Advanced Virtual Spaces for Collaboration in Product Modeling

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Abstract: Recently, information technology offers powerful solutions for classical but increasingly critical problems in product related engineering activities. During eighties and nineties product design, analysis and production engineering changed to description of engineering objects by modeling. Although intensive research produced methods in knowledge-based solutions for engineering, industrial modeling practice did not utilize knowledge technology. At the same time, there were not available appropriate program products for large communities of engineers to handle increasing complexity of product structures and efficient communication of product data and human intent. In recent years, a great change of engineering methodology and software produced these program products both for utilization of knowledge technology and establishment advanced local and global communication. Group work of engineers is increasingly organized around special portals for engineering on the Internet. Author of this paper makes an attempt to organize essential issues in recent communication and knowledge intensive engineering modeling. Paper starts with a discussion on integrated application of product modeling techniques. Following this, methods applied in management of product data (PDM) are detailed. Next section emphasizes aspects, contexts, and intents as primary issues in modeling for enhanced content about relations in product data and decisions of engineers. Finally, methods for management of work in communities of engineers are summarized.

Keywords: Engineering modeling, Product data management, Group work of engineers, Communication of engineers, Modeling of human intent, Application of Internet Portals.

1 Introduction

Industrial products and their production processes have been completely changed during the past two decades. New style of customer demand and dynamically developed technical level resulted establishment of very complex product families and high number of product variants. To cope with the advancements essential developments in engineering have been encountered as organization of project work in international even global communities of engineers, application of computer methods for shape definition, and analysis of engineering objects and manufacturing. By the beginning of the 21st century, an advanced and integrated information technology background had been developed for integrated modeling of structural, mechanical, electrical and electronic elements of complex products. Engineering applications use Internet technology to organize remote individuals and groups working on different platforms into project-based communities of engineers.

The above outlined situation generated a need for integrated understanding of modeling techniques, issues in description of engineering objects, management of product information, embedding corporate knowledge in product models, communication of engineers in wide area computer environments, and features of Internet mediated computer systems.

Author of this paper makes an attempt to organize essential issues in recent communication and knowledge intensive engineering modeling. Paper starts with a discussion on integrated application of product modeling techniques. Following this, methods applied in management of product data (PDM) are detailed. Next section emphasizes aspects, contexts, and intents as primary issues in modeling for enhanced content about relations in product data and decisions of engineers. Finally, methods for management of work in communities of engineers are summarized.

2 Integrated Modeling of Products

In the old times of product modeling practice, unorganized models for islands in product information processing concentrated on particular purposes needed computer technology. Design of a part or a circuit on a printed board and development of equipment control program for manufacturing of complex surfaces were typical purposes of modeling at those times. By the middle eighties, high amount of distributed but not integrated information in models could not serve changed demands by industry any more. To solve the problem, on – going standardization for integrated product information model (IPIM) in the STEP (ISO 10303) project at the International Organization for Standardization [1] was bought in the foreground. At the same time, CAD/CAM system development projects were concentrated on integration of model descriptions.

What covers integration really? An integrated solution for product modeling offers software for creation, storage, retrieval and application of any product related information during the lifecycle of product, from the first sketch or specification to recycling. As an example, recycling must be considered at selection of materials for parts and planning of maintenance of product. Integration assures that output information by any program can be used as input information for any relevant program. In logical sense, associative links are defined between any pair of interdependent information. An important benefit of integration is the increased chance for consistent product information enforced by modeling procedures using model information.

Figure 1 illustrates integrated definition of information at product design. A mechanical unit contains information for shape, technical specification, and relationships of parts. Shape of part is composed by curves, surfaces and solids according to the techniques applied at construction of its model. During processing of geometry, correct information about surfaces and their intersection curves in the boundary of a solid is necessary to accomplish geometric operations as cutting by a surface in three dimensions. Parts are instanced for the assembly unit then placed on other parts in that unit. Information for degrees of freedom (DOF) allowed for relative movements of any pair of parts are also stored in an integrated model.

