Human and Computer in Engineering

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Abstract: Model based computer aided engineering brought a new type of activity of humans who communicate modeling procedures for creating computer descriptions in compliance with design intent. Human-computer interaction is a critical element of computer aided engineering because it seriously affects the success of product design and production engineering by the capability of description engineering objects as they are created and refined in the brain of engineer. This paper discusses selected issues of human-computer interaction as it applied at computer model based group work of engineers. It introduces human related issues and their relationships for human activities in engineering. Then design intent is characterized and intent based history of decisions is discussed. Following this, intent model consisting of primitives and relationships is proposed and explained. Finally, integration of intent modeling in model based development of mechanical products are conceptualized and discussed.

Keywords: Human-Computer Interaction, Modeling of design Intent, Product Modeling, User Interfaces

1 Introduction

Computer based engineering has replaced the conventional way of paper documentation based engineering in the competitive areas of industries during the last two decades. Previously, results of engineering activities recorded and related as documentation in the form of manual or computer handled texts, drawings and pictures. Documentation serves direct understanding of results by humans. It is not suitable as information storage media for computer procedures. Advanced computer modeling has been developed for the purpose of sophisticated description of engineering objects and communication between modeling procedures. However, a new problem complex has been emerged in the area of two-way human-computer communication.

As computers were moved into engineering applications, engineers demanded computer tools suitable for purposeful, correct and efficient computer description of engineering objects. Computer descriptions, in other words computer models of engineering objects were developed in the early years for the first engineering applications of computers as design and computer controlled manufacturing of well-engineered surfaces on mechanical parts. Because main communication tool of engineers is drawing, interactive graphic communication surfaces were developed for modeling systems. Restricted resources of computers generated the main drawback to development of engineering applications of computers at early times. As the computer performance available at engineering offices was increased, old dreams were realized in computer modeling during eighties and nineties. Recently, advanced engineering is based on modeling. Models are created, communicated and applied in worldwide computer systems. Main areas of research and development in human-computer procedures are analysis of design intent [1], role of user interfaces [2] and application of knowledge based methods [3].

Some results and discussion of the research activities in modeling of design intent at the John von Neumann Faculty of Informatics, Budapest Polytechnic are included [4], [5] and [6]. This paper is based on this recent research and outlines human-computer interactions and modeling of design intent by representative issues. It introduces human related issues and their relationships for human activities in engineering. Then design intent is characterized and intent based history of decisions is discussed. Following this, an intent model consisting of primitives and relationships is proposed and explained. Finally, integration of the proposed intent modeling in model based development of mechanical products are conceptualized and discussed.

2 Human related issues

Procedures for human-computer interaction (HCI) should be adapted and enhanced for effective communication of design intent. This is why design intent description intensive modeling is so important. This area is in close connection with knowledge acquisition, data access and authority control, human interactions, behavior of humans, human-human communications and human errors (Fig. 1).

Design intent appears in some form of knowledge, but its source is not a single knowledge base. The related knowledge is not only domain but also product, designer and customer related [7]. Consequently, it cannot be involved in the modeling system in one of the conventional ways. Members of a group of engineers, who are working on a product design, may describe knowledge or cite outside knowledge sources.

Knowledge is often available only for personal access. In some other cases, access to a knowledge source is allowed only for several engineers in a work group.

Quality of a decision depends on the performance of the human decision maker. This performance can be increased by mutual adaptive human-computer interfacing [8]. An engineer at the beginning of her or his career is not well trained. Description of relevant, practice based intent of skilled engineers support beginners at their decision-making. Computer learns decisions of skilled and experienced engineers in order to support decisions of less skilled engineers. Threshold knowledge can be defined and then used for the purpose of making wrong decisions by untrained or careless engineers ineffective to avoid fatal errors in product design and production planning.

Design intent is often based on observations. Problems in product design or production planning are solved during cognitive procedures where designers find out results of decisions. It is very difficult to follow, record and consider human thinking processes. Sometimes variants for types, parameter value ranges and discrete parameter values can be defined as intent. This supports original design intent based changing of decisions with more appropriate ones during application of product models. Understanding of typical situations is enhanced by appropriate intent descriptions from other engineers. An indirect human-human communication can be established by intent description.

