, including the syntax of the instructions and the specific commands that may be used. Declarative knowledge in CAD is defined as understanding what the programm is all about and what it is capable of producing, according to Bhavanani et al. (2000). Chester (2007) presented a declarative command knowledge that is concerned with the exact methods people employ to achieve well-known goals like extrude and revolve. He claims that it is to understand of the 3D CAD instructions or algorithms that are accessible. According to Lang et al. (1991), CAD procedural knowledge is comparable to a subroutine that processes the specific information in the same manner each time, depending on the circumstance. They go on to say that CAD job strategies or processes should be independent of the CAD platform and should work on just about any machine. Chester (2007) offered a word with a similar meaning but a different definition: specific procedural command knowledge, which is concerned with the particular steps people take to achieve well-known goals like extrude and revolve According to Bhavanani et al. (2000), command knowledge is the understanding of the commands (algorithms or tools) and processes that tools inside CAD software are to follow. It has to do with understanding the appropriate software command to use to get the desired result. Chester (2007), on the other hand, redefined command knowledge as precise procedural command knowledge, or the understanding of how to carry out orders given by the system to produce desired results. He argues that having this information gives the operator the ability to use certain CAD software to carry out the required orders. 'Command' and 'strategic' knowledge may be used to distinguish experts in complicated computer systems like CAD, with experts using more of the latter information, according to Bhavnani et al. (2001). He clarified that understanding different approaches to completing certain tasks and the decision-making process are both parts of strategic knowledge. According to Chester (2006), strategic knowledge is the expertise required to choose and apply the proper command knowledge in a way that effectively builds a model and permits future design flexibility.

For modeling activities, procedural, command, and declarative knowledge is the most fundamental knowledge. Only the knowledge representation of the modeling system based on the use of a single 3D CAD platform is the focus of these sorts of knowledge. As users get more expertise, they may efficiently apply these sorts of knowledge to a single type of CAD system. In reality, this doesn't happen very often. Given that actions connected to the development process have an impact on other processes (including design, manufacturing process planning, and production), model developers must be aware of the need to comprehend the general characteristics and tasks in the creation of a model. Additionally, created models are used or used with other kinds of software.

3. CONCEPTUAL KNOWLEDGE IN 3D CAD MODELING

The definition of conceptual knowledge offered by many scholars in the area of education is briefly reviewed in this section. As the modeling processes and common tasks connected with the modeling techniques have been well documented (Ault, 2005; Nestorovic, 2008; Hwang et al., 2009; Nyirenda et al., 2009), the section is not intended to provide a comprehensive review of the definition but rather to highlight its existence in 3D CAD modeling. According to Bloom et al. (1956), conceptual knowledge is the interrelationships between the fundamental components of a larger structure that allow them to work as a unit. According to Groth and Bergner (2006), the phrase may also refer to a networked web of knowledge; a cognitive network in which the connections between nodes are just as significant as the individual bits of information that make up each node. While Because 3D CAD uses a variety of modeling methodologies, each of which has a unique set of capabilities, the technology itself has become increasingly complex. Since these systems are now employed as a crucial tool in the process of developing new products, it is necessary to understand how they interact with one another. Hiebert and Lefevre (1986) assert that this expertise is required to recognize issues, come up with fresh solutions, or modify tried-and-true ones to address new issues. Two key concepts

that support learning challenges in respect to conceptual knowledge are constructivism and schema (McCormick, 1997). Constructivism's in 3D CAD put the emphasis on people developing models that show how they understand how the systems produce their models. Students progressively increase their grasp of the model creation process by creating simple model parts, working their way up to increasingly complex model structures, and finally assembling a finished model. During the model-building process, they will make an effort to incorporate their grasp of the principles. Since this process evolves over time, prior conceptual understanding is crucial. Additionally, several scholars have explored the significance of the knowledge and its connection with procedural knowledge, including McCormick (1997), Rittle-Johnson et al. (2001), Heywood (2005), and Tabaran et al. (2007). These sources make it abundantly evident that information is both present and important in the process of digital product modeling.

4. CONCEPTUAL FRAMEWORK OF CONCEPTUAL KNOWLEDGE IN 3D CAD MODELING

This article's main goal is to provide a conceptual framework for conceptual understanding in 3D CAD modeling. As was previously indicated, the conceptual framework was made up of five constructs that represented students' conceptual knowledge of relevant fields while building virtual engineering models. Each construct is an example of how a group of students have conceptually understood the modeling process under certain conditions.

Model Creation-In 3D CAD, the process of modeling often begins with the definition of a datum or construction plane that acts as the foundation for constructing the base profile. Geometric components, such as lines, arcs, and spines, are used in the production of the base profile and are drawn as vectors in a single open or closed profile that will serve as the base portion (Silva et al., 2002). If parametric modeling is selected as the modeling approach, constraints are now introduced to the profile. By using the same procedure—creating and placing the building plane in the proper location—further development on a model's sub features is built. The user may increase the characteristics of the pieces. In assembly modeling, a finished model is viewed as a single component, and other parts may be built subsequently either in the same or distinct files. Additionally, by giving the necessary parameter, standard engineering parts may also be created using third-party software or specialized computer scripts. These components are then put together utilizing the precise command processes of the appropriate program. Throughout the development process, models are often rotated and placed in desired locations to facilitate user interaction with the models. The above-mentioned rationale leads to the justification for this design. This construct contains fundamental knowledge on many modeling approaches and the components that make up each methodology, including ruled, tabular, and revolved surfaces. This idea is developed in the context of modeling that consists of a single component or an assembly. Regardless of the modeling approaches used, this construct is thought to represent a mental grasp of some elements of the construction of 3D CAD models.

