UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DESIGN AND DEVELOPMENT OF POLE CLIMBING ROBOT

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Electrical Engineering Technology
(Industrial Automation and Robotics) with Honours

by

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BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Electrical Engineering Technology (Industrial Automation and Robotics) with Honours. The member of the supervisory is as follow:

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(Madiha Bte Zahari)

ABSTRACT

Typical high- risk tasks in agriculture, forestry and architecture such as maintaining high-voltage wires on high poles, inspecting, maintaining street lamp on poles, assembling and disassembling frames for building construction and high truss architectures are still required human being to complete the tasks. Sometimes human not able to bring enough tools or equipment when they are doing the high-risk tasks. Therefore, pole climbing robots are useful in helping humans to carrying out the tools. This project is aim to design a pole climbing robot and develop motion algorithm for pole climbing robot to climb poles. Pole climbing robot is a mobile robot that can climb pole and help human to delivery enough tools or equipment at construction side or dangerous place. The design of the body and the gripper are inspired by climbing motion of inchworm and drawn using Solidwork. The body of pole climbing robot is designed with multiple revolute joint by using T-types and I-types joint modules. The end effectors of the robot are two grippers, which are mounted at the end of the body. Each gripper is driven by servo motor and had been develop 4-bar linkage mechanism. Consequently, the pole climbing robot not only can be climbing poles, but also to grasp and delivery object during climbing pole. In near future, the climbing gait of pole climbing robot can be improved and obtain more complicate, including transfer between two poles.

ABSTRAK

Biasanya, kerja berisiko tinggi dalam sektor pertanian, perhutanan dan seni bina seperti menyelenggara kabel voltan tinggi pada tiang yang tinggi, memeriksa, menyelengara lampu jalan pada tiang, memasang dan menanggal bingkai untuk binaan bangunan dan struktur kekuda masih memerlukan manusia untuk menyelesaikan tugas. Kadang-kala, manusia tidak mampu untuk membawa peralatan atau perkakasan yang cukup semasa menjalankan tugas di tempat tinggi. Oleh itu, robot memanjat tiang sangat berguna dalam membantu manusia untuk mengambil peralatan yang jauh ataupun peralatan yang berisiko jika dibawa oleh manusia. Projek ini bertujuan untuk mereka bentuk robot memanjat tiang dan membangunkan algoritma gerakan untuk robot memanjat tiang mendaki tiang. Robot memanjat tiang ialah sebuah robot bergerak yang boleh memanjat tiang dan membantu manusia untuk menghantar peralatan atau perkakasan yang mencukupi di tapak pembinaan atau tempat yang merbahaya. Inspirasi dari gerakan memanjat oleh inchworm, reka bentuk badan robot dan penggenggam dilukis mengunakan perisian Solidworks. Reka bentuk badan robot memanjat tiang direka dengan pelbagai sendi yang berputar mengunakan modul jenis-T dan modul jenis-I. Pengakhiran robot adalah pengenggam yang mana dipasangan pada hujung kedua-dua belah badan. Setiap pengenggam di pacu oleh motor servo dan digabung mengunakan mekanisma 4-bar. Oleh yang demikian, robot memanjat tiang bukan sahaja boleh memanjat tiang, tetapi juga boleh mengenggam dan menghantar objek semasa memanjat tiang. Untuk masa akan datang, gaya memanjat tiang bagi robot ini boleh diperbaiki dan menjadi lebih rumit termasuk pemindahan antara dua tiang.

DEDICATIONS

To my beloved parents

To my beloved family members

To my trusty friends

ACKNOWLEDGMENTS

First and foremost, I thank to for his supervision, Madam Madiha Bte Zahari encouragement, suggestions and trusted throughout the duration of this project. Without him, I can lost and flee away from the tract I should follow. In addition, I also would like to say thank to my Co-supervisor, Mr Aminurrashid bin Noordin, who are gave me many guidelines and best suggestion to finish this report. In addition, I also wanna to appreciate to the lab technicians, Mr Muhiddin and Mr Azhan for helping to print the chassis of this project.

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LIST OF SYMBOLS AND ABBREVIATIONS

3D	=	Three Dimension
ABS	=	Acrylonitrile Butadiene Styrene
AC		Alternating Current
AFH		Adaptive Frequency Hopping Feature
AI	=	Analog Input
CAN	=	Controller Area Network
CMOS	=	Complementary Metal-Oxide Semiconductor
CSR	=	Cambridge Silicon Radio
DC	=	Direct Current
DOF	=	Degree Of Freedom
EEPROM	=	Electrically Erasable Programmable Read-Only Memory
EDR	=	Enhanced Data Rate
FSR	=	Force-Sensing Resistor
IC	=	Integrated Circuit
IDE	=	Integrated Development Environment
I/O	=	Input/ Output
IR	=	Infrared
ISM		Industrial, Scientific And Medical
LED	=	Light-Emitting Diode
MTG	=	Transformation Matrix

PC	=	Personal Computer
PCR	=	Pole Climbing Robot
PID	=	Proportional–Integral–Derivative
PVC	=	Polyvinyl Chloride
PWM	=	Pulse Width Modulation
RAM	=	Random-Access Memory
RC	=	Radio Controlled
RiSE	=	Rapid Pole Climbing With A Quadrupedal Robot
SPP	=	Serial Port Protocol
SRAM	=	Static Random-Access Memory
USB	=	Universal Serial Bus
UT-PCR	=	University Of Tehran-Pole Climbing Robot

CHAPTER 1
INTRODUCTION

A climbing robot is a mobile platform that can help humans to transport a tool to a hazardous or inaccessible place. Pole climbing robot is one of climbing robot that can help humans to climb pole or truss to deliver a tool or equipment at construction side or dangerous place.

