

Collaboration Design System Using Internet and Virtual Reality Technology

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Abstract. Globalization of manufacturing industry makes production bases covering two or more areas and countries. Moreover, in order to timely offer products which respond to consumer needs, it has been becoming important to shorten the lead time of product development. Opportunities to do collaboration work with designers/engineers existing different places are thus increasing. A support system for collaboration design work without physical moving of designers/engineers is strongly demanded to cut down time and cost. This research aims at proposing the intuitive 3-dimensional geometric model construction method and developing a system which supports collaboration design work for the discussion stage of ideas in the upstream of design processes. In this paper, a system which can intuitively build a 3D model and support collaboration design work for designers/engineers being different places by sharing mutually a design object through the Internet is described.

Keywords: Design Collaboration, Internet, Virtual Reality, 3D Modeling, Industry Product Design, Basic Design, CAD.

1 Introduction

Bases for design and development of industrial products are spreading to multiple areas and countries with globalization of manufacturing industry. Under such situation, opportunities to do collaboration work on design and development with remote places are increasing to create a new idea which cannot be hit by only one designer/engineer. This has been become one of the causes to increase time and cost in product development. On the other hand, in order to timely offer products which respond to consumer needs, it has been an important subject to shorten the lead time of product development and to decrease the cost for international competition. In order solve the problems, a technology to realize remote collaboration work on design and development of industrial products without physical moving of designers and engineers is demanded to create a new idea by stimulating each other and to decrease time and cost for the development.

As support systems for collaboration work on design and development of industrial products, systems [1], [2], [8] to collaboratively make and evaluate a product shape

by communication between different places had been proposed. The target of these systems is for the downstream of design processes, in other word, for the detail design process. In these days, it is extremely hard to shorten the time from detail design to production because the streamline of the processes from detail design to production is becoming to the breaking point. Therefore, in order to decrease the lead time of product development, the upstream of design processes must be made higher efficiency [3]. For the upstream of design processes, the function to intuitively create and modify a shape is necessary [9], [10] than the function to strictly define a shape. Sometimes, the function to strictly define a shape disturbs creation of ideas due to its complicated operations required. A support system for the upstream of design processes requires the function to collaborate on discussion.

The objective of this research is to develop a system which enables designers and engineers to execute cooperative work between different places by applying virtual reality technology and communication technology with the Internet. The system supplies a virtual common space as an environment of discussion for designers and engineers being in different places. Since the system has a function to easily construct a three dimensional model by simple and intuitive operations, the intuitive modeling function and the discussion environment can support to create an idea in the upstream of design processes.

2 Outline of Proposed System

In order to realize a function to easily and intuitively construct a three dimensional model, a haptic device is utilized to develop the objective system. Fig. 1 shows the configuration of the proposed system. A haptic device: PHANToM Omni by Sensable Technologies inc., with a touching stylus is used as an operating equipment. It enables designers/engineers to intuitive operation for constructing a 3D model as if they are creating a model with touching. The device is a kind of force feedback display with 6-degree-of-freedom and has the range of 160*120*170 mm for detecting and has the

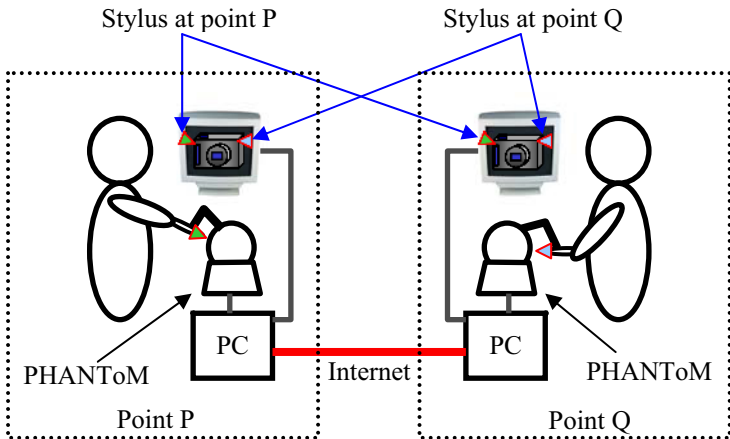


Fig. 1. Configuration of system

feedback force of 3.3 N in the maximum. Designers/engineers indicate the three dimensional position by the stylus of a haptic device, and the returned force from a three dimensional model is also given as touching feeling by the stylus [4]. A common space to discuss design is constructed and supplied for designers/engineers being in distributed places by such systems linked with the Internet.

