Human Intent Modeling Assisted Concurrent Engineering

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Abstract **– Engineers control product and production process information according to their intent. At the same time, they consider intents of other humans. In conventional computer modeling, results of decisions are described as simple facts for downstream modeling procedures. Effective engineering processes need information about the original decisions, especially when an original design should be modified during its development for changed conditions. Recent industrially applied modeling of product is not capable for description of human intent. The authors proposed a method for description of design intent in product model. The purpose of this paper is to introduce main characteristics of design intent and to show details about possible handling of this information in industrial modeling systems. Some essential issues as role of design intent descriptions, the problem of integration of intent modeling in product modeling and characteristics of intent model are discussed. The paper is organized accordingly. It is concluded by a discussion about implementation issues.**

I. INTRODUCTION

Engineers use concepts, methods, experience, and calculation results for generation of model data describing some features of modeled engineering objects by appropriately selected computer procedures. After exchange or communication of a model data set, the same or different modeling procedure and engineer understand and reconstruct it. Development, modification, and application of the model are constrained by results of earlier decisions. At the same time, new results are to be integrated into the model. Engineers at application of the model must have more or less information about the background of decisions of the engineers at the sending station. Recent advanced industrial modeling systems do not offer this function. This situation motivated the authors at their design intent modeling related research. They are working on integration of background information of decisions into product model. Design intent originated background information inherently involves information about modification of the modeled object as it is allowed by the engineer who defined it. Description of intent information in a product model enhances communication between engineers and quality of their work at completion, modification and application of models. Design intent models support product related computer intelligence. Hyperlinks can be placed to establish high-level product model based communication of engineers with the outside world.

Preliminaries of this work are analysis and methodology development by the authors on human-computer interaction procedures (HCI) [1], characteristics of design intent [3], basic modeling of design intent and integration of design intent model in product models [2], [4]. In this paper role, composition, elements and relations of design intent model descriptions are discussed. Results of the reported research can be utilized at handling of design intent at automation of engineering design processes.

The purpose of this paper is to introduce main characteristics of design intent and to show details about possible handling of this information in industrial modeling systems. Some essential issues as role of design intent descriptions, the problem of integration of intent modeling in product modeling and characteristics of intent model are discussed. The paper is organized accordingly. It is concluded by a discussion about implementation issues.

II. PLACE OF INTENT MODELING IN ENGINEERING MODELING

Some recent leading developments of industrially applied modeling systems resulted procedures to support intent communication but they are restricted to facts as constraints [7]. Despite the relatively high level of automatization, performance of a modeling still highly depends on performance of engineers. Human performance depends on a lot of different factors and changes during practice. Beginner can be assisted by knowledge that has been defined by skilled engineers, taking into account a threshold knowledge. This approach is the mutual adaptive interfacing in [8]. Behavior of humans seriously affects errors and quality of decisions. Taking into account some results of analysis of human factors is inevitable [9].

Some relevant concepts for design intent related human-computer interfaces can be found in [6]. Design intent modeling means that human engineer skills are assisted by models of intent of engineers who created the product model objects to be modified, completed or applied at creation of new model entities. Modeling of design intent covers description of concepts that engineers want to realize as a consequence of their decisions. Process of a decision making is described together with methods, knowledge and simple facts applied at it.

Intent modeling is demanded by design practice because results of decisions in present product models are placed as simple facts. This shallow information is appropriate to carry design results in a conventional sense but it is inappropriate for advanced purposes as assistance of understanding, analysis and re-analysis of original decisions at downstream application of the model.

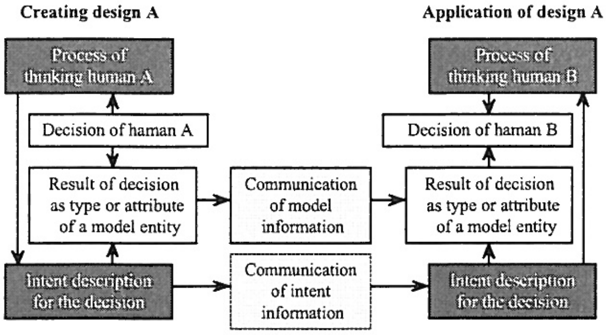

Fig. 1. Intent-assisted revision of decisions

In the recent style of product related engineering modeling, several engineers do engineering activities for the same product. They work at computer stations placed in the topology of worldwide sized computer networks. Recent CAD/CAM systems support model data communication but do not support design intent communication between workstations. This is why thinking procedure of design engineers during model creation can not be continued later during development, analysis and application of models in case of conventional modeling. Finite element analysis in industrial systems, for example, can not accept intent information about the calculation methods, experiences, consultants, etc., which are applied in course of a design process. Therefore, finite element analysis can not produce complete information about the evaluation of a design because it can take into account only simple information as geometry, loads, and restraints.

