

RESEARCH ON VISUAL POINT OF OPERATOR IN REMOTE CONTROL OF CONSTRUCTION MACHINERY

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ABSTRACT: In present the unmanned construction system technology is adapted on initial operation against of the disaster occasion. For instance it has been used in Unzen.

It depends on the scale and site situation of disaster which system should be applied to.

A lot of remote control technology of operating construction machinery has been developed as that technology. Underwater bulldozer was developed in 1968, which is a start of the technology.

Recently the remote control technology has been applied to restoration works for digging, loading and transportation after the eruption of Unzen.

The present study verifies it concerning the operativeness of a remote system that offers the site information by the monitor and operates it.

In the research, it has aimed at the operativeness improvement, the working efficiency improvement, and the tiredness decrease. Arrangement and the operation of the monitor are researched now. Moreover, we do the examination for the system improvement in the future.

In this report, the operation experimentation of 'Remote control in the site 'and' Remote control systems that displayed the monitor and operated the site information' (two kinds of systems) was done.

And, it is the one that the ability and the behavior pattern that recognized the space of the operator were verified.

Keywords: *Remote Control Technology, IT Construction System, Application Disaster, Construction Machinery, Hydraulic Excavator, Spatial Perceptio*

1. Introduction

Unmanned construction is chosen case by case depending on the size of a disaster or the site conditions (degree of danger to people). A typical application of unmanned construction is the initial response to a disaster such as an earthquake or volcanic eruption, such as the volcanic eruption of Mt. Unzen Fugen.

Unmanned construction technology often involves the remote control of construction machinery. The first application of this approach in Japan was a submersible

bulldozer developed in 1968.

Various construction machines operated by remote control have since been developed. For example, remotely operated construction machines were introduced for post-disaster emergency measures following the eruption of Mt. Unzen Fugen and subsequent damaging pyroclastic flows. Such machines are also currently used for debris removal and countermeasure work such as excavation,

loading, transport, leveling and rolling.

The objectives of this research were to improve the operability of remotely controlled construction machines, reduce the time necessary for operators to familiarize themselves with the operation of the machinery, improve the work efficiency and mitigate operator fatigue.

With the general remote control system currently used at construction sites, the operator operates the remote controller based on information obtained from system monitors. This paper reports the results from a device that measured the eyeball movement of the operators while carrying out different tasks such as traveling, excavation or leveling, and clarifies which monitor information was most important for the operators to conduct their work.

The research also compared the cycle time resulting from repeated work operations between an operation using the remote control system and that using direct visual information, to clarify the common characteristics.

2. Experiment

2.1 Overview of the experiment and configuration of the remote control system

Our research was conducted using a hydraulic shovel developed in a project “Development of IT Construction System using Robots,” as shown in Photo 1, and owned by PWRI.

The experiment was conducted at a construction machinery outdoor experiment field in the PWRI compound, and the verification test was conducted mainly with an operation model that assumes excavation and loading at an actual work site with a shovel remotely controlled to conduct the model work.

Our research on remote control technology includes the remote control systems used at work sites and remote control operation using direct visual information. The behavioral patterns of the operator during operation were quantitatively measured using the eyeball movement measuring device shown in Photo 2, and the spatial recognition and perceptual information of the operator were verified. The work efficiency (time) was measured and evaluated as a factor of the operator’s degree of

familiarity.



Photo 1 Equipment configuration necessary for verification



Photo 2 Eyeball movement measuring device

The experiment used two operators experienced in remote control, as shown in Table 1. Both were experienced remote controllers of construction machinery and were already accustomed to unmanned construction, having participated in the operations at Mt. Unzen Fugen.

Table 1 Operators’ experience

Experienced remote control operator	Operator A	Operator B
Age	62	41
Construction machinery operation experience	42 years	15 years
Remote control experience	16 years	7 years

2.2 Flow of experiment

In the experiment, the operators prepared the test field as shown in Figs. 1 and 2, the cameras necessary for remote control were installed, the visual data from the cameras was wired to the monitors in the operation room, and the information from the cameras on the machinery was sent to the operation room by wireless LAN.

The monitor layout is shown in Photo 3. From the camera layout shown in Fig. 1, the top right monitor is the image viewed from external camera (a), top left monitor from external camera (b), bottom right monitor from onboard camera (c), and bottom left monitor from external camera (d) installed on the tower.

In the experiment, an obstacle was placed in the way of the machine, as shown in Fig. 3, and the operators conducted the simple operation of moving the earth mound, filled up in advance, from Point 1 to 2 in the test field in the PWRI compound. One cycle of the test operation consisted of remotely controlling the construction machine to move forward, excavating the fill, leveling the earth and moving back, as shown in Fig. 4.