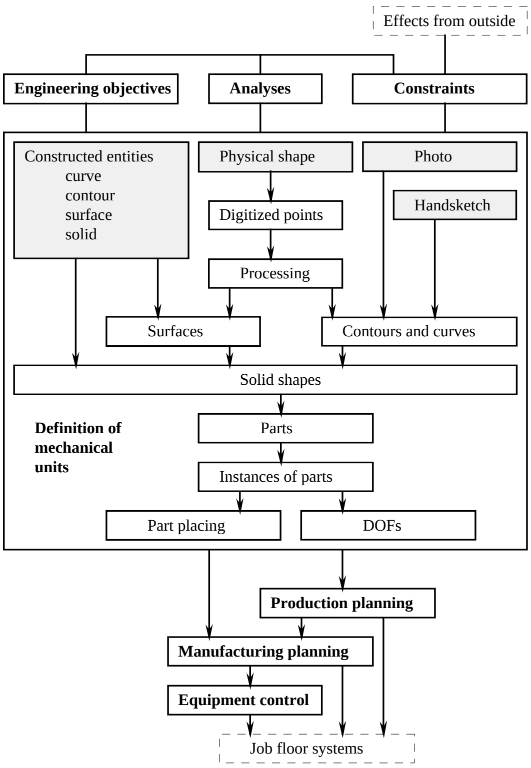

Figure 1

Integrated modeling of a mechanical unit

Other directions of integration are towards analysis, equipment control, production planning (BOM, MRP, scheduling), and product marketing including model-based presentations. Concepts for a shape can be included in a model by construction of curves and contours in model space, as well as selection of built-in shapes as curves, surfaces and solids. Advanced modeling systems can accept and process planar or spatial hand sketches of contours for parts even assemblies. Source of curve and contour information also may be a drawing or a photo. Physical shapes can be digitized than clouds or arrays of points can be processed into correct surface models. Engineering objectives and constraints as defined by earlier decisions, standards, agreements, legislations, etc. control modeling process.

High number of coordinated modeling and problem solving techniques are applied in the present advanced engineering practice [2]. Some techniques can be followed in Figure 2 as they are applied in an engineering process at creation of a unit composed by three mechanical parts. The process can be followed along the arrows. Part is initially defined as a solid box basic feature and two form features, tabulated from *Contour 1* and *Contour 2* along *Vector 1* and *Vector 2*, respectively. The well-proven and presently prevailing method is applied at construction of the part when an initial shape is modified by form features. As it stated above, all surfaces and their intersection curves must be described in the model. Connections of surfaces at curves are described by topology as structure of the shape. In the topological structure, curves (lines) and surfaces are mapped to edges and faces, respectively. Topological edges are connected by vertices. Consistency of topology is assured by construction using appropriate Euler operators and checked by topological rules [3].

Solid shape is completed by non-geometric information and stored as *Part A*. *Part B* and *Part C* are constructed in the context of assembly *Unit 1* in the assembly model space. Some contours are copied from part to part not to be repeatedly constructed them. It is very important, that placing of parts in an assembly must be defined as model information. In case of *Unit 1*, placing of *Part B* and *Part C* are defined by *Contact* and *Coincide* constraints. Placed parts can receive degrees of freedom to allow controlled relative movements in a mechanism. Part B received one translation (1T) degree of freedom to move along the arrow. Finally, cutting with *Surface 2* modifies *Part A* of *Unit 1*. Appropriate region of *Surface 2* is detached by trimming with new boundary lines and curves. Topology is also completed and new surface and curves are mapped. Entities and their attributes are linked by a set of bi-directional associativity definitions to save consistency of the construction at later modification and development activities. Parts often gain multiple applications in same or different assemblies and model of a part may describe a series of variants. Non-associative and non-constrained shapes and dimensions are free to modify. These operations are checked for consistency and collision.

