Development and Trial of a Teleconstruction System

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Abstract

This paper will introduce a multi-designer and multi-construction-machine system which has a realizeability capacity. It also provides a cooperative creation environment from design activity to prototype construction, which is indispensable for product development and the predictive simulation of complex construction projects.
The requirements, the necessary functions and the implementation of a "cooperative tele-designing and tele-construction system" which is distributed on a computer network will be presented. The necessary technologies which have been implemented for a cooperative tele- designing and tele-construction system using the Internet are as follows: (1) visual information display, such as predictive display of geometrical information to compensate for time delay and real-time construction assembly display using multi-axis force information, (2) predictive auditory information presentation using a physical model of block assembly and an information transformation technique, (3) predictive force information presentation, (4) tactile presentation of the state joining as high frequency vibration, and so on. The software system was implemented as a multi-construction -machine system. Necessary agents and their functions are discussed based on the system, as implemented and tested. In the paper, several experimental results including Germany-Japan tele-designing and assembling experiments and the future problems to be solved to realize the widespread usage of multi-operator and multi-designing-and construction -machine systems are discussed.

1: Introduction

With the development of communications technologies such as computer networks and artificial satellites, it becomes possible to operate remote construction machines, prefabrication factories and sites. Researches concerning information presentation technology including virtual reality have been performed by many researchers. However, at the global level we have to take countermeasures, for example, for an accident of an atomic power plant, natural disaster, toxic waste cleanup.

Furthermore, technology transfer for developing countries at the global-level and location-independent information creation by reducing the differences between areas is indispensable. A creative activity support system using multimodal virtual experience is also crucial. The networked, distributed cooperative construction system described in this paper may provide an opportunity for rapid prototyping.

The University of Tokyo group has already developed a tele-machining and tele-handling system, which enables human operator to machine and hale an object in a "different world" such as remote environment or microscale world with reality sensation. The system, as implemented, enable for one human operator to machine and handle an object on one machine. Due to the tendency towards global construction, the need has become apparent for system to enable distributed operators in which designers, expert engineers, and others can cooperate with eachother.

This system requires the implementation of the software system as a multi-agent system. The developed system enables the following activities:
Designers and expert engineers who are located remotely can solve problems and evaluate the functionality of the designed system by actual prototyping or building.
For trouble shooting, teleservice, technology transfer or remote teaching, a specialist can instruct how to operate a construction machine with reality sensation
to teleservice or troubleshoot a broken down construction equipment
to redesign and prototype a detail of a building or assembly sequence of a construction site
independent of the location of instructors, novices and equipment.

2: Basic concept for software design

To implement a building production system which can be operated by multiple operators, it is convenient if the operation information, such as endeffector position and construction state, is presented to the other operators. A lot of processes in the system which contribute to realize the cooperative teleconstruction system have to communicate with each other. For example, visual, auditory, force and tactile information prediction and presentation processes and joystick control process in each operation room (Construction company, design office) have to communicate with other processes in the other operation room (Construction equipment maker) and building parts factory or construction site. Using conventional communication between processes, communication is carried out one-on-one. Therefore, one connection between processes has to be established for each communication. The number of connections between processes increases enormously as number of processes increases to realize a multi-operator system. This may cause (i) inconsistency of control information, (ii) duplicate information transmission through a communication link for all communication between processes, and (iii) reduction of programmability because of complexity. To overcome these problems, the idea of server and multi-agent software implementation are introduced in the system.

3: Software implementation in a multi-agent system

In the system the operation rooms and factories or construction sites are considered as autonomous "site level agents." The total system is considered as "hierarchical multi-agent" where the top level gent is called "server agent" which controls the all information flow. Furthermore, processes working at each site are considered as "process level agents." Each agent communicates with other agents only through the "transmission information management agents" which are installed in each operation room and factory or construction site. The effect of multi-agent software implementation is as follows:
Transmitted information is encapsuled and it is possible to send it without interpreting the data.
Mutual exclusion of control information to the same construction tool can be easily realized.
Programming becomes easy because each process at a site communicates only with the "transmission information management agent."
Autonomy and independence of each site are enhanced because the internal structure of each site is screened.

Agents which control a distributed and cooperative teleconstruction system can be categorized into the following levels:
Operational information input and presentation level --- The agents in this level acquire the operational information from an operator and present it to the other operators. The agents in this level are input control information management agent, operational environment information presentation agent, joining force prediction agent, joining state prediction agent, and so on.
Operational environment management level --- The agents in this level manage the control information of the machine tool and the mutual exclusion can be realized. They are control information management agent, control priority management agent, intention determination management agent, and so on. Control, supervise and judge level --- The agents in this level control the construction equipment endeffector and monitor the construction machine conditions. They are operability checking agent, machine tool control agent, multi-axis force information acquisition agent, construction machine state judging agent, and so on.

4: Visual information presentation and predictive display of geometrical information

Communication delay reduces the operability of bilateral systems because it destabilizes them. To overcome this problem, prediction of geometrical information has been realized for a master-slave manipulation system. In the teleconstruction system, visual information is, of course, important as well as auditory and tactile information for a human operator. Therefore, in the proposed system, visual information was predictively displayed for time delay compensation. In the teleconstruction system, because the shape of the building changes dynamically during construction, the geometrical model must be revised in real-time.

5: Multi-axis force information to visual information transformation method

Any experienced mason knows how to build a wall by feeling , hearing and seeing. As soon as you build a high rise building it becomes more difficult for the crane operator and other construction workers to sense the actual state of joining resulting in guessing the construction quality. By assembling building parts at remote or inaccessible locations it becomes necessary to transform some force information into visual information.

Summary:

This teleconstruction system can reduce the cycle between design prototype manufacturing, which is indispensable for product development and the fail safe building construction. There are many studies concerning "CSCW"(computer supported cooperative work) on computer networks which support cooperative work of multiple operators who are remotely located from eachother. However, almost all applications are concerned with supporting documentation writing in a desktop environment or communication support systems, such as video conferencing. Few studies are concerned with handling "real building components". This is important for idea exchange among engineers because transmitting ideas only through 3D graphical images is proving to be insufficient for many purposes.

The actual experiment has been sponsored by KDD, Hitachi and executed simultaneously at the University of Tokyo under the guidance of Professor Dr.Eng. Mitsuishi(inc.assistants Dr. Horii, Okabe, Teratani, Miyazu)
and at the University of Karlsruhe in 1995.

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