REMOTELY OPERATED CONSTRUCTION ROBOT TELE-OPERATION COMMAND AND CONTROL SYSTEM

AQMAL HISYAM BIN HAMZAH

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

AQMAL HISYAM BIN HAMZAH   BACHELOR OF MECHANICAL ENG. (THERMAL-FLUID) (HONS.)   2015   UTeM

SUPERVISOR DECLARATION

"I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Thermal Fluid)"

Signature : ……

Supervisor : Dr. Ahmad Anas Bin Yusof

Date : ……

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AQMAL HISYAM BIN HAMZAH

This thesis is submitted to Faculty of Mechanical Engineering in partial fulfillment of the requirement for the award of Bachelor's Degree in Mechanical Engineering (Thermal Fluid)

Faculty of Mechanical Engineering
Universiti Teknikal Malaysia Melaka

JUNE 2015

DECLARATION

"I hereby declare that the work in this thesis is my own except for summaries and quotations which have been duly acknowledged."

Signature : ……

Author : Aqmal Hisyam Bin Hamzah

Date : ……

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ABSTRACT

The purpose of this study is to develop a remotely operated construction robot tele-operation command and control system. Robots have major impact in human life, human have trusted robot on doing various job from simple repetitive job to dangerous situation. A remote controlled robot have able to help human on solving life threatening situation that need experts to be at the specific location which in this case is human. Robot have high reliability and exceptional manoeuvrability if been controlled by human using remote controlled mechanism. Remote control system allow human to carried difficult task at several distance away. The system will be developed using master slave control system that will be used in the control of the hydraulic construction vehicle. Master slave system consist of two part, which is a controller as a master, and a mini-excavator as a slave. The remote controlled system will be controlling the movement of the excavator, the boom, arm, swing, and the bucket of the excavator. The control system will be developed using two method for the initial method which using the Arduino programming and the SKPS wireless transmitter. The remote controller project is developed by using PC base system that will process the data from the remote control and send output data to the slave system. This system uses Arduino coding logarithm that been developed in 'sketches', then been sent to the Arduino board by USB making the Arduino as the controller. The Arduino system that attached with wireless receiver will receive data from the remote control and process the data to be sent to the output digital pins. The remote controller system using Arduino as the controller has been successfully tested by actuating pneumatic cylinder in and out when the PS2 controller button is pressed.

ABSTRAK

Tujuan kajian ini adalah untuk membangunkan sebuah robot pembinaan tele-operasi yg menggunakan sistem perintah dan kawalan jauh. Robot mempunyai kesan yang amat besar dalam kehidupan manusia, manusia telah meletakkan kepercayan pada robot untuk melakukan pelbagai pekerjaan, dari pekerjaan berulang yg mudah kepada keadaan yg berbahaya. Robot kawalan jauh mampu menyelesaikan keadaan yg mengancam nyawa yang memerlukan pakar iaitu manusia untuk berada di lokasi yang tertentu. Robot mempunyai kebolehpercayaan yang tinggi dan pergerakan yang luar biasa jika dikawal manusia menggunakan mekanisma kawalan jauh. Sistem kawalan jauh membolehkan manusia untuk menjalankan tugas yang sikar dari jarak jauh. Sistem ini akan dibangunkan dengan menggunakan sistem kawalan "*Master Slave*" yang digunakan dalam kawalan kenderaan pembinaan hidraulik. Sistem "*Master Slave*" ini terdiri daripada dua iaitu pengawal sebagai *"Master"* dan lengan hidraulik kenderaan pembinaan sebagai "*Slave*". Sistem kawalan jauh ini akan mengawal pergerakan penggali, lengan, ayunan dan baldi penggali. Sistem kawalan akan dibangunkan dengan menggunakan dua kaedah iaitu untuk kaedah awal ia menggunakan pengaturcaraan Arduino dan pemancar tanpa wayar SKPS. Projek kawalan jauh ini dibangunkan dengan menggunakan sistem asas komputer yang memproses data dari alat kawalan jauh dan menghantar data kepada sistem hidraulik. Sistem ini menggunakan logaritma pengekodan Arduino yang dibangunkan dalam 'sketches', kemudian dihantar ke papan Arduino menggunakan USB menjadikan Arduino sebagai pengawal. Sistem Arduino yang dipasang dengan penerima tanpa wayar akan menerima data dari alat kawalan jauh dan memproses data dan akan dihantar ke pin digital. Sistem kawalan jauh menggunakan Arduino sebagai alat pengawal telah berjaya diuji menggunakan penggerak silinder pneumatik melalui operasi masuk dan keluar apabila butang kawalan jauh PS2 ditekan.

