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Development of an Advanced Way of Improvement of the Maneuverability of a Backhoe Machine

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The operation of a backhoe machine requires great skill. Construction industries have a lot of problems because of the shortage of skilled workers, and the backhoe operator shortage is a typical and most severe example. A new method to operate a backhoe is proposed in this paper. A new type of master operational unit has developed to control the position and velocity of the bucket instead of the conventional type lever system. By using the new master unit even an inexperienced operator can control the machine very easily. The operator also can feel some force applied to the bucket bilaterally. That enables the unskilled operator to execute a good work level for a complicated backhoe task.

Key Words: robotized backhoe,new operational master unit, bilateral master-slave control, electoro-hydraulic mechanism,

1 Introduction

Although backhoes are widely used at the construction sites, it is very difficult for unskilled workers to operate the machine correctly and speedily. The reason of the difficulty of the operation comes from the machine having been designed not for human beings but for the machine itself, which means the backhoe works most speedily and effectively in the present design if it is correctly controlled. Therefore, once one becomes a skilled operator, he loves the speed and power of the persent machine, and does not want for it to be converted anymore, even though it looked for him a terrible machine at first.

But it is said that it takes some or several years for a new operator to become a skilled one, especially when to finish the surface of the ground straight and beautifully. Therefore, it is very difficult to find enough numbers of skilled operators to the machine, especially when urgent completion of the work are urged. And when the unskilled worker operates the machine it often changes to quite a dangerous one for the people around it, and so his mental burden becomes enormous.

To solve these problems the authors planned to develop technologies to make this popular but sometimes awful machine be an easy-operated and safe one even for an operator who touches the machine for the first time. Our targets for the time being are as follows:

1. The operation of the machine should be fit to our three-dimensional sense directly.
2. The straight path operation of the bucket should be done easily without any special skill.
3. The operator can leave the seat of the machine and can operate it as usual when for instance he has to approach to the construction site to look into the place.

Furthermore,

4. The operator should feel the applied force to the bucket to understand some changes of the situation.

To realize these targets, the authors planned to apply robot technologies to the machine:

1. The machine should be converted to be controlled by a computer.
2. A new operating unit should be developed for the operator to get easy sense of the direction of an operation.
3. The operating unit should be actuated by the feedback force which applies to the bucket from the object to be handled or from the environment, which means that bilateral master-slave control technologies for manipulators are necessary, and also that the master unit should contain some actuators.

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Although many reseaches have been executed for bilateral master-slave control systems for manipulators [1] [2] [3], those are for electrical driven manipulator systems, and both the master- and the slave manipulators have almost same size compared with our target system, in which the master unit would be much smaller than the real backhoe manipulator. Takeda and his colleagues [7] applied bilateral control method to the combination of an electrical driven master manipulator and a hydraulically driven slave manipulator, in which case both the master- and the slave manipulator configurations were similar.

2 The backhoe machine to be controlled – A modified version

Trade name	MItsubishi ME08
Weight	720kg
Bucket volume	$0.02M^3$(JIS)
Bucket width	350mm(standard)
Whole length	2,700mm
Whole width	700 ~ 900mm
Whole height	1,400mm
Maximum volume of	700kgf

表 1 Specification of the original backhoe machine

A standard mini-backhoe machine produced by Mitsubishi-Caterpiller Co. was converted into a computer controlled machine, as shown in Fig.1.

The conventional on-off type valves were changed into hydraulic servo-valves, which are controlled by the electric signals from the main computer. The proposed computerized backhoe system works with these servo-valves that allow changes in the flow volume of oil into the cylinders by the computer signals. Thus, the speed control of the movement of the bucket is feasible.

A linear encoder was attached to each cylinder to measure the change of the speed of the cylinder. Two pressure sensors to the both sides of each cylinder were also installed to detect the pressures of both sides of the cylinder.

Pressurized oil to the machine can be supplied either from the original oil unit in the body of the machine or from a hydraulic power unit which is put near the backhoe machine. The hydraulic power unit is mainly used during the experiments to prevent overheat of supply oil in the original oil unit.

The main computer is a Transputer(T-800). A V-25 board which contains V-25 processor is also used to drive servo-motors of the master control unit. V-25 processor is a one chip micro-computer whose main processing unit is compatible to i8086.