1.0 Background

Pole climbing robots have become an interesting area for research in the last few years. Pole Climbing Robots (PCR) forms a branch of climbing robots which are usually considered for inspection and maintenance of structures with circular cross section. Based on Stewart-Gough's platform, PCR is used to climb ahead tubular structures with using extra special devices (Y. Wang, 2011). Without using extra devices, the PCRs cannot dispatch between poles and trusses. The locomotion capability of the robot is to be enriching in the following two manners:

i) The potential to climb many objects including poles, shaft and trusses, and

ii) The ability of shipping between various objects to climb (for example,

From poles to branches).

Although the locomotion can be fulfilled by PCR, but some PCRs also lack of manipulation function and climbing mechanism. The climb mechanisms for a robot can be categorized as static and dynamic climbing. For static climbing, holding and body- expanding actions are exchanged, like climbing motion of an inchworm. This kind of climbing robot frequently requires two practical grippers and can be used to climb across a branch of poles or trusses. For dynamic climbing, holding and

climbing actions occur at once. This kind of climbing resolve in continuous motion, therefore it can be utilized in applications of pole climbing robot.

However the process has been made in the development of PCR that can climb pole, their capabilities and functionalities can be further developed for operative applications. The following characteristics are desired for PCR included:

i) Orientation to sort differentiation of the climbing media.

ii) Orientation to various types of the climbing media.

iii) Potential to defeat boundary on the climbing media.

iv) Capability of shifting between separate objects.

v) Ability to hold and bring objects while climbing on a pole.

Nowadays, pole climbing robot was designed and developed by many researchers with several purposes. To develop a best PCR for construction site, the design of the robot is really important in order to ensure the robot able to climb all size of pole or trusses and manipulate its function when it is climbing pole in construction side. The size and geometry of the robot should be considered make sure it is able to climb some bend and T-junction of the pole or trusses. In addition, the type of material used for the robot also needed to be considered.

1.1 Project Objectives

The objectives of this project are as follows:

- To design a pole climbing robot.
- To develop motion algorithm for pole climbing robot to climb poles.
- To study the stability and kinematic motion of the pole climbing robot

1.2 Scopes

By narrowing the needs for this project, a few guidelines are proposed to ensure that this project will achieve its objectives. The scopes covered for this project are:

i. Two grippers with 4-bar linkage mechanism are mounted at both end of the pole climbing robot, as the design of the pole climbing robot.

ii. The design is inspired by the motion of inchworm.

iii. Using ABS plastic type materials as the body of pole climbing robot.

iv. Using Arduino Uno as a controller to manipulate the motion of the pole climbing robot.

v. The motion of the PCR will be motivated by the recognition of climbing actions of inchworm.

vi. Using five servo motor to control the movement of the pole climbing robot, which two motor control the gripper of the robot to climb the pole and stabilize the body of the robot when its operate. Another three motor is used to control the movement of the body of robot.

1.3 Problem Statement

Robots have found in many fields, such as heavy industrial, construction, military, medicine, education, entertainment, homing and social services. Typical high- rise tasks in forestry and architecture such as maintaining high-voltage wires on high poles, inspecting, maintaining street lamp on poles, assembling and disassembling frames for building construction, and high truss architectures are still required human being to complete the tasks. It is critical and importunate to acquire a climbing robot to support human being from those heavy and dangerous duties. Climbing robots are useful when a task requires the use of far reaching tools or is tools that risky if carried out by humans.

The motion of PCR while climbing is the one should be considered as problems associated with navigation on pole or trusses. As it can be seen the piping includes a range of cross section diameters, bends of 90° and 45°, T-junctions, step changes on cross section size, and also obstacles with large diameters. Therefore, the manipulation robot is needed to overcome step changes in the cross section and operate in a range of cross section diameters without using an extra arm.

Even though the design and the motion of PCR which can be affect the performance of robot, the stability of the robot is play important role and the robot should be stable enough while it climbing on a pole. The most significant thing should be considered is the stability of the robot while it performing the function. Therefore, the stability of the robot should be analysis after prototyping the PCR.

Based on the movement of PCR, the kinematic algorithm of the robot needed to be analysis with the theory of industrial robotics and capable to perform climbing pole and its function. All the consideration while develop this project will provide many advantages to the robot capability. Analysis the kinematic algorithms and the stability can make the improvement and novelty for the PCR will ensure the robot gives best performance.

