

Virtual Space with Enhanced Communication and Knowledge Capabilities

László Horváth, Imre J. Rudas

Institute of Intelligent Engineering Systems, John von Neumann Faculty of Informatics, Budapest Tech
Bécsi út 96/B, H-1034 Budapest, Hungary
horvath.laszlo@nik.bmf.hu, rudas@bmf.hu

Simona Vaivoda, Zsuzsa Preitl

Dept. of Automation and Applied Informatics, Fac. of Automation and Computer Science, "Politehnica" University of Timisoara
Bd. V. Parvan no. 2, RO-300223 Timisoara, Romania
Gs1961@aut.utt.ro, zsuzsap@aut.utt.ro

Abstract: Engineering for development, production, and other product related company activities are being organized in virtual systems for lifecycle management of product data. This new age of engineering is a result of the continuous development for step-by-step moving of product design, analysis and other production engineering activities from conventional environments to modeling environments during the eighties and nineties. However, more developments were needed in knowledge based decision assistance in order to realize modeling of human intent, increasingly complex product structures, and efficient communication of product data. In recent years, a great change of engineering methodology and software produced program products in knowledge technology and advanced local and global communication. Group work of engineers is increasingly organized around special portals for engineering on the Internet. Although intensive research activities produced outstanding methods in knowledge-based solutions for engineering, these methods have not widespread in the industrial modeling practice. This paper attempts to evaluate the possibility that recent communication and knowledge intensive engineering modeling can be developed into communication and knowledge intensive virtual space technology. Paper starts with a discussion on integrated application of different groups of product modeling techniques. Following this, methods are evaluated for the management of product data (PDM). Next section emphasizes aspects, contexts, and intents as primary issues in modeling for relationships in product data and decisions by engineers. Finally, methods for the management of engineering activities for lifecycle of products are summarized, considering communities of engineers around Internet portals.

1 Introduction

By the beginning of the 21st Century, information technology for engineering had been developed into integrated modeling of structural, mechanical, electrical and electronic elements in products. Engineering applications utilize Internet technology to organize remote individuals and groups on different hardware, software, and modeling platforms into project-based communities of engineers.

The new situation in engineering generated a need for integrated understanding of modeling techniques. The following issues have primary importance.

- Description of engineering objects.
- Management of product information.
- Embedding corporate knowledge in product model.
- Communication of engineers in wide area computer environments.
- Features of Internet mediated computer systems.

A study by the authors focused on interrelations of modeled objects, description of highly associative products, communication between engineers and modeling procedures, and application of stored experience in engineering. High number of coordinated modeling and problem solving techniques were considered from the current advanced engineering practice. Authors published the results in [2].

An integrated experimental system for modeling of engineering objects and product lifetime management (PLM) was established in the Laboratory of Intelligent Engineering Systems at the Institute of Intelligent Engineering Systems, John von Neumann Faculty of Informatics, Budapest Tech. The purpose of this new laboratory is verification of results of research projects in knowledge and communication intensive engineering. Based on comprehensive and robust professional engineering software, this installation comprises recent advanced CAD/CAM, human-computer, collaborative, product data management, Internet portal, and intelligent computing software.

This paper gives an evaluation about the development of recent communication and knowledge intensive engineering modeling into communication and knowledge intensive virtual space technology. Its contribution is a new approach to integration of current modeling procedures regarding the following essential issues.

- Integrated shape centered descriptions.
- Scenario of product data management.
- Characteristics of human intent.
- Knowledge in product modeling.
- Communities of engineers.

Paper starts with a discussion on integrated application of different groups of product modeling techniques. Following this, methods are evaluated for the management of product data (PDM). Next section emphasizes aspects, contexts, and intents as primary issues in modeling for relationships in product data and decisions by engineers. Finally, methods for the management of engineering activities for lifecycle of products are summarized, considering communities of engineers around Internet portals.