A 3D model constructed at the point P by simple and intuitive operations using haptic devices is located in the common space and is simultaneously displayed on the both screens at the points P and Q. The 3D model constructed at the point P is also touched and remodeled at the point Q by using the devices. Therefore, a 3D model in the common space can be simultaneously operated by designers/engineers being in distributed points. The system then realizes cooperative and confrontational work by processes of constructing a 3D model and holding conversation each other from different places.

3 Method to Construct 3D Model

A currently used 3D CAD system constructs a model by set operations of fundamental forms so called primitives such as a cuboid, a cylinder, a sphere, etc. The primitives are defined by complex operations which are the indications of the type, the position, the direction and the form parameters. And the operations are executed on a display, in other words, a 2D space. The operations in a 2D space are not intuitive for 3D model construction. Such operations are convenient for detail design but they are not suitable for the early stage of design. For the problem, there have been research works to construct a 3D model by simple and intuitive operations. VLEGO [5] can intuitively build a 3D model by combining several primitives in a virtual space, but it is difficult to intuitively define each primitive. BlueGrotto [6] can input figure recognition by handwriting in a virtual space, and builds a 3D model more nearly intuitively. But, since BlueGrotto does not have feedback of the tactile sense in the construction process of a 3D model, it is difficult to intuitively specify the position and direction in the virtual space.

As mentioned above, the system proposed in this research enables designers/engineers to construct a 3D model in a virtual space by simple and intuitive operations using a haptic device which can sensuously indicate the position and direction of primitives composing a 3D model in a 3D space. A basic system was developed to verify effectiveness of the proposed method. The system has the following functions;

- Construction of primitive shapes, that is, a cuboid and a cylinder,
- Construction of a 3D model by combining primitive shapes, and
- Shape modifications, that is, delete, enlargement/reduction, copy, movement, turn, and chamfering.

Fig. 2 shows a cuboid primitive and a cylinder primitive constructed by the developed system. A cuboid primitive is defined by the line AB which represents the diagonal line of a cuboid to be constructed and is given by a drag and drop operation of the stylus of a haptic device in a 3D space. A cylinder is also defined by same operation.

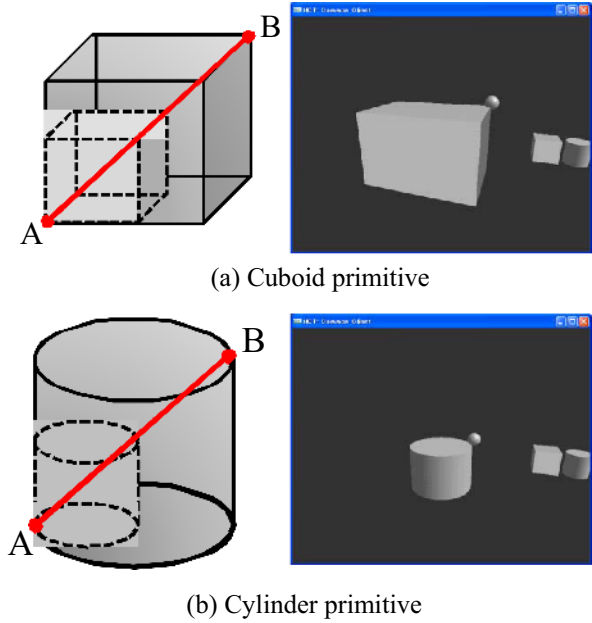


Fig. 2. Construction of primitives

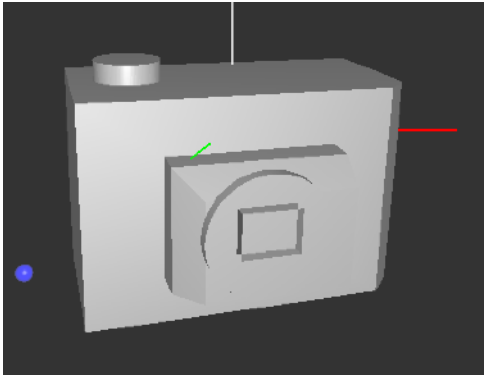


Fig. 3. An example: a constructed model

The position and direction for a primitive addition and a form modification are easily and intuitively specified according to the tactile sense given by the stylus of a haptic device.