The system diagram of the newly converted backhoe machine is shown in Fig.2.

3 Master command lever

The conventional command levers basically correspond to the each on-off valves, which also correspond to each cylinders for the boom, the arm, and the buket. Actually, one lever contains two command shift operations. In case of the machine which we utilized, the left lever commands the boom and the buket movements, and the right lever commands the arm movement and the swing motion of the body around the center of the mobile part of the machine. Fig.3 shows these correspondence of the lever operations with the indication of the actual movements of the machine, eliminating the indications of the swing operation from the right lever.

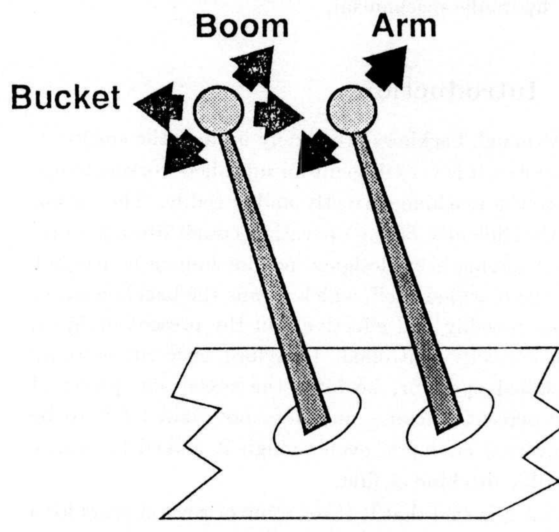

Fig.3 Correspondence of the operations of the manual command levers with the movements of the conventional backhoe machine

The problems for the unskilled operators to control the machine exist in these correspondences. When an operator wants to move both the boom and the bucket at the same time, the shift operation of the command lever to a diagonal derection makes it possible. But the case of the straight path movement of the front surface of the bottom of the bucket should be one of the most difficult example. In this case, the speeds of three cylinders for the boom-, the arm-, and the bucket movements shold be controlled at the same time, which means the operator has to shift the two

