CAD with use of Designers' Intention

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Abstract

Cooperative design among product designers and process planners is widely executed in machine industries. Technical information is transferred among them through CAD/CAM systems. Typical information is related to part and product models mainly described by geometric shapes in CAD systems. An important characteristic in cooperative design is that designers reciprocally transfer information to make their decisions. Moreover, the decision making may be affected by other designers' decisions or their own former ideas. These information is not transferred in present CAD/CAM systems.

Cooperative design requires the construction of communication network as the infrastructure among designers, and the development of adequate communication information to describe the way of thinking as designers' intention. This paper proposes the network system with use of active database, and deals the designers' intention as the communication data.

Designers' intention is introduced as the essential information to combine the required functions and the geometric models of designed objects.

The new architecture of CAD is developed that combines the three dimensional solid modeler with designers' intention modelling system. A case study explains how to use the designers' intention especially in modification design process.

Introduction

Cooperative design is required in machine design for decision making in the design process needs the different viewpoints. The decision making by a designer is affected by others' decisions and own former ideas. The present CAD/CAM systems transfer the geometric models of design objects mainly, and designers can not understand others' way of thinking with use of them. The real time conversation among designers are required to acquire the missing information, however, often it is hard because of the spatial and periodical problems. It is desired to transfer the designers' way of thinking via computer systems as well as design object descriptions.

Design process starts in general by the input of the requirements/specifications. They are decomposed to the detailed ones. At the same time designers may generate the attributes/geometric shapes of the design solution in their heads. The design process is to include the decomposition process of functions, the development process of getting detailed attributes/geometric shapes, the geometric modelling process, and the function/performance analysis process.

The design process is progressed by imagination, remembrance, reference, calculation and so on in the designers' heads. Designers may explain the reasons/ideas for decomposition, development, modelling, and other decisions, however, they are not clearly described in the CAD systems in spite of the importance and usefulness for designers to understand others' way of thinking that may affect their decision making.

The designers' intention is defined here as a chain of various reasons, ideas, and activities according to the design progress, starting by the required function and ending at the specification of geometric shapes with technological information which satisfy the required function. The CAD systems have to manage the design process so that they can transfer the designers' intention among designers to understand with each other.

Designers' Intention Modelling

The architecture of CAD systems is shown in Fig.1 which includes not only the geometric modeler but also the design process manager and the designers' intention modelling system.