Intent based modeling is an indirect application of knowledge through human considerations in product design. At the same time, knowledge is added by humans through intent into the design. This modeling is a contribution to models that can describe information about characteristics and behavior of the modeled object in different conditions as well as can dispute and abandon unacceptable and non relevant decision attempts by engineers other than original designers, at modification, development and application of models.

In Fig. 1., a typical situation in engineering activities communicated between two modeling station is shown. An engineering object is designed at *workstation A*. In the course of the application of the model created at the *workstation A,* a need is emerged for revision of the model at the *workstation B*. Engineer at the *workstation B* demands design intent information to assist this activity. However, this information is not available even in recent models.

To complete product modeling and communication systems with intent entity related representation and software tools, first role and place of intent information should be defined. Role of intent determines basic requirements against intent modeling. Place of intent answers the questions about source and communication of intent information.

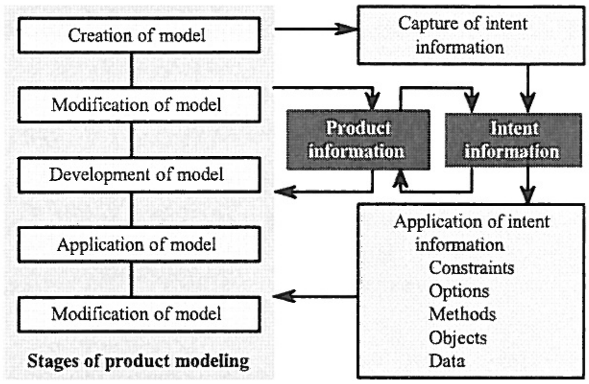

Fig. 2. Product and intent information

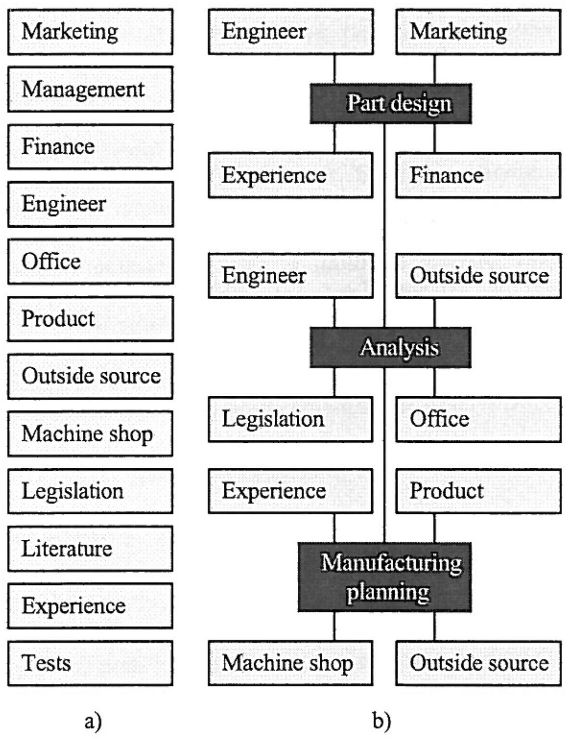

Fig. 3. Sources of design intent primitives

Design intent model an assists engineering activities at all stages of product modeling. This is essential where some earlier defined model entities are applied or integrated into a larger model (Fig. 2). Existing intent information is completed and applied and new intent information is defined and captured. Essential applications are constraining, decision on options, selection of methods, selection of objects and including product data.

Intent information for a given fact in a product model is a composition of independent or dependent elements of intent description called as intent primitives. Sources of intent primitives considered by the authors are listed in Fig. 3/a. As examples to highlight the problem, some most relevant sources are attached to three main stages of the mechanical part related engineering process in Fig. 3/b.

