A STUDY OF INFORMATION INTEGRATED CONSTRUCTION

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Abstract: In order to control execution based on data from construction machinery, and thus computerize and rationalize project execution, information integrated construction systems are being developed[1]. Meanwhile, to perform tele-operation of construction machinery, telecommunication systems and mobile network systems for construction are being developed. However, these systems being developed for civil engineering are not compatible; standards are required to promote the use of information integrated construction systems and to achieve more efficient work throughout the life cycle. We hope that the development and promotion of information integrated construction systems will be continued through international cooperation by a new working group formed at the ISO, etc. The authors propose a universal transformer for remote systems as an actual universal platform for information integrated construction systems.

Keywords: tele-operation, unmanned construction works execution, universal transformer

1. INTRODUCTION

Japan has many chains of steep mountains and fast-flowing rivers, and is well known for its frequent seismic and volcanic activities. Its geological features are more fragile than those of other countries, and faults and fractured zones are widely distributed throughout the country. Further, Japan has a large rainfall, much of which is concentrated in the rainy season and typhoon season. Rapid urbanization has led to the development of residential land in foothills and on mountainsides. As a result of the combination of these natural conditions and social trends, natural disasters such as debris flow, landslides and land slips cause many fatalities and damage to valuable property. In fiscal 2001, there were as many as 608 geotechnically induced disasters.[2]

Especially in a volcanic disaster, debris flows run down the slopes of the volcano as sediment from volcanic activity starts sliding down, following heavy rainfall. In anticipation of the recurrence of debris flows, it is necessary to remove the rocks urgently and to maintain river channels and sediment storage to prevent expansion of the disaster area. However, rock removing operations during volcanic activity are still too dangerous to be performed due to the risk of a secondary disaster caused by a pyroclastic flow, for example. A technology for performing the work by tele-operation from a safe place needs to be developed.

2. UNMANNED CONSTRUCTION WORK EXECUTION IN JAPAN

The first example of civil engineering works by unmanned machinery in Japan was that done by an amphibian bulldozer in the aftermath of a disaster in 1969. In this case, the works were carried out by both manned and unmanned machinery, and the execution of work was controlled by visual observation. Further, in the case of caisson laying works by unmanned machinery, the machines were tele-operated while watching the images displayed on a screen. These tele-operations were quite simple compared to the operations done by unmanned machinery in Japan today, and so their use did not become widespread.

The technology of civil engineering works by unmanned machinery was shown to be practical during the reconstruction works at Fugendake of Mt. Unzen. These reconstruction works were performed by unmanned machinery manipulated from outside and laying started in March 1994. The unmanned operations started with a bulldozer excavating the ground and collecting the soil, a backhoe loading the soil to a dump truck, and the dump truck moving to a safe place. Wireless tele-operation was performed from a tele-operation room aided by images sent from a tele-operated camera fixed at a high place, tele-operated cameras mounted on the unmanned vehicle, and so forth. The basic composition of unmanned machinery employed here is shown in Fig. 1.[3]

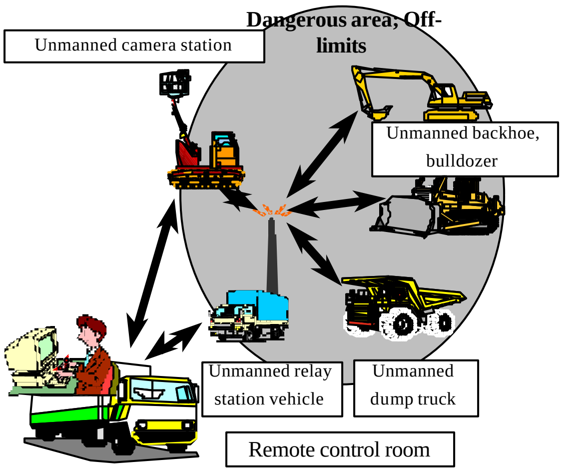

Fig. 1 Tele-operation System for Unmanned Construction Works

Following substantial practice in restoration works at various disaster-stricken areas of Fugendake of Mt. Unzen, the number of cases of construction works performed by unmanned machinery has increased remarkably.