2 Integration in the Context of Product Development

By the middle eighties, extensive but non-integrated information in models could not serve the changed demands against product engineering in the industry any more. Therefore, development of CAD/CAM systems was concentrated on integration of separate model descriptions. As a general solution, development of comprehensive standard for integrated product information model (IPIM) was brought into foreground. This work was coordinated by the International Organization for Standardization (ISO) within the STEP (ISO 10303) project [1].

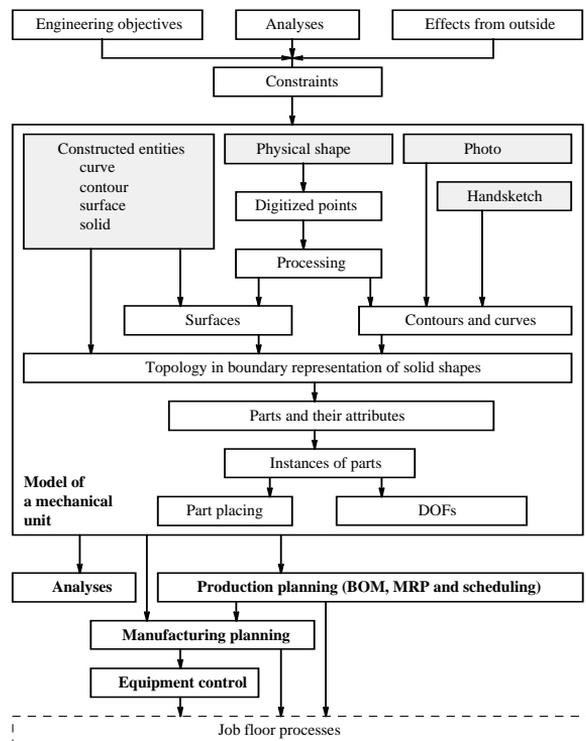


Figure 1
Integrated description of a mechanical unit

What does mean integration in the context of product development? Integrated solution for product modeling is demanded to offer software tools for creation, storage, retrieval, and application of arbitrary product related information during the lifecycle of a product, from the initial specification to recycling. Interdependencies of engineering activities are emphasized. For example, recycling must be considered at selection of material for parts. Other typical area of interdependency is definition part design in the context of manufacturing. Eventually, lifecycle management and assessment of products are considered, as they are discussed in [9] regarding approaches and visions towards sustainable manufacturing.

Integration assures that output information by any program can be used as input information for any relevant program. An important benefit of integration is increased chance for the consistent product description as enforced by modeling procedures. Regarding the related processes, one of the important issues is workflow. In [10], a new mathematical model has been introduced for workflow system synthesis. This model is partly based on a methodology formerly developed for processing network synthesis, the P-graph framework. This framework includes a specific modeling techniques and effective algorithms for network synthesis.

Fig. 1 explains integrated definition of shapes and their relationships for consistent information at design of mechanical units. Model describes information for shapes, technical specification, and relationships of shapes. Shape of a part is described by its boundary. By using of the well-approved boundary representation, curves and surfaces constituting the boundary are connected by Euclidean topology in a solid shape. During processing of geometry of a solid, correct information about surfaces and their intersection curves in the boundary is necessary to accomplish correct geometric operations. For example, when a solid is cut by a surface in three dimensions, high number of operations refreshes geometry and topology for changed shape of the solid. Solid shape is completed by part attributes to achieve part model. For repeated application of a part model in the same or different units, parts are instanced.

Relationships are defined between pairs of parts in a mechanical unit by placing and allowed movement information. Placing is defined by constraints while movements are allowed according to degrees of freedom (DOF) of relative movements. It can be concluded that associative engineering objects are described and that higher level engineering objects are described in the context of lower level objects.

Primary sources of shape information are constructed or built-in shapes in model spaces in the form of curves, contours, surfaces, and solids. Other sources of the same importance are described as follows.

- Planar or spatial hand sketches of contours for parts and assemblies.