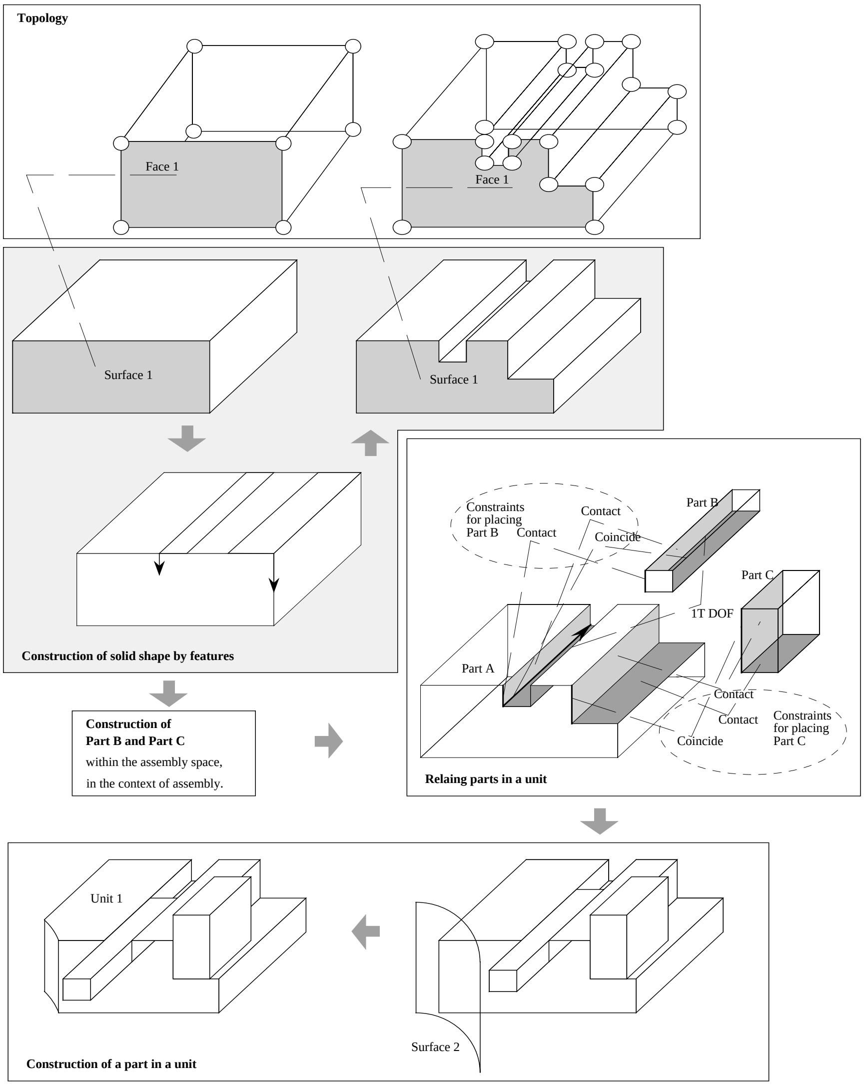

Figure 2

Techniques for integrated modeling of a mechanical unit

3 Product Data Management

During the nineties, model data bases became more end more complicated. Besides product based organization of data, two addtitonal demands were arised.

Results of different modeling systems were required to handle in the same data system and engineering process oriented services were demanded. As comprehensive program products to fulfill these new demands, pruduct data mangement (PDM) systems were established for product centric data base management. PDM systems are integrated with modeling systems and offer functionality for information handling, change management, control of engineering processes, and handling of product structure. At the same time, PDM systems manage integrated operations with other company activities. By now, consistency and other problems in entire product information environment can be explored efficiently by using of PDM functionality.

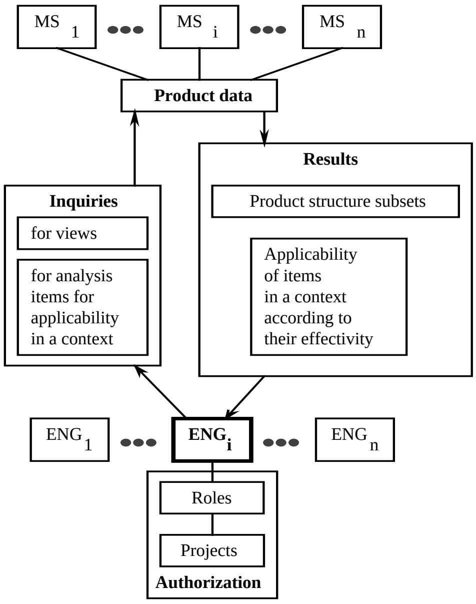

Figure 3

Product data management

Essential functions of PDM systems can be surveyed in Figure 3. 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. Several view related functions include copy and comparison. 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. An additional function of PDM systems is checking applicability of a part or other item in a context. Criteria of application are called as effectivity. This function is supported by specification of effectivity range for 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 Intents

In this part of the paper, three main concepts are explained to highlight the difference between conventional and recently introduced style of definition of engineering objects in modeling. Shapes and other entities are created in context of existing entities. This concept allows for automatic definition of essential associativities and assures consistency of the shape model during lifecycle of product. Contextual links are specified as constraints and when any entity in contextual realtion changes, the linked entities are also changed. Contextual links can be defined in one direction or in both directions of changes. In Figure 4, generator (c_g), path (c_p),and spine (c_s) curves, and a pivot point (P_j), are given for creation of a swept surface in their context. The context is specified as follows. Generator curve is connected to the end of the path curve at its pivot point. The surface is then created as swept one by moving the generetor curve along path curve, while normal of plane of the of the generator curve coincides the tangent (*t*) of the spine curve at each point along the path curve.