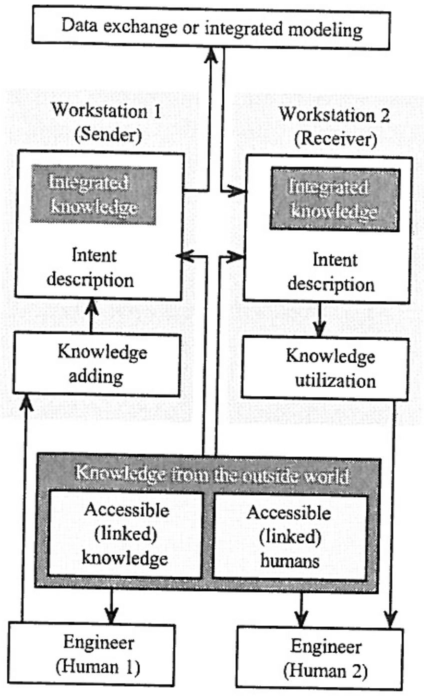

Fig. 4. Knowledge transfer

Knowledge descriptions are involved in or linked to intent descriptions (Fig. 4). Accordingly, processing of knowledge during processing of an intent description can be done inside or outside the intent processing system. Outside processing is really an automated request for the help of an expert or consultant from outside. Sometimes, human owner of knowledge does not allow access. In this case, human expert or consultant should be called. This human may be the original developer of the product model, application of which is to be assisted by design intent description. Intent model is communicated between the sending and the receiving workstations in the best format to describe intent entities. For the purpose of an average intent communication task a customized IGES neutral model transfer format completed with intent entities seems to be appropriate. If not, model description capabilities of the STEP international product modeling standard by the ISO can be applied where information and model description languages are available for programming complex, knowledge oriented design intent descriptions [5].

III. DESIGN INTENT MODEL AND ITS APPLICATION

The authors proposed a method for the definition of design intent in [4]. After role and place of intent information are defined, structure, composing primitives, and essential characteristics of design intent description were analyzed. Using results of this analysis, modeling of design intent was designed by using of the method proposed by the authors.

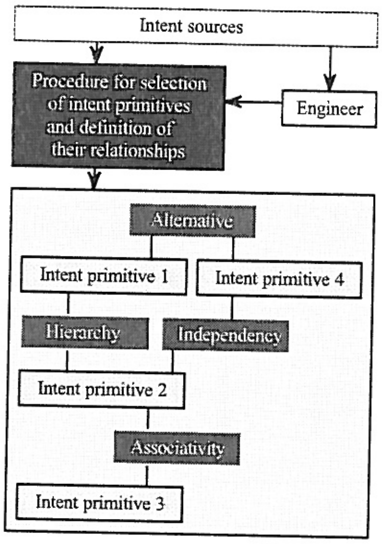

Fig. 5. Intent modeling by primitives and constraints

Four intent primitives are included in the example of Fig. 5. All of them must be taken into account at a decision making. Relationships defined between intent primitives give information to arrange intents in a structure. Processing of this structure produces a decision by the engineer who is responsible for it. However, that engineer is also responsible for definition and application of constraints defined by the relationships between pairs of intent primitives. This method, proposed by the authors, guarantee the quality of the model.

Engineers often define intent primitives that are alternatives. The selection of a solution taking into account alternatives is not always assisted by an additional relationship for hierarchy of alternatives. If not, the problem can not be handled by relationship definition; effect of the related intent primitives should be evaluated. The simple structure in Fig. 5 is typical for simple decisions. However, solving complex problems is the area of effective application of intent modeling. Intent model must be completed with an information that carries a measure of impact of intent primitives. Impact of an intent primitive sometimes is simply the consequence of its source.

Impact of different intent primitives is weighted by description of factors that can affect decisions, and can be used to affect revised decisions during the lifetime of the model. Fig 6 illustrates the two basic situations at creation and modification of design intent as a result of effect of changes in the outside world. Inputs for creation of an intent simultaneously with creation of the related product model entity or entity attribute value are the related human decisions and outside intent sources. Related decisions are defined by associativities. Creation of design intent is followed by an analysis of effect of the newly involved intent primitives on the actual decision. The result defines factors of impact of intent primitives on the decision and it is stored together with design intent description.