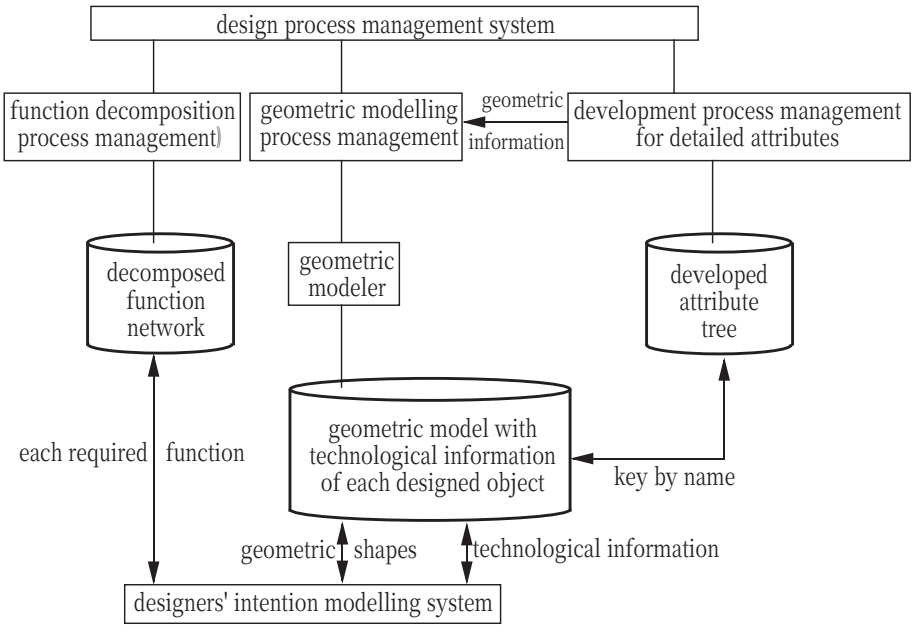

Fig. 1 CAD system architecture with designers' intention modeler

The function decomposition process manager generates the decomposed function networks according to the input of designers. The network is shown in Fig.2 where a function is decomposed to detailed ones. During the function decomposition, designers may hit upon ideas which generate geometric shapes, analyze functions and performances of the shapes and again decompose the functions. These chains of ideas, reasons, activities of modelling and decomposition *etc.*, geometric models and decomposed functions which are the results of activities are made by the designers input, and gathered as designers' intention to make a network where nodes are reasons/ideas, geometric models/decomposed functions, and activities. A chain of nodes shows how to decompose functions and how to generate geometric models which are peculiar to each designer.

Designers' intention is generated and managed in CAD systems. The designers' intention modelling system is a subsystem of the CAD system whose architecture is shown in Fig.3. Designers operate also the function decomposition processing system and the three dimensional solid modeler.

The designers' intention is generated by the designers' input to select the function in the decomposed function network, to describe the reasons, ideas, and activities, and is terminated by the designation of geometric shapes with technological information which satisfy the selected function. Geometric shapes consist of planar, cylindrical and conic faces, and straight and circular edges appeared in the geometric models of designed objects that are generated in the geometric modeler.

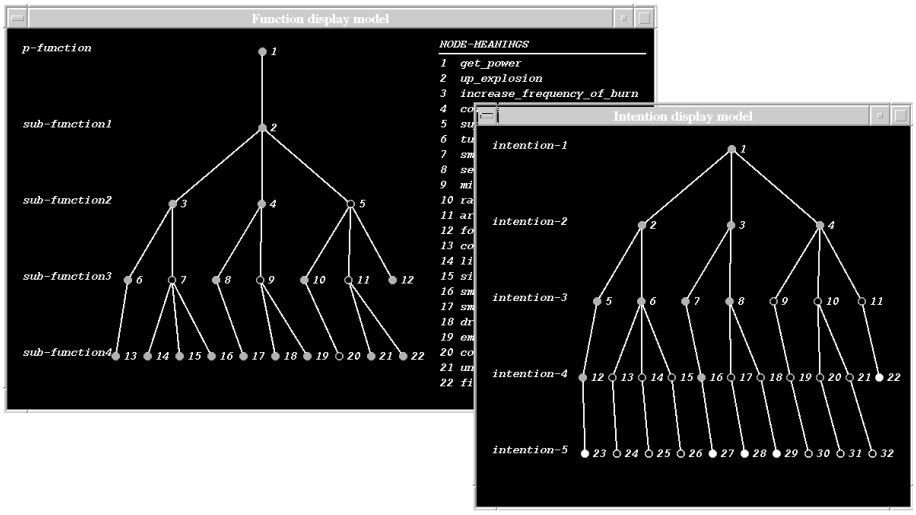

Fig. 2 Decomposed function network and chains of ideas, activities etc.

There are two different ways to designate geometric shapes, those are direct and connotational ways. The direct way designates the shapes by the face and edge numbers of the geometric models. It has the problem that the numbers may change during the design process when the models are modified.

The developed system adopts the connotational way which uses the geometric conditions, and maintains the shape designation correctly in case of shape modifications. Figure 4 shows that the guiding function is realized by the shapes designated by a set of some geometric conditions. When designers designate the shapes by a set of geometric conditions, the set is sent to the geometric modeler to require the face and edge numbers as a return from the modeler, which are connected to the designers' intention. Generated designers' intention is gathered to construct a network which is combined with the geometric models of designed object.

When revising the product design, it is possible to make judgement on whether the designers' intention is satisfied and maintained with those changes. Figure 5 shows an example of flow description how to generate designers' intention.

