EVALUATION OF OPERATIVENESS CONCERNING INTERFACE OF REMOTE CONTROLLED BACKHOE

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Abstract:
Operation of the man-machine interface should be easy and intuitive for efficient works when using a remote-controlled underwater backhoe. Moreover, operation is preferable to be unwearying. Tiredness in the operation of the backhoe front part by the similar-figure-interface becomes a serious matter of concern in the site experiment of an underwater backhoe. The aim of this research is to evaluate the operativeness of the joystick-type-interface that is newly proposed. The operativeness of the joystick and that of the similar-figure-interface were compared in the pointing experiment.

Keywords: Interface, Underwater backhoe, Teleoperation

1. INTRODUCTION

As the need to construct, inspect, diagnose, maintain, and repair deep quay walls, bulkheads, and offshore airports continues to soar, it is becoming increasingly necessary to perform these works safely and efficiently. Among these, the inspection and diagnosis of port and harbor structures is indispensable and much of this work must be done manually by divers. Research on underwater unmanned execution that is necessary to resolve this problem is being performed continually, and with the importance of mechanized execution sure to continue to increase in the future, efficient execution that prioritizes safety must be performed.

2. BACKGROUND TO THE RESEARCH

In FY2004, the remotely operated backhoe was given a trial in actual ocean waters. Participants interviewed after the trial reported that the analogous interface limited long-term continuous work because it caused fatigue. It was decided that the operating characteristics of interfaces must be studied to resolve this problem.

Its operating characteristics should be intuitive and simple, and place a small physical burden on the operator, so an interface suitable for long-term work had to be developed. Therefore an interface that can be operated as efficiently as the analogous interface used for the actual ocean water trial and that produces little fatigue when used for a long time was necessary.

And it was also assumed that future underwater work will include inspection and diagnosis followed by maintenance work on underwater structures. In this case the front of the backhoe will be controlled at the same time as sensors and repair equipment are operated.

An interface that can be used to perform complex operations with one hand was presumed to be effective. In order to resolve these problems, this research proposed an interface equipped with a laterally installed three axes joystick as an interface that can be used to control the front with one hand, and that can ensure the same operating characteristics as the analogous input device as it reduces fatigue experienced by the operator.

The trial was performed by having operators remotely operate the front of the mini-shovel with various kinds of interfaces to perform comparative evaluations of the time and correction frequency required to point to targets in succession and, based on interviews, the operating efficiency and fatigue.

3. EVALUATION OF THE NEW INTERFACE

3.1 Operation entry method

It is necessary that the interface be easy to operate intuitively in order that it can be operated more efficiently. As the intuitive operating method, two patterns were proposed: the coordinate command method in which the lever is installed laterally and is raised and lowered and moved forward and backward to move the bucket end coordinate in the corresponding direction, and the joint direct command method in which the operator sends commands directly to the boom or arm. As the operation entry method, a joystick sold on the market was used as the device that satisfies the previously studied operation entry method by permitting one-handed operation with 3 or more degrees of freedom. The joystick is equipped with a button and switch-lever and it is assumed that it will be able to fully handle future complex operations. Figure 1 and Figure 2 shows the proposed operation entry methods.