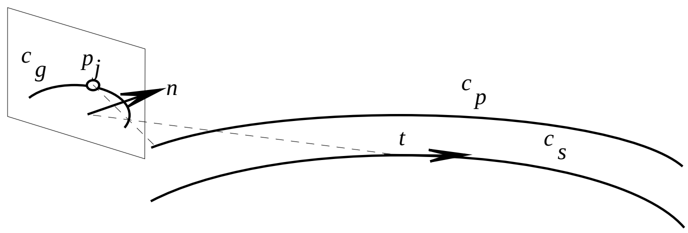

Figure 4

Definitions of a swept surface in context of three curves

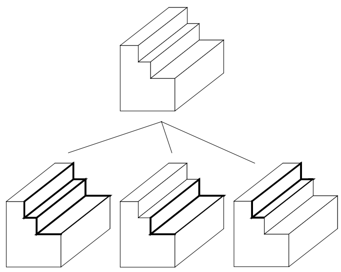

Figure 5

Aspects as form features

Modeling in an actual aspect is a means for engineers to define a modeled object according to its model or application environment [5]. In Figure 5, form features are defined according to three different aspects. Two steps are considered as components of a single form feature for planning of control of manufacturing equipment. At the same time, steps have different functions in the construction so that they are defined at part design as different features.

An engineering process is always controlled by intent of different humans. Most of decisions are affected by intent of several humans [4]. Three essential characteristics of design intent are type to categorize its content, status to describe its strength and status of the human who is its source (Figure 6). Intent characteristics in a product model are especially beneficial at handling multiple intents at a single decision. Technical content of intent can be represented as knowledge.

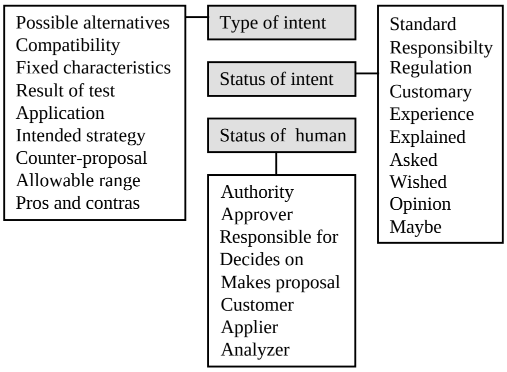

Figure 6
Main characteristics of a human intent

In order to illustrate how human intent controls product modeling, essential intents and their embedding in product model are given in Figure 7. Engineering objectives determine behaviors of a product at given sets of circumstances called situations. Functions are modeled as functional associative links (Figure 10). Intended consistent product structure is assured by structures as topology as well as 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 associativities or simple parameter values.

Development of knowledge engineering produced high number of procedures for emulation of activities even intelligence of human expert during eighties and nineties. At the same time, teams engaged in development of engineering modeling systems made efforts to elaborate simple and effective methods to embed knowledge in product modeling procedures and models. This is why application of knowledge-based methods in engineering is difficult because it must be acceptable by responsible experts who apply it in modeling at challenging product development. Non-verified knowledge, collected form different sources may be dangerous. Consider that a simple decision can change the financial position of a company. Consequently, knowledge should be corporate one. It is captured within work groups or projects by human definition, extraction from some successful practice, verification, and experience and shared amongst participants of work groups and projects. Engineers embed knowledge in models by responsibility and hierarchy-based acceptance. Conditions for application of knowledge can be specified by circumstances as parameter ranges, products or their views, and contexts.

