Towards human controlled intelligent product engineering systems

Article · January 2011

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Towards Human Controlled Intelligent Product Engineering Systems

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Abstract: - Requirements against work of engineers have changed. Customers demand well-engineered products in high number of variants with short innovation cycles. Product engineering has been extended to market related activities and recycling. The result of this development is a powerful information technology for engineering in the form of model based lifecycle management of product information. In these environments, high amount of information for heterogeneous engineering objects needs high number of coordinated decisions. In order to establish appropriate solution for the above task, more intelligent features of modeling systems are needed than in current engineering systems. The authors analyzed the current status of application of knowledge based methods in product modeling and proposed a modeling method where human intent driven objectives and contextual connections are represented for the application of models. Intent modeling and human dialogue are necessary because intelligent engineering processes must be under continuous and strict control by authorized and responsible humans.

Key-Words: - Knowledge based systems, Intelligent engineering, Product model, Knowledge based product definition, Modeling of human intent, Content based product model.

1 Introduction

Introduction of knowledge based problem solving methods in development and application of products is a very slow process because engineer must see all details of problem solving process. In case of conventional closed knowledge based processes humans can not take the responsibility for the results of engineering activities. The utmost purpose of this development is product modeling systems that can represent analytical, problem solving and learning capabilities of humans. Current intelligent computing represents efforts to achieve similar results by using of rule sets, Fuzzy logic, evolutionary computing, neural networks, machine learning, knowledge acquisition, and cognitive methods. On the way to intelligent engineering, the authors took an attempt to develop methods and model entities in order to assist decision making in product lifecycle management (PLM) systems representing leading industrial practice currently and in the next future.

The basic concept in engineering activities by the authors is shown in Fig. 1. Currently, humans have two different roles at control of product definition and virtual prototyping activities in PLM systems. One of the roles is the classical direct control of product definition and virtual prototyping processes. The second role is an indirect control by adding capabilities to model generation in the PLM system by extracting human expertise, intelligence, and experience.

The above explained concept gives the basic objectives of the work that is reported by the authors in this paper. Three objectives were defined (Fig. 2). The first is analysis of direct control of product definition in order to reveal main characteristics. The second objective is application of result of the first objective at the definition of methods to substitute direct control by indirect control. The third objective is implementation of the indirect definition in model entities in order to enhance intelligent content of product model.

In accordance with the above objectives, paper starts with analysis of the engineering characteristics in current PLM systems. Following this, possible applications of indirect control are explained. The subsequent parts of this paper introduce the decision assistance in current PLM systems by using of indirect control, describe a new method for knowledge based content in product model, and discuss implementation of the proposed modeling in current PLM systems.

2 The Current Classical Product Model

As a result of a comprehensive analysis by the authors in current industrial product models [1], state-of-the-art was concluded. The authors call the currently prevailing product model as classical product model (CPM). Despite CPM represents a very advanced engineering technology, its product representation capability is restricted to definition of engineering objects (EOs), placing EOs in product structure, and free definition of relationships between EOs (Fig. 3). Shape objects are placed in an object space called as model space characterized by a coordination system. Any other information is mapped to shape information. In Fig. 3, Engineering objects A and B are placed in the model space one of the relationship between them is 1 DOF allowed relative movement.