- Curve and contour information captured from a drawing or a photo.
- Digitized physical shapes in the form of clouds and arrays of points are processed into surface models.

Constraints for the definition of a mechanical unit are extracted from engineering objectives, results of analyses, and other outside effects such as earlier decisions, standards, agreements, legislations, etc. Directions of further integration of mechanical units are analysis, equipment control, manufacturing planning, and production planning. Other areas of integration may be marketing, customer services, and recycling.

Integrated modeling of a part and a mechanical unit are summarized in Fig. 2 and Fig. 3, respectively. In the example of Fig. 2, a part is initially defined as a solid box. Following this, the initial shape is modified by two form features, tabulated from *Contour 1* and *Contour 2* along *Vector 1* and *Vector 2*, respectively. These modifications result in the final shape of the *Part A*. Connections of surfaces at curves are described by topology constituting structural description for the boundary of the shape. In the topology, curves (lines) and surfaces are mapped to edges and faces, respectively. Vertices connect topological edges. Consistency of topology is assured by the application of appropriate Euler operators at its definition. Topology can be checked by topological rules [3]. Solid shape is completed by non-geometric information and stored as *Part A*.

Parts are assembled into units and therefore are constructed in the context of context of assembly, considering an assembly model space. Some contours in parts are copied from part to part not to be repeatedly constructed them.

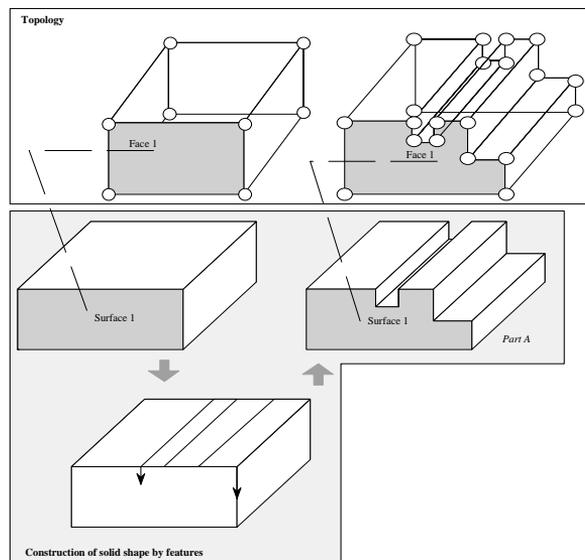


Figure 2
Integrated modeling of a part

Part A, *Part B*, and *Part C* constitute the *Unit 1* in Fig. 3. Placing of *Part B* and *Part C* on *Part A* is defined by *Contact* and *Coincide* constraints between parts. In order to allow its controlled relative movements *Part B* gets one translation (1T) degree of freedom to move along the direction denoted by arrow. As a complex operation on the shape of *Part A* cutting with *Surface 2* modifies shape of *Part A* so that shape of *Unit 1*. In the course of the cutting operation, a region of the *Surface 2* is defined by its trimming with new boundary lines and curves. Topology is also completed and new surface and curve entities are mapped to topological entities.

In the model of a mechanical unit, entities and their attributes are interrelated by bi-directional associativity definitions. This method is essential to save consistency of the construction at its modification and development. Non-associative and non-constrained shapes and dimensions are free to modify. However, in these operations, checking for consistency and collision is strongly recommended.

3 Management of Product Data Systems

During the nineties, model databases became more and more large and complex. Besides product structure based organization of product data, two additional demands were arisen. One was that models from different modeling systems were required to handle in the same product data system. The other was a strong demand for engineering process-oriented services. In order to fulfill these new demands, product data management (PDM) systems were established for product centric data base management.

