Behavior Model Assisted Decisions in Active Modeling Supported Engineering

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Abstract - This paper addresses the problem of application of intelligent model features for engineering modeling in industrial CAD/CAM systems. The reported research was started from earlier results in development of integrated feature based product modeling. An active model is proposed that integrates knowledge from modeling procedures, generic part models and engineers. Paper discusses the scenario of the related intelligent modeling based engineering. Then essential methods for application of computational intelligence in computer model based engineering systems are detailed including knowledge driven models as well as areas of their application. Next, behavior based models with intelligent content together with specifications and knowledge for the design processes are emphasized. Finally, the proposed active modeling is detailed and possibilities for its application are outlined.

Keywords: Engineering modeling, behavior modeling, virtual environment, computational intelligence

1. Introduction

Shapes, assembly relationships, joints, tolerances, finite element meshes and other engineering objects are described in process-centric model based development of products using digital definition techniques in recent CAD/CAM systems. Two essential modeling methods are feature and associativity definitions. Product is positioned for e-business among others by the application of a model-based approach. Scope of engineering modeling is being extended to the entire life cycle of products. Comprehensive application of virtual technology is an essence of the concept of digital enterprise where all engineering activities and equipment controls are done within a highly integrated modeling system.

Engineers expect computer assistance increasingly at their decisions in changed industrial environments where quick and efficient engineering decisions are needed to survive competition in the market. One of the important objectives of next future research in this area is human decision assistance during interactive part modeling sessions. This modeling needs representations that describe behavior of modeled objects for various circumstances. Then this model can be used at analysis of object behaviors in virtual. Demand for modeling that is appropriate for this purpose motivated the authors to investigate possibilities and means of new enhancements in knowledge based active model objects.

Recent advancements in part related engineering modeling is motivated by expectations for high performance of parts and well-engineered shapes. Performance of a modeled object can be assessed by using of various implementations of finite element analysis. Advanced shapes are best produced by advanced surface model driven and computer controlled manufacturing of parts and tools for making them [6]. Part model objects are integrated into product models by using of structure and associativity definitions. Part design is protected against modification by shape, dimension and associativity constraints. Despite these fantastic advancements some important aspects of modeling such as application of active models it could not follow this evolution. However, the present situation in modeling is good starting point for development of virtual environment based engineering modeling where advanced knowledge technology is integrated with advanced product modeling technology.

Purpose of the reported research is getting more information about nature and characteristics of feature based product models then development of a unique active modeling approach and method. The research involves analysis of structure and behavior of typical features. The purpose of this paper is to give an outline of an advanced concept and a modeling method in intelligent engineering modeling for implementation in industrial CAD/CAM systems. Preliminary of the reported research is development of a methodology to integrate manufacturing process modeling with form feature based part modeling by the using of relationship and constraint definitions [1].

Paper discusses the scenario of the related intelligent modeling based engineering. Then essential methods for application of computational intelligence in computer model based engineering systems are detailed including knowledge driven models as well as areas of their application. Next, behavior based models with intelligent content together with specifications and knowledge for the design processes are emphasized. Finally, the proposed active modeling is detailed and possibilities for its application are outlined.

2. Knowledge based modeling by intelligent model objects

The model, for which new or modified features are to be defined at various stages of an engineering process, is typically created in a different modeling system and by different engineer than the actual activity. At the same time, multiple designer operation modes in concurrent group work of engineers is assumed where the same model is handled by several engineers. An additional important characteristic of models is their knowledge content. Both modeling procedures and designers may utilize model-related knowledge in order to achieve an effective product modeling process. Knowledge communication can be associated with model data communication to assist multiple designer and multiple modeling system related problem solving. Knowledge content of model entities can be utilized in the design process at definition of product objects and simulations. An initial concept to integrate knowledge in modeling was to include knowledge to modeling procedures of CAD/CAM systems. This approach supports representation of generally applicable and domain related knowledge. However, most of the knowledge is company, product, even engineer related. This content changes from company to company and product to product. The only effective way is integration this knowledge in models of abstract or instance engineering objects in model objects. This approach is anticipated to be one of the most researched and developed areas in model based engineering design during the next few years. Significant part of knowledge as necessary at later processing of a model is model, modeled object or modeling system specific or simply is not available at the application of the model (Fig. 1). This knowledge is exchanged between modeling systems together with models. Built-in knowledge helps engineers at development, modification, and application of the model. It can prevent model quality from deterioration at its later application and modification. By now, knowledge content and other advanced features resulted a modeling where models can answer most of important questions about the modeled real world object before, during and after their manufacturing. Recently, advanced modeling systems that include models of this kind are called as virtual environments**.**