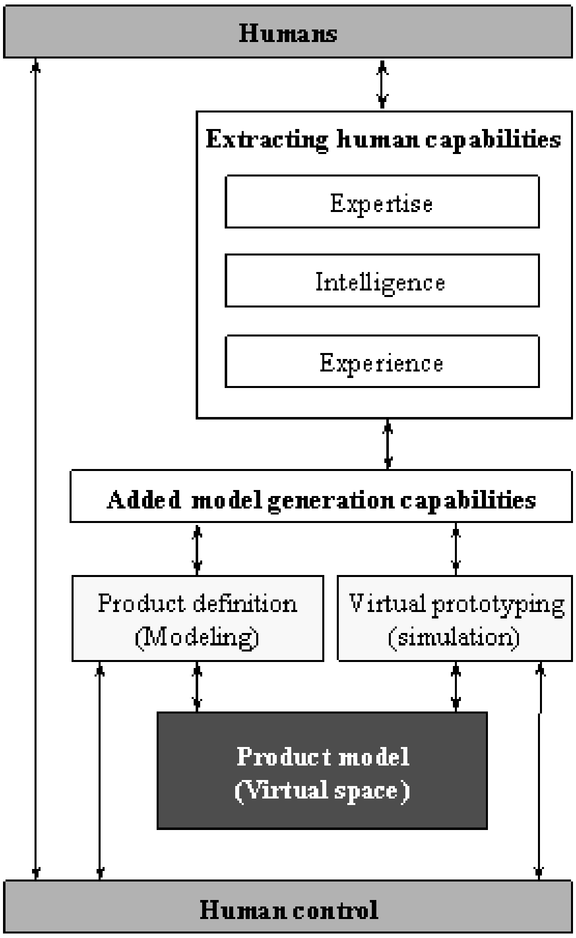

Fig. 1. Human control and added capabilities

Recently, classical product modeling was developed towards capturing human expertise and experience in the product model. This is on the way of including knowledge in product model. Application of this knowledge is called as knowledge advising by modeling system (Fig. 4). Simple knowledge is represented that is understandable by engineers. An analysis of knowledge advising is given in part III. of this paper. Knowledge advising is supported by intelligent computing and expert functions. Influencing humans are in dialogue with model entity handling procedures. Because several humans may have parallel influence on the definition of a single EO, organizing of these influences is critical. In recent systems in is not beyond formal management of group work.

Before starting with analysis of current intelligent characteristics and introduction of a new method by the authors, let’s see several typical related works and opinions below.

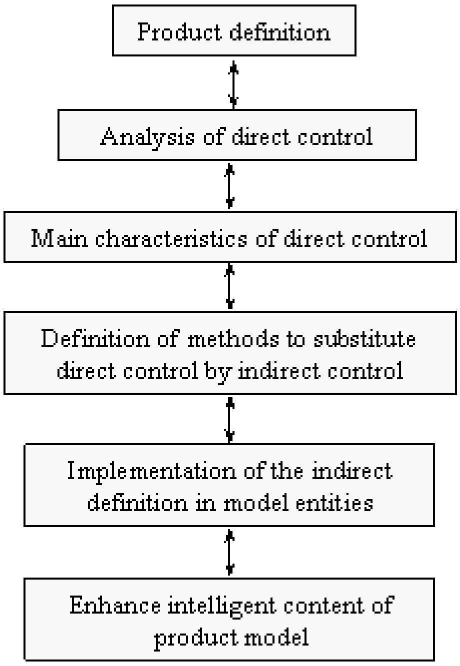

Fig. 2. Objectives of the reported research

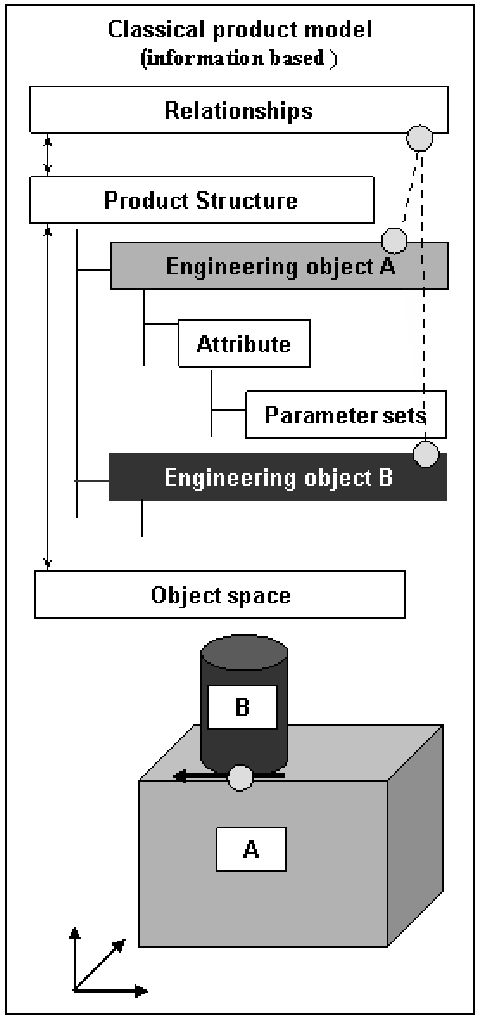

Fig. 3. Classical product modeling

Product lifecycle management (PLM) is considered in the book [5] as a new paradigm to manage products all the way across their lifecycles, in the most effective way. That book outlines a wide area of engineering activities including simulation that demands highly organized information system in order to support integrated definition of product entities for lifecycle application.