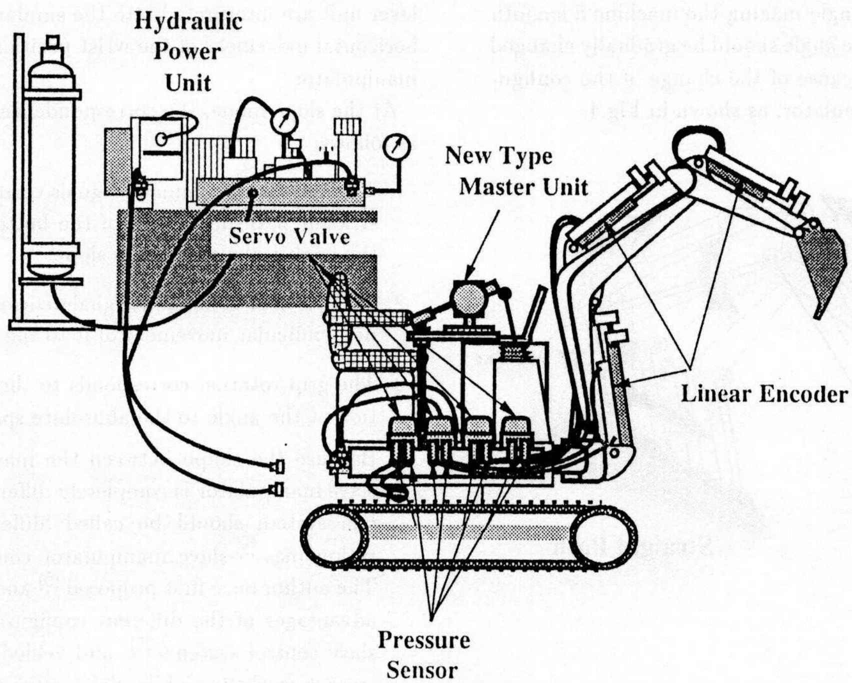

Fig.1 The converted backhoe machine

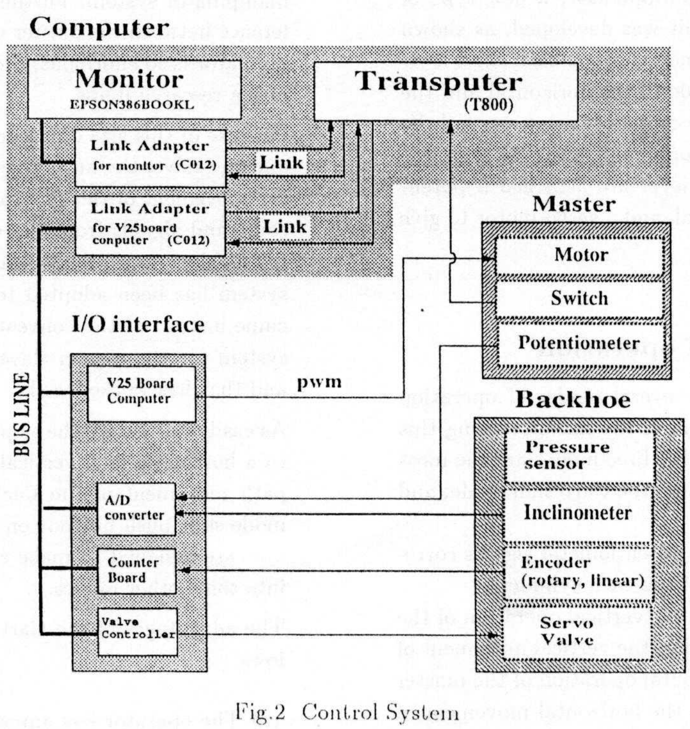

Fig.2 Control System

levers at the same time. And the shift should not be the mere changes of the levers into a diagonal directions but into an angle making the machine a smooth movement. And the angle should be gradually changed during the task because of the change of the configuration of the manipulator, as shown in Fig.4.

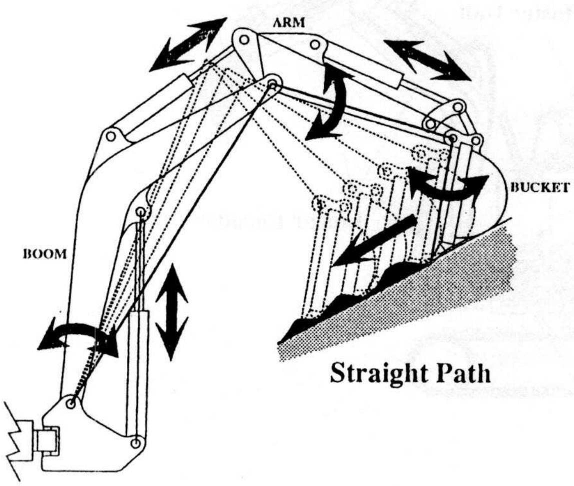

Fig.4 Movements of the mechanical arm correspoded to a straight path of the bucket

To make the command operation much easier and right fit to the sense of the operator, a new type of master command lever unit was developed, as shown in Fig.5. The master command lever is basically a lever with three degrees of freedom, the horizontal and the vertical swings around the center of each axes, and the grip rotaion around the horizontal shaft. To each free movement of the master lever are attached a potentiometer to get input signal, and a servo-motor to give output actuating power.

4 Basic modes of operation

Although there can be several modes of operation for the master-slave system of the machine using this master command lever unit, three modes are the most general ones: the joint mode, the Cartesian mode, and the slope mode (Fig.6).

At the joint mode, each potentiometer signals correspond to the movement of the each cylinders.

At the Cartesian mode, the vertical operation of the master lever is interpreted to the vertical movement of the bucket, and the horizontal operation of the master lever is also converted to the horizontal movement of it. The grip rotation of the master lever is signalled to the movement of the cylinder for the bucket. Therefore, the vertical and horizontal rotations of the master lever unit are interpreted into the similar vertical and horizontal movement of the wrist position of the slave manipulator.

At the slope mode, the correspondences of these are as follows:

1. The horizontal command signals correspond to the straight path movement of the bottom surface of the bucket along with the slope.
2. The vertical command signals correspond to the perpendicular movement of it to the slope.
3. The grip rotation corresponds to the bucket rotation at the angle to the abusolute space.

