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Remote Control of Ordinary Backhoe Using Pneumatic Robot System

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ABSTRACT

In disaster sites, the remote control of construction machinery is required to ensure the safety of the workers. However, the current remote control systems are limited in types of machines and numbers. A remote control system we have developed has advantages in portability and dexterity by using lightweight pneumatic robot arms. The effectiveness of the system has been confirmed with a small type backhoe. In this research, a system was developed to improve flexibility. First, the moving angle of the robot arm was enlarged. Then, the sliding system was developed to move the robot back and forth so that the robot arms can operate not only the levers to control the arm of the backhoe but also that of the acceleration. Moreover, CCD camera was attached to inform the vision from the backhoe. The system was applied to an ordinary backhoe whose bucket size is 0.28 m^3. Some field tests were conducted and the effectiveness of the developed system was proven.

KEY WORDS

Key words; Pneumatic Robot, Pneumatic Artificial Muscle, Remote Control

INTRODUCTION

In disaster sites, the remote control of construction machinery is required to ensure the safety of the workers. However, the current remote control system is limited in types of machines and numbers. The remote control systems for construction machinery can be classified into two approaches. One is “Conversion Type” and the other is “Installation Type”. The “Conversion Type” approach converts ordinary construction machinery into remote control systems[1][2]. For example, a system has already been developed to realize remote control by replacing a valve in the construction machinery to a remotely controllable valve. Conversion type systems, though, require significant time and effort because conventional remote-controlled construction machinery is larger than ordinary equipment and is available in only limited types and quantities.

On the other hand, the “Installation Type” approach is to install a remote-controlled robot system on ordinary construction machinery. Since the remote control can be successfully realized with any construction machinery near the disaster site, the quick restoration work is available. The system requirement for the “Installation type” is portability and easy installation to the construction machinery.

A remote control system we have developed from the “Installation Type” approach has advantages in portability and dexterity by using a lightweight pneumatic robot arm. This system can easily be carried and installed on ordinary construction machinery. Using the developed pneumatic robot system, the effectiveness of the remote control system for construction machinery with a small type backhoe was confirmed [3].

In this research, a system was developed to improve versatility and flexibility. A sliding system was developed so that the pneumatic robot arms can operate not only the levers to control the arm of the backhoe but also that of the acceleration. Moreover, we attached CCD camera to the robot system to inform the vision from the backhoe to the operator. We conducted some field tests to evaluate the effectiveness of the remote control system.

PNEUMATIC ROBOT SYSTEM

Pneumatic Robot Arm

Figure 1 shows pneumatic robot arms newly developed and the driving system of a joint. The pneumatic robot arm has six degree-of-freedom. Because the structural components are made of MC nylon, carbon rods, aluminum and the Pneumatic Artificial Rubber Muscles (PARMs)[4] as actuators, the arm is very light in weight. The total weight of the arm is approximately 3 [kg]. Because the robot arm is lightweight, quake-resistant, portable and dexterous, it is effective in its role as part of a remote control system for construction machinery.

Each angle is driven antagonistically with two PARMs connected to a link in parallel. A 5-port servo valve controls supply and exhaust air to PARMs[3]. Then the difference of contraction of two PARMs creates joint torque as shown in Figure 1. A rotary encoder was set to each joint and the rotation angle was measured and controlled.

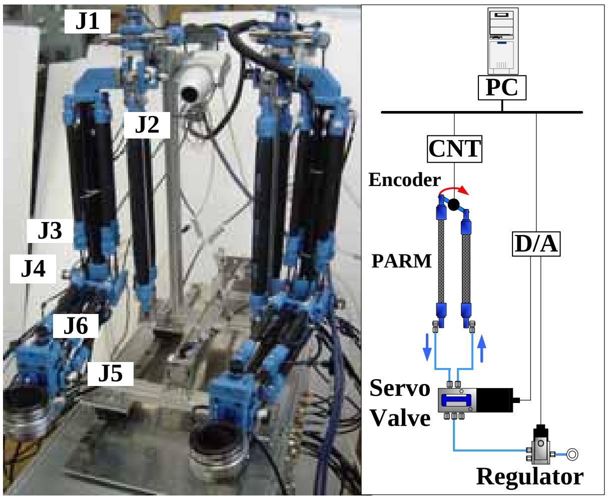


Figure 1 Pneumatic robot arms (left) and Muscular Driving System (right)

Table 1 Movable angle of robot arm (Shoulder joints)

	Available Angle [deg]	
	J1	J2
Previous Arm	±28	±28
New Arm	±45	±40

The robot arm contains of a wrist joint that enables the robot hand to move up, down, left, and right, the elbow joint which bends and twists the robot arm and the shoulder joint which turns the shoulder and rotates the entire arm. In previous research, available angle of each joint of the arm is about 30 [deg] and the robot arm can operate a small type backhoe because of short distance of the levers equipped with the backhoe. However, levers of the ordinary backhoe are separated. Therefore, we improved shoulder part of the robot arms to expand the available angle. The shoulder part, that is J1 and J2 in Figure 1, were newly developed. PARMs with 20 [mm] size in diameter and with 340 [mm] in length (MAS-20: manufactured by FESTO) were used the joints to improve the contracting length. As a result, larger available angle (over 40 [deg]) was realized as shown in table 1.

