Ontology for CAD/CAM Integration

Basel Alsayyed Ahmad

Department of Mechanical Engineering United Arab Emirates University (UAEU)

ABSTRACT

CAD/CAM integration has been an open ended problem for the factory automation. Many approaches have been followed to make the full integration, such as Computer Aided Process Planning (CAPP), and Form Feature (FF) approaches. Among other approaches those two approaches made the biggest impact however, they became shorter than the full integration. In CAPP, there are two methodologies, one is the variant and the other is the generative, which is used for the integration. In FF, a geometric feature is mapped to a manufacturing feature in a logical order. The geometric parameters of the geometric features are used as the base for the mapping and other manufacturing parameters are either defined at the process level or deduced from the geometric parameters. The problem with the above approaches is that it does not have all the aspects of manufacturing process and all other manufacturing environment aspects. The problem is data management for both CAD and CAM. Software developed to integrate CAD/CAM have many shortcomings due to the limitations of the knowledge representation and maintenance. Ontology is fairly new logy that has been used in many areas to model very complex problems in aircraft, automotive industries as well as in medical and other fields. Ontology, is the logy of defining knowledge domains thoroughly in plain English, then predefine the relations among the different entities in a domain. In this paper, a meta model will be developed using the ontology approach to demonstrate the solution for the CAD/CAM integration problem. An example of manufacturing process will be used to look at its different aspects of CAD/CAM.

Keywords:-ontology, knowledge modeling, CAD/CAM modeling, process modeling, CAD/CAM integration, CIM

1. INTRODUCTION

In the past three decades CAD/CAM has marked a major if not the major advancement in product development arena. CAD and CAM, however developed closely but separately. This resulted in newer problems facing not only the CAD/CAM but the different product lifecycle phases. In this paper the focus is on the sharing of information in two major phases of the product development, namely CAD and CAM. As products and processes gets more and more complicated, the need to have a seamless flow of information and knowledge related to the product and the process is becoming more of a need than a want. In this work, focus is on building a knowledge model that encompasses all knowledge related to the CAD and CAM. A knowledge modeling tool, protégé is used to model the knowledge at three levels. The authors acknowledges their appreciation to Stanford medical

2. LITERATURE SCAN

Ontology has been used in many disciplines. Our focus in this paper is on usages related to design or CAD and to manufacturing or CAM. However, as ontology is a fairly new logy, ontologies related to other than design and manufacturing has been cited. Following are the cited papers and articles that are related to ontology usages in many domains. According to Chang and Terpenny, ontologies can be applied to develop accuracy and decrease search time [1]. Gómez-Pérez, shows how ontologies aim to capture consensual knowledge in a generic way; they may be reused and shared across software applications and by groups of people. According to Tserng the two main elements of ontology are concepts and relations [2]. Kingston proposed a prototype to ontology development based on multi-perspective modeling [10]. It claimed that it can resolve some of the common problems in ontology development. One of the main objectives of multi-perspective modeling was to simplify ontological diagrams by removing the necessity for multiple inheritances or other multiple linking within an ontology. Chang and Terpenny's research explored the ontology-based method to solve the limitations in present computer-based information systems for product design [1]. They have developed a framework for an ontology-based data integration and decision support environment for e-Design. The framework can guide designers in the design process, can make recommendations, and can provide decision support for parameter adjustments. Morbach described the development and applications of ontology for CAPE (Computer-Aided Process Engineering), OntoCAPE [14]. It demonstrated how the methodology used to develop OntoCAPE explained how the ontology has evolved from its skeletal, informal specification to a complete, formal specification. The history of OntoCAPE further showed exemplarily that ontologies are dynamic systems, which evolve and change according to prevailing conditions and requirements. The focus today is on innovation: products differentiated from those of competitors that are also affordable, reliable, and early to market. Küçük developed an ontology for electrical power quality (PQ) domain, called PQONT [28]. The purposed ontology will serve as a shared vocabulary for the involved parties in the domain as well as basic formal description and classification resource for the researchers in the PQ domain. Kim showed the ability of the assembly design (AsD) ontology to be logical can capture both assembly and joining intents by a demonstration with a realistic mechanical assembly [15]. An Assembly Relation Model (ARM) is enhanced using ontologies that represent engineering, spatial, assembly, and joining relations of assembly in a way that promoted collaborative assembly information-sharing environments. For the reason that designers are no longer just exchanging specific geometric data, but rather more knowledge about design and the product development process, including specifications, design rules, constraints, and rationale. Tserng proposed an outline to conduct knowledge extraction by establishing project risk ontology [2]. More specifically, the study proposed the ontology-based risk management (ORM) framework to enhance the RM performance by improving the RM workflow and knowledge reuse. This ORM framework aimed to verify the project risk ontology could enhance RM workflow performance within the construction organization by case study, and hence decrease risk impact on the project. Through the implementation of the ORM framework and the ontology development model, the selected contractor could integrate knowledge reuse in the RM operation. According to Yang, ontology has been applied by many researchers to model engineering and design-related knowledge to facilitate knowledge reuse and information sharing among applications [5]. As an explicit specification of a conceptualization, ontology plays a significant role in these aspects: sharing information, integrating different applications, implementing interoperability and reusing knowledge. Although research about ontology has its root in the computer domain, ontology has been applied in a variety of domains due to the advantages. Han and Park proposed an outline for process-centered knowledge model and enterprise ontology for the context-rich and networked knowledge storage and retrieval required during task execution [3]. Enterprise ontology is intended to assist the acquisition, representation, and manipulation of enterprise knowledge.