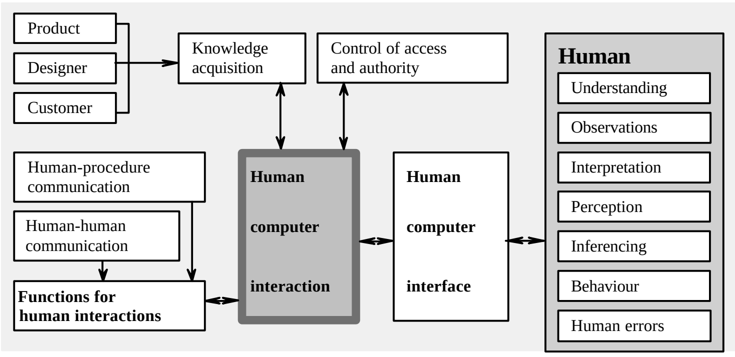

Fig.1. Human related issues

A typical knowledge assisted engineering process is outlined in Fig. 2. Engineer is working on a product design. Experts are asked to help at solving special problems. Both of the humans define product design and knowledge items. Inferencing assists decision-making and generates engineering objects. Results are explained for humans and knowledge is extracted by machine learning for knowledge base. Modeling system generates and uses internal model and knowledge representation. Small dark rectangles illustrate on Fig. 2 that all communications are potential points of intent distortion.

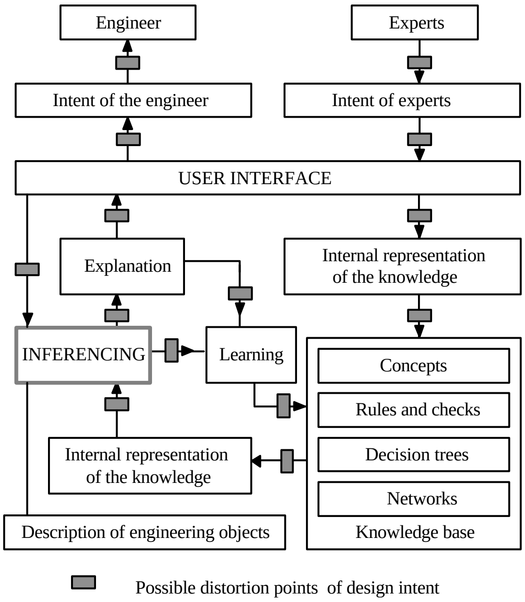

Fig. 2. Distortion of human intent during engineering modeling

3 Characteristics of design intent

Main attributes of intent entities are listed on Fig 3. Type of intent refers to its main content. Status of the intent gives information about the origin of the intent information or knowledge. It varies from the *standard* to the *maybe*. The standard intent is based on given standard. If the status of intent is responsibility, it is based on decision of a person who is responsible for the design. There are weak intents as opinion and maybe. Application of intent requires information about the status of the human who defined the intent. For example, a counter-proposal may come from an authority or a human who only makes a proposal. The two situations are not the same despite the same technical content. Sometimes a design is a reasonable compromise of several humans in different positions. The methodology that is proposed by the authors includes an archive of design intents that helps at reconstruction and modification of a decision or sometimes at investigation of quality or criminal cases.

Status of the human means a given position or role in the design and planning environment. The range of aims of communication starts with informing and ends with command. Lists may be defined according to the application.