Sliding System

The acceleration lever of the backhoe is apart from the operation levers and the robot arm cannot reach it even the shoulder joints were improved because a human operator bend and rotate ones west to operate the levers. Therefore, a sliding system was developed to move the robot system back and forth as shown in figure 2. Linear sliders and a pneumatic cylinder were attached with the frames that fix the robot arms on the sliding guide. Therefore, robot arms can move about 200 [mm] backward and operate the acceleration lever.

Air Gripper is set to the tip part of the robot arm as shown in figure 1, therefore the robot arm can grasp not only the operation levers but also that of the acceleration of the construction machinery. The robot arm can rotates gripped lever using the wrist joint.

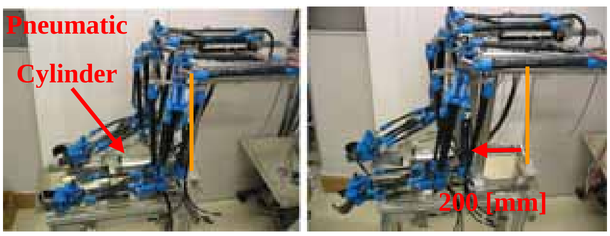


Figure 2 Sliding System

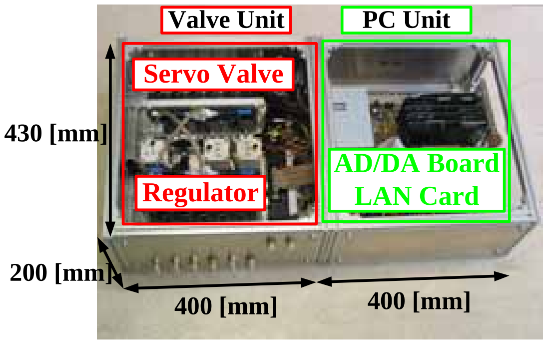
Control Box

Figure 3 shows control boxes for the pneumatic robot system. The boxes are divided into three units. One is a PC box which contains a PC board and sampling boards. Second one shown in figure 3-(a) contains pneumatic instruments such as servo valves and pressure regulators. The outer dimensions of the boxes are both 400 [mm] × 430 [mm] × 200 [mm]. The third box as shown in figure 3-(b) is power source unit supplying electric power to the PC unit and valve unit and an access point for wireless LAN network. The outer dimension of the box is 200 [mm] × 430 [mm] × 200 [mm].

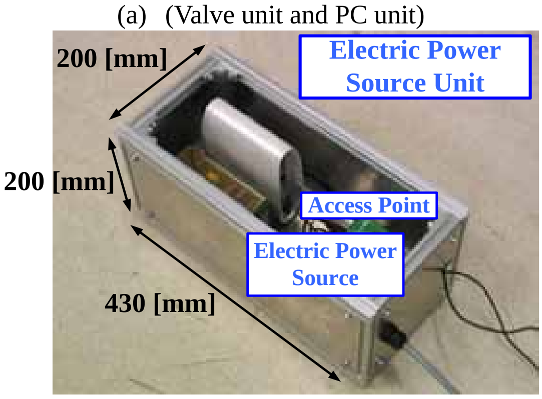
The total weight of the robot system is about 40 [kg] and can be installed easily on construction machinery with minimal effort.

Remote Control System

Figure 4 shows a remote control system. An operator uses joysticks to input the target tip position for the robot arm from the master side. Then a laptop PC reads the joystick values and transmits the values to the control box at the slave side via wireless LAN (IEEE 802.11b). Then the robot arm, grasping the levers of construction machinery in advance, manipulates the levers according to the transmitted value. As a result, the joystick motion and the construction machinery levers are synchronized. We have confirmed that the response delay is less then 200 [ms] which is acceptable for remote control.