Cochrane described three principles of reuse, i.e., the separation of information from knowledge, the separation of product knowledge from manufacturing process knowledge, and the correct classification of manufacturing knowledge [6]. Brandt advocated the idea of Process Data Warehousing as a means to provide a knowledge management and integration platform for such design processes [9]. The key idea behind our approach is a flexible ontology-based schema with formally defined semantics that enables the capture and reuse of design experience, supported by advanced computer science methods. Turk addressed the ontology can be used to map a research area, to design a curriculum, to structure the agenda of a conference, to provide keywords and classifications for bibliographic databases or knowledge management in general [18]. The fundamental principle for the creation of the ontology was that construction informatics research is a process eventually providing new mechanisms for the construction industry's work and with a potential of transforming the industry as a whole. Hori articulated the different meanings and roles of strategic knowledge and considers how knowledge-based systems can exploit strategic knowledge [24]. In his paper, he presented an overview of the diverse dimensions of strategic knowledge and a microscopic model. However, the usage of strategic knowledge also remains an open question. Wriggers presented ontologies that were formally described with OWL-DL, the language from the description logic (DL) family, which combine advantages of structure (e.g. frame-based) and logical approaches to knowledge representation [11]. CBS, class (concept)-based similarity, query formulation support algorithm allows reducing the amount of routine work needed to input information and enforce domain model integrity. It can be viewed as a means for physical system and engineering problem description auto-completion based on the information provided by the user. It supports inheritance of the components, properties and relations from classes, creation of virtual components corresponding to complex structural relations model verification, etc. Chen addressed the mechanism for integrating ontology-based product lifecycle knowledge of effectively integrate the heterogeneous product knowledge distributed among different enterprises during a products lifecycle, thereby facilitating sharing of this product knowledge [4]. The ontology-based integration and sharing process for product lifecycle knowledge has two parts – integration and sharing. Study results facilitate integration and sharing of product lifecycle knowledge to satisfy participate product knowledge demands during a product lifecycle and thus increase product development capability, reduce product development cycle time and cost, and ultimately increase product marketability.