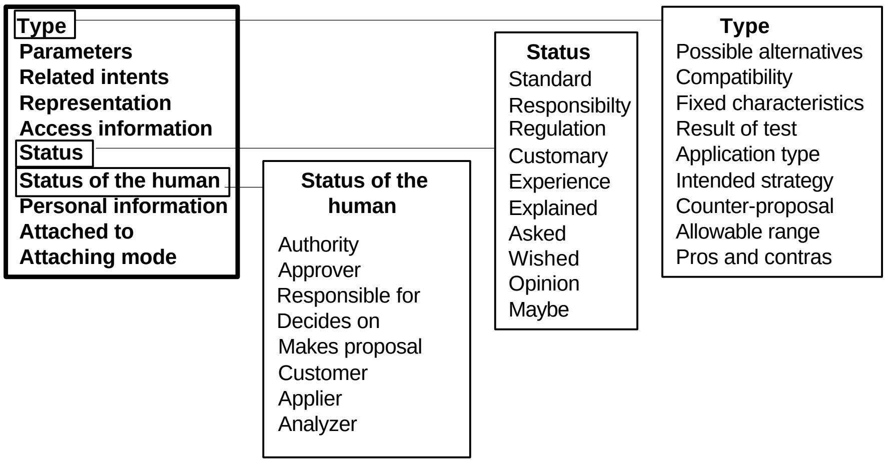

Fig. 3. Attributes of design intent

Basically, there are intent definitions regarding design and application of the model (Fig. 4). In other case a video shows a shape that the designer likes and is insisted on. An intent definition for application of a part model among others may involve the preferred type of application, strategy and process parameters. There are suitable alternatives that can be taken account without notice from the user of the model. Allowable range of some parameters can be defined within which the model can be modified without any permission from the original designer. The information on possible modification of the model shortens product development cycle.

Fig. 5 summarizes some important elements of an intent description. Intent can be attached to a decision on an entity, a parameter of an entity or a relationship of entity parameters. A relationship can act as a constraint depending on the intent of human. Basically, an intent description consists of a history description of a decision. A list containing entities that are referred in the intent description and act as information sources needed at processing of the history can be involved. It should be emphasized that Fig. 4 shows one of the possible styles of the history. A very simple history can be for example a simple result of a decision of the management or even an authority without any explanation. The history can be considered as a chain of explanations for a decision. Generic product models can involve generic intent models.

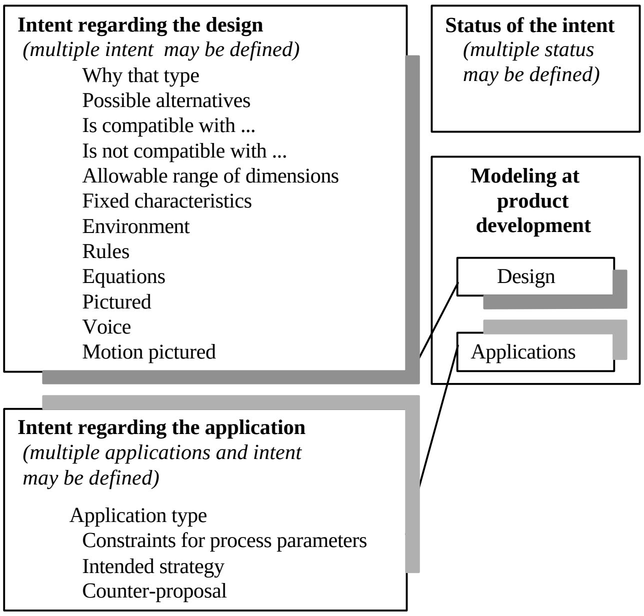

Fig. 4. Intent for design and model application

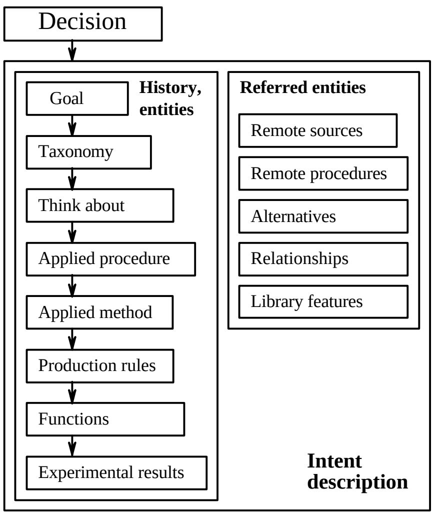

Fig. 5. Record of the history of decision making

Intent description on the Fig. 5 starts with a goal that is defined and a related taxonomy is revealed. This is followed by a consideration of the applied procedure. This is the result of a thinking process of the engineer. In other words, engineer did not use any idea from handbooks, etc. Then the applied method is selected taking into consideration of the choice that is offered by the selected procedure. Alternative procedures and methods can be involved or referred. The procedure needs input data that has been defined using production rules, functions and experimental results. The origin of the experimental results is an important element of the intent description.