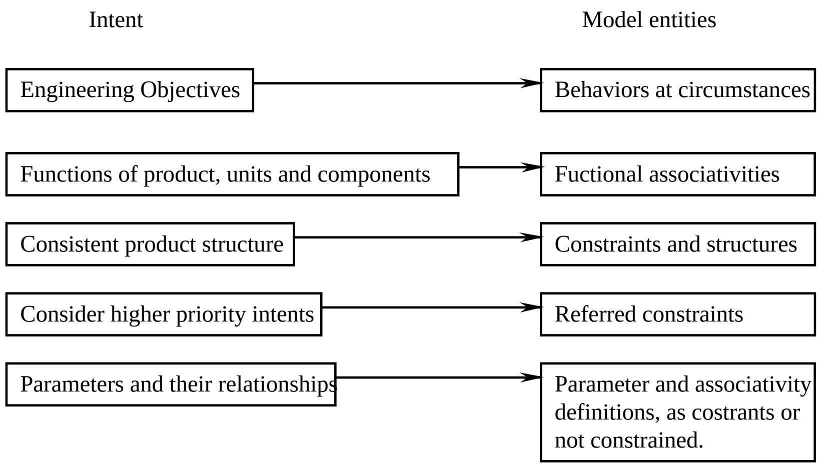

Figure 7

Several essential human intents and their description in product model

Simple efficient and engineer understandable forms of knowledge description are formulas, rules, checks, and reactions. They have an emphasized role in present engineering modeling. Formula is a record of an associative link. Rule predicts actual value of parameters, while check verifies just defined parameters. Reaction is an action programmed for given circumstances. Sources, content, applications and purposes of embedded knowledge are outlined in Figure 8.

Engineering objects in products are defined by sets of parameters. Methods are available to reveal combinations, selection of suitable combinations, and choose the optimal combination of parameters (Figure 9). Analysis of interactions between parameters and selection of the most influential parameter are accomplished by using of knowledge-supported associativity definitions. Optimization uses design objectives, limitations, and other criteria for creation of engineering objects with more or less parameters.

Models of shape-oriented objects as mechanical units in machines, household appliances, electric equipment, electronic devices, computers, etc. describe associativities those relate shapes by dimensions, placement, movement, etc. Function of objects and their functional relations are not described in earlier models. A recent method offers description of functional system of a product

(Figure 10). Functional associativities are defined between functional elements, functional subsystems, and variants.