First, the designer selects a required function "move a part along a direction". Second, it is decomposed into two, those are "support" and "limit" functions. Then the designer generates the geometric models in his/her head. Two decomposed functions are realized by some geometric shapes of the models respectively, those are designated by two sets of geometric conditions.

The designer also selects another "beautifully looking" function which leads to introduce the symmetrical shape of the product. Dimensions are added to the geometric models to fulfill the symmetry.

An example of expressions is shown in Fig.6 used for describing geometric conditions which appear in the designers' intention to designate geometric shapes that satisfy the "support" and "limit" functions.

It is a hard work, however, to describe the designers' intention especially in the form of geometric conditions like shown in Fig.6. Most designers agree that the natural language is more effective to describe the functions and the reasons. Hand-written sketches are also used to describe geometric models of design objects in earlier design stage. These descriptions are available in the developed system by using multi-media database each of which is connected

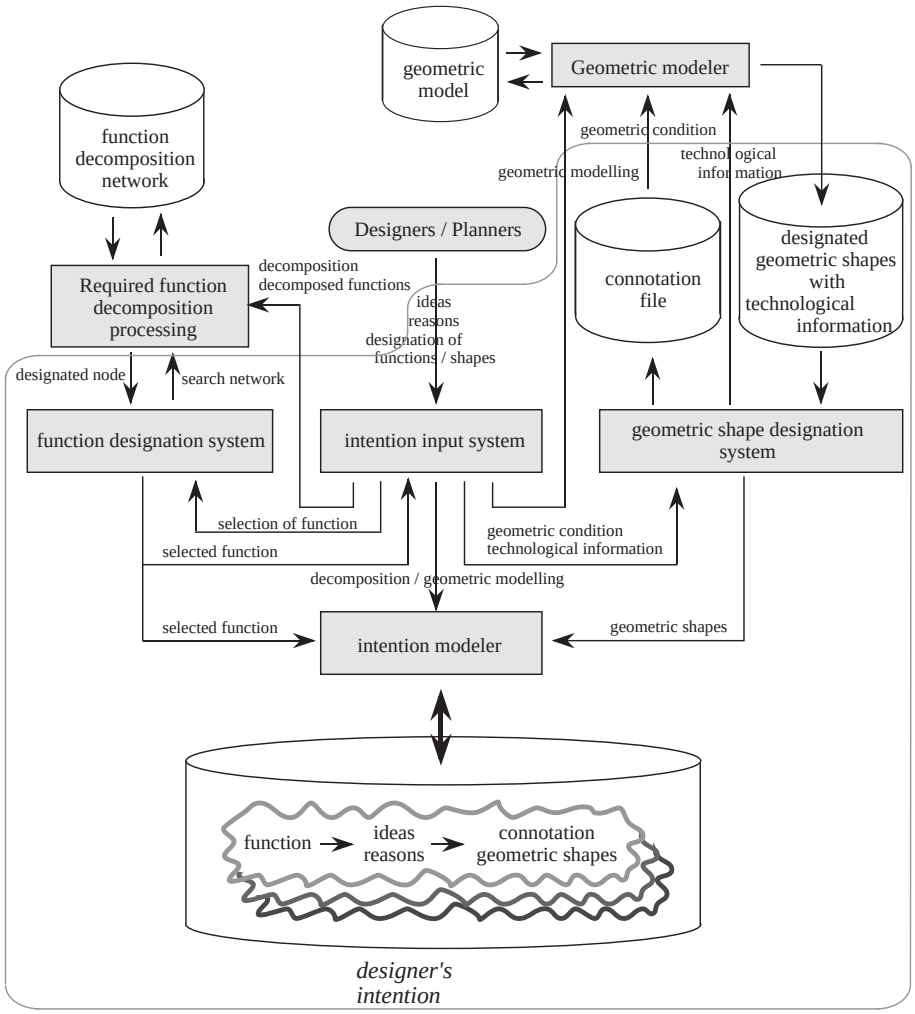

Fig. 3 Designers' intention modelling system

with nodes in the chains of designers' intention.