4 Modeling of design intent

Main procedure of creation and processing of design intent are outlined in Fig. 6. Intent entities are created during product modeling. These entities are represented, related to results of the design process and used by product modeling and product model application procedures. The product model may be applied in the same modeling system or in other modeling system with different modeling capability and entity set. Consequently, a conversion may be needed during a data exchange. Model data conversion can be governed by design intent information. This is the first possibility for application of design intent model description. Intent information is then used at application of the model or communicated to the user of the model. Finally, intent data is stored with the product model then it is used at its later applications.

Intent model is proposed to compose by related elementary intent descriptions called as intent primitives. Four intent primitives are included in the example of Fig. 7. All of them must be taken into account at decision making. Relationships defined between intent primitives to arrange them in a structure. Processing of this structure produces a decision by the engineer who is responsible for it. However, that engineer is also responsible for definition and application of constraints described by the relationships between pairs of intent primitives. This method, proposed by the authors, guarantee the quality of the model.

Engineers often decide on intent primitives that act as alternatives. The selection of a solution taking into account alternatives is not always assisted by additional relationship for hierarchy of alternatives. If not, the problem can not be handled by relationship definition; effect of the related intent primitives should be evaluated. The structure in Fig. 7 is typical for simple decisions. However, solving complex problems is the real area of effective application of intent modeling. Intent model must be completed with an information that carries a measure of impact of intent primitives. Impact of an intent primitive sometimes is simply the consequence of its source.

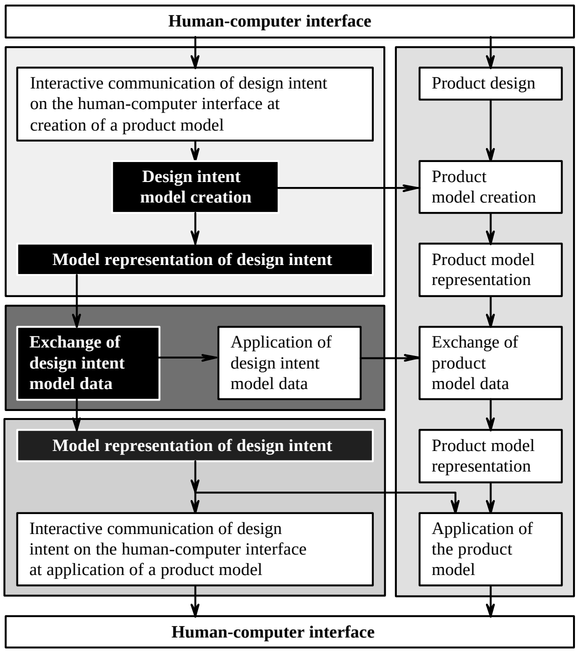

Fig. 6. Creating and processing of design intent

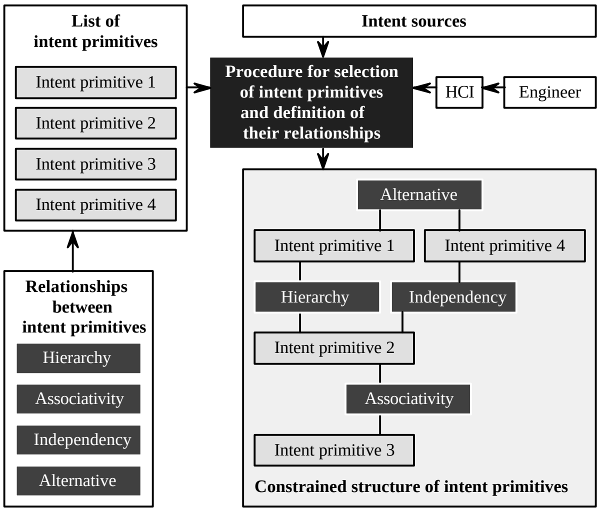

Fig. 7. Intent model

There is a place, where intent information is created or stored. From the point of view of intent modeling, the information for source of intent is important to describe in intent model. Intent information mapped to given fact in a product model is composition of independent or dependent intent primitives. As an illustration of the problem, some of the most relevant sources are attached to main stages of the part related engineering process in Fig. 8/b. Also, Fig. 8/a involves a list of sources of intent primitives considered by the authors.