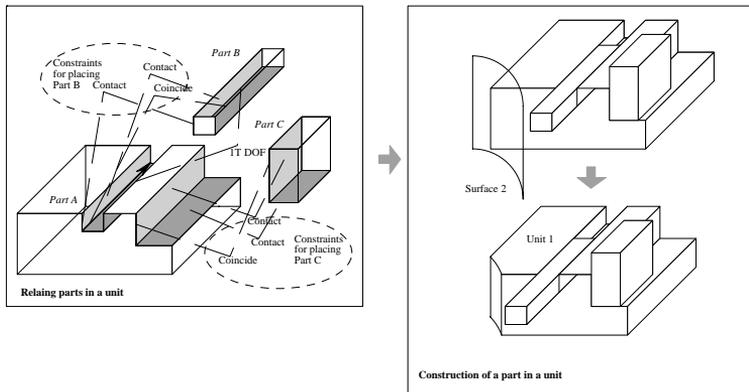


Figure 3

Integrated modeling of a mechanical unit

PDM systems were developed in integration with modeling systems. By now, they offer functionality for flexible product information handling, change management, control of engineering processes, and handling of product structure. Advanced PDM systems are integrated with other company activities. They are capable of efficient exploration of consistency related and other problems in a complete product information environment.

Essential PDM functions are surveyed in Fig. 4. Product data is handled for modeling systems $MS_1 - MS_n$. Engineers $ENG_1 - ENG_n$ are working in a group. Multiple projects and roles can be assigned for an engineer. Engineer can define, retrieve and maintain product structure subsets called as views. View can be selected by parameters, copied to other points in data structure of the same or other product. In this way, arbitrary context of model information can be handled as a unit.

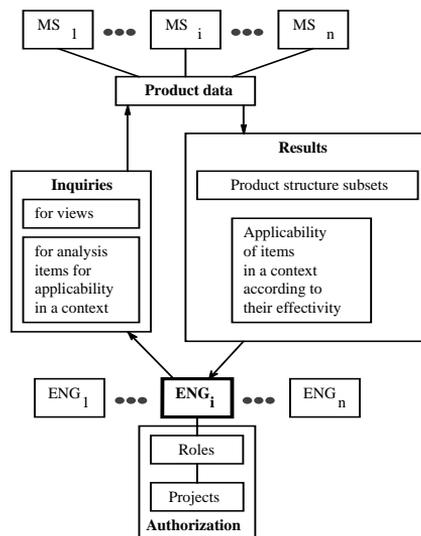


Figure 4

Scenario of product data management

Additional function of PDM systems is checking the applicability of a part or other item in a given context. Criteria of application are called as effectivity. This function is supported by specification of effectivity range for product items. Views can be selected according to effectivity. Project and role based authorizations are mapped to view, access and modify data sets in extended enterprises.

4 Contexts, Aspects, and Human Intentions

Three concepts in the title of this part highlight the main difference between conventional and future style of definition of engineering objects in product modeling. Shapes and other entities are created in the context of existing entities.

Contextual connections of modeled product objects are applied at automatic definition of associative connections, assuring consistency of model during the entire lifecycle of product. Contextual links are specified as constraints. When an entity changes, the entities contextual with it are also changed. Contextual links can be defined for changes in one direction or in both of directions.

A typical contextual link is explained in Fig. 5. A swept surface is created in the context of a generator (c_g), a path (c_p), and a spine (c_s) curve, and a pivot point (P_j). The context is specified as follows.

- Generator curve is connected to the end of the path curve at the pivot point.
- Moving of the generator curve along the path curve creates the swept surface.
- Normal of plane of the generator curve coincides the tangent (t) of the spine curve at each point along the path curve.

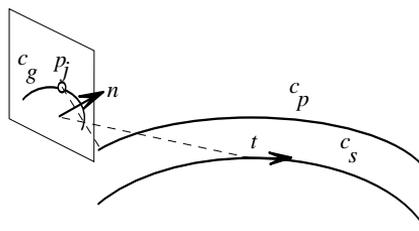


Figure 5

Definitions of a swept surface in context of three curves

Modeling in an aspect is a means of definition of modeled objects according to their function and application. In Fig. 6, three different form features are defined according to one manufacturing and two different construction aspects. Steps are merged into a single form feature consisting for planning of the control of production equipment. At the same time, individual steps have different functions in the construction. Extraction of form features from shape representations can be applied for intelligent dimensioning of mechanical parts [5].