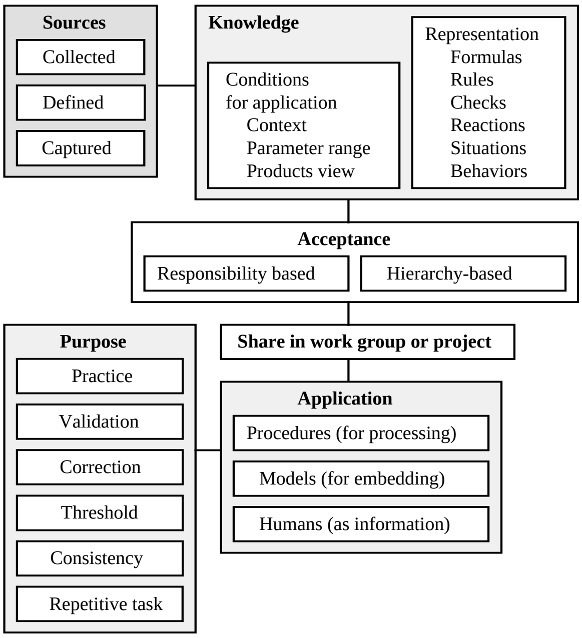

Figure 8

Knowledge in product modeling

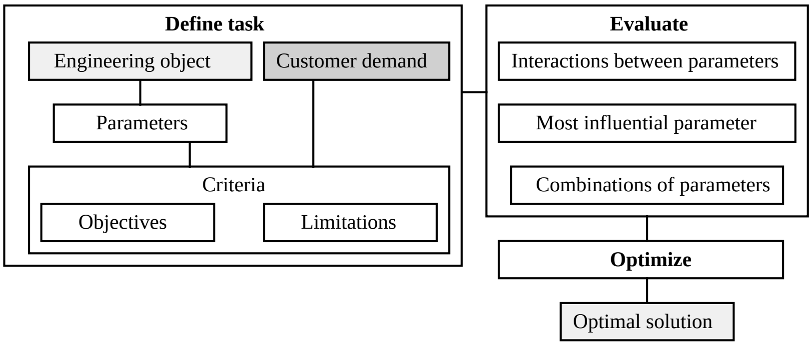

Figure 9

Handling object parameters

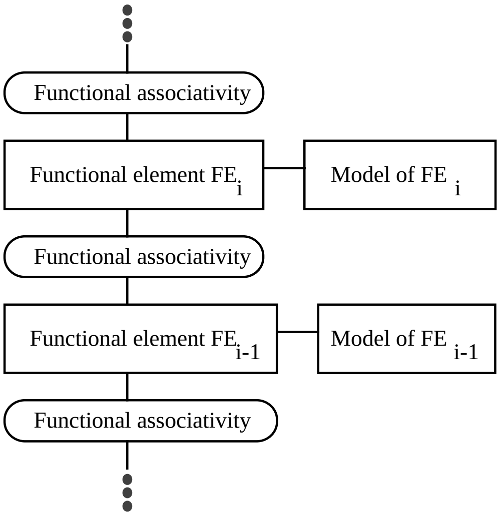

Figure 10
Modeling of functions of a product

5 Communities of Engineers

In the previous parts of this paper, integration of computer procedures and data sets, and embedding of human intent are emphasized. One may think that communicatin of humans has replaced by communication of computer procedures. This is one of the most tipical misunderstandings in modeling. One of the most important and effective development in engineering during the last decade was in communication of humans. Humans control high amount of information making thousands of decisions with personal responsibility. Integrated modeling together with embedding human intent and proven knowledge in models have resulted a great change in engineering work. Other essential change is that communities of engineers engaged in integrated modeling of products changed to use standard Internet technologies to establish a more effective communication in the recent years. Engineers at extended companies and their partners in supply line work in less or more wide area computer systems, where software functionalities are available for purposes defined according to product related objectives (Figure 11). Product lifecycle collaboration is provided for remote engineers and groups. Participants can work on 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.

Members of groups initiate and participate in workflow and engineering changes, access the same database, share the same resources, keep track of projects, tasks and resources at any time. The data is identical for all perticipants. All modifications are propagated to all workstations to maintain data integrity. Simultaneous and independent work is established at workstations, sometimes regardless of the network connection between them.

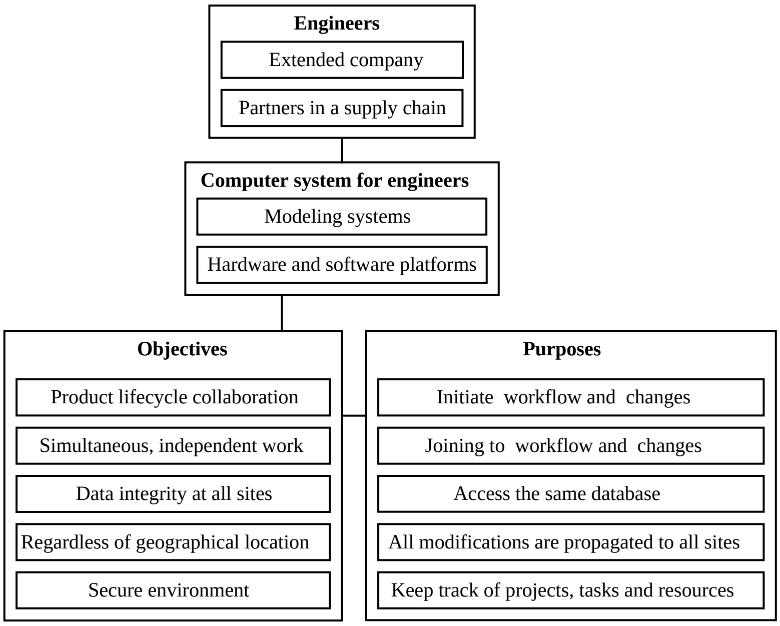

Figure 11
Communities of engineers

6 Laboratory for Intelligent Engineering Systems

An integrated system for modeling of engineering objects and product lifetime management (PLM) was established at the Institute of Intelligent Engineering Systems, John von Neumann Faculty of Informatics, Budapest Tech in 2005. Based on comprehensive and robust engineering software from Dassault Systemes, a fully integrated experimental installation comprises recent advanced CAD/CAM, human-computer, collaborative, product data management, Internet portal, and intelligent computing software. Figure 12 gives an outline of the computer and application system of Laboratory for Intelligent Engineering Systems. In its center, there is a portal server to organize work of members of teaching, learning, and research projects. Structural units of the system are sectors for teachers, engineering modeling research, and intelligent computing. Appropriate software is prepared in virtual system of a cluster of workstations for computer laboratory hours and larger projects.

