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# DEVELOPMENT OF REMOTE CONTROL SYSTEM FOR FIELD ROBOT

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**ABSTRACT**

Hydraulic excavators are the representative of field robot and have been used in various fields of construction. Since the excavator operates in the hazardous working circumstance, operators of excavator exposed in harmful environment. Therefore, hydraulic excavator automation and remote control system has been investigated to protect from the hazardous working environment. Remote control system of hydraulic excavator needs various equipments. In this paper, the method to construct the remote control system is proposed. The remote control system is consisted of a manual and auto mode. Manual mode controls a hydraulic cylinder as open loop control. and auto mode controls the end effecter of excavator using tracking control system. The efficiency of remote control system was evaluated through the field test.

**KEY WORDS**

Field Robot, Remote control, Excavator, Teleoperated Excavator, End Effecter Control

## INTRODUCTION

The hydraulic excavator of field robot has been used in various fields of construction. However, a number of the skilled operator is gradually reduced by the hazardous working environment. Thus, automation and remote control system of excavator have been investigated to protect the operation special situations that present safety or health risk to operators and to operate easily the skilled operator working [1].

We constructed the remote control system with various equipments. Which are remote operator station components and excavator side components, the models of these two parts will be presented to analyze. The simple diagram for the remote control system of excavator is shown in Figure 1

We applied to two control type of Remote control hydraulic excavator system, manual mode and auto mode. Manual mode is control method in the generality of case and auto mode is control of end effecter using inverse kinematics. [3, 4] Also, controller for tracking control system was applied the model reference adaptive controller. [5] The designed controller was implemented by using LabVIEW software.

the structure of the remote control excavator system is described. In the following section, the remote operating system procedure is presented and the efficiency of remote control system was evaluated through the experiments. Finally, concluding remarks are represented in last section.



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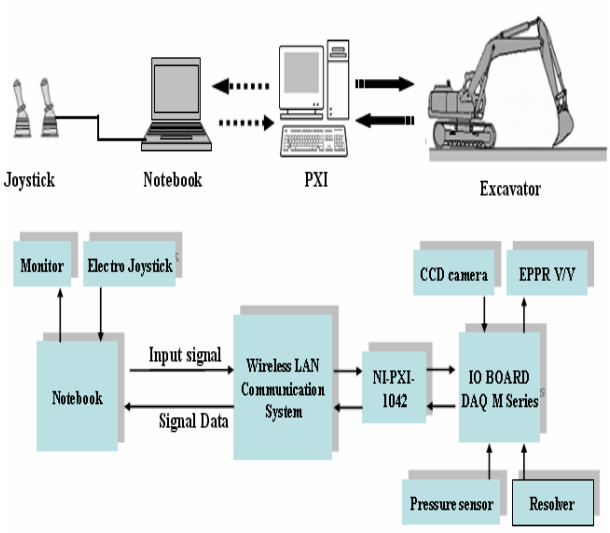


Figure 1 Remote control system

## FIELD ROBOT SYSTEM

Since a remote control hydraulic excavator system consists of remote operator station components and excavator side components, the models of these two parts will be presented to analyze.

### Excavator side components

Figure 2 Excavator side components

Figure 2 show the excavator side components. As shown in figure, the angle of boom, arm and bucket are measured through the resolver attached in each joint. Pressures of hydraulic cylinder are measured through the pressure sensor attached in each cylinder. Detections of obstacle are measured through the ultra sonic sensor. The environment around excavator displays in CCD camera. The angle of CCD camera is controlled Pan/Tilt motor. Each links of excavator are operated by EPPR V/V which controls pressure & flow valves of MCV. Using RF (Radio Frequency) communication, receive a joystick signal. The wireless LAN used in communication between remote operation and excavator. The inverter (dc to ac) is used for a source of electric power service. Computer interfacing for control the hydraulic excavator signal is set up using 6704 DAQ equipment manufactured by National Instrument Corp.
In the hydraulic excavator, which was purely mechanically actuated, had to be modified to enable electronic, drive-by-wire control of the various hydraulic circuits. The excavator is conventionally controlled using pressure-controlled joystick. These joystick, operate in the pilot system. These spool valves supply directional control of the main cylinder. For remote control electronic valves were placed in the pilot system. This system should change servo-valve or electro-proportional pressure valve (EPPR V/V) system. In this paper, used by electro-proportional pressure valve system which worked by electronic signal.