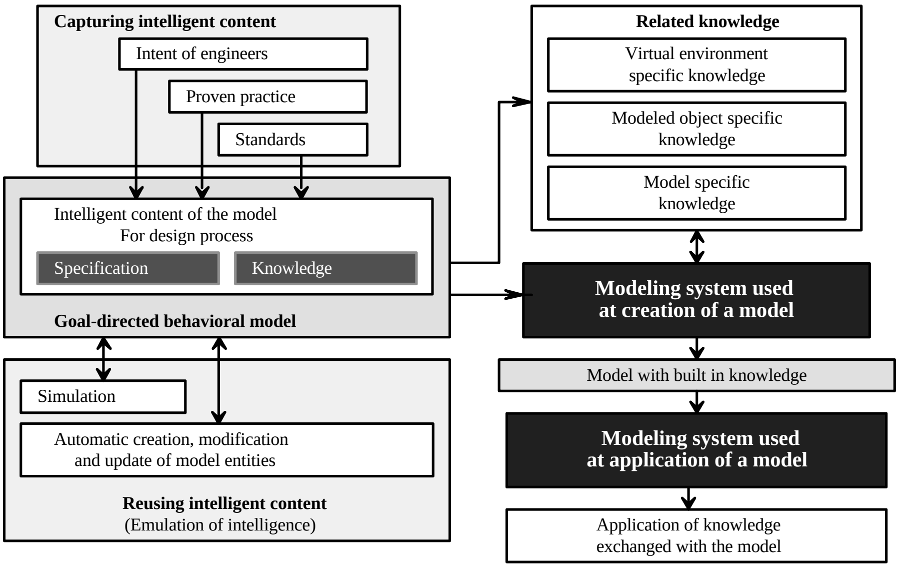

Fig. 1. Knowledge in the proposed modeling

Model having the capability of reaction using behavior related knowledge acts as an intelligent design of the modeled objects. It communicates built in knowledge with modeling procedure or human to save earlier decisions and human intent while new decisions and intents are captured in the model. Knowledge content of model is developed together with development of the model. Behavior based model with intelligent content involves specifications and knowledge for the design processes (Fig. 1). Specifications are results of design with appropriate explanations. Model of design intent can be described as specification in [2]. Knowledge normally is related to a specification but it is also may be independent of any specification. Definition of specifications and knowledge may require authorization according to role of engineers in the product development team and stage of the design process.

Forms of knowledge most appropriate for engineering are formulas, rules, and checks. Compliance of the model with proven practices and standards must be ensured. Behavior based modeling offers a conversion of implicit engineering practice into explicit knowledge. Creating a new model is enhanced by application of models of abstract objects. An abstract object carries characteristics of a set of similar objects. At creating of an object instance from the model of an abstract object, actual characteristics of the instance object are set. This process can be automated by including actual knowledge in model objects. Model of a generic object may involve domain, company, and designer related knowledge. Model of an instance object generally contains domain, company, product and designer related knowledge. Information on origin and validation of the utilized knowledge should be included otherwise responsibility for the product cannot be evaluated.

Creating of model objects as autonomous intelligent agents in a virtual environment may be initiated by a human or a computer procedure (Fig. 2). Intelligent agents are autonomously working procedures in the software system with goal-directed behavior interacting with their environment [5]. Human control is realized directly by interaction with model creating procedures or indirectly by instruction or knowledge placed in agents. This modeling environment constitutes a reactive system. Series of circumstances are identified and responded by models in the virtual environment. Goal-directed behavioral representation in agent-based modeling of engineering objects offers advanced simulation by emulation of intelligence. Models serve automatic or human controlled interactive, real-time simulations. Simulations are applied for analysis of critical situations and events during manufacturing and application of the modeled product. Simulation is a key technique for virtual prototyping where advanced modeling is applied to move physical prototyping activities into virtual environments. Real time simulation for assessment and analysis can be assisted by appropriate intelligent procedures. This is allowed by knowledge-driven modeling that captures and reuses intelligent content (Fig. 1). At the same time intuition, creativity and innovation of humans are also utilized in the course of their direct application, offered by interactivity, or by enriching the knowledge of agents. Enhanced competition-orientation of design engineering urges and stimulates application of behavioral techniques.