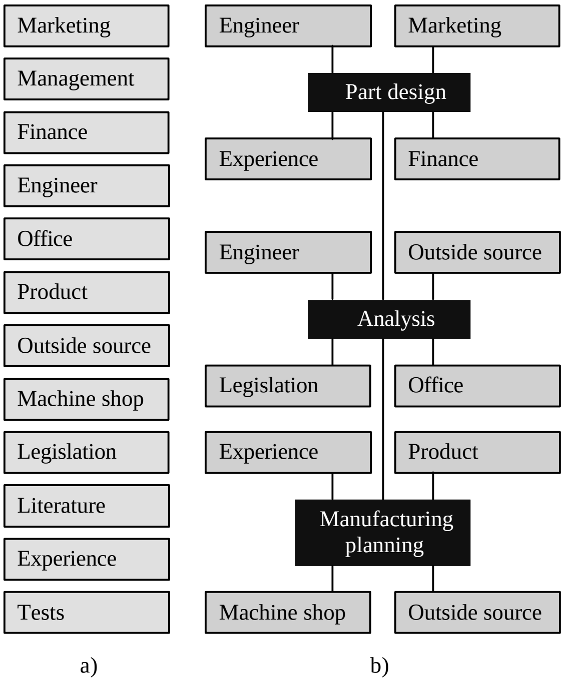

Fig. 8. Sources of design intent primitives

Composition of an intent description is outlined in Fig 9. List of intent primitives in Fig 9 is not intended to be a complete one, it only illustrates some important example areas. The intent modeling is intended to be fully integrated with product modeling. Most of product modeling related information is associated with design and analysis of mechanical parts and assemblies and planning of computer controlled manufacturing of mechanical parts. Consequently, component (i. e. mechanical part) related information and knowledge are often demanded and utilized by intent model definition procedures. Intent description is connected to the related product model entities by associativity definitions.

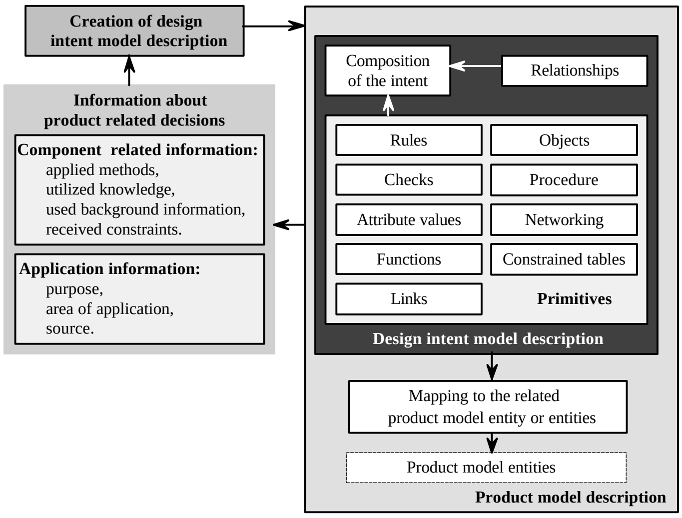

Fig. 9. Composition of intent description

5 Integration of intent modeling

Virtual technology based associative integration of intent modeling with modeling for design, analysis and manufacturing planning of mechanical parts is a prerequisite of application of intent modeling in advanced modeling practice. Activity of human in computer aided engineering is conceptualized on Fig. 10 [9]. The engineer who selects object or planning function initiates the interface process. According to the user interface applied, lists, hierarchical menus and geometric sub-spaces are constituted by choices. Lists and menus refer to objects. After selection the appropriate list or menu element an object are created together with its attributes. Selection also can be done by procedures. Capturing design intent is assisted by navigators that offer solutions for engineers in accordance with the situation. Then problem solving procedure creates objects according to human instructions. Restitution of results of human or computer activities (objects, attribute values, error messages, etc.) make evaluation possible. Humans or problem solving procedures evaluate results and events. The story is visualized by viewing procedures. Advanced graphic user interface (GUI) is expected. Media user interface (MUI) is an extended toolkit for effective man-machine communication.