Photo 3 Monitor configuration

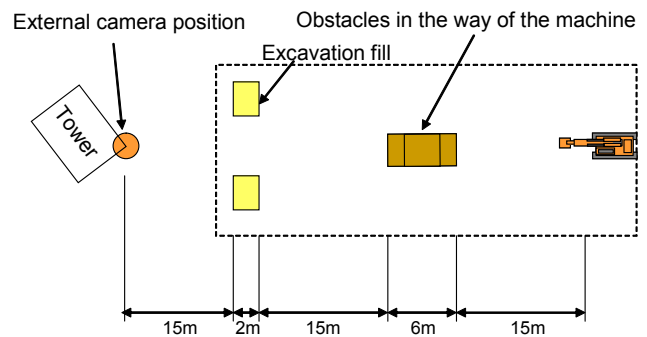


Fig. 2 Relationship between obstacle and excavation earth fill

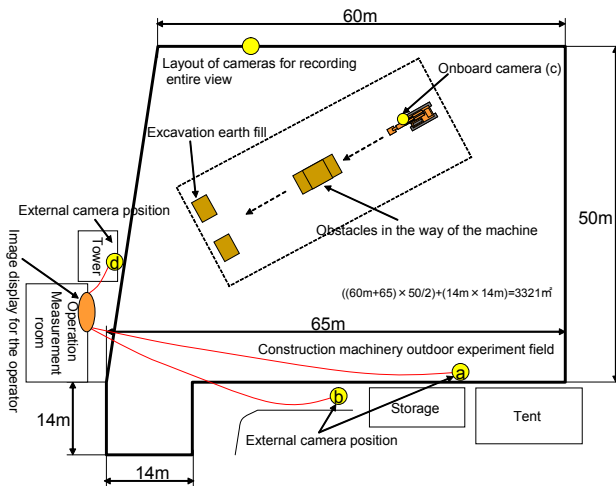


Fig. 1 Plan view of the test field

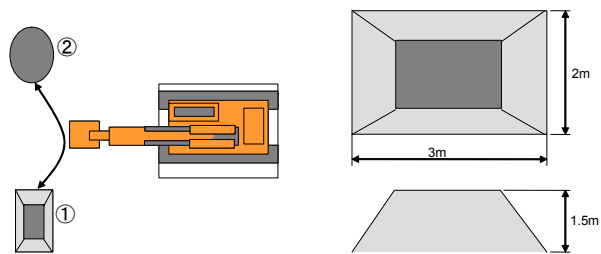


Fig. 3 Size of obstacle and shape of excavation earth fill

The experiment involved measurement with a remote control system five times by each of the two operators and remote control operation using direct visual data three times for Operator A and once for Operator B.

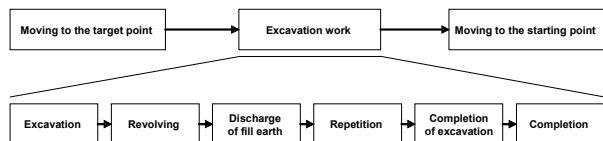


Fig. 4.1 Cycle movement

For the remote control system, the experiment was conducted in the operation room, as shown in Photo 4. Operators in the operation room were screened from direct visual contact with the outside by closed curtains.

For the experiment using direct visual data, operators remote controlled the machinery while they were stationed atop the tower with a direct view of the work site.



Photo 4 Operation using the remote controlled system



Photo 5 Operation using direct visual data

3. Experiment Results and Discussion

3.1 Information from the monitors of the remote control system

In our experiment, measurements were made for each of the work modes (traveling, excavation or leveling) using the eyeball movement measuring device. The results of measurements were summarized to clarify which monitor the operators mainly watched during each work mode to obtain the information they most needed.

Tables 2 and 3 combine the data from the device that monitored the eyeball movements of Operators A and B, respectively, with the times that they watched the monitors for each work mode. The values in the tables are the average over the measurements in all the experiments conducted.

As shown in Tables 2 and 3, a similar tendency is seen for Operators A and B. As they moved the machine forward, they mainly watched the bottom right monitor and bottom left monitor. During excavation and leveling, the top right monitor and bottom right monitors were most frequently watched, followed by the bottom left monitor.

For reference, the operators visually checked the two locations (excavation point and discharge point) alternately during visual operation according to the eyeball movements measured as shown in Table 4.

Table 2 Monitor check times of Operation A

Operator A	Traveling (moving forward)	Excavation	Leveling	Traveling (moving back)
Top right monitor	8	208	65	22
Bottom right monitor	22	208	65	22
Top left monitor	6	24	13	15
Bottom left monitor	27	171	69	24

(times)

Table 3 Monitor check times of Operator B

Operator B	Traveling (moving forward)	Excavation	Leveling	Traveling (moving back)
Top right monitor	7	152	72	17
Bottom right monitor	16	152	72	17
Top left monitor	6	44	23	3
Bottom left monitor	15	76	24	7

(times)

Table 4 Direct visual check times during visual operation

	Operator A			Operator B	Average
	First check	Second check	Third check		
Fill location	100	86	87	88	90
Discharge location	88	82	72	58	75

(times)

3.2 Comparison of cycle time between operation using the remote control system and that using direct visual check

The cycle time was compared between the two types of remote control operation, as shown in Figs. 6 and 7, but there was no major difference in cycle time in this

experiment. However, after the third operation, the total cycle time showed a slight difference between the two operators: about 728 s for Operator A and about 868 s for Operator B, and the cycle time converged thereafter.