Product model definition requires well-organized preparation by using of information modeling method due to the complexity of information. Authors in [6] describe a product information-modeling framework in order to support the full range of PLM information needs. It is intended to capture product, design rationale, assembly, and tolerance information to the full lifecycle. Semantic interoperability with next-generation PLM systems and capture the evolution of products and product families are also considered.

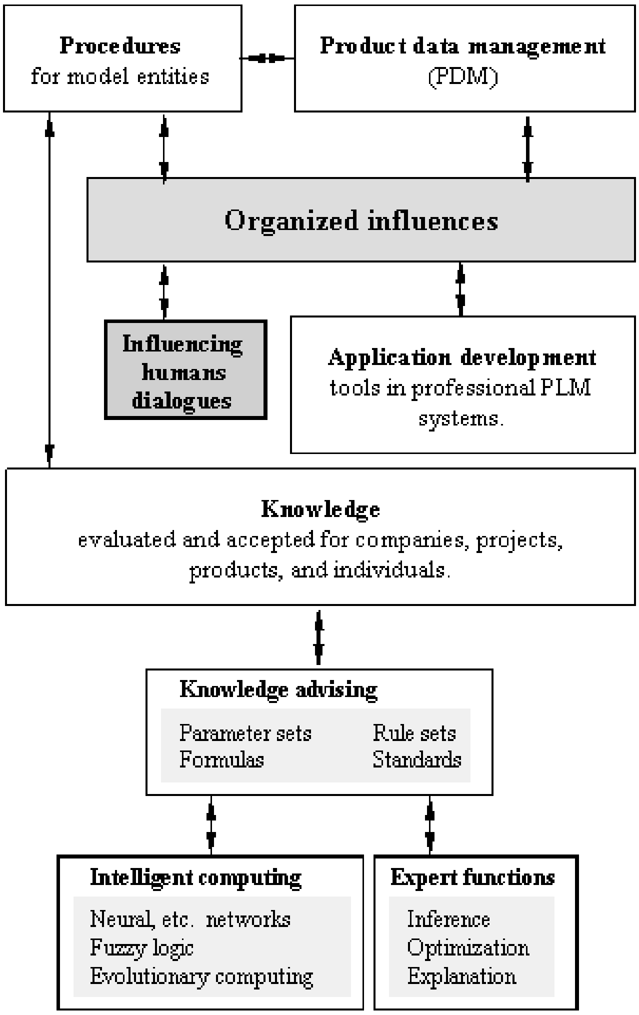

Fig. 4. Knowledge support in CPM

In [7], issues at capture, representation and retrieval of design intent are discussed, a definition for design intent is presented, and a context-based inference system is proposed to capture design intent from product data. Design space is defined on corporation level and design level. Authors of [8] emphasize importance of construction history, parameters, constraints, features, and other elements of design intent and suggest implementation of product model data exchange with the preservation of design intent, based on the use of newly published parts of the International Standard ISO 10303 (STEP).