Some functional descriptions by natural language are analyzed to exact the key words and their sequences which are also used together with geometric conditions in order to make triggers to start communications among designers by the communication network system mentioned in the next section. CAD system used in cooperative design should also include communication network system to transfer design information among designers.

Communication Network System

Communication network system transfers design information among designers. They communicate with others before and during making decisions. There are several communication control method. The broadcasting is the simplest but inefficient way, and designers have to evaluate and select the information which needs time and pains. Conversation model based communication had proposed to improve the broadcasting shortage. Information senders are required to designate the receivers before starting communication in this case to increase efficiency that require designers making efforts.

They have to communicate also after making decisions for they may affect on others' design process, however, it is difficult to find whom they should communicate with. The above methods are not effective to reduce the difficulty. The communication network system using the active database is introduced in the developed CAD system. Active database is

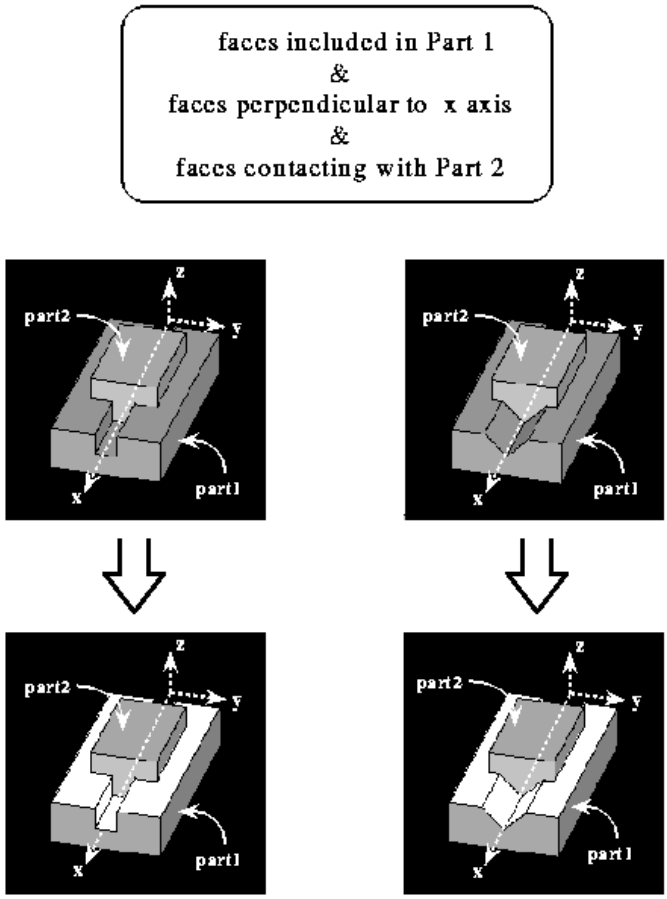

Fig. 4 Face designation by connotational way to specify the guide faces

used here as a combination of database system and communication control system. It can reduce the designers' effort by realizing the following two functions.

(1) To support designers to designate the communication partners before and during decision making

(2) To start the communication automatically with necessary persons after decision making

These two are realized by preparing the conditions in the database which each designer declares for receiving design information from others. Designers describe their intentions as chains of nodes according to the design progress. Functions and connotations among design information described in nodes are send and stored as follows for trigger condition of each designer to start communication by the active database.