Because the shape between the master- and the slave manipulator is completely different, this control system should be called 'different configuration master-slave manipulator control system'. The author once first proposed [5] and asserted the advantages of the different configuration master-slave control systems [5], and veified them by the reseach works for a bilatelal master-slave manipulator system [2].

The control method proposed here using the master command lever is one of the typical and good example of the different configuration master-slave manipulator system. Furthermore, as the size difference between the master unit and the slave manipulator is so enormous, there exist a lot of interesting research items.

Because of this size difference between the master and the slave, the authors expected the danger of the movement of the slave arm when the position command signals from the master unit were sent to the slave arm. Therefore, the velocity control system has been adopted to control this big machine instead of the conventional position control system for the master-slave manipulator system, and that has worked well.

As easily estimated, the slope mode can be applied to a horizontal or a vertical or any other straight path movement of the bucket (Fig.7). And the mode shift push buttons on the grip of the master unit are assigned to make shift the persent mode into some other modes.

The advantages of the Cartesian mode are as follows:

(a) The operator has almost no necessity to care about the angle of the bucket to prevent, for instance, overflowing of soil from the bucket, because the angle of the bucket is commanded by the absolute angle to the ground surface.

(b) The operator does not need to pay attention to the speed of each cylinders, because the speed of the wrist position of the mechanical arm is easily commanded.

From these advantages, the operator feels less mental burden and he can focus mainly on the work itself.

At the slope mode, even a beginner can operate the machine and finish the slope surface. as easily and beautifully as the well skilled operator. The inclination angle of the slope θ is inputted into the computer (1)from the keyboard of a console monitor, or (2)by pointing two points of the slope A and B with the actual bucket. Therefore, the operator can focus only into the speed of the horizontal movement of the bucket, avoiding to care about the angle of the slope.

5 Experiment

An Experiment was executed to confirm the maneuverability of the proposed new command system. The experiment consists of carrying a metal can in the bucket from the first point just in front of the caterpiller to the end point just above a small metal backet passing through a fence, and of throwing away the metal can into the metal backet (Fig.8).

This work needs the control of all the three cylinders at the same time, and so, it is rather hard work for a complete beginner.

In case of operating the original manual lever system, the beginner needed to move one-by-one operation of each cylinders and it took around 45 seconds for him to finish the work, and sometimes collided the bucket into the fence. In case of the newly developed system, it took only 11 seconds to execute the same task.

The second experiment to use the slope mode was also executed. The result was quite satisfactory.

Another experiment was done to evaluate the effect of bilateral force feedback informations. Following four types of objects were pushed against the stopper made of iron.

(a) A tyre with no air
(b) A tyre with air
(c) A wood
(d) The stopper itself

Fig.9 shows the results of the experiments. In the figure, the dotted lines denote the y-directional forces, and the solid lines denote the x-directional forces.

From the figure, we can find that only x-directional forces changes at the time when the object is pushed to the stopper, and this indicates the effect of the feedback force as a way to know some of the work environment.

6 Conclusion

A newly developed command lever unit and the converted computerized backhoe manipulator have been tested to improve the maneuvalability of the widely used conventional backhoe machine. The result has been quite satisfactory. Even a beginner could operate the machine easily. The force feedback signals to the master operation unit denote the feasibility of effective use of such informations.

参考文献

[1] M.Ejiri, Characteristics of a bilateral servo-mechanism (in Japanese), Proc.JSME, vol.31, no.230, pp.1485-1491, 1965-10.

[2] T.Arai, E.Nakano, Bilateral control for manipulators with different configurations, Proc. 1984 Internationl Conference on Industrial Electronics, Control,and Instrumentations, pp.40-45, 1984-10.

[3] Miyazaki, Hagiwara, Parallel control method for bilateral master-slave manipulator (in Japanese), J.Robotics Society of Japan, vol.7, no.5, pp.446-452, 1989-10.

[4] Takeda, Yoshinada, Ootsubo, Development of a bilateral manipulator for construction works (in Japanese), Proc.1st Symposium on Construction Robots, pp.391-396, 1990.

[5] E.Nakano, T.Arai, Bilateral master-slave manipulator with different configurations, Japanese patent pending, no.S59-63984, 1984.