### Remote operator station components

Figure 3 show the remote operator station components of remote control hydraulic excavator system. As shown in figure, an operator of excavator works using a monitor which displays from a video camera and two electronic joysticks which controls real activity. Using RF communication, send a joystick signal. Using wireless LAN of notebook, receive a sensor signal of excavator and a vision signal. For Computer interfacing for control the remote operator signal is set up using 6036E DAQ equipment manufactured by National Instrument Corp.

Figure 3 Remote operator station components

## TRACKING CONTROL SYSTEM DESIGN

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The Remote controlled hydraulic excavator system is consisted of the manual and auto mode. Manual mode control the cylinder displacement through open loop control and auto mode control the end effect using feed back control system. Figure 4 show the manual mode and Figure 5 show the auto mode. The inverse kinematics coordinates are defined to detect the end effect of the developed excavator is represented in Figure 6

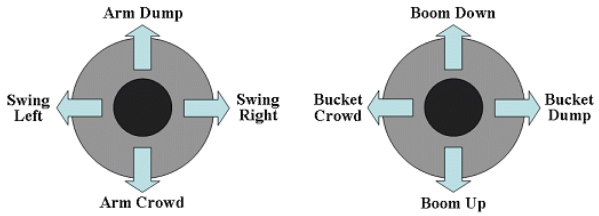

Figure 4 Operate of joysticks in Manual mode

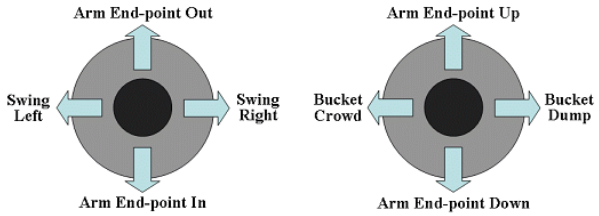

Figure 5 Operate of joysticks in Auto mode

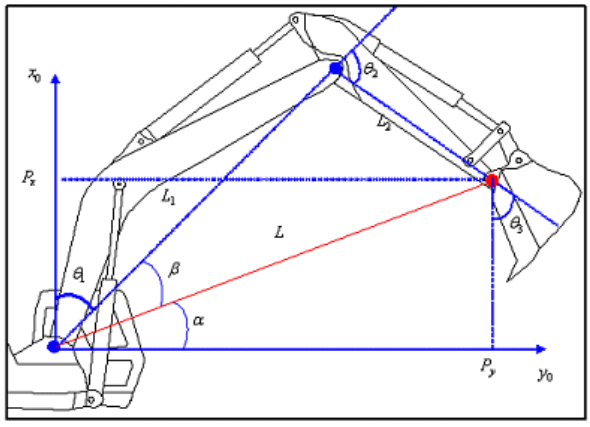

Figure 6 Coordinate of excavator system

The input signal of auto mode is position value of end effect of arm. The derivative of angle of each links using inverse kinematics is induced as

$$\cos\theta_2 = \frac{L_b^2 + L_a^2 - L^2}{2L_bL_a} \quad (1)$$

$$\sin\theta_2 = \sqrt{1-\cos\theta_2^2} \quad (2)$$

$$\theta_2 = a\tan 2\left(\sin\theta_2, \cos\theta_2\right) \quad (3)$$

$$\alpha = \tan^{-1}\left(\frac{P_x}{P_y}\right) \quad (4)$$

$$\beta = \cos^{-1}\left(\frac{L_b^2 + L^2 - L_a^2}{2L_bL}\right) \quad (5)$$

$$\theta_1 = \frac{\pi}{2} - \alpha - \beta \quad (6)$$

$$\gamma = \theta_1 + \theta_2 + \theta_3 \quad (7)$$

$$\theta_3 = \gamma - \theta_1 - \theta_2 \quad (8)$$

## EXPERIEMENT

In order to evaluate the tracking performance of the proposed end effecter control system using inverse kinematics. The system is corded Using LabVIEW software of National Instrument Corporation. Figure 7 is response of end effecter of arm for the horizontal signal. Figure 8 is response of boom angel. Figure 9 is response of arm angle. Figure 10 is error response of boom and arm.