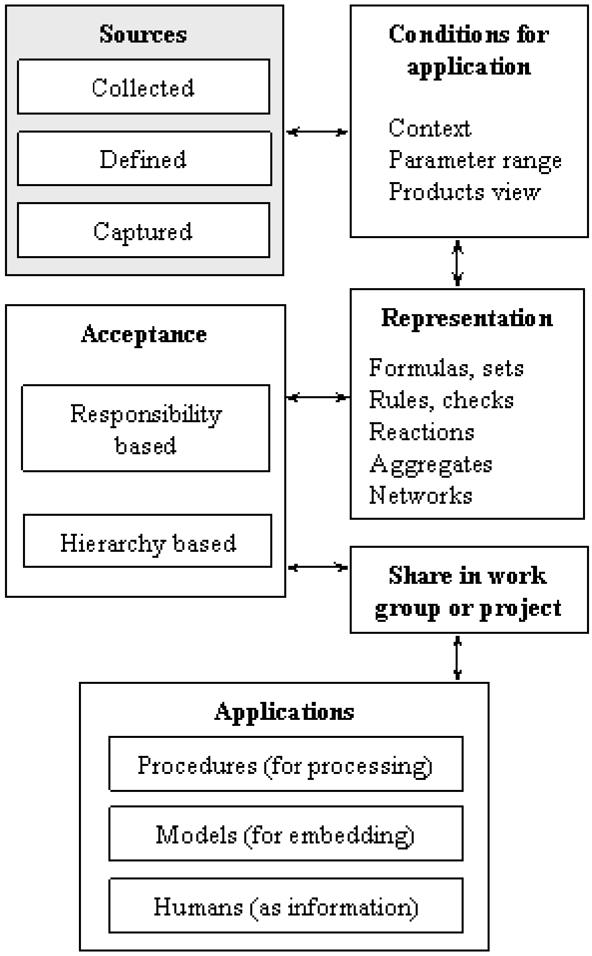

Fig. 5. Knowledge process at EO definition

Industrial product modeling systems offer essential knowledge definition and problem solving modeling capabilities as it is discussed in papers [9] and [10]. Rules define some entities or activities in the modeling process depending on well-defined circumstances. Checks recognize situations with different levels of severity. A reaction reacts to well-defined events by given activities in the modeling process. Parameters relations are reorganized into new categories. Rules, checks, formulas and other relations can be organized into relation sets. Parameters are optimized for minimum, maximum, etc. according to essential or user defined algorithms. An advanced modeling capability facilitates analyses for constraint satisfaction. Design of experiments capability allows for perform virtual experiments among others in order to find interactions between parameters and the most influential parameter.

Considering an engineering process centered concept, product data management (PDM) integrates and manages all the product objects. In [11], web-based PDM systems are reviewed. The PDM methodology is integrated with web architecture. Currently available PDM systems those have been integrated with web-technologies are reviewed. High importance of content based assistance in modeling of large scale systems is inevitable.

3 Assistance of Decisions in Current Practice

Because professional engineering processes at product development request responsibility or hierarchy based acceptance of the knowledge that is programmed in procedures for processing for engineering object (EO) definition, embedded in models during engineering object (EO) definition, or applied by humans as information (Fig. 5). Only evaluated and proved knowledge are allowed to include at specified conditions. The source where knowledge is collected, defined, or captured must be known and verified. This is necessary because knowledge is used at decisions with company, group, and personal responsibility.

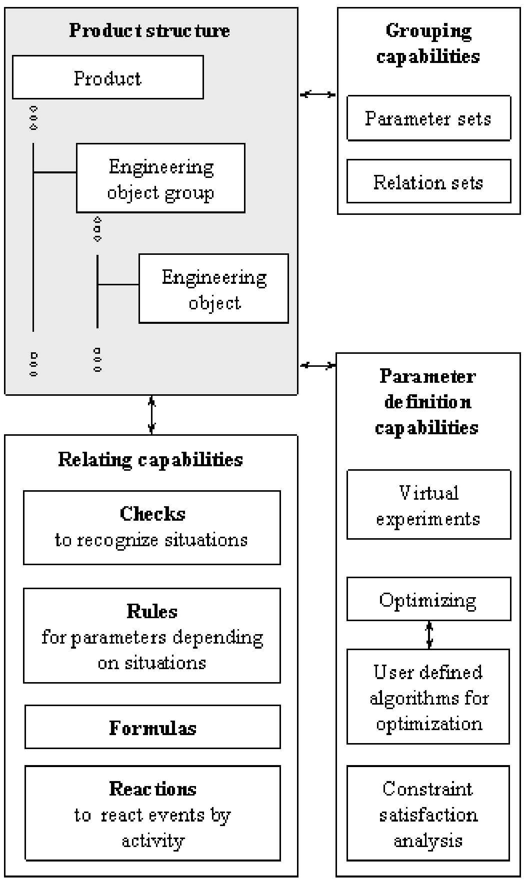

Fig. 6. Knowledge based modeling capabilities

Knowledge is applied for several professional purposes. It may represent proven practice in an area, company, or product. It also applied for validation and correction of decisions, among others to ensure consistent product model. Proven practice is necessary for repetitive tasks. Threshold knowledge is applied by EO definition processes in order to avoid erroneous calculations, etc.

Current PLM systems offer knowledge based modeling capabilities in order to assist knowledge based definition of EOs. These capabilities are for relating, grouping, and definition of EO parameters (Fig. 6). Simple and user understandable rule and check sets, arbitrarily complex formulas, and reactions can be included in the model structure for the purposes as it is briefed in Fig. 6. High number of constraints can be analyzed in a single system, built in and user defined algorithms can be applied for optimization, and plans can be defined for virtual experiments. Grouping capabilities are applied to define parameters and relationships for EOs in the form of groups.

In [4] redesign and design for customizations of products are extended. During product development process, a change to one part of the product often results changes to other parts. An analysis of change behavior based on a case study in rotorcraft design is introduced. Mathematical models were developed to predict the risk of change propagation in terms of likelihood and impact of change. Likely change propagation paths and their impact on the delivery of the product were analyzed.