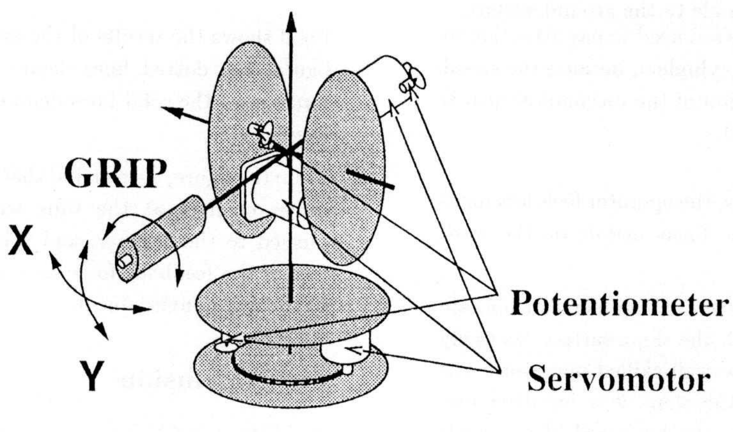

Fig.5 A newly developed master command lever unit

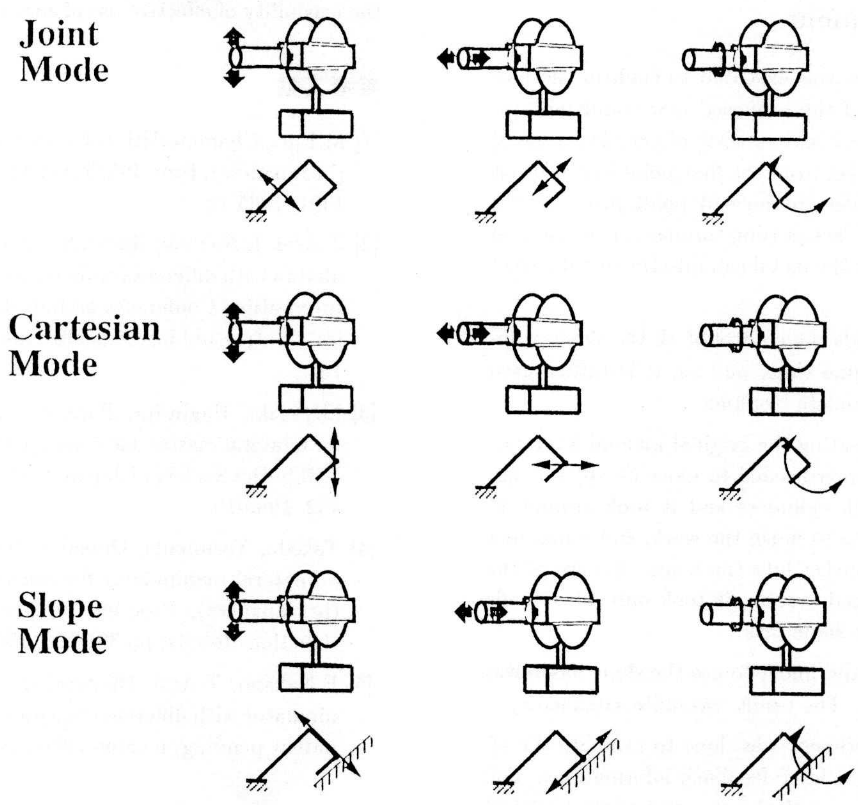

Fig.6 Three modes of the correspondence between the master and the slave movement