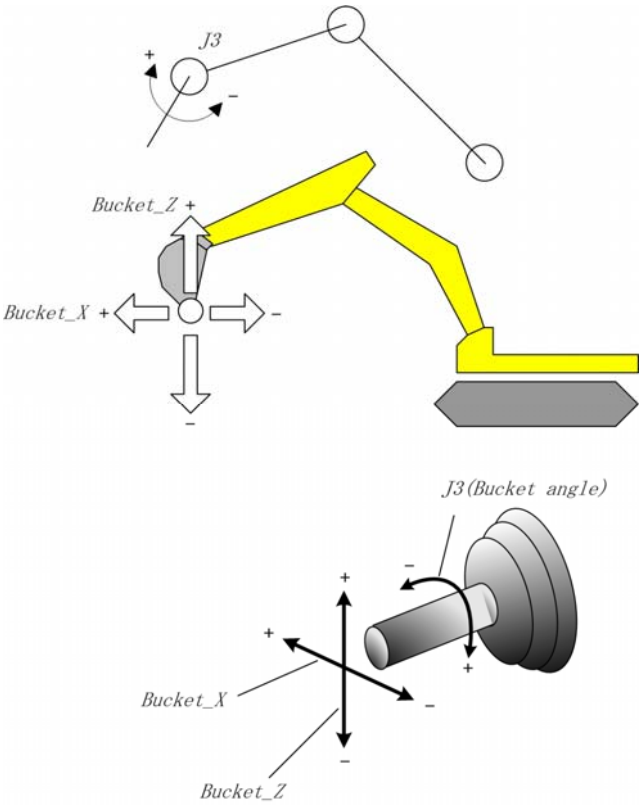

Figure 1 Coordinate Command Method

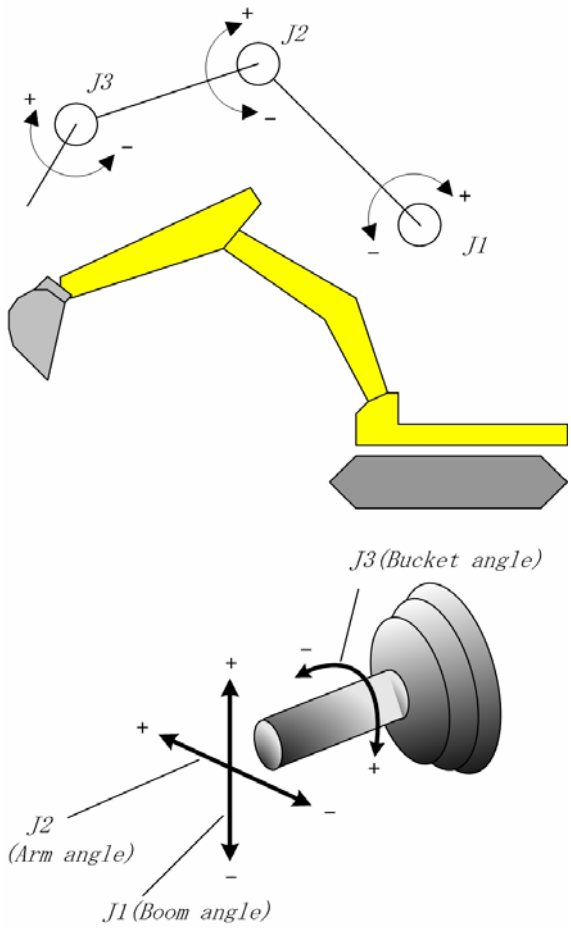

Figure 2 Joint Direct Command

3.2 Trial conditions and evaluation method

In the trial, joystick (1) was used for the coordinate command method that was performed using a joystick and joystick (2) was used for the joint direct command method. The trial conditions were pointing continuously until reaching the goal from the start position from the smaller to larger numbers as shown in Figure 3 by five operating methods: remote operations including wireless remote control, analogous interface, joystick (1), and joystick (2), and operation by an operator on the backhoe. Each of these operations was repeated three times. Pointing means moving the claw on the left end of the bucket so that it is at a marker, and a case where the claw was not on the marker because the backhoe could not be operated as planned was added to failure frequency and the operator tried again to point at the market. The test subjects were three qualified mobile construction machinery operators.

The pointing trial had to be done quickly and accurately. The trials were evaluated on the principle: the shorter the time required to point to the marker, the more efficient the operation, and the lower the failure frequency, the more accurately it responded to commands. To test fatigue, the subjects operated each system continuously for 30 minutes. Because of differences between the individuals, they were asked to compare and rank the operating systems. They were interviewed to find out the reasons for their ranking: not physically fatiguing or the operating method was easy to understand and so on.

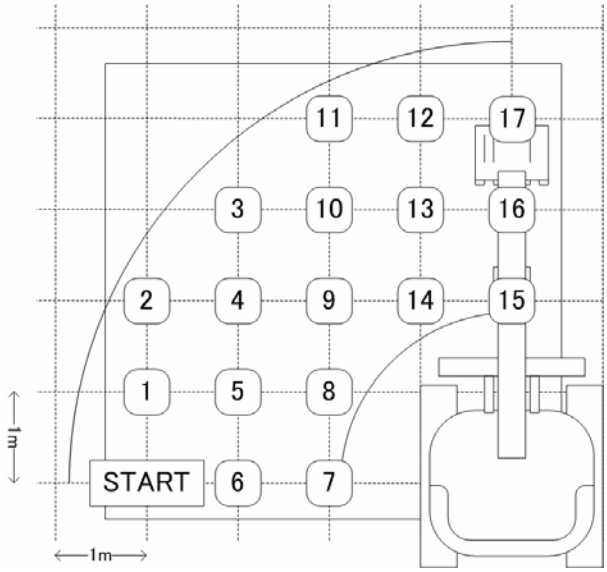

Figure 3 Point Marker Layout Diagram

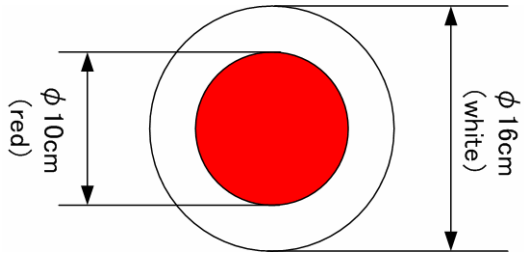

Figure 4 Point Marker

3.3 Pointing test

The test was performed using a 0.09m^3 class mini-backhoe. It was manufactured for remote operation, and can be operated by an operator riding the backhoe, remotely by a remote control device or by wired remote control using a personal computer. Figure 5-7 shows the interfaces that were used for remote operation. Figure 8-9 shows the test in progress.