Functions handled by a designer is send through function decomposition process management system to the outside language analysis system to compare with pre-defined function names, and classified into three. Those are, simple function, set of a function and its decomposition, and set of functions with their periodical relations. These are registered as the trigger condition, and the communication network system is raised when other designers' handling functions match with them. Three classes indicate the priority of the communication. A designer may describe the geometric conditions in the chain of intention to designate the geometric elements which realize the required functions. Geometric shape designation

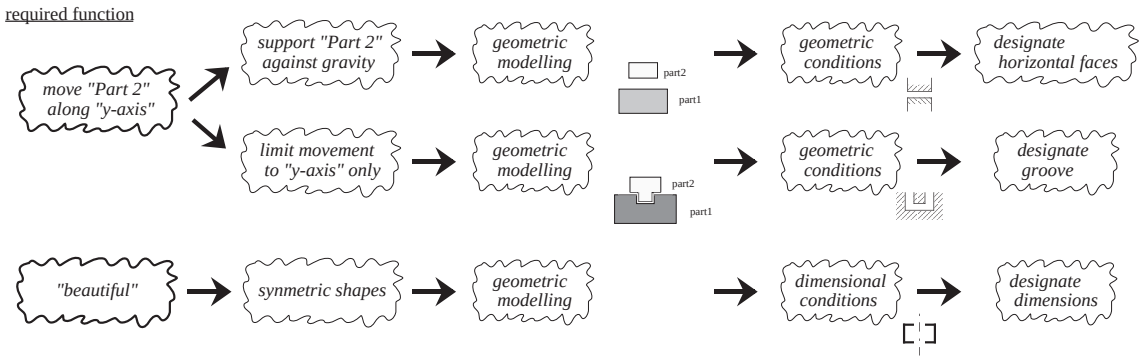

Fig. 5 Generation flow of designers' intention

system sends the geometric conditions in the connotation file and the designated geometric elements to the active database where they are also stored for the trigger conditions of each designer. Designated geometric elements are evaluated and renewed by the geometric modeler by using the connotation file whenever the geometric models of designed objects are modified.

When other designers handle the geometric elements which is designated by a designer, the active database generates the trigger to the communication network system. If the geometric conditions given by the designer become unsatisfied by other's geometric handling, the active database gives the first priority to notify the designer through the communication network. Figure 7 shows the architecture of the communication network system using the active database, which is integrated with cooperative CAD system. Input of each designer is send to CAD system as well as active database where it is compared with three kinds of conditions prepared for individual designer. When they match, the active database generates the trigger to notify the designer that some other designers have interests in the same functions, handle the same geometric elements which he/she handled, or finally with the geometric condition that he/she gave unsatisfied. The designer is able to ignore this notification. When the designer asks to get more detailed information, the system delivers corresponding designers' IDs and their designers' intention to the requester which must be helpful to start communication to understand with each other.

Whenever each designer makes decisions to handle functions or geometric elements of designed objects, the communication network system looks for designers who may be affected on by the decisions automatically with use of the active database system, and help him/her to start communication. Designers may use the system actively also to look for the communication partners, for instance, to ask questions by searching the condition database in the active database. The condition database is always renewed by the additional data from the designers' intention modelling system where the functions, geometric conditions and geometric elements are arranged from the generated each designer's intentions according to the design progress.

Case Study

A case study is introduced here using an example shown in Fig.6. Three designers cooperate to make this geometric model ; designer A is in charge of supporting function, designer B takes charge of limit movement function, and designer C decides the appearance from the viewpoint of industrial design. Figure 8 shows the design solution which is connected with three designers' intentions each of them includes the geometric conditions shown in Fig.6. Geometric conditions to realize the support function is registered as the trigger condition for