3. STANDARDIZATION OF TELE-OPERATION [4]

In tandem with the diffusion of construction works by unmanned machinery, however, different operating systems have been developed by respective machine manufacturers on their proprietary architectures, causing a problem of lack of compatibility.

Figure 2 shows a case where manufacturers A, B and C are using a tele-operated device of their own specifications. As the basic functions, the devices wirelessly send instructions to the receiver on the actions that the operator should perform on the machine. The receiver passes the signals electrically to the controller, which in turn controls the solenoid valves through an electric interface.

However, even if the basic system is the same, the following differences still exist:

1) The communication protocol for transmission from the operating panel to the receiver and data frame are different.
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3) The specifications of the interface from the controller are different, etc.

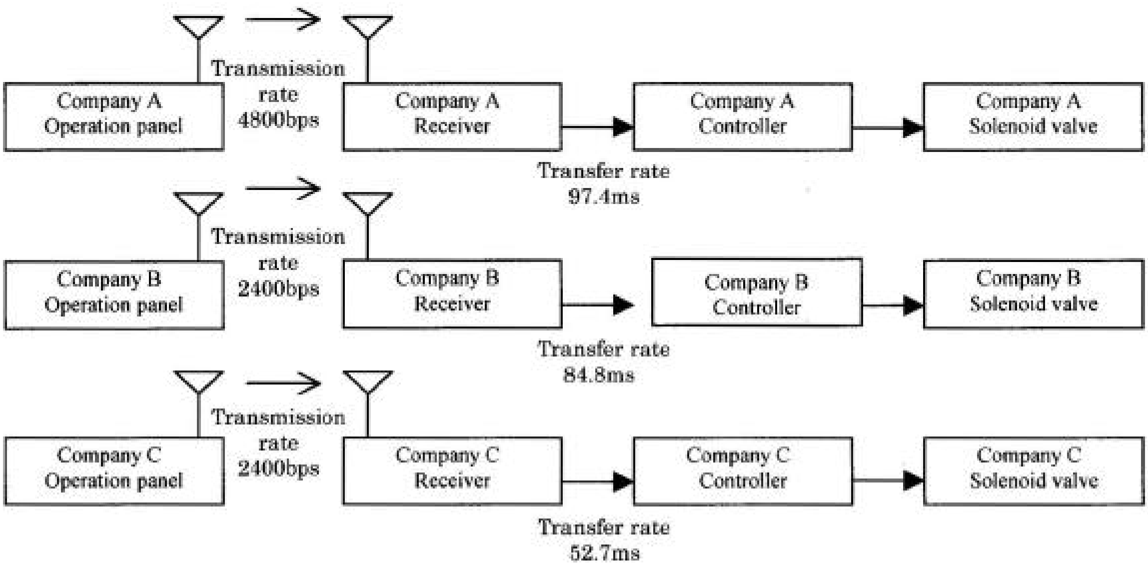

Fig. 2 Control Block Diagram of a Tele-operation System

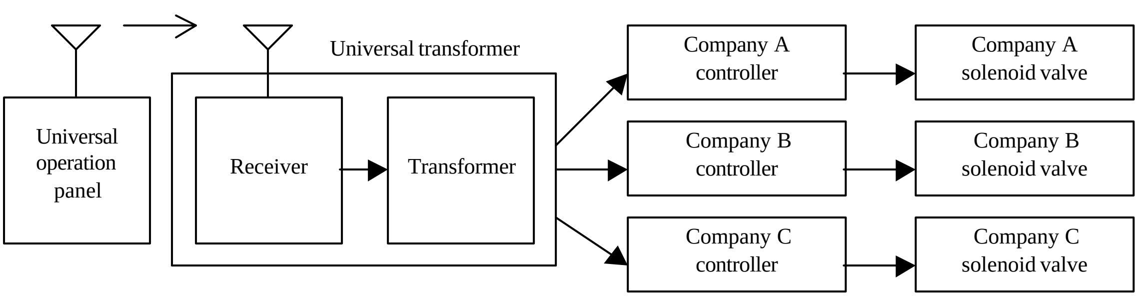

Fig. 3 Control Block Diagram of a Universal Tele-operation System

A solution to this problem is obviously to develop a universal system that can operate the unmanned machinery for construction works of different manufacturers. As Japanese law does not allow the receiver itself to be modified, we developed a universal transformer which acts as a transformer between the receiver and the controller. The system is shown in Fig. 3.