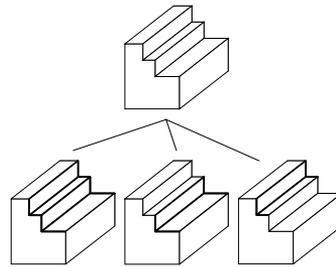


Figure 6
Aspects as form features

Typical engineering processes are controlled by intent of different humans. Intent of several humans must be considered at decision [4]. Description of intent characteristics in a product model would be especially beneficial at these multiple intent based decision. In order to establish intent modeling, as result of an analysis, a set of characteristics was concluded for design intent. Characteristics include type to categorize its content, status to describe its strength, and status of the human who is its source (Fig. 7). Technical content of intent is to be represented as knowledge.

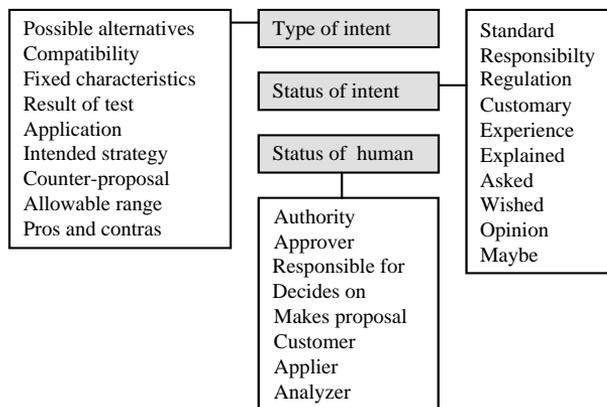


Figure 7
Characteristics of human intent

Typical intents and their representation in product model are given in Fig. 8. Engineering objectives determine behaviors of a product at given sets of circumstances called situations. Functions are modeled as functional associative links between pairs of product objects (see details in Fig. 11). Intent for consistent product structure is represented by structures as topology and constraints. Higher priority intents come from chief engineers, authorities, etc. Finally, engineers make decisions on parameters and their relationships then record them as constrained and unconstrained associative definitions between or parameter values for product objects.

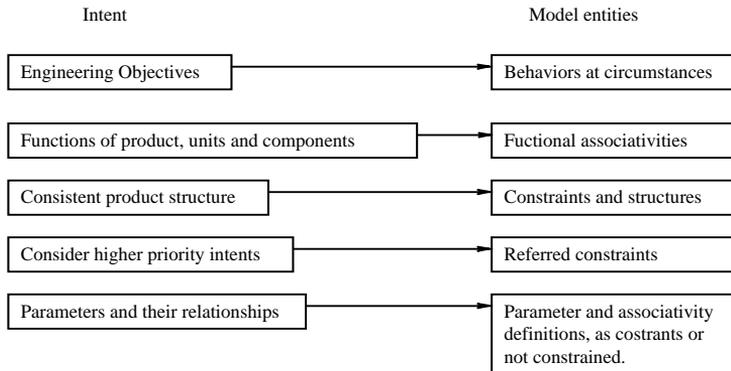


Figure 8

Typical intents and their description in product model

Knowledge engineering produced methods for emulation of activities and intelligence of engineers during eighties and nineties. In that time, efforts to achieve effective methods to embed knowledge in product modeling procedures and product models were mostly failed. One of the causes of difficulties at application of knowledge-based methods in engineering is that knowledge must be acceptable by responsible engineers. Application of non-verified knowledge makes supervision of engineering activities difficult and it can be dangerous.