4 New Knowledge Content in Product Model

The classical product model can not represent background of decisions on engineering objects but only simple facts. This situation leads to critical problems at the application of product model. At definition of a product, responsible engineers must consider, accept or reject intent of other humans. However, intents and their background are unknown.

At management of product changes during development of high number of unstructured relationships among engineering objects must be evaluated in order to track consequences of an actual change. This is increasingly problematic with increased number of EOs in large classical product models in the current industrial practice. Responsible engineer, who receives related decisions in a product model, must revise, coordinate, and modify earlier decisions. However, reconstruction of the original decisions is impossible. A consequence can be drawn from the above short criticism of CPM that information in the CPM is

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not enough for engineering activities at model applications. Something more content is necessary.

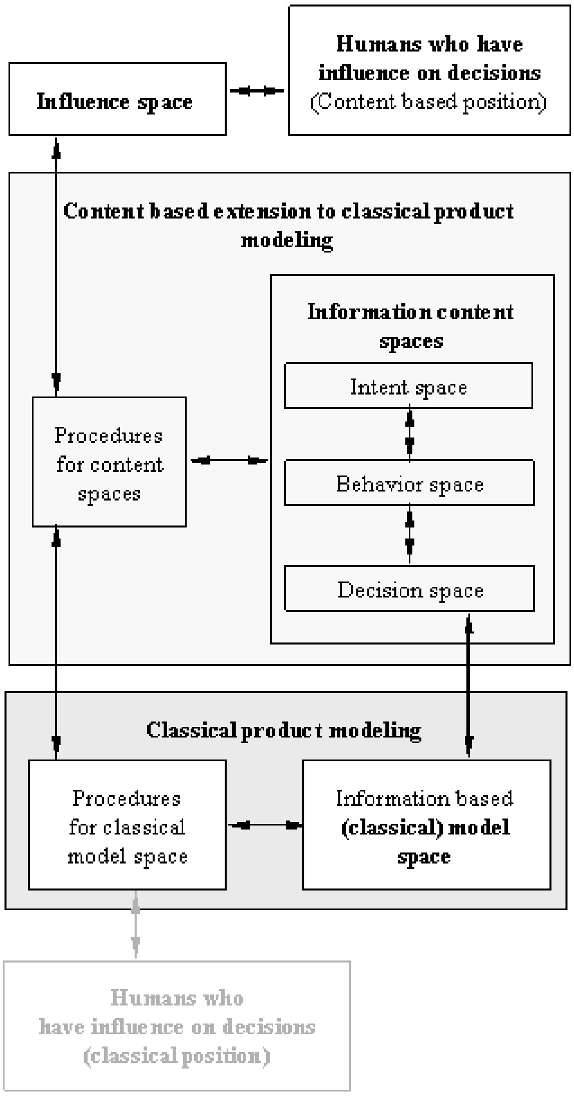

Fig. 7. Knowledge based modeling capabilities

The proposed solution is outlined in Fig. 7. Knowledge based content in the product model is represented as content of modeled information. This content is generated by using of intent of humans and always contextual with decision results on EOs in the classical product model. At the same time, the only way to decisions is through human intents and human intent based engineering objectives. Intents, objectives, and decisions are contextual and coordinated. In the classical product modeling, human controls object definition directly. In the proposed modeling, humans are repositioned to define information content. Coordination of human influences is assisted by an influence space that is contextual with intent space.

According to its purpose, intent space assures human control over product development process, behavior space represents definitions for engineering objectives, and decision space represents modifications in the affect zone of an engineering object along change chains. Contextual connections represent target objects in the context of other objects. The authors introduced the new concept of change affect zone that includes a set of engineering objects those may be modified as consequence of a modification at an engineering object.

Modeling of human intent is outlined in Fig. 8. The main purpose is to extract elements from the human thinking process for the definition of engineering objects and partial decision points. The content is controlled by humans according to the demand of the actual and related engineering activities. Fig. 8 also shows examples for human thinking process elements.

The proposed model has been completed according to Fig. 9. Information content is placed on five levels. Model creation is controlled by humans and it is allowed only level by level. In order to establish connection between classical product model and information content level, a multilevel structure is added to the classical product model. In this structure, information is organized on levels for identification, application data, associative connections, descriptions, and representations of engineering objects. Associative connections include all of the contextual connections in the classical product model.