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LIST OF ABBREVIATIONS

TEODOR	=	Telerob Explosive Ordnance Disposal and Observation Robot
ROV	=	Remotely Operated Vehicle
DOF	=	Degree of Freedom
LAN	=	Local Area Network
IDE	=	Integrated Development Environment
GPS	=	Global Positioning System
LCD	=	Liquid Crystal Displays
PLC	=	Programmable Logic Controller
IEC	=	International Electro technical Commission
DAC	=	Digital to Analog Converter
USB	=	Universal Serial Bus
PC	=	Personal Computer
USB	=	Universal Serial Bus
LED	=	Light Emitting Diode
PCB	=	Printed Circuit Board

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CHAPTER 1

INTRODUCTION

1.0 INTRODUCTION

This study covers on the development of a remote-controlled system for operated construction robot tele-operation using command and control system. This chapter will be focusing on the background of construction robot tele-operation, objective, scopes and the initial problem detection during this study.

1.1 BACKGROUND

Robot have been a major achievement in human history. From time to time robot have evolve from a simple mechanism of waving to robot who can dance. Robot is consider the greatest single attempt of mankind to produce an artificial, sentient being. Nowadays, manufacturers are making robotics increasingly available. One obvious advantage of robot is, it can do repetitive actions or jobs that considered too dangerous for humans. A robot is capability fit for going into building that have been set up with explosive material. Robots are also used in factories to build cars, electronics equipment and even used in candy bar factories. Robots also now been used in medicines, capable in military tactics, for identifying and finding objects underwater

and the most sophisticated is using robot for planets exploration. People who have lost arms and legs have implementing robotic technology to gain their life back.

Remote controlled robot is another perfect robotic mechanism in order to get the hand to hand feel between the user and robot. A robot that equipped with a remote controlled mechanism solely focusses on using during dangerous situation to humans such as fire rescue, hurricanes disaster, explosions and deep sea exploration that requires the more expert individuals to be at the specific location which in this case is human.

For example a remote-controlled, heavy-duty robot TEODOR (Telerob Explosive Ordnance Disposal and Observation Robot) is designed and manufactured by Telerob, a business unit of Cobham Unmanned Systems. This robot is capable in enhanced bomb disposal situations and been used by Explosive Ordnance Disposal (EOD) teams. The robot that been controlled by human using remote controlled have high reliability and exceptional manoeuvrability. The robot can identify and disarm booby traps, fireworks, improvised explosives devices and other dangerous objects in closed areas, buildings and vehicles. It also can perform surveillance, investigations and monitoring of object in abnormally dangerous conditions. The TEODOR bomb disposal robot system have been work together with military and law enforcement unit of more than 41 countries worldwide (Kable., 2014)

Based on the example, it have proven that robot is capable to do a variety of work or task that been instructed from the human and even can surpass human capabilities at certain limitations. The tele-operation system is intended to allow human to carried difficult task at several distance away, a perfect example is organize excavation project on collecting soil in a high radiation containment area. Human cannot possible do that due to the exposed of high emissivity of radiation, thus a remote controlled robot used is suitable in that type of exposure. A remote controlled mechanism can be controlled easily without hesitation and have the flexibility to perform various task at different places. Human must be able to interact well with its specified controlled robot in other to complete the task successfully.

1.2 OBJECTIVE

The research aims is in developing a command and control system for controlling a mini excavator from afar using a remote control mechanism that have been programmed using Arduino Programming. The goal of this research is to develop ways to program a controller connection in order to move hydraulic actuator that uses to control the movement of levers on top of the mini excavator.

1.3 SCOPE

The scope of this research is to develop a coding logarithm using Arduino Programming in order to move the mini excavator. By implementing Arduino Programming, another scope of this research is to move and control the excavator arm using a remote command and control system.

1.4 PROBLEM STATEMENT

Nowadays most excavator belong to master-slave type. The disadvantage of this system is that it requires the operator to be well trained, fully skilled and needed to be in the chair of the excavator. Most of Remotely Operated Vehicle (ROV) to date use a Fuzzy PD controller as their control logarithm whereas intuitive fuzzy design does not clearly outperform well-tuned conventional controllers, furthermore it has been limited success in precise motion control if disturb by unknown factors (Albertros et al., 1998). Excavator arm used in construction or even saving lives, in order to do its specific task, an operator is needed at the excavator indirectly exposed hazardous elements to the operator itself.