(a) (Valve unit and PC unit)



(b) Electric power source unit

Figure 3 Control box

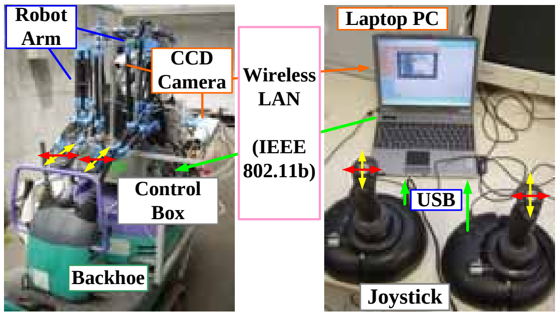


Figure 4 Remote control system

Generally, construction machinery such as a backhoe has two pairs of operation levers. One is to control a movement and the other is to control the arm of it. When an operator controls the construction machinery, one can choose and control any levers. According to the remote control, the operator is far from the machine, therefore it is difficult to move and control the robot arms precisely between two command levers. To make it easier to operate, we programmed the movement of changing the levers in advance by defining the trajectory of the movement. When an operator pushes a button on the joystick, the robot arms move to the lever from one side to another automatically. CCD cameras, which are helpful for remote control, are attached to the robot system. The vision from the CCD camera is provided to the operator through the wireless LAN.

EXPERIMENT

To confirm the availability of the system, we tried to apply the robot system to an ordinary backhoe. The backhoe used in the experiment was Grand Beetle 60SR (KOBELCO Construction Machinery Co., Ltd.) whose bucket size is 0.28 [m^3]. Some experiments were conducted including the movement of the construction machinery. First, we removed the sheet from the backhoe and set the control boxes. Then, the robot arms were mounted on the boxes. About 30 minutes were needed with two persons to set up the system. Figure 5 is the photo of the remote control system installed in the operating room of the backhoe.

Figure 5 Developed remote control system installed in the operating room of the backhoe

The contents of the experiment are as follows:

(a) First, the backhoe moves forward.
(b) Second, the robot arms change the levers.
(c) Third, simulated excavating actions (move the boom forward and the arm down) and the backhoe rotate about 90 degrees to the left.
(d) Simulated dumping actions (move the boom forward and open the bucket) are done and the backhoe rotates about 90 degrees to the right.
(e) The robot arms change the levers.
(f) Finally, the construction machinery moved backward.

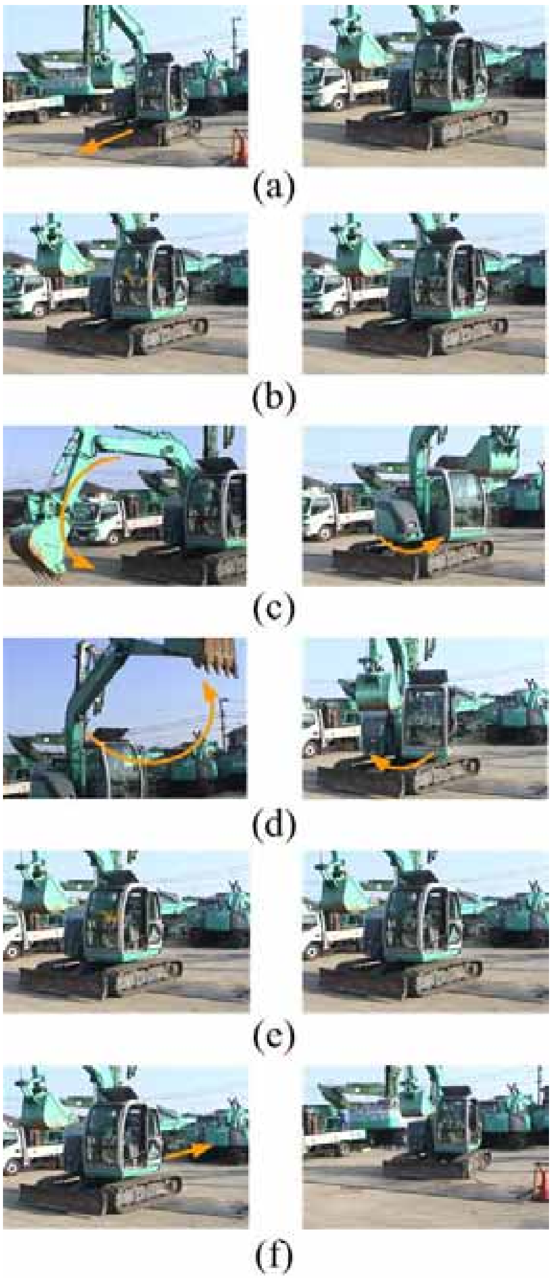


Figure 6 Remote control experiment

Table 2 Operation Time

Task in figure 6	(a)	(b)	(c)	(d)	(e)	(f)
Operation Time [s]	20	9	30	21	9	13

The remote control was conducted with the above-mentioned contents. Figure 6 shows the photos during the experiment and table 2 indicates the operation time of each task referred above. The operation was conducted smoothly and it took only 9 [s] for changing levers. The effectiveness was confirmed.

CONCLUSION

A lightweight remote control system of construction machinery was developed using pneumatic robot arms. We improved the system to realize the manipulation of an ordinary backhoe. Remote control experiments were conducted with an ordinary backhoe whose bucket size is 0.28 [m^3]. The availability of the remote control system was confirmed from the field experiments.

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