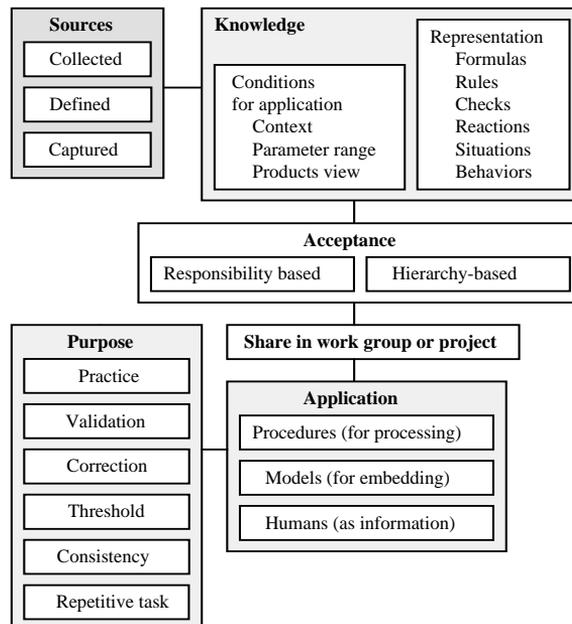


Figure 9

Knowledge in product modeling

Sources, content, applications, and purposes of knowledge are outlined in Fig. 9. Knowledge is best to capture in work groups and projects by direct definition by humans, extraction from successful practice, verification, and experience. It is shared amongst participants of work groups and projects. Engineers embed knowledge in models by responsibility and hierarchy-based acceptance. Circumstances as parameter ranges, products or their views, and contexts can specify conditions for application of knowledge.

Simple, efficient and engineer understandable forms of knowledge description in current in present engineering modeling are formulas, rules, checks, and reactions. Formula is a record of an associative link. Rule predicts while check verifies actual value of parameters. Reaction is an action programmed for events of given parameter values. As an example, an application tool is shown in [7]. This tool utilizes knowledge-based-engineering environment in a PLM system. It uses design rules for aerospace structures to add details to a conceptual design.

Product and related engineering objects are defined by sets of parameters. Modeling procedures reveal combinations, select suitable combinations, and choose optimal combinations of parameters (Fig. 10). Analysis of interactions between parameters and selection of the most influential parameter are requires support by knowledge representations and associative parameter definitions. Design objectives, limitations, and other criteria can be applied for the creation of set of optimal parameters for product objects.

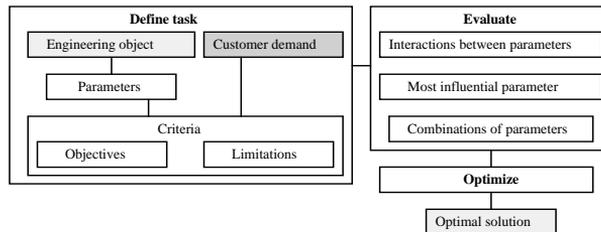


Figure 10
Handling object parameters

Model description of functions and functional relations of product objects is relative new. Functions are attached to shape oriented product model in the form of functional associative definitions for parts, functional subsystems, and product variants (Fig. 11).

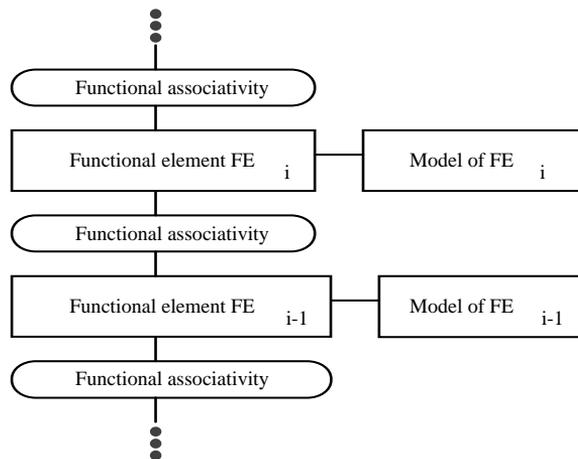


Figure 11
Modeling of functions of a product

5 Communication Related Issues

Despite high level of communication between modeling procedures communication of humans has not been replaced by communication of computer procedures. Moreover, one of the most important and effective developments in engineering could be experienced in communication of humans during the last decade. Humans control the processing of high amount information and make thousands of decisions with their personal responsibility. At the same time, integrating cooperative procedures and embedding human intent and proven knowledge descriptions in product models a great change in automated engineering during the forthcoming years.