3.ONTOLOGY FOR KNOWLEDGE MODELING

Ontology is the new approach, followed in this paper, to modeling aspects of CAD/CAM. It can accommodate CAD aspects and parameters as well as the CAM aspects and its parameters including the manufacturing processes, their relations and the other aspects of the manufacturing processes. What is ontology? Ontology is the full description of all entities in a knowledge domain, including properties and relations. What is a knowledge domain? A knowledge domain is a field or a scope of a subject. Ontology modeling via protégé is used to model aspects of CAD and CAM. Example of milling process is used to walk through the modeling of the milling features in CAD and the modeling of the CAM aspects of the same milling features. Protégé is used as a knowledge platform, where knowledge is acquired and represented in a standard formal way. All aspects of one or more knowledge domain can be modeled using the same platform. The value of using the same platform to model is that it is integrated by design. Every knowledge aspect should have a predefined entities description as well as predefined general set of possible relations among the different entities. Properties and relations could be used in one knowledge domain and reused in as many domains are needed to be on the same platform. Protégé is a tool developed by Stanford University, medical school. However, it can be used as a knowledge acquisition tool as well as a knowledge solution. It can be used very much to model any knowledge domain. The authors acknowledge their appreciation to Stanford Center for Biomedical Informatics Research especially for putting out this valuable tool and supporting it.

4 PROPOSED KNOWLEDGE MODEL ARCHITECTURE

The proposed new knowledge model architecture is build based on four layers. The first layer is the lowest which is merely the data related to all entities within the knowledge domain. The second layer is called the meta model layer, which encompasses the first level of knowledge. Meta model contains description of the knowledge domain at the meta level. This means in the meta model we have types of entities description and types of properties, relationships among the different meta model entities. More will be explained in the meta model section. The third layer is referred to as the class layer. The class layer contains specifications of meta classes. Where as in the meta layer there are types of entities, in the class layer there are specific types of those meta entities. The fourth layer is the application layer. In this layer knowledge based systems are built as individual applications to guide and drive product development aspects. Different applications can be built independently and mutually exclusive from each other yet use the same knowledge model. Different knowledge based systems need different combinations of the pre-defined meta knowledge. With the proposed architecture it is possible to tap into the needed meta knowledge through the class model needed for a certain knowledge based systems. Figure 1 below shows the relationship among the knowledge mentioned above.