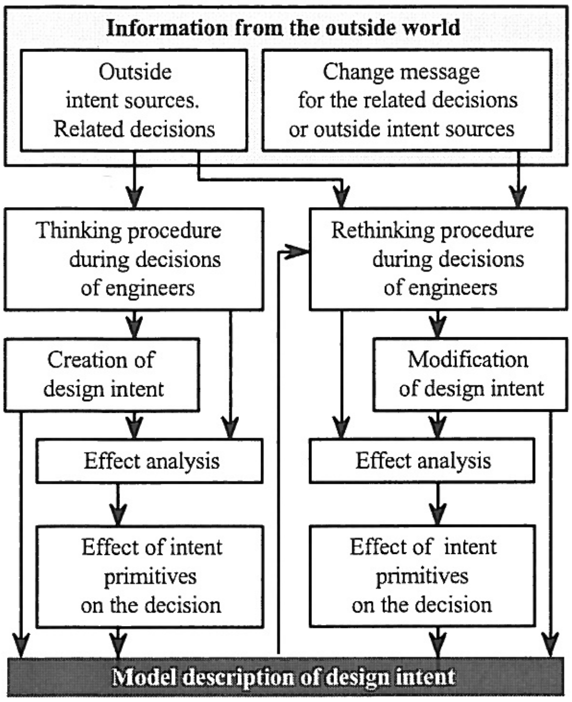

Fig. 6. Effects from the outside world on the intent model

Any change of the related decisions or the related outside intent initiates a human rethinking procedure and possibly modifies new intent entities or impact factors or both of them. Rethinking is often done by an engineer other than the original maker of the processed decision. Associativity definitions are utilized as assistance to the automation of rethinking processes when an earlier decision needs revision initiated by changes in its associated environment. When, for example, a previously prevailing thesis is over, all related decisions need revision. The method proposed by the authors offers an assistance to reveal related decisions in associativity integrated models. A dynamic model environment is established for continuously developed product related intelligent engineering.

When design of a new product starts, some of the earlier defined design intent descriptions are utilized to realize a continuity in product design at the company. For this purpose, stored situation dependent intent descriptions are applied at initial creation of the model. Engineers also can establish self-assistance by definition and storage of intents including circumstances for later tasks of similar circumstances.

Sometimes intent is not effective because other intent is stronger at the prevailing circumstances. However, changes in circumstances during later development or application of the model can give more chance for that intent. If it is not included in the model, there is not much chance of successful reconstruction of the original thinking process to beneficial application of an earlier abandoned intent. The scenario of intent model definition is outlined in Fig 7. List of intent primitives is not intended to be a complete one; it only illustrates some important example areas. Most of product modeling related information is associated with design, analysis and computer controlled manufacturing of mechanical parts. Consequently, most of intent model description definition procedures demand and utilize component (i. e. mechanical part) related information and knowledge as applied methods, utilized knowledge, background information and received constraints. Intent description is connected to the related product model entities by associativity definitions.