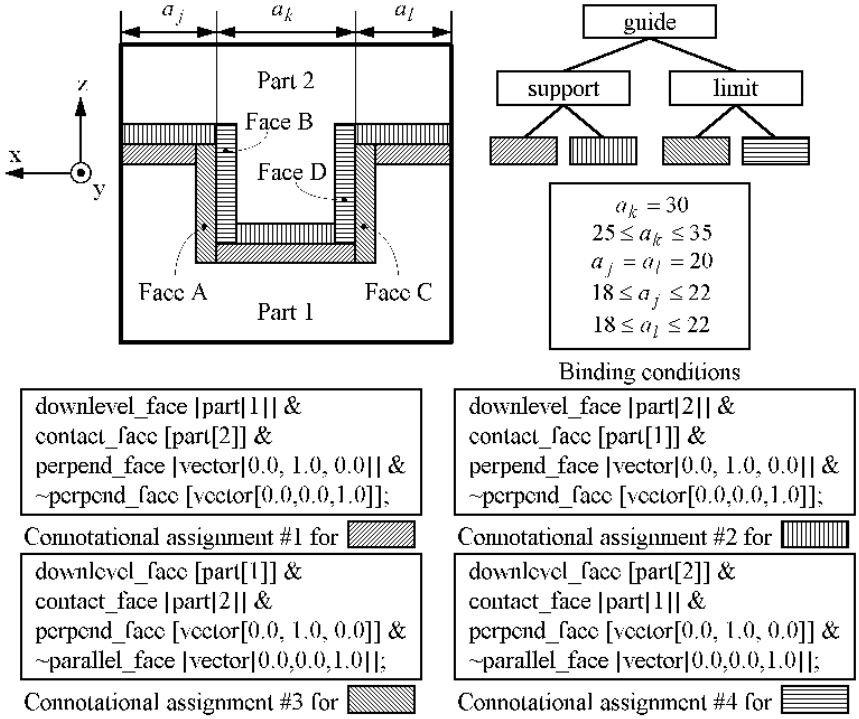

Fig. 6 Example of designers' intention expression

designer A, to realize the limit movement function for designer B, and dimensional equations for designer C.

When another designer D modifies the shape as shown in Fig.9(b), the active database detects that geometric conditions for designer B and C are not satisfied, and generates triggers to notify to them. Receiving it, when designer B enlarges the width of the upper part to satisfy his/her geometric condition like Fig.9(c), the geometric condition of designer C is still unsatisfied. Then, designer C re-modifies the shape to satisfy own geometric condition like Fig.9(d), which leads the geometric condition of designer B unsatisfied again. The communication network system notify again to designer B. Modification is continued until the active database has no need to generate triggers.

Conclusions

Communication among designers and planners is to be emphasized in concurrent design. Especially designers' ways of thinking should be modelled because of the importance and usefulness for designers to understand with each other and make decisions.

Designers' intention is defined in this paper as a chain of reasons/ideas, activities such as geometric modelling and functional decomposition, geometric models and functions which are the output by the activities. The chain starts from a selected required function and terminates at specified geometric shapes with technological information which satisfy the required function.

Designers' intention modelling system is proposed combined with three dimensional solid modeler. Another essential subsystem is the communication network system among designers. Active database is introduced into the communication system in order to help the designers looking for partners to communicate with.