Situation is based on a series of circumstances and analyzed as an application of a virtual environment for problem solving purpose. Virtual environment is used to determine the influence of prevailing circumstances on certain parameters in the model. Circumstances are created by humans or generated automatically in the virtual environment. There are two typical simulations in the engineering practice. Best appropriate variants are selected or consequences of a decision are revealed for given set of circumstances. The first simulation allows revealing all parameters that influence a selected parameter. The second simulation allows determining impacts. It is best applied to design modifications. Variants can be adapted or combined by engineers and the new variant can be analyzed in the virtual environment.

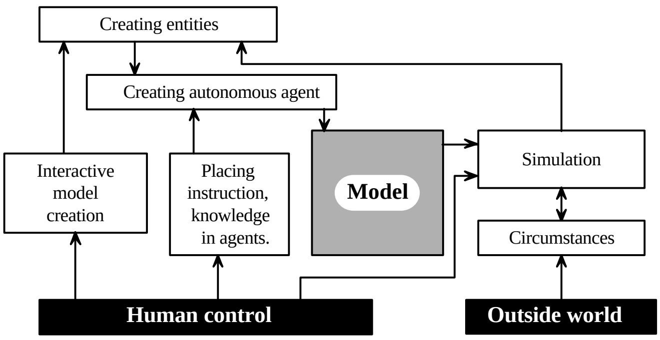

Fig. 2. Model objects as agents

Advanced shape centered engineering design uses form feature driven shape-modeling [8]. Form features are elementary build blocks for shape modeling and act as modifiers for previous shapes. A sequence of shape modifications generates the final shape of the part. Other non-geometric part and part manufacturing information, including suitable and available manufacturing resources, can be mapped to form features. Typical representation of form features includes unified topology and geometry. Virtual prototyping sometimes is completed by rapid prototyping. Rapid prototyping equipment can be driven by voxel model that is a spatial subdivision model of the shape. A method for conversion of topology-geometry based shape model to voxel model and manipulating voxel model for rapid prototyping is discussed in [4].

3. Associative modeling and its application at intelligent model objects

An effective way for integration of product model related partial models is definition of associativities between model entities [3] (Fig. 3.). Creation and modification of model entities rely on definition then maintaining of associativities. Associativities can be maintained by definition of them as constraints. Maintaining associativities during modification of an entity in a model often need propagation of the change to other entities. Propagation of any model change at any stage of modeling process ensures consistency of the whole product design with all related intents, goals, and decisions. Knowledge can be attached to associativities. Modeling procedure generates associativity alternatives for an actual situation and offers human to choose. This feature of modeling systems prevents erroneous associativity definitions by humans. Modeling procedures propose the most appropriate constraints for a part placement while human drags the part into position by a pointing device. Mechanical constraints are created then used to adjust part position and establish contacts automatically.

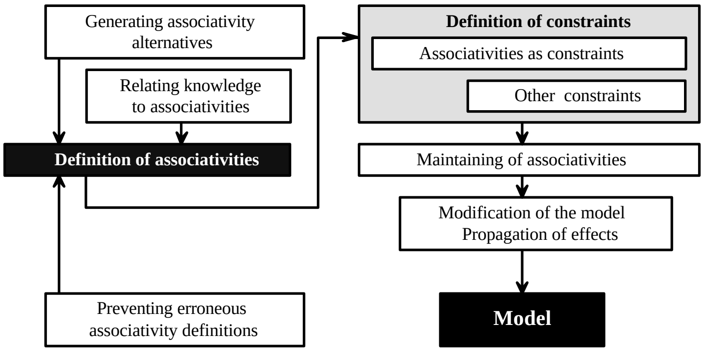

Fig. 3. Associativities in knowledge based models

Creating and global modification of a multi-surface shape complex as a single surface while preserving design characteristics demands shape definition related knowledge in modeling procedures and models (Fig. 4.). Taking styling, mechanical design and manufacturing knowledge and specification into consideration often results conflict to be resolved by the designer who is responsible for the related decisions. Knowledge acts according to the purpose and specification of modification. A typical purpose is to fit a complex surface in a solid model [7]. Rules, checks, control curves carry knowledge to the related modeling activities. Input parameters as guiding surfaces, other entities, and digitized physical geometry are used by knowledge assisted surface modification. Valid design constraints such as point, tangent, and curvature continuity specifications must be unbroken during modifications. Topology related knowledge is applied to propagate effects of surface modifications. Other important area for application of intelligent computing is recognition of sketched shape and creating surface model by using of it. Other surface related intelligent modeling is utilized by reverse engineering to transform shape related knowledge from the physical world to virtual.