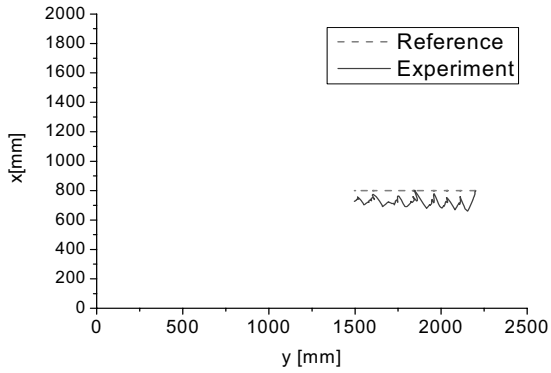

Figure 7 Response of end effecter

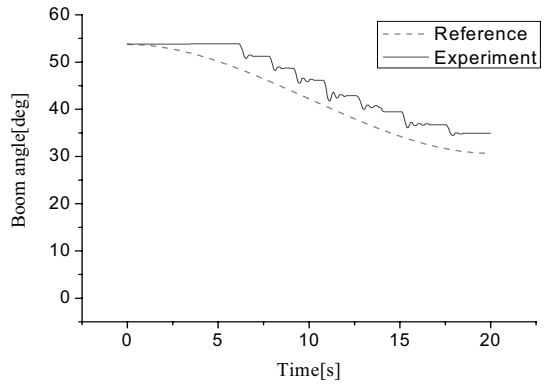

Figure 8 Response of boom angel


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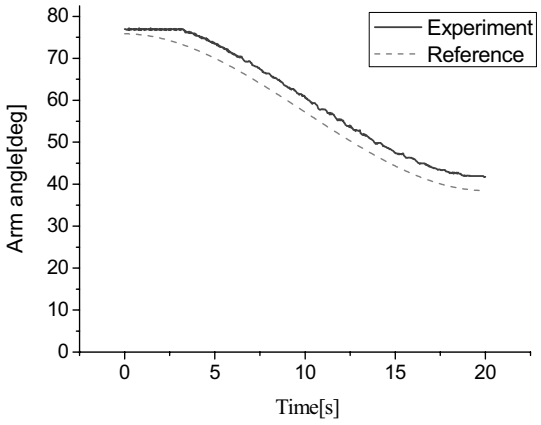


Figure 9 Response of end effect

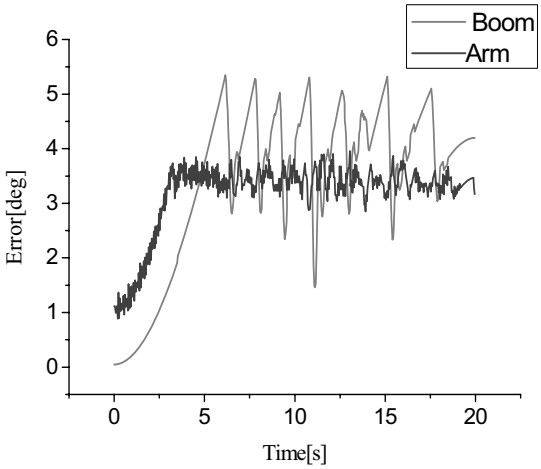


Figure 10 Response of end effect

## CONCLUTION

Hydraulic excavator system, i.e. one of famous field robots, can perform various works in the construction fields. We developed the remote control hydraulic exactor system. The developed system is possible to use in harmful working environment without getting on an operator. Therefore, operator of remote control excavator can work safety. Operator of auto mode of joysticks control can work easy. The remote control hydraulic excavator system was manufactured. The efficiency of system has been evaluated through the field test.

## ACKNOWLEDGEMENTS

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