CHAPTER 2
LITERATURE REVIEW

This chapter had been discussed about the literature review of the earlier research. It is consists of the products that have been developed by institutions before this project. This chapter contains the theory and implementation of the components, equipment and programming language used in the previous project.

2.0 Pole Climbing Robot

M. N. Ahmadabadi (2010) introduced three UT-PCR (University of Tehran Pole Climbing Robots). These three robots intend to reduce the complicate and increasing the payload of the robots. The first robot, UT-PCR1 inspired from animal pole climbers such as Pandas or Koala Bears, which hold a pole or tree for climbing, as shown in Figure 2.1(a). Figure 2.1(b) is shown that the UT-PCR2 proposed to decrease the complexity of the robot and it aimed design is inspired from human climbers, which use a strap and their weight to stably and steady climb poles. The major advantage of this design is in its ability of bring high payloads and its natural stability. Furthermore, it has a simple design, a light structure, simple mechanism, and fast climbing speed in addition to a simple controller. UT-PCR3 is similar to UT-PCR2, but uses a track instead of a wheel to increase its contact with poles and increase its stability. Accordingly, UT-PCR-3 is more compact than its ancestors as shown in Figure 2.1(c).

(a) UT-PCR1 (b) UT-PCR2 (c) UT-PCR3

Figure 2.1: Three design of UT-PCR. (M. N. Ahmadabadi,2010)

M. Tavakoli (2008) stated that the pole climbing robot can be designed with minimum degrees of freedom, such as 3D Climber as shown in Figure 2.2. 3D Climber is a climbing robot with the proficiency of manipulating over 3D human-made structures. They had using serial configuration as climbing mechanism due to increase workspace and manipulability for a multipurpose robot. The designed climbing module consists of a 3-DOF planar serial arm and a Z-axis rotating mechanism.

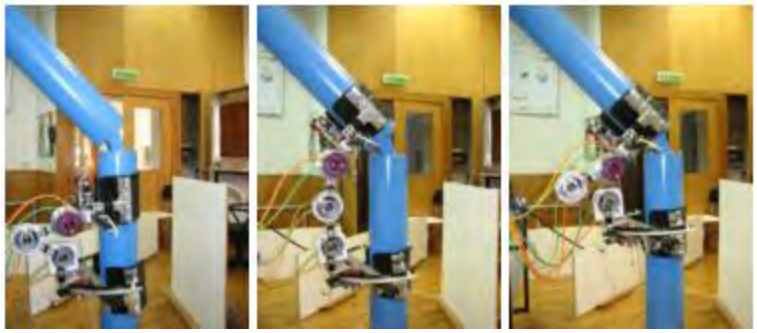

Figure 2.2: The design and climbing mechanism of 3D Climber.
(M. Tavakoli, 2008)

P. Polchankajorn and T. Maneewarn (2011) stated that a modular snake robot is proper to perform different types of locomotion such as crawling, rolling and climbing, as shown in Figure 2.3. In order to climb a pole, the robot must apply sufficient grasping force around the pole while pushing its body up the pole against the gravitational force. The helical configuration can be used for this type of motion, because the helical form can provide grasping action while allowing the robot to move upward. For the wheel-based modular snake robot, its wheel can be adjusted to

be perpendicular to the ground plane so that the robot can roll its wheel upward vertically as in the non-wheel robot.

Figure 2.3: The prototype wheel-based modular snake robot.
(P. Polchankajorn and T. Maneewarn, 2011)

M. R. Zakerzadeh (2005) proposed a hybrid pole climbing and manipulation robot with minimum DOFs. The proposed pole climbing robot consists of three main parts is shown in Figure 2.4, the three-DOF planar parallel mechanism, the serial z-axis rotating mechanism and the grippers. Combining the three-DOF planar parallel mechanism with a rotating mechanism around the pole axis provides two rotations and two translations, which is necessary to achieve the design objectives as explained in the last section.

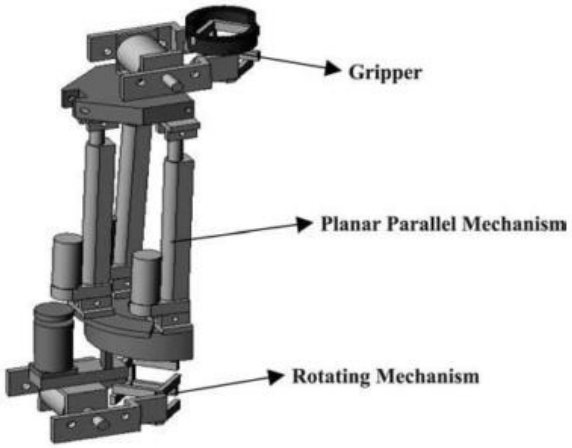

Figure 2.4: Hybrid pole climbing and manipulation robot with minimum DOFs.
(M. R. Zakerzadeh (2005)

Y. Guan and L. Jiang (2009) designed a biped climbing robot which is called as 'Climbot' and shown in Figure 2.5. The design of Climbot is inspired from the