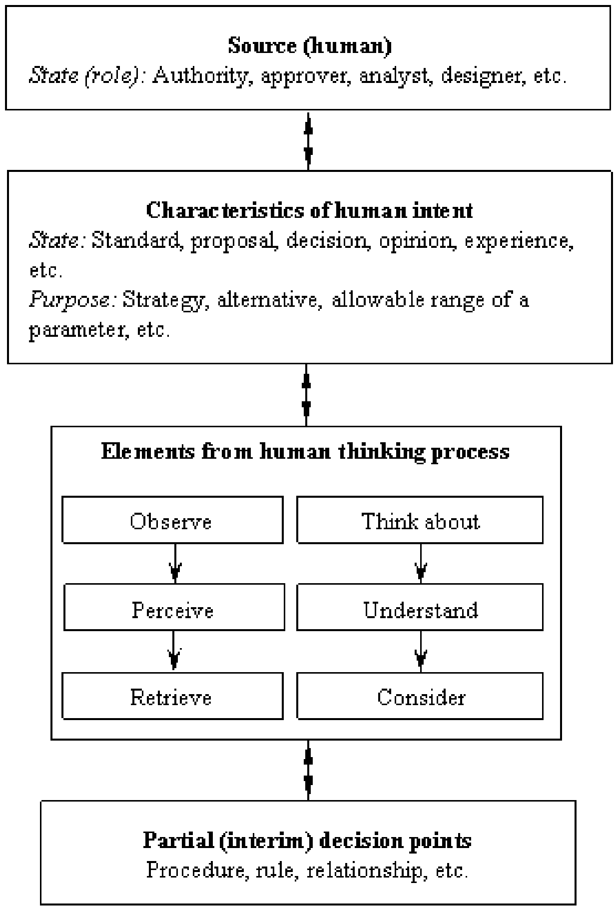

Fig. 8. Model of human intent

ISBN: 978-960-474-273-8

Beyond a more organized and human intent driven extension of the classical product modeling, the proposed model is also intended to be a framework for more intensive application of intelligent computing in engineering. Because engineers are responsible for their decisions, the conventional closed problem solving procedures can not be applied.

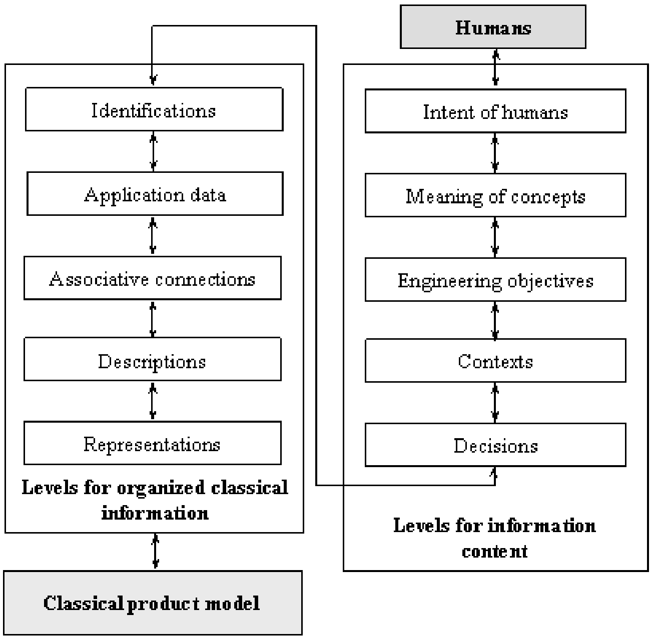

Fig. 9. Extended multilevel product model

5 Conclusions and Future Research

In this paper, a new light of knowledge based engineering is introduced and a new model is proposed in order to match with the demands from current and future industrial product definition. Highly integrated paradigm of lifecycle management of product data includes contextual connections with the world in which a product is defined, marketed, and applied. The authors analyzed the currently prevailing method of product modeling and defined it as classical product modeling. They proposed an extended product model in which humans are repositioned from direct control of engineering objects and their parameters to indirect control by the definition of intent on engineering objects. The model extension called information content includes model entities for coordinated intent from different humans. Intent definition is applied for the definition of engineering objectives. The only allowed way to the definition of decision entities is consideration of engineering objectives and contextual connections.

The next step in the reported research is definition of the above entities in order to define entities for the implementation of the proposed modeling in representative PLM systems. For this reason, practice oriented content model structures and model development processes are to be planned and evaluated.

6 Acknowledgments

The authors gratefully acknowledge the grant provided by the NKTH-OTKA Fund for Research of the Hungarian Government. Project number is K 68029.

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ISBN: 978-960-474-273-8