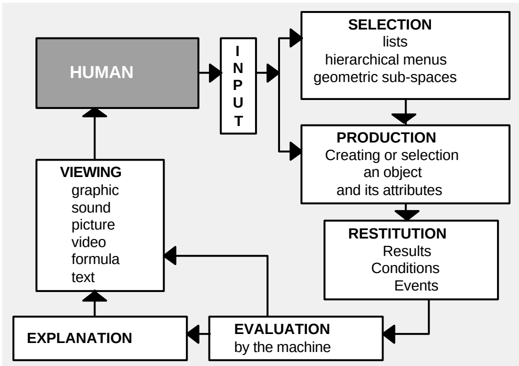

Fig. 10. Activity of human in computer aided engineering

Integration of intent modeling in model based engineering as an extension is outlined in Fig. 11. Aspects of human, procedures and model data are detailed and connected [10]. Computer procedures create model entities using definitions by engineers. Data exchange between modeling systems and collaborative communication amongst humans within a group of engineers constitute basic communications [11]. When a new or modified constraint is involved in the model, it is very difficult or impossible to detect and resolve conflicts with other constraints [12]. On the other hand new constraints often should be propagated across the product model according to the relationships amongst the relevant parameters. Design intent modeling extension to product modeling system consists of tools for definition of intents by human including importing intents, adding intents to product models and description of intents. Constraints, relationships and history records in the model are most important connection points for intent description. History record of the modeling process involves some decision-related information, however it is often impossible to reconstruct the full background of a decision.

A study of recent CAD/CAM systems gave an evidence for the authors that one of the most important human intent related issue in present day product modeling is application of constraints. Example on Fig 12 explains application of constraints. As usual, engineer gets constraints (C_1 and C_2) as results of earlier decisions, decide amongst shape variants then defines new constraints (C_3 - C_5) as results of personal decisions. Constraints C_4 and C_5 represent coincidence at the appropriate faces of the involved parts. The above outlined capability of modeling systems was the starting point at development of the proposed method. In the lack of intent definition, later modification and application of the model can not be done without active participation of the original decision-maker. Moreover, in the normal industrial practice an engineer can not remember all details of an earlier decision, especially if it was prepared, for example, by the help of a communication among members of an ad hoc group of engineers.