The universal operating panel together with the universal transformer enables us to operate unmanned construction machinery of different manufacturers. We then evaluated the developed universal tele-operation system using a backhoe which is commonly used for unmanned construction works. We tested tele-operation of three backhoes of three manufacturers operated respectively by the three manufacturers' proprietary tele-operation systems and by the universal tele-operation system. We compared the level of response and reliability (occurrence of communication failure), and found that the universal tele-operation system functioned well in actual operations.

4. INFORMATION INTEGRATION FOR UNMANNED CONSTRUCTION WORKS EXECUTION

Initially, the role of unmanned construction works execution was considered satisfactory if preliminary works such as removal of rocks or soil could be performed from a remote place, as data on execution control were not considered crucial. However, as the use of unmanned construction works is becoming popular for buildings having more complex structures as shown in Table 1 below, the need has arisen for control of unmanned construction works execution to enable progress management and quality control.

Table 1 Kinds of Construction Works Performed by Unmanned Machinery

Type of work	Unmanned construction machinery
Rock excavation	Backhoe, bulldozer, hydraulically operated breaker
Earth excavation, removal of earth	Backhoe, bulldozer, amphibian bulldozer, dump truck
Check dam	Backhoe, bulldozer, crawler crane, dump truck, vibration roller
Revetment	Backhoe, bulldozer
Groundsel	Backhoe, concrete pumping vehicle
Vertical wall	Backhoe, concrete pumping vehicle
Pre-cast concrete armor units	Backhoe, crawler dump truck

Cases of control of unmanned construction works execution practiced by various construction companies are as follows:

(1) A system for controlling excavation work completed
A system for controlling excavation amount completed (work quality completed) used for excavating the ground for constructing a dam
(2) A system for controlling spreading
A system for controlling spreading of concrete and soil and sand laid out on the ground for constructing a dam
(3) A system for laying area control
A system for marking the area for banking of soil and sand on the surface of RCC concrete before laying the frames for soil and sand with a tele-operating marking machine using an automatic chasing total station or GPS
(4) A system for compaction control
A system for controlling the status of compaction of soil and sand or concrete used for constructing a dam

The concept of the progress control system is shown in Fig. 4. [5]

Although the basic structure of execution control is almost the same among manufacturers, the architecture such as the data transmission method and software used tends to vary. As an example, the features of compaction control systems are shown in Table 2.

The table on the next page shows that architectures vary from manufacturer to manufacturer, and so no single signal receiver is able to control execution data of a given unmanned machine. As a result, even if a universal tele-operating system were to be developed, various receivers corresponding to the respective machinery of different manufacturers would still be needed for controlling the execution of construction works. In addition, as we take into consideration the need for promotion of information integration for unmanned construction works execution, standardization of execution control systems is crucially important.

In case of operation by unmanned machinery, three-dimensional coordinates for the machinery, posture and volume of control, etc. are required for surveying when constructing a building and controlling operations. In addition, it is efficient to make the information on the location and posture of machinery available to the operator.

We therefore consider that the following data are required for controlling the unmanned construction works execution.