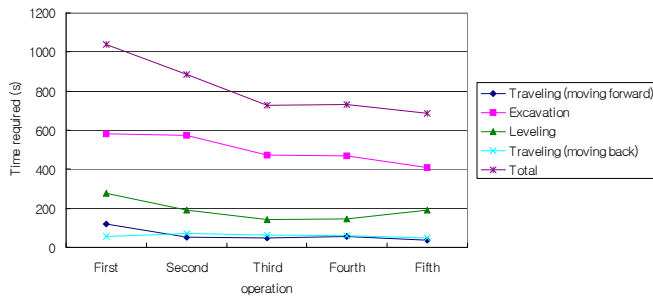


Fig. 5 Working time for Operator A

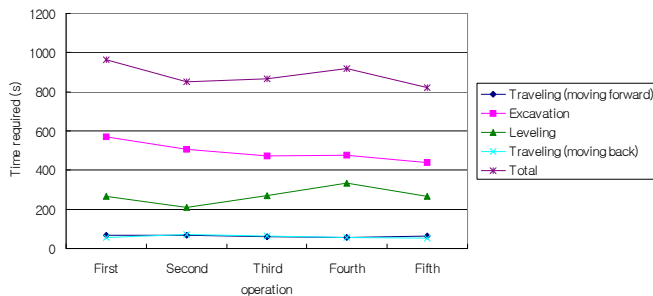


Fig. 6 Working time for Operator B

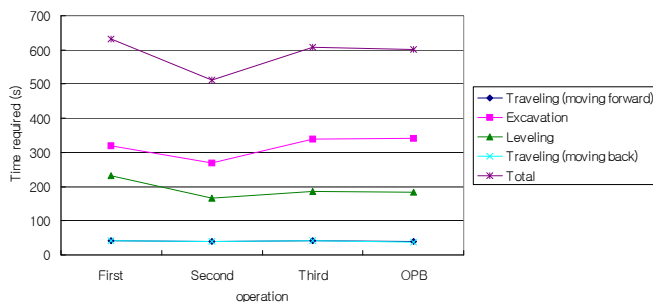


Fig. 7 Working time for visual check operation

For the working cycle time with the visual check, the cycle time of both Operators A and B shows a similar tendency. With an average cycle time of 588 s, the work efficiency was about 261 s better than when using the remote control system (849 s on average).

4. Discussion

4.1 Information from the monitors of the remote control system

In the remote control system with operators checking

many monitors to control the machines, the operators tended to visually check particular monitors for each work mode (traveling, excavation or leveling). In particular, the angle from onboard camera (c) was the same for all types of work.

Regarding the path of movement of the eye during visual-based operation of excavation and discharge of earth as identified by the eyeball movement measuring device, the eye movement repeatedly shuttled between the center of the hydraulic shovel bucket and the earth release point during excavation. Compared with the remote control system, the operators tended to check two monitors instead of direct visual recognition when the range of work exceeded the scope of the onboard camera, such as during excavation and leveling.

4.2 Comparison of cycle time between operation using the remote control system and that using direct visual information

In this experiment, the machines were operated by veteran operators, using a model of an actual system configuration used at an actual work site. There was no major difference in cycle time between the two operators after the second or third operation. This tendency was also seen when using the remote control system or direct visual information, indicating that the operators were sufficiently familiar with operating the machinery.

The difference in cycle time between the two operators is considered to be due to the difference in amount of information due to the length of remote control of construction machinery.

Regarding the results of remote control operation using direct visual information, there was no difference in cycle time between Operators A and B. This suggests that the operators could directly recognize the information of the inside of the test field by direct visual check, which helped them to quickly establish an image of the work. One possible reason for the reduced cycle time for visual operation and faster establishment of the work image is that the experiment was performed after the remote control system experiment.

5. Summary and Future Tasks

This study on the configuration of displaying information on monitors from cameras is that the image angle of onboard camera (c) greatly assists smooth remote control at the site. To improve remote control operation, it is suggested that work efficiency could be improved if the operators can obtain accurate information on the work yard conditions and specific work content.

In general, the simulation visually stimulated the operator and caused him to take action (response). However, the trend of familiarization revealed by the experiments suggested that work action (appropriate reaction) will occur not only as a result of visual stimulation, based on the recent results of ecological psychology, but also as a result of a wide variety of information including past experience.

Further study is needed on the position of onboard camera (c), which facilitates appropriate remote control and improves work efficiency and precision, and on the information needed to improve work efficiency and precision of remote control operations.

References

- [1] M.Moteki, K. Fujino, and T. Ohtsuki: Spread of Unmanned Construction Technology to Construction Sites and the Future Technical Needs – Report on the Verification Experiment of Remote Control System, Compendium of the 12th Construction Robot Symposium, pp. 89 to 96, Sept. 2010