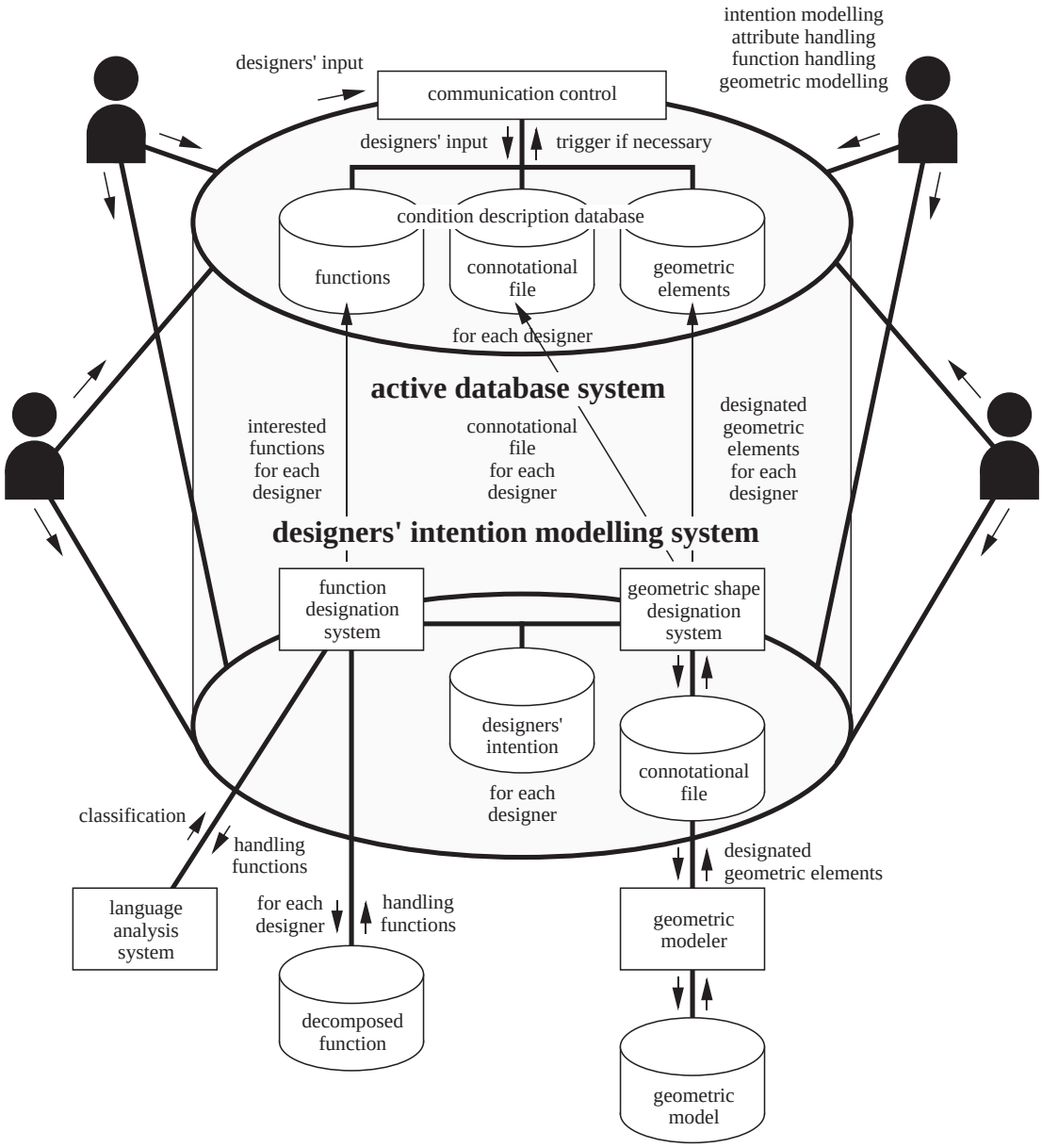

Fig. 7 Communication network system architecture

Effectiveness of designers' intention which is transferred through communication network system based on active database is made clear through a case study in modification design. Feasible architecture of new CAD system can be proposed that handle the design knowledge described in the designers' intention.

Acknowledgement

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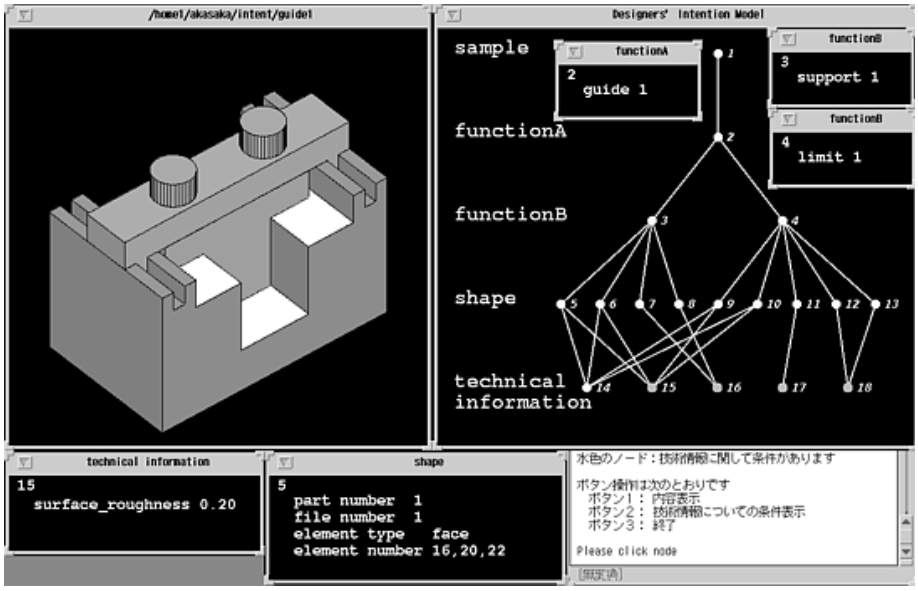