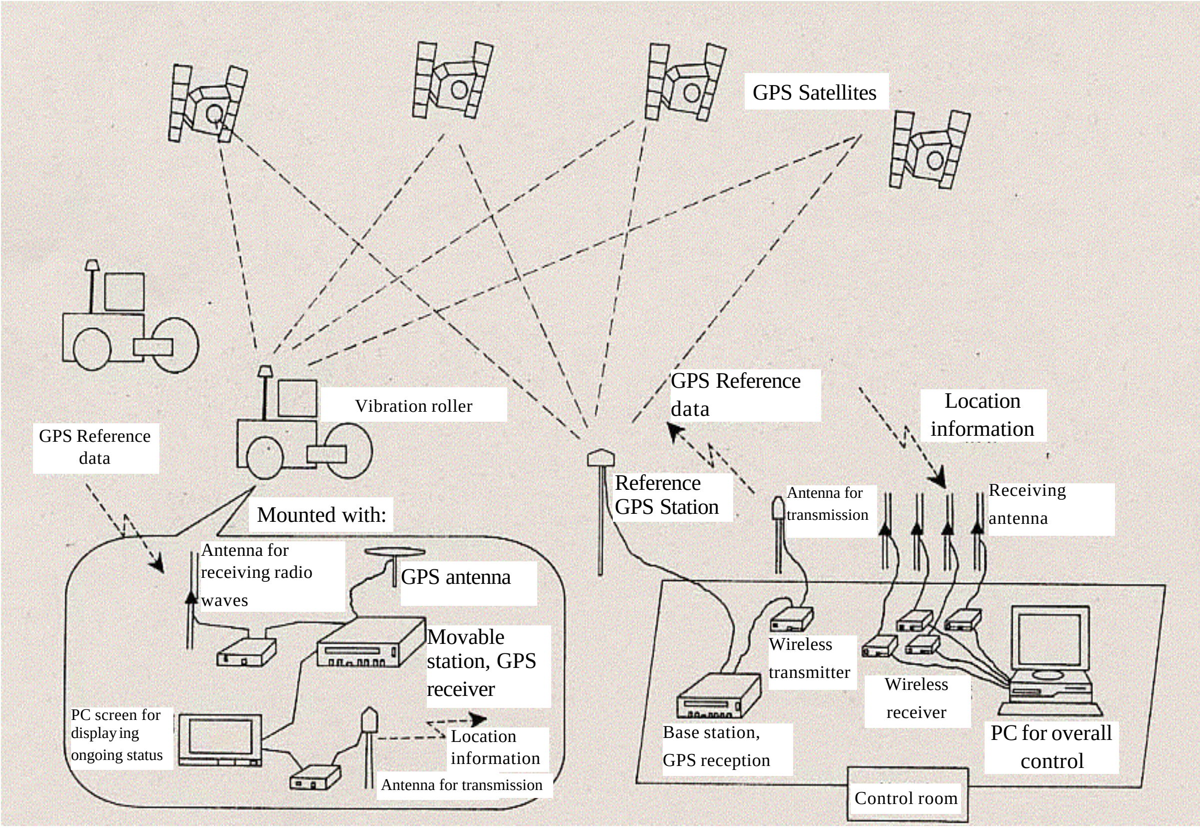

Fig. 4 Conceptual Diagram of System Structure

Table 2 Comparison of Compaction Control Systems of Different Manufacturers

		Company A	Company B	Company C	Company D
GPS		Trimble Co. 40000 SE/GGK method	Trimble Co. 40000 GGK + GGA method	Leica Co. 2 frequency receiver	Trimble Co. GP-DX1-GGK method
Data transmission		SS wireless	Specified minor electricity + SS wireless	Specified minor electricity + SS wireless	Specified minor electricity + SS wireless
Software used		Proprietary	Proprietary	Proprietary	Proprietary
Contents of data	XYZ	o	o	o	o
	Start of vibration: ON/OFF	o			o
	Direction of advance				o

1) Three-dimensional coordinates of the machinery (X, Y, Z),
2) Posture of the machinery (θx, θy, θz),
3) Degree of control of the machinery (example: height of the blade of a bulldozer), and
4) Measurement data of the structure (example: RI measuring instrument).

Figure 5 shows an example of the system structure for acquiring the execution control data. The three-dimensional coordinates use the GPS method, with radio messages sent from the transmission device of the unmanned machinery to the receiver in the operating room. The posture of the machinery will be measured and controlled using a gyro-compass and an inclinometer, and some types of machinery will be equipped with control volume sensors and measurement sensors. Signals from those attachments will be transmitted wirelessly to the receiver in the operating room by the transmission unit of the unmanned machinery, where they are stored in a computer.