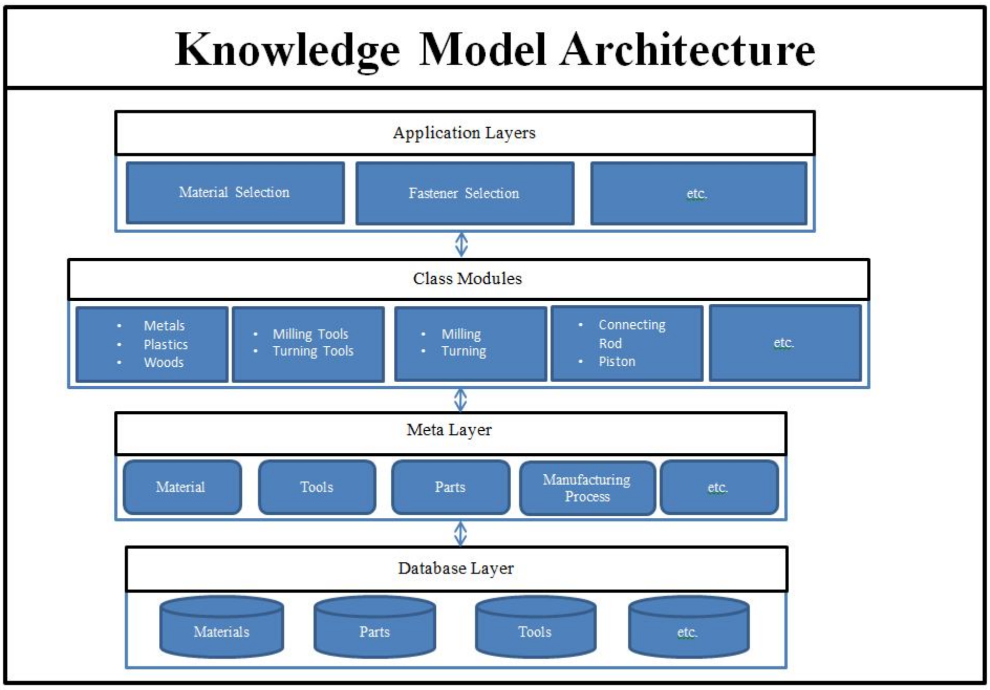

Figure 1 Knowledge model Architecture

5.META-MODEL

Meta model contains meta data, information and/or knowledge, which is a high-level information about a knowledge domain entities. All entities are referred to as “a thing”. The meta model includes all “things” related to the domain. A knowledge domain is the description of entities in a subject, a field or discipline. Regardless of the different subjects or fields, in a meta model we encompass all the different fields entities. As different fields are different the modeling of knowledge within a domain is handled differently. And thus, the knowledge model of one field is may be done on a totally different platform resulting in a set of knowledge domains which presents a challenge to integrate them. Depending on how we use the knowledge in the different applications, the integration platform plays a major factor. A realistic look at the different applications that would be needed to be developed for the different aspects of the product development cycle shows the extensive range and variety of those applications. Different applications have different types of knowledge, and different ways of representation and usage. This variation occurred not only in the design related knowledge, but also in the CAM related applications. Despite the major breakthroughs that were achieved in the CAD/CAM area, it always was and still a challenge on how to put the puzzle together. What is needed is a common platform and reference for: 1) knowledge acquisition, 2) knowledge representation and 3) knowledge management. In this paper, the authors laid the foundation for establishing such a platform using protégé as the tool for all the main three functionalities above. A knowledge models at the meta level is demonstrated in this paper using the milling process. However, the meta ontology of the mailing process is expandable to include as many processes as needed. The beauty of this meta model is that it allows for the addition of new meta model classes, which could be merely “things” not of the same type as the existing meta classes in the model. This feature of the meta model make the knowledge model very flexible, hence there is no limit on how far we can expand it. It is an open architecture where it can expand horizontally as well as vertically. Horizontally it will expand to new aspects of the knowledge model within the domain; and vertically it builds up the knowledge on available meta classes while preserving the meta relations at the highest level and at the same time allowing to add additional relationships at the children level of the meta classes. Introducing the meta model of CAD/CAM will be a milestone that would help the product development lifecycle. By making the knowledge reusable it will shorten the product development cycle. Not every application needs to build its own knowledge model. Additional knowledge can be added to the meta model should it be needed, however the infra-structure of the meta model will be reusable. Figure 2 shows a partial snapshot of the meta model for the CAD/CAM.