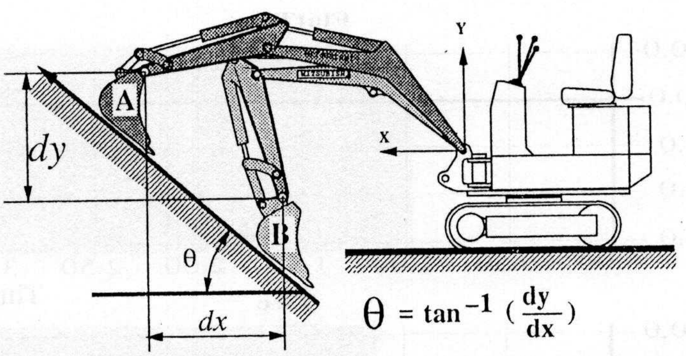

Fig.7 Indication of the inclined angle of the slope

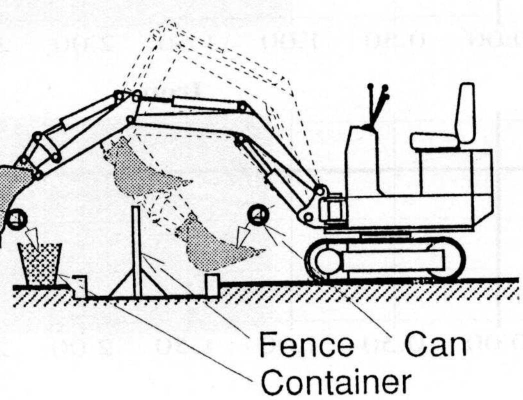

Fig.8 An experiment carrying a metal can passing through a fence and putting it into a container

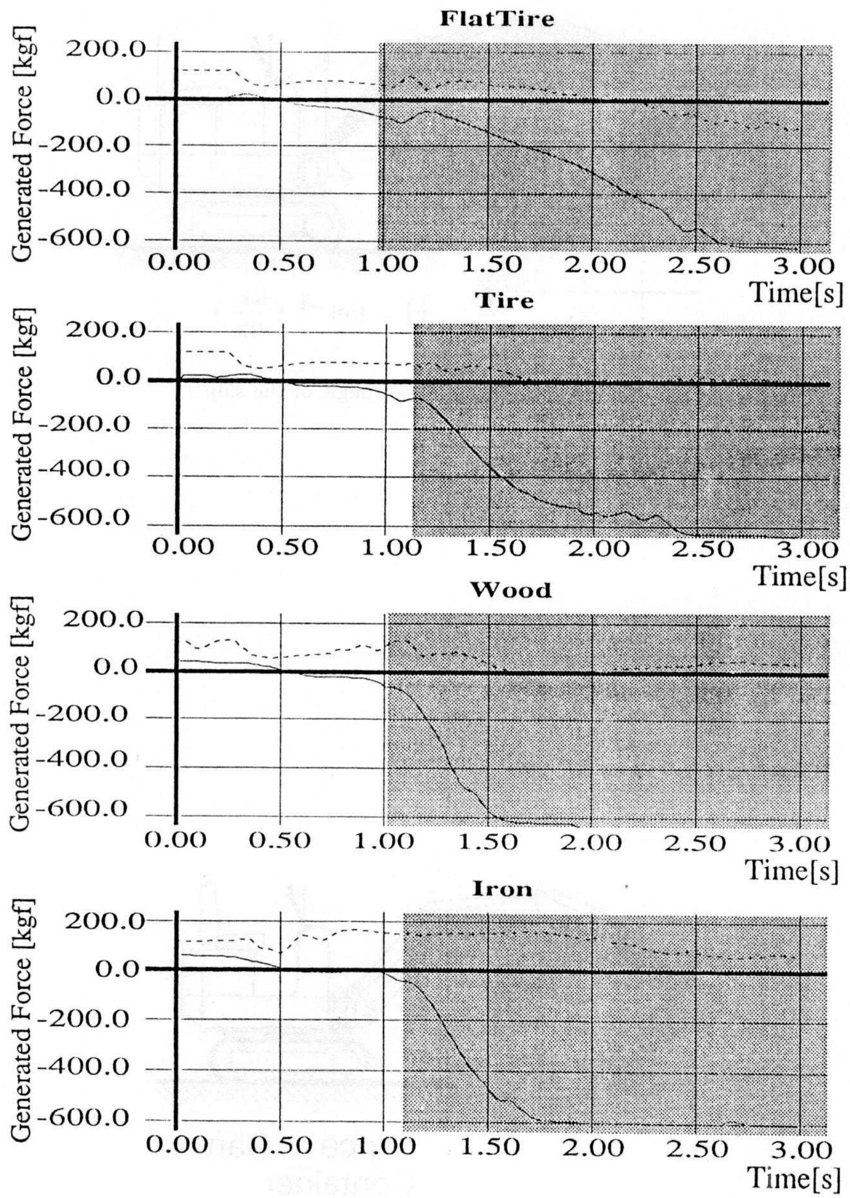

Fig.9 The detected forces