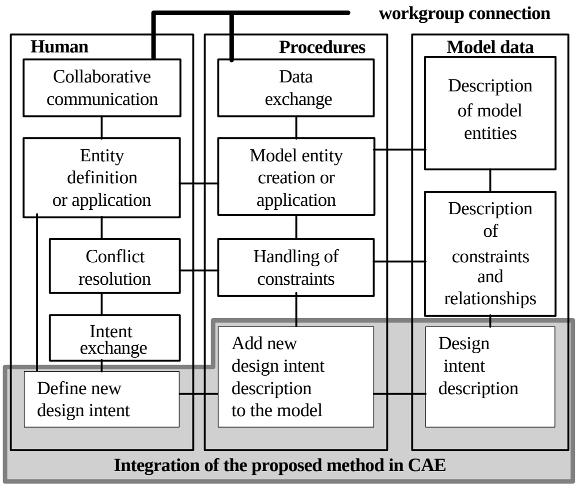

Fig. 11. Integration in computer aided engineering

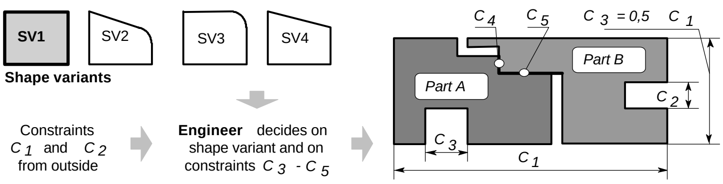

Fig. 12. Constraints in models of engineering objects

Styled surfaces are wide spreading in products. Fig. 13/a. shows a section of a complex surface that consists of six component surfaces (*A*-*F*). Structural requirements are considered then surface types and dimensions are decided. Relationships of dimensions are defined and values of dimensions are calculated. Fixed values are defined as constraints. Other parameter values can be modified within a given range, however this range can not be described in the part model so that one of the possible values should be considered as a constraint to permit later changes of the dimension to the illegal range. The type and shape of the surfaces should be decided despite the possibility to change the shape of free form surfaces *B* and *D* and flat surface *C*. At the same time component surfaces *A* and *F* should be flat and component surface *E* should be cylindrical. All component surfaces are described using rational B-spline functions that offer easy modification of the shape. Consequently, type of A, E and F surfaces should be constrained to avoid modification of their shapes as free form surfaces. There is a relationship between dimensions A4 and R1. These are described in the part model that is created by the modeling system.

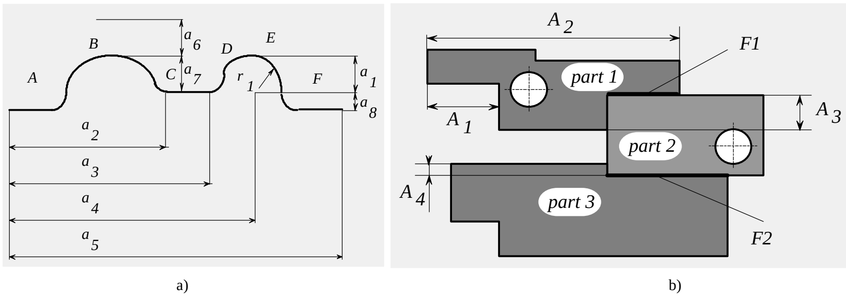

Fig. 13. An example for surface model

The task is styling the above detailed surface complex without changes that are not allowed by structural or production requirements. Description of design intent using the method proposed by the authors helps styling. Some example elements of the intent description:

- *Decision on relationship A_4-R_1.* This decision is based on a method by an expert who defined several alternative solutions. These are involved in the intent model.
- *Shape of component surfaces B and D.* Modification of these free form surfaces is allowed. Although $A_{1\ min}$ and A_{5max} dimensions limit the modification of these surface components.
- *Shape of flat component surface C.* This surface can be modified as a free form surface if mating surfaces of other parts are modified accordingly. Cost consequences can be estimated by a procedure that is related to the intent description and can be accessed through Internet.
- *Fillet surfaces* connecting component surfaces can be modified.

Styling engineer may create additional intents for other styling and manufacturing planning procedures. Styled surfaces are often hard to manufacture. A minor modification of the surface may result substantial cutting of the manufacturing costs. For this purpose, the design intent description can involve ranges of allowable control point positions or other allowed ranges of shape characteristics and features.

An other typical example in design of mechanical systems can be seen on Fig. 13/b. The parameter model in the model of *part 1* includes the relationship *A2=3,1 A1*. The intent model may include the method that was used at the determination of this formula. Sometimes parameters from the application environment determine parameters of given entities during the product design. Quality of the design may be deteriorated by modifications of parameters that seem logical but contradict to some of the purposes. However, because this problem generally emerges at the application of the product model, it can not be seen at the stage of the design process where the modification is done. The importance of the design intent description is essential in these cases. An engineer could think that the dimensions *A3* and *A4* are limited only by the contact constraints at the faces *F1* and *F2*. Other limiting factor can be, for example, the minimum allowed value of the gap between *part 1* and *part 2*. This additional limit may be resulted from considering parameters of entities other than the *parts 1-3*.

Conclusions

Human activities as well as definition, modeling and saving of design intent for group work of engineers are discussed in the paper. Important issues are discussed to highlight characteristics of human-computer procedures and the proposed modeling of design intent. Basic ideas and procedure of intent modeling, role of design intent information, source of intent and composition of intent description are emphasized as key issues. Design intent description is communicated between engineering modeling systems together with product model information. Interrelations, relationships and constraints constitute main connection points for an intent description in part models. One of main areas of application of intent model is decision on change or delete of results of earlier decisions at application of product models where the original decision maker is not accessible and the only way for modification or evaluation of a decision is design intent description.

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