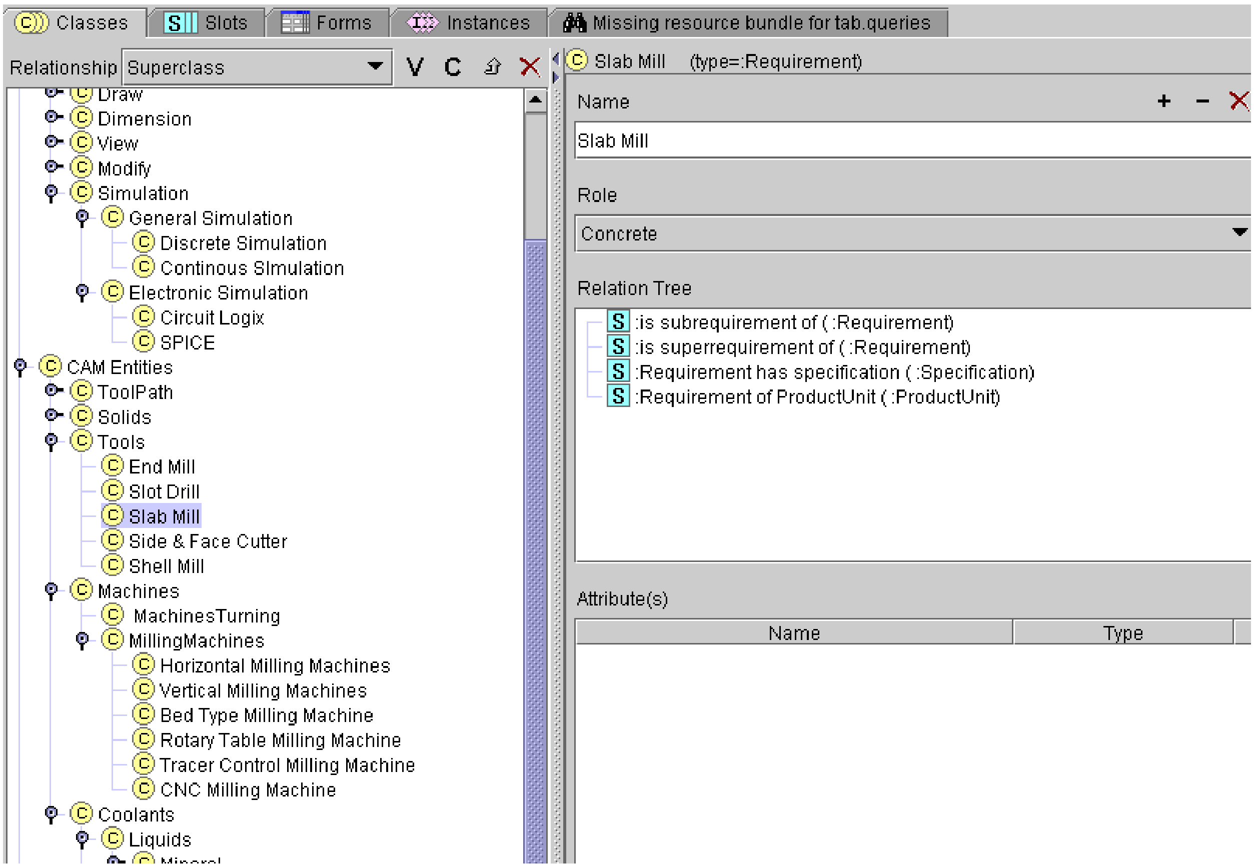

Figure 2, CAD/CAM Meta Model

6.CAD/CAM KNOWLEDGE MODEL

The knowledge model includes in addition to the entities of the domain all the properties and their relationships. It also could include other ontologies for different domains. An example of related knowledge needed for most knowledge based systems is the materials ontology. Figure 3 shows the materials ontology as part of the CAD/CAM ontology. It could be maintained separately by the materials experts and only referred to needed knowledge in it at the meta level as well as the class level. As we can build a knowledge based system to help the selection of the component materials, we could need some of the materials properties for a knowledge based system for simulating a certain performance parameters of the same or different components. The two knowledge based systems would then share the same material meta model. Examples of the CAD/CAM ontology meta classes are tools, workpiece or parts, material, process, machines etc. Knowledge about the material could be used be used by multiple knowledge based systems and by multiple meta classes. One of the metal cutting rules are related to the relationship between the materials and the cutting tools. And always parts are made of materials. In this example a relationship is defined at the meta level as “CAM entities are made of Material” and another form of the same relation as “Part is made of”. So both parts and tools could utilize the materials knowledge for their materials assignment. However, knowledge could still be utilized at a higher level; a rule in the metal cutting theory could state " material of the tool has to be tougher than the part or workpiece material.

