MODELING OF ROBOTIC DRIVER FOR TELE-OPERATED SYSTEM OF A HALF SCALED ARMORED VEHICLE

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ABSTRACT

Soldiers play a significant role in contributing a security environment to a country from enemies' threat. However, in conducting their military operations, the soldiers are prone to many challenges that might endanger their lives. Therefore, to reduce the harm risk in military operations, this research is focus on the development of robotic driver system which consists of throttling, braking and steering mechanisms that will be used for tele-operated system of half scale armored vehicle. In developing the robotic driver system, at the initial stage, a design of robotic driver system is proposed. Then, the robotic driver system is modelled by using MATLAB Simulink software with a non-parametric model approach by using a 2^{nd} order transfer function. Besides, a position tracking control of robotic driver system has been conducted using Software-In-Loop simulation (SILS) and Hardware-In-Loop simulation (HILS). On the other hand, a vehicle model is developed by considering lateral and longitudinal motions. This vehicle model will act as a platform to test the robotic driver system performance on various driving scenario. Moreover, a simple PID controller of this robotic driver system has been proposed to get the best performance. The results obtained from HILS will be validated with the SILS of robotic driver system. The results show that for throttling and braking validation processes, there are minor deviation error of vehicle speed which are around 16% and 13% respectively. Moreover, an error of 10% was recorded for the yaw rate of the vehicle from the steering system of robotic driver.

ABSTRAK

Tentera memainkan peranan yang penting dalam menyumbang keselamatan dari ancaman musuh. Walaubagaimanpun, dalam menjalankan operasi ketenteraan mereka, tentera terdedah kepada pelbagai cabaran yang mungkin menjejaskan keselamatan mereka. Oleh itu, untuk mengurangkan risiko bahaya dalam operasi ketenteraan, kajian ini akan memberi tumpuan kepada pembangunan sistem robot panduan yang terdiri daripada mekanisma pendikit, brek dan stereng yang akan digunakan untuk sistem tele-pengendalian kenderaan perisai separuh besaran. Dalam membangunkan sistem robot panduan, pada peringkat awal, reka bentuk sistem robot panduan telah dicadangkan. Kemudian, sistem robot panduan itu dimodelkan dengan menggunakan perisian MATLAB Simulink berdasarkan pendekatan model bukan prametrik dengan menggunakan perintah 2 rangkap pindah. Selain itu, pengesanan kedudukan sistem robot panduan akan dijalankan melalui simulasi SILS dan HILS. Selepas itu, model kenderaan dibangunkan dengan mengambil kira pergerakan menegak dan pergerakan melintang. Model kenderaan ini akan bertindak sebagai platform untuk menguji prestasi robot dalam senario pemanduan yang pelbagai. Selain itu, kawalan mudah untuk sistem robot panduan ini juga dicadangkan dengan menggunakan PID kawalan untuk mendapatkan prestasi yang terbaik. Keputusan yang diperolehi daripada HILS akan disahkan dengan keputusan SILS sistem robot panduan. Keputusan yang diperolehi menunjukkan bahawa bagi pengesahan pendikit dan brek, terdapat ralat pada kelajuan kenderaan sekitar 16% dan 13%. Manakala kesilapan 10% dicatatkan untuk kadar rewang kenderaan untuk stereng bagi sistem robot panduan.

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APPROVAL

I certify that an Examination Committee has met on **28th APRIL 2016** to conduct the final examination of **MUHAMMAD AKHIMULLAH BIN SUBARI** on his degree entitled '**MODELING OF ROBOTIC DRIVER FOR TELE-OPERATED SYSTEM OF A HALF SCALED ARMORED VEHICLE**'. The committee recommends that the student be awarded the degree of Master of Science (Mechanical Engineering).

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DECLARATION OF THESIS

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LIST OF ABBREVIATIONS

ROV	Remotely operated vehicle
RPV	Remotely piloted vehicle
UAV	Unmanned air vehicle
UGV	Unmanned ground vehicle
ABS	Antilock braking system
ECU	Electric control unit
DOF	Degree of freedom
HILS	Hardware-In-Loop simulation
SILS	Software-in-loop simulation
PID	Proportional-Integral-Derivatives
m	Mass of body
g	Gravitational acceleration
C	Shape factor
B	Stiffness factor
D	Peak value
E	Curvature factor
$\dot{v}$	Vehicle acceleration
h	Height of vehicle from c.g.
θ	Road inclination from normal
F_x	Lateral force
F_y	Longitudinal force

M_z	Aligning moment
∂	Steering angle
I_z	Moment inertia about z-axis
t	Wheel track of the vehicle
T_a	Torque delivered by the engine to front wheel
T_b	Torque applied to each wheel due to brake
ω_{ij}	Wheel angular speed
C_f	Viscous friction coefficient
l_f	Distance of front axle to the c.g. of the vehicle
l_r	Distance of rear axle to the c.g. of the vehicle
a_x	Longitudinal acceleration
a_y	Lateral acceleration

CHAPTER 1

INTRODUCTION

1.1 Introduction

Tele-operation is defined as a working mechanism using a machine or robot which is remotely controlled from a distance. Normally, the term tele-operation is describe as the direct and continuous human control of the tele-operator which is also commonly referred as tele-robotics (Sheridan, 1992). Furthermore, tele-robotics can be referred as the remote control of a robot, known as a tele-chair. Signals are transmitted to the tele-chair and the feedback signal to the human once the mobile robot responds to the instruction given by the human (Rouse, 2011). At the end of 1940, the history of tele-operation has been evolved where salve manipulator for the chemical and nuclear material handling had been developed in the Argonne National Laboratory. Then, adoption of video technology and force feedback to the tele-operation allowed the first telepresence system became reality.