In order to make the execution control system universally applicable, rather than to standardize the GPS mounted in the machinery or other measuring instruments, it is necessary to establish a common protocol as hardware and a common data frame as software (as shown in the middle of Fig. 5 on the next page denoted by "Universal Platform[1]").

As the communication protocol, a de facto standard must be used, for which we suggest a type of data frame. The XML (eXtensible Markup Language) data format will be used, because it allows universalization even if the types and models of machines and the execution control data are different, and because increases in the kind and volume of data in the future can be handled.

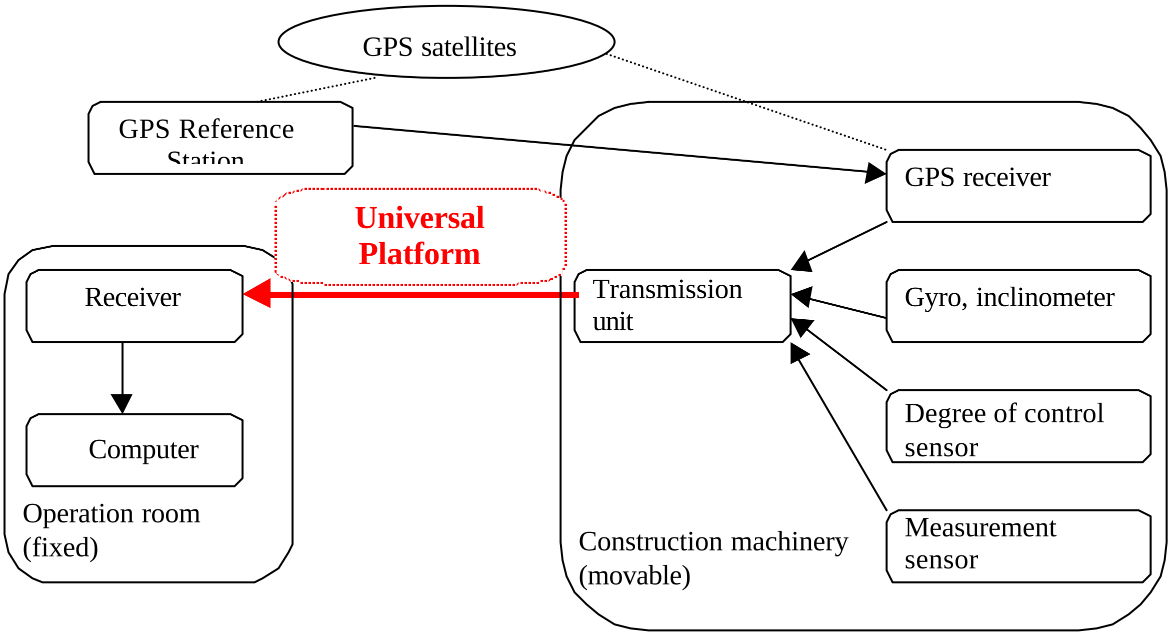

Fig. 5 Block Diagram of Execution Control System

<Execution control data>
<Kind of machinery> Backhoe </kind>
<Manufacturer> Company A </Manufacturer>
<Model> 200 </Model>
<Three-dimensional X > xxxx </ Three-dimensional X>
<Three-dimensional Y > yyyy </ Three-dimensional Y>
<Three-dimensional Z > zzzz </ Three-dimensional Z>
</Execution control data>

Fig. 6 Execution Control Data Frame (example)

Based on the data frame shown in the figure above, it is possible to make the execution control data universal through transmission/reception of execution control data of unmanned machinery.

5. CONCLUSION

We attempted to universalize tele-operation and confirmed its effectiveness. However, we encountered problems such as differences in architecture due to proprietary design specifications and due to different ranges of information available, because approaches toward universalization are not the same.

We therefore believe the industry should establish a common architecture (standard) for control of unmanned construction works execution, based on which each manufacturer can develop its own structure. The current status of the system is still far from reaching a practical level, but the country should urgently establish a universal standard architecture, which allows the information to be used for processes other than construction works.

Preferably, a neutral public institution should set up a task force of relevant participants for developing and promoting the standards.

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