Manipulation-According to Baba et al. (1998), manipulation is a modeling activity whereby changes on the models are created. By changing the model's geometry or characteristics, the model is altered. Utilizing the system's resources has the ability to significantly cut down on design errors and design time while also improving consistency and documentation simplicity (Wang et al., 2008). The benefit of having this information, according to Wang et al. (2008), is that it cuts down on the time needed to adapt designs and concepts, which speeds up the manufacturing process. All linked components and design sheets are immediately updated whenever a part or assembly is modified, causing all related files to be altered at the same time as the primary part. The justification given above illustrates the task's relative relevance in the 3D CAD modeling process. In order to create a rich variety of design variants, this construct thus contributes the conceptual knowledge of manipulation activity within the framework of computer aided product modeling process.

Exploratory Visualization-Quantifying and visualisation, according to Yoshimura (2007), are crucial steps in the product development process made possible by 3D CAD modeling systems. This is because it allows designers to judge or assess models more accurately. The system's built-in model allowed designers to evaluate the product organically rather of having to cognitively extrapolate real-world elements from a collection of technical drawings. Additionally, being aware of the visualization features offered by CAD systems would enable users to construct models more quickly (Fitzmaurice et al., 2008). In order for features to be added to or updated to create a full object, the user must be able to navigate between basic or complicated model structures (Jong et al., 2009). Users may utilize feature manager, for example, to quickly alter or fix inadvertent errors by selecting the appropriate entities straight from a complicated model structure. This justification of the importance of the 3D CAD modeling work supports data that is pertinent to the suggested architecture. As a result, this construct is utilized to indicate conceptual comprehension of activities referred to as visual model exploration, which would speed up the process of creating models.

Model Transfer-This construct exemplifies the conceptual comprehension of the need for data sharing (model transfer) in order to transmit models for usage by downstream applications. Every CAD user must understand and be familiar with data transmission since developed models are utilized for downstream applications (Pratt et al., 2001; Kim et al., 2008). According to Kurimoto et al. (2002), these downstream tools are connected to model analysis, productivity assessment, and creation of geometric data for machining. The requirements of other users should be considered throughout the model development process. If models cannot be ported to another platform, they are useless. For instance, improper use of geometry or topology to create a 3D CAD model prevented connected applications from reading relevant data. As a result, it's critical to create models that can be used more effectively throughout the organisation. In order to enable a progressive development of a product model, which includes the transfer of data for downstream users, this construct is built based on users' conceptual understanding of sharing and exchanging models' data across multiple platforms.

Collaboration-This design is made up of key ideas for teamwork tasks during the creation of 3D models. The construct deals with the comprehension of different forms of interaction and cooperation in the creation of a product model in any dispersed teamwork setting. By delegating duties to team members, the collaborative CAD framework in product development makes it easier to create a hierarchical product structure with single and compound components (Janardanan et al. 2008). A core product model allows for the consistency of each team member's unique perspective on the product. A web-client with expertise in part design supports the actual design of a single component, whereas a web-client with expertise in assembly design supports the definition of the assembly relations between components (Bidarra et al. 2002). In collaborative modeling, certain commercial CAD systems are integrating client-server architecture features for multiuser services. This construct is built on users' conceptual knowledge about the creation of a product model inside the framework of a collaborative CAD system.

5. IMPLICATIONS FOR THEORY DEVELOPMENT AND RESEARCH

The main repercussion is that the proposed framework now recognizes a group of constructs that include conceptual knowledge in 3D CAD modeling specific to the field of mechanical engineering. With regard to the way knowledge is represented in CAD modeling, the framework clearly identifies the research topics that are pertinent to the study of 3D CAD modeling in the context of the aforementioned field. The discovery and inclusion of such contextual aspects on the use of the modeling system in the product development process might be done to further enhance the conceptual framework, which is based on research. To argue that the suggested framework should be seen as a different sort of knowledge representation in 3D CAD modeling would be premature. Simply put, the framework aims to identify and categories the areas of study that make up conceptual knowledge in virtual modeling. Consequently, the conceptual framework is now intentionally descriptive in character.

6. CONCLUSION

The conceptual framework was put up to solve problems with how conceptual information is currently understood in 3D CAD modeling. The framework recommends a supplementary strategy that involves community and academic sources in the knowledge representation phase of the modeling process. In other words, the framework outlines how students may make the most of the modeling system's capabilities within the designated knowledge domain so that teachers and others involved in engineering education can make choices about how to teach and study the modeling system that are well-informed. Years of study have highlighted the advantages of conceptual understanding in a given knowledge area, but the topic of conceptual knowledge in 3D CAD modeling has received very less attention. To build a virtual 3D CAD model using the new framework, research is required to define and evaluate the information's interactions with other types of knowledge (command, procedural, and strategic), as well as to identify any possible benefits of comprehending the knowledge. Higher education institutions should prioritise conceptual knowledge research in 3D CAD modeling in the future to develop competent engineers.

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