Fig. 3 shows an example of 3D models constructed by the developed system. As shown in Fig. 3, a primitive has relationship with several primitives; in other words, a primitive is defined on another primitive. The relationship between primitives is defined as an object-oriented database by a hierarchical structure with a parent-child.

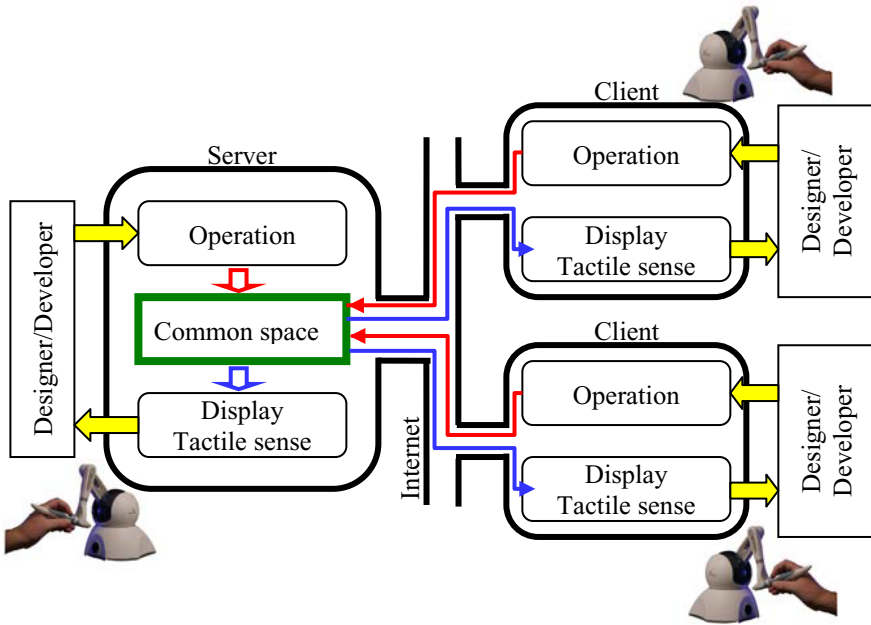


Fig. 4. Construction of common space

4 Construction Method of 3D Virtual Common Space

A 3D virtual common space is constructed by a Haptic Communication Toolkit [7] which is a kind of network library to communicate tactile sense information between haptic devices. In order to realize the frame rate of 1 kHz which is necessary for comfortable feeling in touching, the Haptic Communication Toolkit has restriction that transmitting and receiving data must be less than 256 bytes. As shown in Fig. 4, a 3D virtual common space is built in the server by making transmitting and receiving data limited in 256 bytes. The common space in which designers/engineers exist at the same time is realized by holding the information of the virtual space in common at the server and clients. The transmitting and receiving between the server and a client is executed in following processes.

As shown in Fig. 4, primitive information input by a designer/engineer on the site of a client is fed into the server and the unique ID is given to the primitive. The primitive with the unique ID is instantly constructed in the common space which is located in the server, and is identified and shared by the server and clients in real time. Primitive information input on the site of the server also constructs the primitive form in the common space by giving the unique ID, and the primitive is simultaneously identified by the server and clients. The model constructed in the common space by combining the primitives defined from the server site and client sites is shown on the displays of the server and clients and the tactile senses by haptic devices are returned to designers/engineers being in the sites of the server and clients, respectively.