Communities of engineers in integrated modeling of products are moving into standard Internet environments. Substantial developments support this tendency in recent PLM technology. In [8], collaborative virtual prototyping of product assemblies is introduced for the Internet. Paper [6] describes an integrated product and process modeling (IPPM) framework for collaborative product design through the Internet. Hierarchical and heterarchical dependencies are applied between decomposed smaller design problems.

Software functionalities are available for human communication purposes according to product related objectives (Fig. 12). Product lifecycle collaboration is provided for remote engineers and groups. Participants can use different hardware and software platforms and modeling systems, regardless of geographical location.

Using recent achievements in information technology, engineers work in well-organized, powerful, professional, economic, dynamic and secure environments.

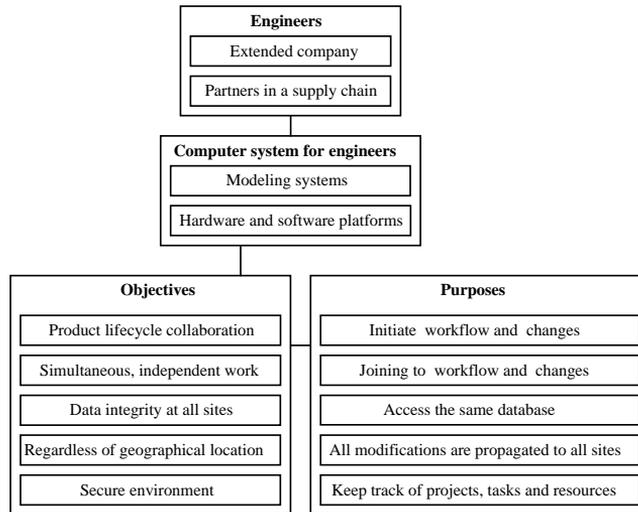


Figure 12
Communities of engineers

All authorized group member initiate workflows and product changes, access the same database, share the same resources, and keep track of projects, tasks and resources at any time. The product data is identical for all participants. All modifications are propagated to all workstations to maintain integrity of product data. Independent workstations are active simultaneously, sometimes regardless of the network connection.

Conclusions

This paper focuses on evaluation of capabilities of PLM systems to accommodate communication and knowledge centered intelligent computing methods. For that reason, it contributes with a new approach to integration of current modeling procedures regarding the following issues.

- Integrated description of a mechanical unit.
- Scenario of product data management.
- Characteristics of human intent.
- Knowledge in product modeling.
- Communities of engineers.

Lifecycle solutions for product modeling provide assistance for engineers in order to assure consistency at definition of new engineering objects in product model.

Product centric data base management in PDM systems is integrated with product modeling other company activities. Modeling activities of engineers are organized around portals on the Internet establishing communication intensive collaboration.

This paper evaluates effects of the new technology and environment on engineering modeling in order to prepare the development of knowledge and communication intensive intelligent procedures for current PLM systems with the following characteristics.

- Integrated solutions for product modeling.
- Product centric database management.
- Possibility for description of contexts, aspects, and intents in product model.
- Advanced definition of engineering objects.
- Handling of interrelated product object parameters.
- Modeling of product functions.
- Advanced communication within groups of engineers.

Engineering decisions are typically controlled by intent of more than a single human. Saving human intent in product model is preferred in one form of engineer friendly representations. Personal responsibility for decisions requires controlled knowledge and makes application of intelligent computing at engineering difficult.

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