Fig. 8 Display of "designers' intention" model in CAD system

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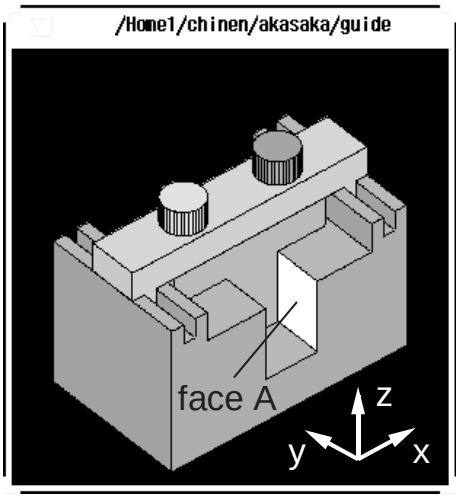
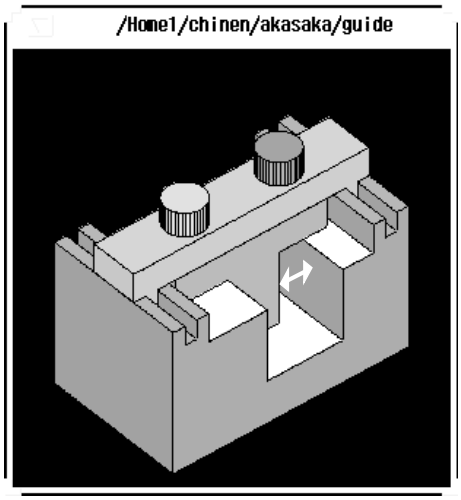
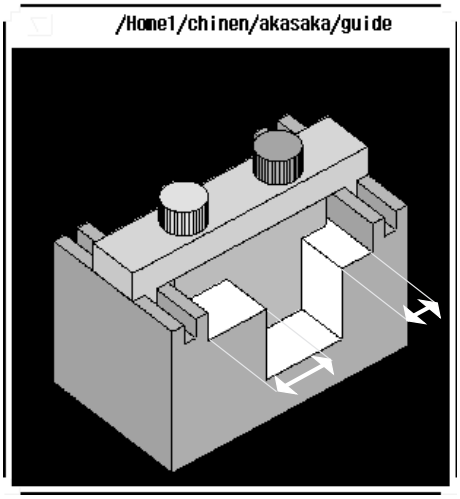


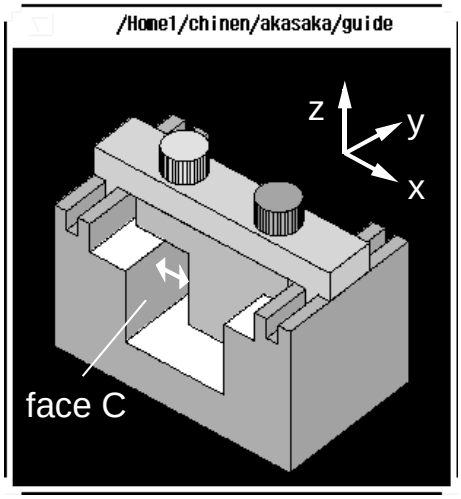
(a) Start modification – move face A along x-axis



(b) Not satisfy the contact – move face B along x-axis



(c) Satisfy the contact but not satisfy the symmetry – move face C along x-axis



(d) Satisfy the symmetry but not satisfy the contact – move face D along x-axis

Fig. 9 Example of modification design to maintain the function with use of intention