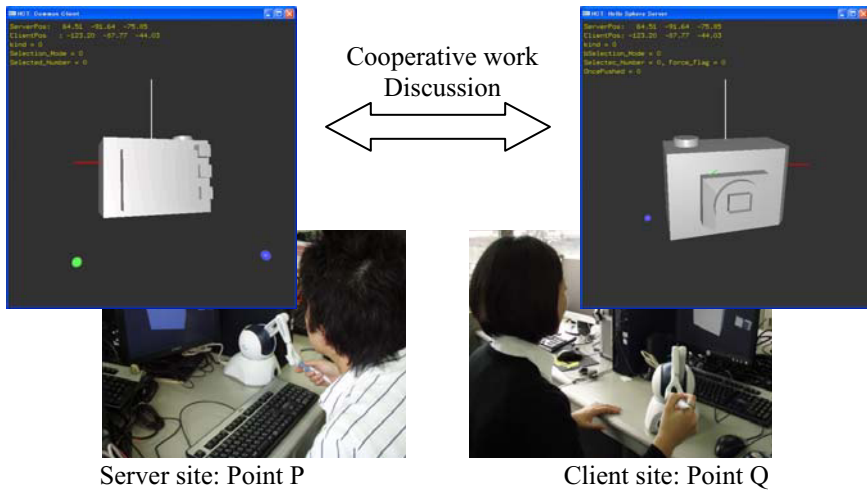


Fig. 5. Cooperative design work between remote places

In the communication between the server and clients, 5 streams are prepared for the following data flow:

1. the coordinate values x , y , z of the stylus tip of a haptic device,
2. the direction vector of the stylus of a haptic device,
3. primitive information: the type, defining parameters, and parent-child relationship,
4. operation information: operation type and operating parameters, and
5. model information from the server to the clients.

As the results, designers/engineers can corporate design work with the 3D model constructed in the common space. The system can be applied for plural clients by constructing the server-clients structure. Fig. 5 shows the corporate work using the system. As shown in Fig. 5, designers/engineers are able to discuss design by constructing and modifying the design shape intuitively from different places as if they are staying in a same place.

5 Evaluation of Developed System

The aim of this research is to offer a system which enables designers/engineers existing different places to make cooperative work and discussion on product design by having a 3D virtual space in common. There have not been any ideas and methods to quantitatively evaluate the degree and depth of cooperative work and discussion. Therefore, in this research, the functionality for cooperative work and discussion is quantitatively judged by comparing the times to execute tasks by the developed system and a commercially available CAD system. A system having a shorter execution time of a task is evaluated as possessing high functionality for cooperative work and discussion than a system having a longer execution time of a task.