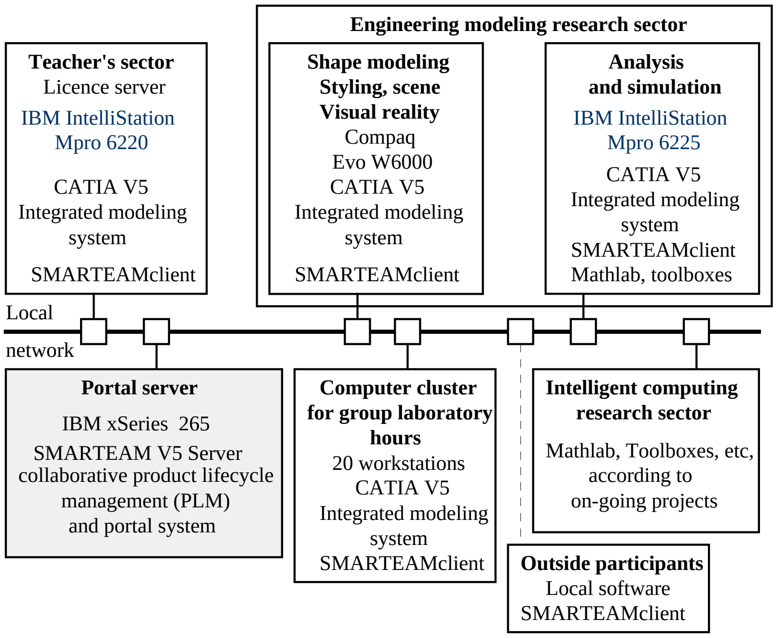

Figure 12

Laboratory for Intelligent Engineering Systems

Software includes comprehensive installations of CATIA V5 and SMARTEAM products of Dassault Systemes. The SMARTEAM system has functionality for management of product data, collaboration through standard Internet browsers, navigation through product data, Internet based, project-oriented, collaborative portal, collaboration on product data in a concurrent engineering environment, bi-directional data exchange with multiple enterprise applications, access the SMARTEAM API from different platforms via the Web, and multi-site work in different physical locations to access the same database. The CATIA V5 system provides comprehensive functionality for digital product definition and simulation. It is fully integrated with the SMARTEAM system. Participants, inside the system or at outside stations, can join to the portal server so to the group work organized around the laboratory system through SMARTEAM clients.

Conclusions

This paper emphasizes essential issues in recent engineering modeling such as integrated solutions for product modeling, product centric data base management, contexts, aspects, and intents as primary concepts in definition of engineering objects, handling of interrelated parameters, modeling of product functions, and functions for communication of engineers.

Lifecycle integrated solutions for product modeling provide assistance for engineers to assure consistency at definition of new engineering objects in product modeling by contextual and other associative links to existing and planned engineering objects. Modeling activities of engineers are organized around portals on the Internet establishing a communication intensive collaboration. Consistency of models is enforced by modeling systems. Product centric data base management by PDM system is integrated with multiple product modeling systems and other company activities.

Application aspect can be described by definition of engineering objects as features. A proven application of the feature concept is form feature. Extending the feature principle to other areas in modeling is one of the most effective method to inrease described technical content. An engineering process is typically controlled by intent of more than one human. Most of decisions are affected intent of different humans. Associativities, constraints, features and embedded formulas, rules, checks, and reactions as simple knowledge representations contribute to enhanced intent content of product models. Functional associativities are defined between functional elements, functional subsystems, and variants. Personal responsibility of decisions requires controlled application of knowledge. Considering situation based multiple intent difficultates application of intelligent computing at engineering.

Integrated modeling methods together with embedding human intent and proven knowledge in models have resulted a great change in engineering work. An additional useful methodology serves reveal of combinations of parameters, selection of suitable combinations and chooses the optimal combination.

One of the most important and effective developments in engineering during the last decade occured in communication of humans. Communities of engineers engaged in integrated modeling of products use standard Internet technologies for effective communication. Members do simultaneous, independent work, initiate and participate in workflow and engineering changes, access the same database, share the same resources, keep track of projects, tasks and resources at any time.

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