Repositioning of a feature by dragging then dropping it using graphic interaction by human during development of a part model is an effective operation. It is followed by its mathematically correct automatic fitting into the new environment and reconstruction the old environment without any additional human interaction. This feature of intelligent modeling is called as automatic contextual change of model. It is enabled by behavior based, reactive geometric model. Other important area of knowledge based modeling is nonlinear mathematical optimizing of mechanical parts by using of numerical algorithms. Mathematical programming optimizes design for design goal while satisfies specific design limits. Design limits such as material strength or allowable displacement, are functional requirements of the design process. Design goal represents the optimization intent such as cost, volume, time, mass, stress, and displacement. Sensitivity analysis provides information about the degree to which a change in each design parameter influences the structural performance. At adaptive analysis, a converged analysis solution is achieved automatically.

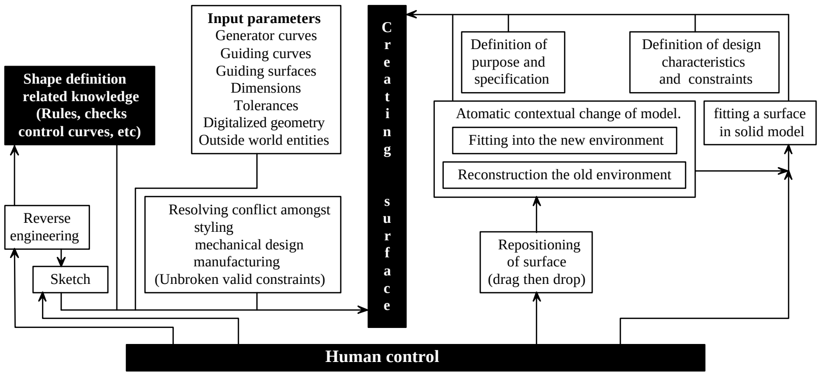

Fig. 4. Intelligent creating of complex surface features

4. An approach to feature based active model

The authors proposed an active part model that is able to inform engineers about consequences of including a new, a modified, or a new instance entity in the model. It comprises knowledge from three sources, namely modeling procedure, generic part model and designer.

Modeling of a part is considered as a single process from conceptualization to manufacturing even to life end procedure, according to the scope of product modeling. The feature approach has extended by active knowledge. Comprehensive groups of features are applied as volume adding and subtracting form features, boundary (surface) features, form conditioning features, finite element features, load features, machining features, measurement features, associativity features, rule features and check features. Design alternatives, offered by humans or part modeling procedures, can be recorded in the part model with the related knowledge attached. Intelligent modeling methods are useful in every day engineering practice. Engineers specify the required characteristics of entities.

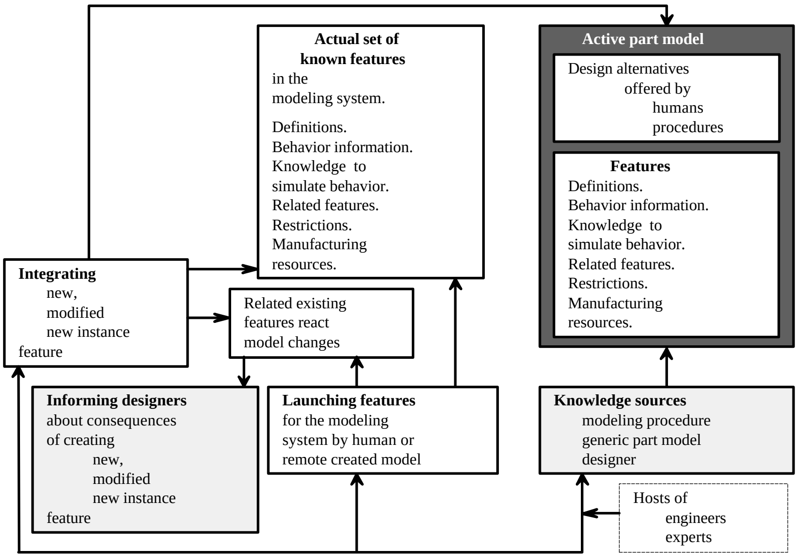

Fig. 5. Feature based active modeling

There is an actual set of known features in the modeling system at each moment (Fig. 5.). Newly defined features can be launched for the modeling system by human or remote created model. Most of the features are generic ones and part models apply their instances. Other features are defined for a single model and can or must not be included in other models. Privacy policy is an important aspect at implementation of this approach. Some features, for example, can be applied in certain projects only. Features are in possession of information and knowledge necessary to simulate behavior of the modeled objects. When a new or modified feature is included, previously defined feature data, restriction definitions for prospective features and production resource information are applied at integration of the new feature in the existing part model. Receiving this information, the associative existing features react to any feature related model development activity. Consequently, features are aimed to create information about the effect of model changes and to communicate this with the related features. The above outlined approach also offers a solution for reconstruction of exchanged models in remote receiving CAD/CAM systems.