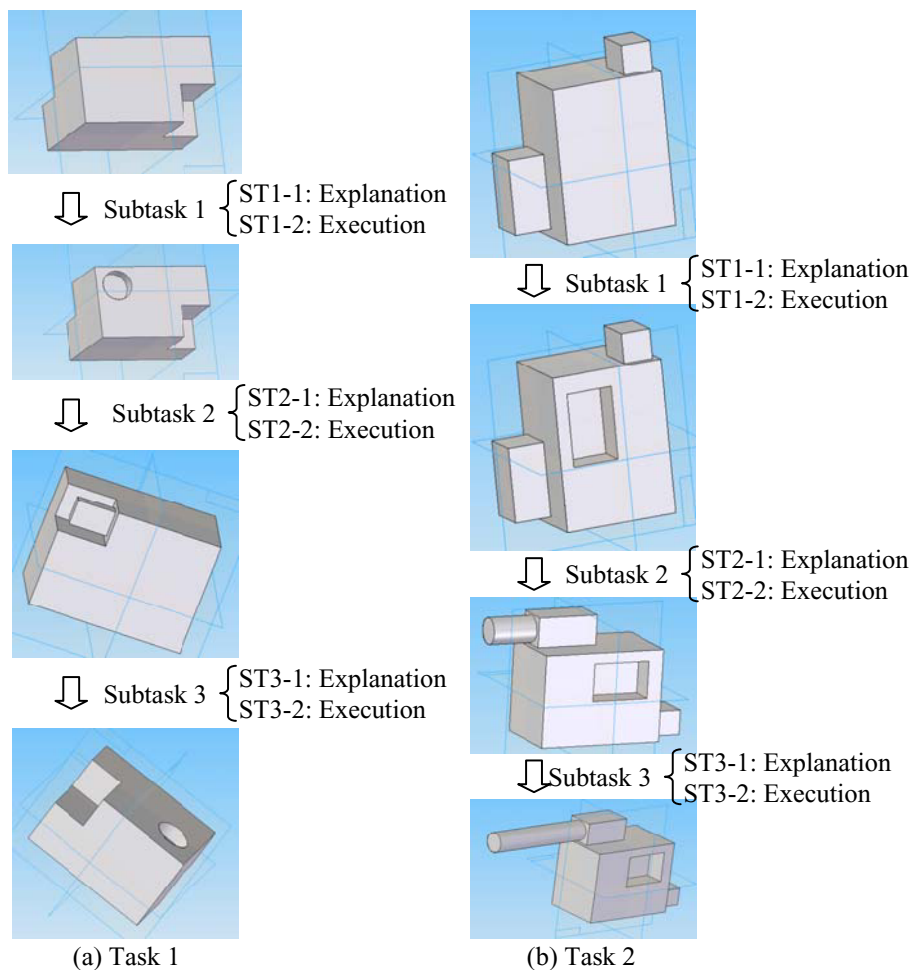


Fig. 6. Evaluation tests

The two tasks shown in Fig. 6: Task 1 and Task 2, were executed by 10 unaccustomed persons with from 22 to 24 years old. To execute the tasks, 5 persons of the 10 persons used the developed system and other 5 persons tried to use a commercially available CAD system: Solid Edge Ver19. As shown in Fig. 6, each task had three subtasks, and each subtask was executed in the two steps: the task explanation step and the task execution step. In the task explanation step, the specified person had the role to explain the subtask. The explanation for using the developed system was performed from the server site to a client site through the Internet. And the explanation for using the commercially available CAD system was carried out by only talking.

Table 1 and Table 2 show the results of the times to execute each subtask by the developed system and a commercial CAD system. As shown in Tables 1 and 2, the times to understand the explanation of the subtasks by using the developed system

Table 1. Results of Task 1

Task 1		Developed system	Commercial CAD
		Time [s]	Time [s]
Explanation	Subtask1-1	16.7	53.3
	Subtask2-1	26.8	88.3
	Subtask3-1	27.3	57.5
	Sub-Total	70.8	199.1
Execution	Subtask1-2	25.0	65.6
	Subtask2-2	18.0	57.8
	Subtask3-2	33.3	57.5
	Sub-Total	76.3	180.9
Total		147.1	380.0

Table 2. Results of Task 2

Task 1		Developed system	Commercial CAD
		Time [s]	Time [s]
Explanation	Subtask1-1	16.7	53.3
	Subtask2-1	26.8	88.3
	Subtask3-1	27.3	57.5
	Sub-Total	70.8	199.1
Execution	Subtask1-2	25.0	65.6
	Subtask2-2	18.0	57.8
	Subtask3-2	33.3	57.5
	Sub-Total	76.3	180.9
Total		147.1	380.0

were from 30 to 40 % for the times in the case of using of a commercial CAD system. And the times to execute the subtasks by using the developed system were also from 30 to 40 % for the times in the case of using of the commercial CAD system. Therefore, it is understandable that the developed system has the effectiveness for understanding the will of a person existing in a remote place. It can be interpreted that the developed system is useful for cooperative work and discussion of designers/engineers being in different places. And the system is also useful for discussion to evaluate product design.

6 Conclusions

In this research, a method which enables designers and engineers existing in different places to execute cooperative work and discussion is proposed in order to hit new and unique idea. The method was realized by applying virtual reality technology and

communication technology with the Internet. Virtual reality technology made simple operation to construct a 3D model and intuitive communication between designers and engineers being in different places. And the Internet constructed the virtual common space which realized a communication place without physical moving of designers and engineers. A basic system based on the proposed method was developed and the usefulness of the system was confirmed by simple experiment. According to the experiment results, understanding of will in the case of using of the developed system was improved from 30 to 40 % in comparison with non-using of it.

In this study, it was inspected by a basic system that a system to execute discussion using the Internet between designers/ engineers existing different places was useful for cooperative design work of products. The development of practical systems will support to cooperate on design work between remote places without physical movement and to create novel ideas from discussion.

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