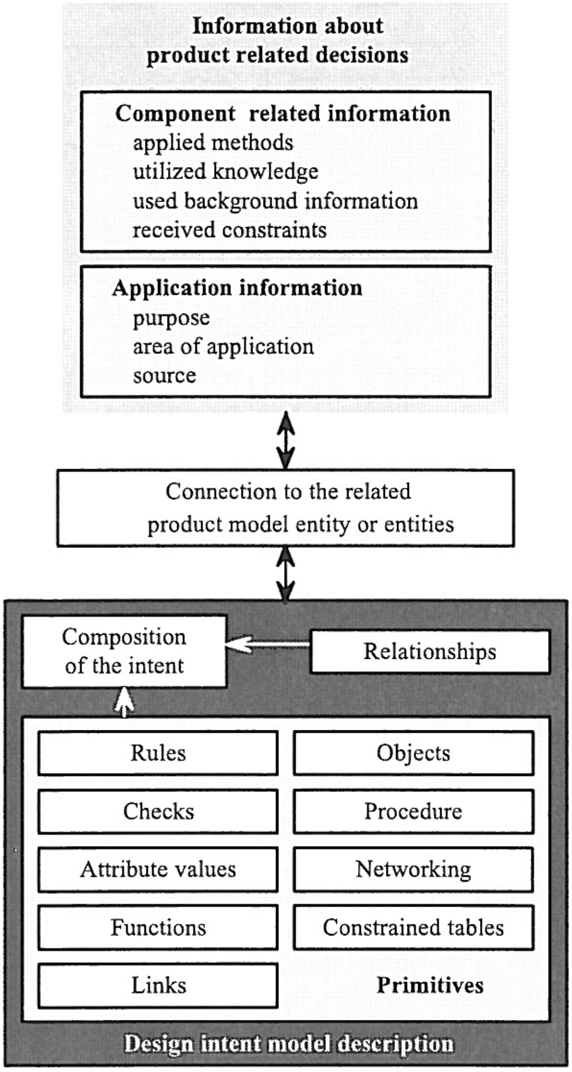

Fig. 7. Product and design intent model

IV. IMPLEMENTATION OF INTENT MODEL IN PRODUCT MODELING

The proposed method is intended to apply in an inherently very complicated virtual system. This leading engineering practice was developed to a very high level during the last decade. The main problem is not about the implementation of results of the reported work in product modeling but about implementation of human thinking procedure in intent modeling. Intent modeling practice utilizes existing results from product modeling, knowledge engineering and human-computer interface modeling.

In the every day modeling practice, design intent should be restricted to design related opinion, experience, decision, law, thesis and instruction. These are defined by authorized person and are taken into account by other authorized persons. As it was stated above, most of design intents can be defined in some form of knowledge, which is often acquired in the course of engineering processes. When an engineer explains a decision, the *for some extent*, *perhaps* or *maybe* normally are allowed.

Intent is defined by a set of attribute values, procedures, and object interrelations. The authors have proposed attributing of design intent entities as it can be seen in Fig. 8. Three basic attributes are type of intent, status of intent and status of decision-maker. Representative values of these attributes are listed in Fig. 8. Actual sets of intents are defined according to the domain, field, and task of applications.

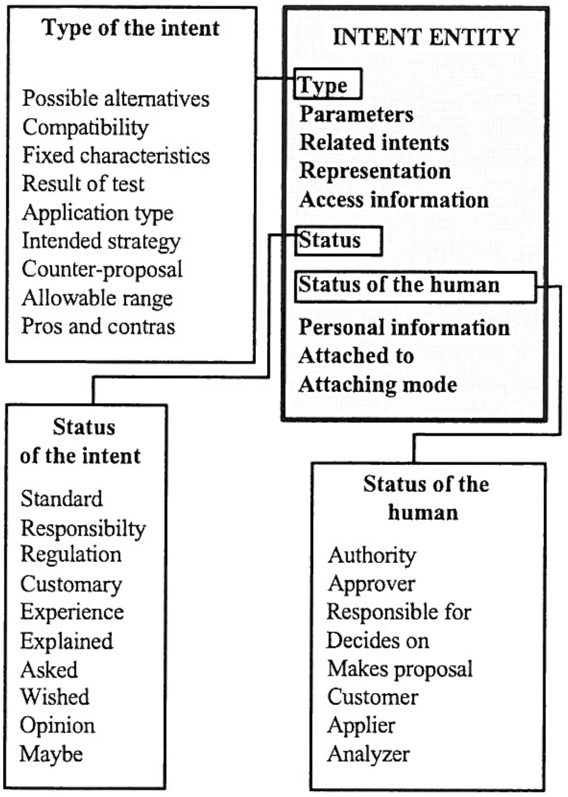

Fig. 8. Attributes of intent entities

Intent is attached to a decision on an entity, a parameter or a relationship of parameters. A relationship can act as a constraint depending on the human intent. Basically, an intent description consists of a history description of a decision. A list is included for entities that are referred in the intent description and act as information sources at processing of the history. Fig. 9 shows one of the possible styles of the history. A very simple history can be, for example, a simple result of a decision of the management or even an authority without any explanation. The history can be considered as a chain of explanations for a decision. Generic product model can be applied together with generic intent model.

On the example of Fig. 9 a goal is defined and a related taxonomy is revealed. This is followed by a consideration on the applied procedure as the result of thinking of the engineer. In other words, engineer did not use any idea from handbooks, etc. Then the applied method is selected taking into consideration of the choice that is offered by the selected procedure. Alternative procedures and methods can be involved or referred. The procedure needs input data that has been defined using production rules, functions and experimental results. The origin of the experimental results is an important element of the intent description.