Definitions and behavior information for features can be placed by engineers and experts in their hosts and can be accessed through Internet. In this way, advice taking can be made available for remote residence engineers.

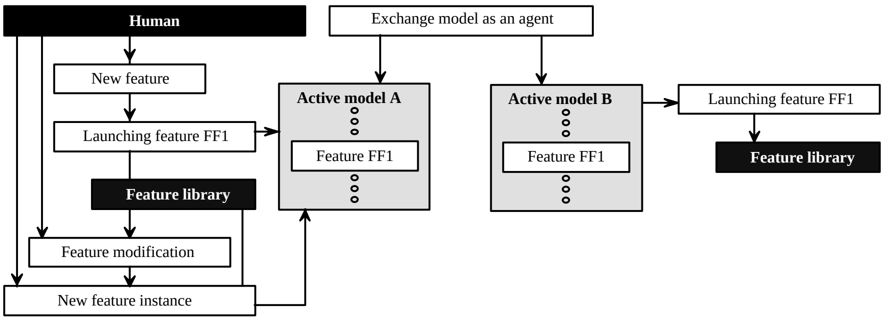

Fig. 6. Feature in active model

Feature definition in case of agent based active model is outlined in Fig. 6. Feature definitions are stored in feature library in the modeling system *A*. During creation of an active model, human defines a new feature *FF1*. Other possibilities are definition of modifications or instances for new features. Besides feature instance specifications, knowledge to launch the feature *FF1* by active model in the modeling system *B* is also included in the model.

Conclusions

The reported research is an attempt to apply recent modeling techniques to establish intelligent modeling of products. Paper discusses feature, associativity and constraint driven model definitions as potential connection points of intelligent content. An outline of the proposed process-centric development of products using digital definition techniques in the form of active model is given. The proposed model includes model representations that describe behavior of modeled objects for different circumstances. Some knowledge-based means of enhancements in active modeling are analyzed. Automatic, reactive feature based propagation of changes in models at any stage of the modeling processes produces product design consistent with intents, goals and decisions. Feature models involve specification and knowledge representations necessary to simulate behavior of the modeled objects. Active models act as agents after exchange them with other modeling systems for their development and application.

Acknowledgments

The authors would like thank Hungarian – South African Intergovernmental Science & Technology Cooperation Programmes for the financial support. Project number is DAK-3/02. The authors also gratefully acknowledge the grant provided by the OTKA Fund for Research of the Hungarian Government. Project number is T 037304.

References

[1] László Horváth, Imre J. Rudas, “Virtual Technology Based Associative Integration of Modeling of Mechanical Parts,” in *Journal of Advanced Computational Intelligence*, *Intelligence,* Vol 5, No. 5 2001, pp. 269-278.

[2] László Horváth, Imre J. Rudas, Carlos Couto, “Integrationration of Human Intent Model Descriptions in Product Models,“ i*n book Digital Enterprise* - *New Challenges Life-Cycle Approach in Management and Production*, Kluwer Academic Publishers, pp: 1-12.

[3] L. Horvath, I. J. Rudas, "Integrated Associative Modeling of Parts and their Machining Process by Features", *in proceedings of the ICMT 2001 conference*, Singapore, pp. 316-321.

[4] Gy. Herman, "Voxel Based Geometric Modeling in CAD, a New Approach", in *Proceedings of INES'2000, 2000 IEEE International Conference on Intelligent Engineering Systems*, Ljubljana, Slovenia, pp: 53-56.

[5] M. Tambe, W. L. Johnson, R. Jones, F. Koss, J. Laird, P. Rosenbloom, and K. Schwamb, “Intelligent agents for interactive simulation environments, “ in *AI Magazine,* v. 16, n. 1, 1995.

[6] Les Piegl - Wayne Tiller: *The Nurbs Book*, Springer-Verlag, 1997

[7] Freitag, S., Opitz, K.,: Enhancements in blending algorithms, in *Hewlett-Packard Journal*, October 1995, pp. 24-34

[8] Mannistö, T., Peltonen, H., Martio, A. Sulonen, R.: Modeling generic product structures in STEP, *Computer-Aided Design*, Vol. 30, No. 14, 1998, pp. 1111-1118