In recent years, an adoption of these robotic technologies in the field of space exploration, search and rescue, national defense, entertainment, police special weapons and tactics operation, health care and personal assistance have been widely applied (Chen *et. al.,* 2010). Firstly, this system has been used in medical surgery by developing robotized medical tele-echography (Courreges *et. al.,* 2005). Then, tele-operated also has been used for space exploration using robot satellite (Oda, 2000) such as Lunokhod 2 in 1973 (Severny *et. al.,* 1975). Nowadays, most of the researchers involved in the development of the vehicle tele-operator system. Vehicle tele-operation can be defined as the operating system for a vehicle at a distance from the human interaction. Tele-operation is often implemented in 'difficult-to-reach' environment in order to improve the task efficiency and to reduce human risk (Kelley, 1968).

Since the development of the tele-operation occurred over different periods and environments, vehicle tele-operation is referred as a numerous term such as ROV (Remotely Operated Vehicle). ROV is a heavy vehicle technology by developing humanoid robots to drive a lift truck (Hasunuma *et. al.,* 2002). Other than ROV, another vehicle tele-operation is also known as RPV (Remotely Piloted Vehicle), UAV (Unmanned Air Vehicle) and UGV (Unmanned Ground Vehicle). The ROV and RPV refer to the tele-operated systems, while UAV and UGV, both consist of tele-operated autonomous systems. Moreover, this technology has been applied in military application in order to develop UAV and UGV used tele-operated system (Fleming, 2003).

Nowadays, the tele-operated vehicle is needed in military operation to give better security to the soldiers during battlefield (Parker & Howard, 2009). It also widely used for mine clearance at nations devastated by armed conflicts (Debenest. P. *et. al.,* 2005).

Besides, the tele-operated vehicle might be used to transport equipment, carry some weapons, collect intelligent information and detect the threats (Czapla *et. al.,* 2013). A lot of research have been carried out such as autonomous military UGV (Davis, 2012), humanoid robot (Jentsch *et. al.,* 2004) and tele-operated military UGV (Jessie Y C Chen, 2010) in order to reduce human intervention directly during a war.

Meanwhile, an armored vehicle system can be divided into two category which are known as wheeled and tracked armored vehicles (Chen *et. al.,* 2013). P. Horback (1998) had discussed the advantages and disadvantages between these two armored vehicle where tracked armored vehicle has a better mission travel time off-road and suitable for all weather. However, it has a bigger size which can be easily targeted by the enemy. Then, the wheeled armored vehicle has an ability to attain fast road speed on-road but acquired longer time for off-road. It also more vulnerable to small arms, grenade and mines with great in agility and not easily targeted by enemy.

Besides, both of the armored vehicles has a capabilities to operate during offensive and defensive tactical due to unique combination of firepower, mobility and protection (R. Steeb *et. al.,* 1991). Despite all of this criteria that exist on armored vehicle, the fundamental theory on how to drive the armored vehicle were similar. It required a steering mechanism for maneuvering, throttling mechanism to accelerate and braking mechanism to halt the armored vehicle from motion.

1.2 Problem Statement

During battlefield, most of the soldiers are directly exposed their life in danger zone since they become one of the targets by their enemies. The soldiers might get injured or severely risk their life while driving the armored vehicle to launch the firing attack towards the enemy in the battlefield. However, the soldiers need to be protected in order to reduce the huge losses. Hence, a non-direct involvement of soldier in conducting the armored vehicle or gun mechanism need to be developed as a solution to overcome this problem. Therefore, an unmanned ground vehicle (UGV) is developed to reduce the loss risk of the soldiers in battlefield.

An unmanned ground vehicle (UGV) is known as vehicle that operates while in contact with the ground and without an on-board human presence in the vehicle. UGV can be used in many conditions where it may be inconvenient, dangerous, or impossible to be handled by a human operator. The UGV mainly consists of a robotic driver which is used to operate the armored vehicle automatically. Besides, it also has a control room and wireless communication for the human operator and transferring the input given into the robotic driver system. Therefore, in this study, a new mechanism of a robotic driver will be developed in this study. This robotic driver will allow steering, throttle and brake to be operated automatically by the human operator in a different location.

1.3 Background of the Study

For the vehicle to be fully operated, there are three major driving mechanisms that need to be considered namely steering mechanism for wheel rotation, throttling mechanism to control the acceleration of the vehicle and braking mechanism to halt the vehicle from motion. These three mechanisms are considered the major components to drive and control a vehicle. By referring to previous research works such as modification of vehicle handling characteristics via steer-by-wire (Yih & Gerdes, 2005), control strategies of steer-by-wire system (Jianmin *et. al.,* 2010) and how to make steer-by-wire feel like power steering (Odenthal *et. al.,* 2002), steering mechanism has evolved from a conventional to the steer-by-wire system.

However, most of the vehicles are still using conventional steering compared to the steer-by-wire method. Conventional method can be divided by two categories which are rack-and-pinion and pitman arm steering systems. A rack-and-pinion steering system consists of gear set that enclosed in a metal tube, with each end of the rack protruding from the tube. A rod, called a tie rod**,** connects to each end of the rack where the pinion gear is attached to the steering shaft as shown in Figure 1.1. The rack-and-pinion gear set is used to convert the rotational motion of the steering wheel to the linear motion to drive the rack mechanism either to the left or right position according to the steering wheel input.