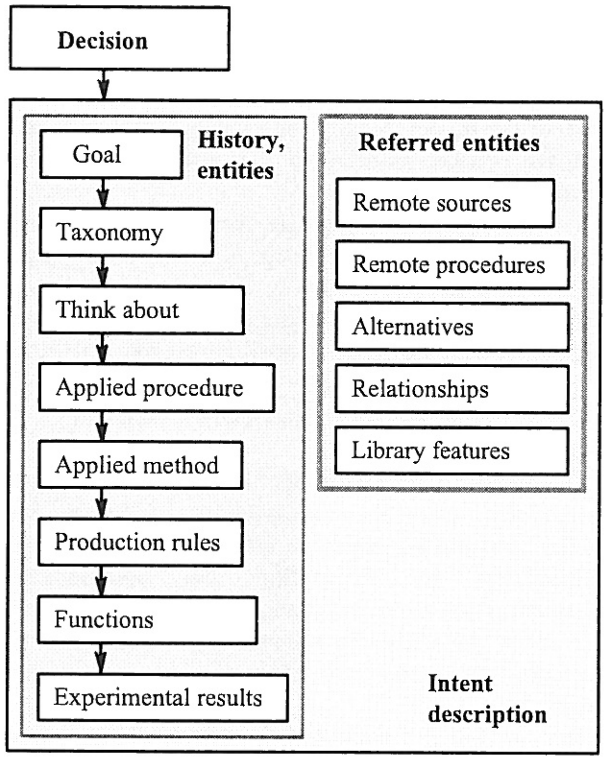

Fig. 9. History as described by design intent

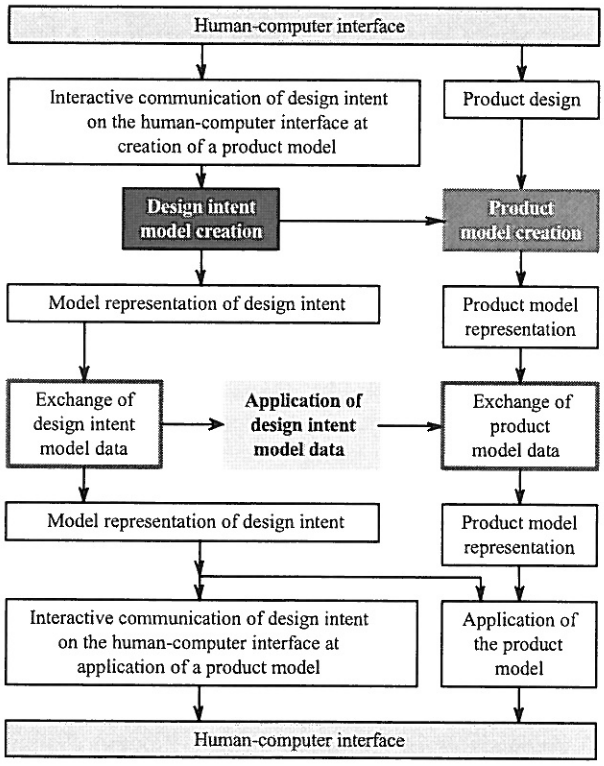

Fig. 10. Exchange of design intent information

Intent entities which are created during product modeling are represented, related to results of the design process and can be used by product modeling and product model application procedures in the same system. The product model may be applied in the same modeling system or in other modeling system with different modeling capability and entity set (Fig. 10). The consequence of this difference is a conversion during the data exchange. Model data conversion can be controlled by design intent information. Intent information is then used at applications of the model or communicated to the users of the model. Finally, intent data is stored together with the product model then it is used at its later and downstream applications.

It is important to emphasize that one of the primary objectives of modeling of design intent is enhancing the quality of products. Quality is defined on the basis of customer demand. Consequently, design intent is in close connection with the desire of fulfilling customer demands.

V. SUMMARY AND CONCLUSIONS

The authors reported an analysis on role, integration, composition, elements, and relations of design intent models. The primary objective is to develop principles and methodology for description and communication engineering intent in conventional CAD/CAM systems. This is an important for efficient application of virtual technology in product related engineering design in the future.

The proposed associativity driven intent model definition consists of definition of intent primitives and relationships between pairs of them. One of the most valuable features of the design intent model is that it carries product related computer intelligence by the product model extended with intent description. A human centered knowledge transfer is realized. Knowledge description can be involved in or linked to the intent description. Intent description is considered as a powerful tool for quality assurance. Intent modeling can be integrated with high level advanced product modeling by the using of open architecture features of the related modeling software systems.

VI. ACKNOWLEDGMENTS

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