CHAPTER 2

LITERATURE REVIEW

2.0 INTRODUCTION TO TELE-OPERATED VEHICLE

Tele operation means simply to operate a vehicle or a system over a distance. Distance can vary form tens of centimetres or in micro manipulation to millions of kilometres which exceed for space applications. Tele operation as a part of robotics has a long and rich history. Nowadays many fields of science and economy, such as medicine, industry, nuclear power stations and army. Tele operation have evolved into more complex and integrating more robots adaptations, mechanisms, control systems and many other devices. These are the reasons that distribution of control signals between such multiple tele operation signals is important and compelling (Farkhatdinov, I. and Ryu, J.H., 2008).

There are numerous investigations were done using the adaptations of tele operation. Remote control and coordination of mobile manipulators was studied (Seraji, H., 1998). Controllers to distribute control signal and coordinate multi-robot systems is designed by the researchers. Locomotion of a mobile manipulator coordinating have been presented in (Chung. J.H., 1998). Investigations in control of cooperating mobile robots was also described in (Thomas. G., 2000). In many the cases human was giving direct motion commands and they were distributed in multi-

object system. Intelligence of humans plays significant role in control of multiple-object systems.

Human's intelligence and skills can be used in tele operation system in order to certificate safety and high quality of robotic system. In making decisions during tele operation of several object quickly, humans solely rely upon high intelligence and well developed sensory system. It is important to design friendly and intuitive human-robot interface in order to make the remote control easier (Farkhatdinov, I. and Ryu, J.H., 2008).

For this research, tele operation concept have been implemented in means to control a mini excavator. Mini excavator used in this research is a type of construction vehicle that is used in isolated and small areas of project. This mini excavator can be used only by one individual. The person who in charge controlling the excavator must use the lever on top of the excavator to move the direction of the arm and also the excavator itself.

2.1 CONSTRUCTION VEHICLE

According to Occupational Health and Safety Act, 1993 under the code of Construction Regulation, 2003, "Construction vehicle" means a vehicle that been used for means of conveyance for transporting persons or material or both such persons and material, as the case may be, both on and off the construction site for the purposes of performing construction work. Particularly, construction vehicle is design for carrying out heavy duty construction such as soil operations, heavy lifting, and also use during as emergency. It is usually known as heavy machines, heavy trucks, engineering equipment, construction equipment, heavy hydraulics or heavy vehicles.

2.2.1 Excavator as Construction Vehicle.

Excavators used in construction site and their role have been increasingly extended due to their high applicability and economic feasibility for many types of works and become complicated machine of high technologies. 60% of the entire

production in heavy construction equipment have been covered by these excavators. And will be expected that the percentage of excavators in industrial site will be increased (Moon, S. M. et al., 2009).

An excavator uses hydraulics or a wire rope pulley system to dig holes or trenches and is, therefore, of the called a digger. Bobcats and backhoes are also called excavators. An excavators has a long boom arm and a cab that is mounted on a pivot. The boom is connected at an elbow to a stick that holds the bucket. Attachment of the 'bucket' can be replaced with different attachment depending on the condition of the job site. The cab can pivot in a full circle. Because 360 degree rotation is available, another name for an excavator is a 360 digger (Kevin, F. and Stonecypher, L., 2009).

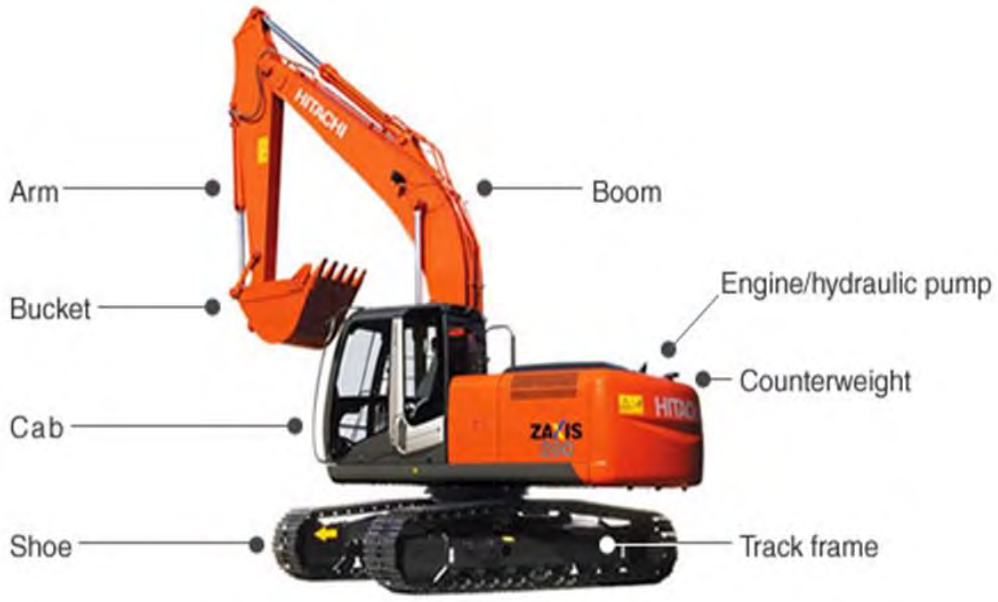

Figure 2.1: Component of excavator
(Source: Hitachi contsruction machinery, 2010)