Figure 5 Remote Controller

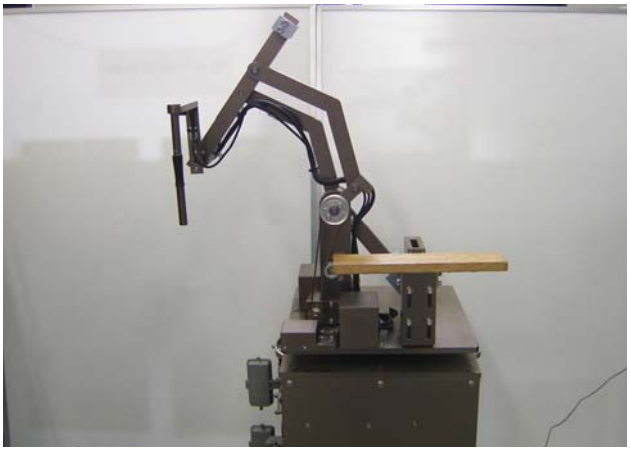

Figure 6 Similar Figure Interface

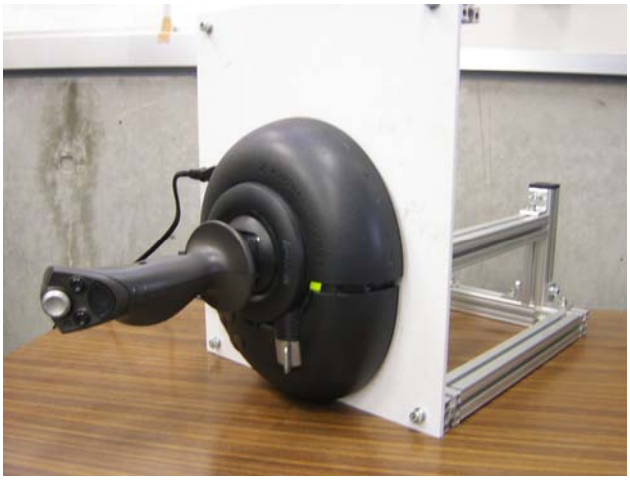

Figure 7 Joystick

Figure 8 Appearance of Teleoperation

Figure 9 Experiment Situation

3.4 Test results

Table 1 shows the results of using data obtained for the three tests by each of the three operators to calculate the average pointing time and error frequency for each interface and comparing the calculation results for each interface with the analogous interface assumed to equal 1. And the fatigue and operability are shown in Table 2 based on interview results.

Table 1 Comparison of Operating Efficiency

	Onboard	Remote Controller	Similar Figure Interface	Joystick TypeA	Joystick TypeB
Pointing Time (sec per point)	11.3	21.8	23.4	25.5	23.5
Ratio of Time	0.48	0.93	1.00	1.09	1.01
Error frequency (Frequency per point)	0.71	2.24	1.63	1.86	1.90
Ratio of Error	0.43	1.37	1.00	1.14	1.17

Table 2 Results of Interviews Concerning Fatigue and Operability

	Fatigue				Operability			
	Operator_A	Operator_B	Operator_C	Total	Operator_A	Operator_B	Operator_C	Total
Remote Controller	5	4	5	14	2	4	4	10
Similar Figure Interface	3	2	2	7	4	2	2	8
Joystick Type_A	2	3	4	9	3	1	3	7
Joystick Type_B	2	3	4	9	3	4	3	10

(Fatigue)
5:A consecutive operation for two hours or more is possible.
4:A consecutive operation for one hour or less is possible.
3:It is possible to work for four hours if there is an interval.
2:It is possible to work for one hours if there is an interval.
1:It is not possible to work for 15 minutes or more.

(Operability)
5:It is possible to operate easily.
4:It is necessary to think about the input.
3:It is possible to operate somehow or other.
2:It is necessary to become accustomed.
1:It is difficult to operate.

3.5 Findings

Table 1 shows that the pointing time was short and error frequency low when the operator was riding the backhoe. The results show the effects of deterioration of visual information, because an operator riding a machine directly observes the work, while a remote operator obtains visual operation by viewing a TV monitor. When the operator used the proposed joystick, the pointing time was almost identical to that when using the analogous interface, and the error frequency was a little higher. This is presumably a result of the inability of an operator using a joystick to obtain backhoe attitude information. This can be improved by changing the way the picture is shown by the color graphics display and the position of the TV camera to add backhoe attitude information. The interview results revealed that it caused less fatigue than the analogous interface, but the operators also stated that in its present state, it would be difficult to use it for a long time. They felt fatigue caused by raising their arm in the Z axis direction with their elbow on the support point. This can be improved if it is possible to perform the prior operation with the wrist by reducing the quantity of operation of the lever. As another way to improve its operability, a specialized arm rest has been proposed.

4. CONCLUSION

The interface proposed by this research allows the operator to perform complex operations with one hand, obtaining operating efficiency almost equal to that of the analogous interface. The fatigue felt by the operators was lower than that felt using the analogous interface. The results indicated that long-term use will cause fatigue, but the testing clarified challenges to be resolved to improve the operability and fatigue properties of the interface. In the future, research on the inspection and diagnosis of underwater structures will be undertaken aiming for more practical development performed with reference to the results of this research.