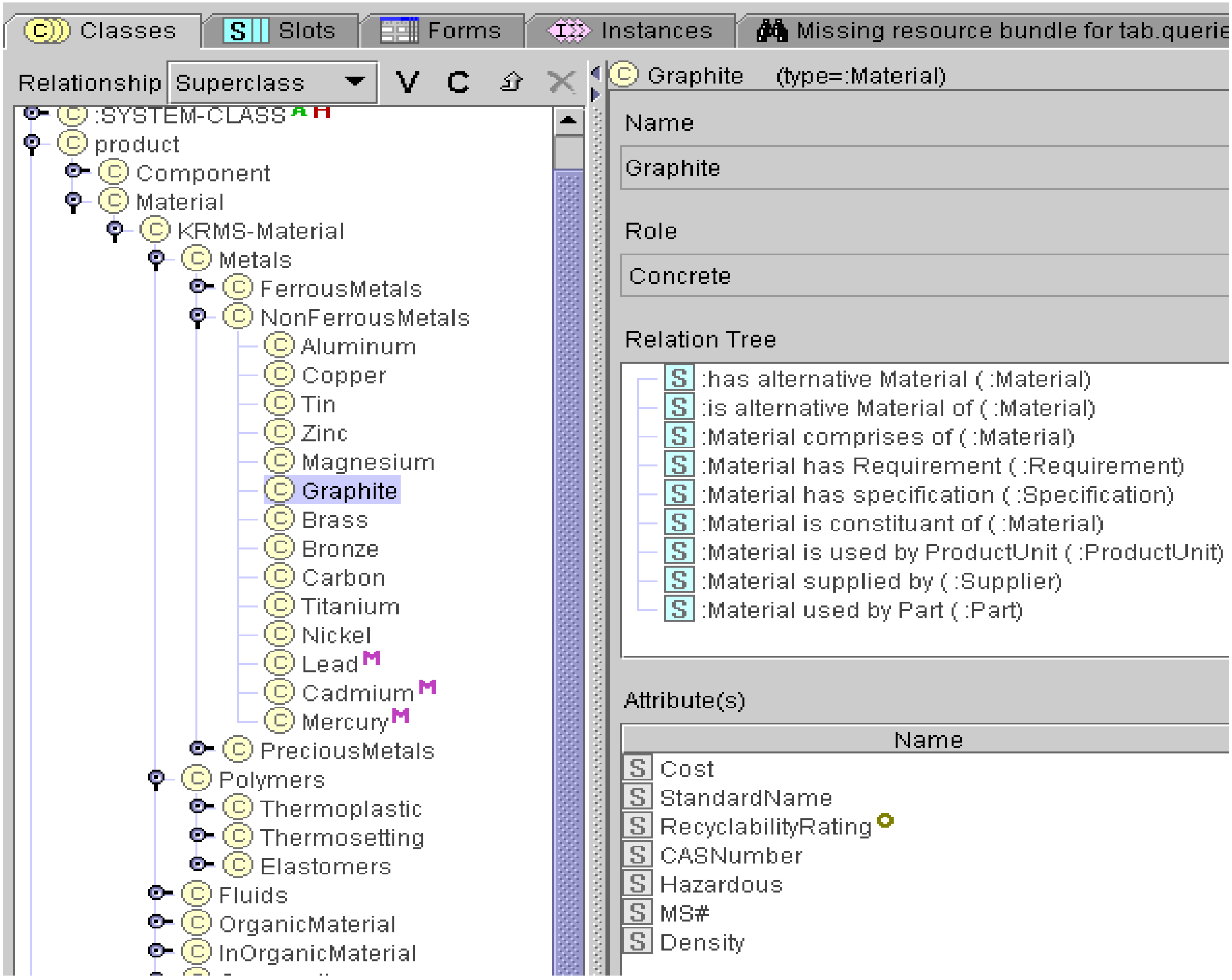

Figure 3, Material Ontology included in CAD/CAM ontology

7.CONCLUSION

This paper has tackled the application of a new logy (ontology) to help the full integration of CAD/CAM and beyond. With the predefined meta model, sub-models can be developed based on the same meta model for different aspects of CAD and CAD and can easily communicate the data/info/knowledge among them. An example of the integration has been developed using protégé platform. It includes CAD aspects of the product, CAM aspects as well as material selection models. Milling process has been used as an example where different aspects of the process have been modeled. Also materials ontology has been linked to the integrated model, where materials properties can be related to process parameters. This research paved the way for a different direction for the future of CAD/CAD integration as well as the whole product development integration. More ontologies can be developed based on the same meta model and easily integrated and directly used with other ontologies which share the same meta model.

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AUTHOR

Dr. Basel Alsayyed is an assistant professor at the department of mechanical engineering in the United Arab Emirates University. With over 16 years of experience in academia in many colleges and universities, and over 12 years of industrial experience, most of which are in the American automotive industry, Dr. Alsayyed has a passion for education in general and teaching in particular. Teaching is an art, a trust, a valuable transformation of students using certain methods and tools, and it is holy, are all part of his belief. He practices it in all aspects of his life, and to Dr. Alsayyed, students are the most valuable element in the education process; their needs have to be addressed in any continuous improvement discussion of the education process. Integration of academia and industry goals and activities are paramount. Sensing the industry needs and prepare future engineers to meet the challenges is an important dimension of Dr. Alsayyed's activities.

Dr. Alsayyed research interests are in the areas of advanced manufacturing, quality & reliability, renewable energy, ngineering education and knowledge management.