2.2.2 Excavator Component

Undercarriage that includes the tracks, track frame, blade and the final drive are the fundamental mechanism of an excavator. The final drive has a hydraulic motor and gears that provide drive to the tracks. The operators cabin, engine, counterweights, hydraulic and fuel tanks are attached to the undercarriage, enabling the excavator to

swing 360 degree without any interruption. The excavator engine main function is to drive the hydraulic pumps that provide oil at a high pressure to the slew motor, rams, track motors, and several accessories. Usually, the boom can move only up and down, or in addition also shift towards the left and right of the machine. The boom end is attached with an arm that imparts the force for digging into the ground. At the arm end, a bucket is attached for carrying the soil. Additionally, there are numerous other categories of attachments with the excavator that are used for boring, crushing, lifting, and ripping (Orfano, F. and Swagatam, 2009).

An excavator arm can be equipped with a couple of hydraulic cylinder, this type of excavator usually known as a hydraulic excavator. A hydraulic arm consist of a bucket and a boom. Hydraulic cylinder in excavator arm usually located on top of the arm. A boom is where the transaction of energy between the hydraulic onto the bucket happen. The actual excavator arms is moving like a parts human hand movement that move on the wrist and the elbow. Figure 2.2 below shows a sample of excavator arm (Source: Open source ecology, 2013)

Figure 2.2: Sample of excavator arm
(Source: Open source ecology, 2013)

Other main parts of an excavator is hydraulic cylinder. Hydraulic cylinders is used to move the arm of the excavator, it work by extracting energy from the fluid and convert it to mechanical energy to perform useful work. Hydraulic cylinders are also called linear actuators can extend and retract a piston rod to provide a push or pull force to drive the external load along a straight-line path. In an excavator, a hydraulic cylinder are used to drive the boom which attached and connect to the bucket part (Esposito, A. 2009). Inside a hydraulic cylinder it consist of a rod and a piston, the piston is positioned by the end of the cylinder and also act to prevent the oil to leak. Higher pressure of oil in the cylinder will allow the piston rode to move the arms of the excavator (Haga et al., 2001). The simplest type of hydraulic cylinder is the single-acting cylinder. It consist of a piston inside a cylindrical housing called a barrel. Attached to one end of the piston is a rod, which extends outside one end of the cylinder. At the other end is a port for the entrance and exit of oil. Different from hydraulic cylinder used in excavator, it uses the mechanism of double-acting cylinder. Double-acting cylinder can be extended and retracted hydraulically. Thus, an output force can be applied in two directions which is extension and retraction (Esposito, A. 2009). Figure 2.3 shows a sample of hydraulic cylinder (Flemings, 2012).

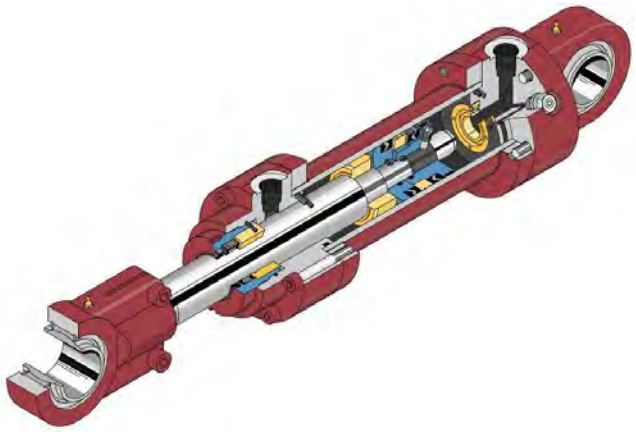

Figure 2.3: Sample of excavator hydraulic cylinder with cross-sectional view (Source: Flemings, 2012)

Another crucial part in an excavator is the boom swing. The purpose of the boom swing is for offset digging around obstacles or along foundations, walls, and forms. Another use is for moving in areas that are too narrow for cab rotation (Vikrant, 2008). This swing motion involves an outside race, the internal race, ball bearing and