# DESIGN AND DEVELOPMENT OF 3-RRS PARALLEL PLATFORMS USING SIMMECHANICS

MOHD JOHARI @ ESA BIN IBRAHIM

A project report submitted in partial fulfilment of the
requirements for the award of the degree of
Master of Engineering (Mechatronics and Automatic Control)

Faculty of Electrical Engineering
Universiti Teknologi Malaysia

DECEMBER 2015

Specially dedicated to my beloved family

# ACKNOWLEDGEMENT

First of all, thanks to Allah s.w.t for the continuous blessing and for giving me strength and chances in completing this project report. Special thanks to my project supervisor, Dr. Mohamad Amir Bin Shamsuddin and Assoc. Prof. Ir. Dr. Ahmad ‘Athif Bin Mohd Faudzi for the continuous guidance & support, and helpful comments throughout this research.

My family deserves special dedication for their constant support and for their role of being the driving force towards the success of my project. To my lovely wife, Shadatulnadia Binti Mohd Khasani, thanks for always being there for me. My sincere appreciation also goes to everyone whom I may not have mentioned above who have helped directly or indirectly in the completion of my master project.

Last but not least, I would like to convey my utmost gratitude and appreciation to the Ministry of Education (KPM), Universiti Teknologi Malaysia (UTM) and Politeknik Malaysia for their support.

Mohd Johari @ Esa Bin Ibrahim.

# ABSTRACK

Parallel platform is highly used in the field of engineering for simulation of vehicle motion. Parallel platform normally used in aviation industry and recently in gamming sector. The system is able to actuate physical motions in giving the user to experience how the vehicle would respond. With input given, parallel platform encapsulates occupants and creates effect of being inside a moving vehicle and create real time environment. This project will study and use kinematic mathematical modeling to determine of the possible motion characteristic when the linear displacement of the platform is restricted. The Micro Servo Motor is used as parallel mechanism with a platform as its load. The 3-DOF parallel platforms composed of a moving rectangular platform that connected to a fixed base with the same shape by three (RRS) extendable legs. The extremities of each leg are fitted with a 1-DOF revolute joint (R) at the base connected to one revolute joint from servomotor and a 3-DOF spherical joint (S) at the platform legs are actuated using revolute joints (R). The three axes of the revolute joints at the base are arranged in 120 degrees and the axis of every one is parallel to the opposite segment of the triangular base. 3-RRS parallel manipulators allow the platform to rotate and translate. Validation will do in MATLAB/Simmechanics and experimental shows similar movement. The results show the position of platform when the signal is trigger to the legs joins.

# ABSTRAK

Platform selari biasanya digunakan dalam bidang kejuruteraan untuk simulasi pergerakkan kenderaan. Platform selari biasanya digunakan dalam industri penerbangan dan baru-baru ini dalam sektor permainan video. Keupayaan sistem untuk memberi gerakan fizikal pengguna untuk merasakan bagaimana kenderaan akan bertindak balas. Dengan input yang diberikan, platform selari merangkumi pengguna dan mewujudkan kesan ketika berada di dalam kenderaan yang bergerak dan mewujudkan persekitaran masa nyata. Projek ini akan mengkaji dan menggunakan model matematik kinematik untuk menentukan ciri-ciri gerakan yang mungkin untuk dikekang 3 darjah kebebasan (DOF) mekanisme selari apabila anjakan linear platform adalah terhad. Mikro Servo Motor digunakan sebagai mekanisme selari dengan platform sebagai beban. Platform selari 3-DOF terdiri daripada segi empat tepat platform bergerak, yang dihubungkan dengan pangkalan tetap dengan bentuk yang sama oleh tiga (RRS) kaki dilanjutkan. Setiap kaki dilengkapi dengan bersama 1-DOF revolute (R) di pangkalan disambungkan ke satu revolute bersama daripada servomotor dan bersama 3-DOF sfera (S) pada kaki platform yang digerakkan menggunakan sendi revolute (R). Tiga paksi sendi revolute di pangkalan disusun dalam 120 darjah dan paksi setiap satu adalah selari dengan segmen yang bertentangan dengan asas segi tiga. 3-RRS selari manipulator membolehkan platform untuk berputar dan menterjemahkan. Pengesahan akan dilakukan di MATLAB / Simmechanics dan eksperimen menunjukkan pergerakan yang sama. Keputusan menunjukkan kedudukan platform apabila isyarat adalah diberi kepada sambungan kaki.

# TABLE OF CONTENT

# LIST OF TABLES

# LIST OF FIGURES

# CHAPTER 1

# INTRODUCTION

## 1.1. Introduction

Parallel platforms are commonly used in the field of engineering for analysis and verification of vehicle's performance and design. The ability of particular system to the physical motion gives the user to feel how the vehicle would respond. A parallel platform encapsulates occupants and creates effect of being inside a moving vehicle.

This project will study and present a mathematical method of kinematic for determination of the possible motion characteristic for constrained 3 degree-of-freedom (DOF) parallel mechanism when the linear displacement of the platform is restricted. 3-DOF parallel robots composed of a moving rectangular platform connected to a fixed base with the same shape by three (RRS) extendable legs.

The ends of each section are equipped with an angle joint 1-DOF (R) at the base and a spherical joint 3-DOF (S) to the platform. The three axes of the revolute joints at the base are arranged in 120 degrees and the axis of every one is parallel to

the opposite segment of the triangular base. 3-RRS parallel manipulator consists of three identical, which allow the platform to rotate and translate. Normally the used parallel platform is 6 DOF [1]. Figure 1.1 the 6 DOF are consist six degree of freedom movement is the motion of a platform. It is described as:

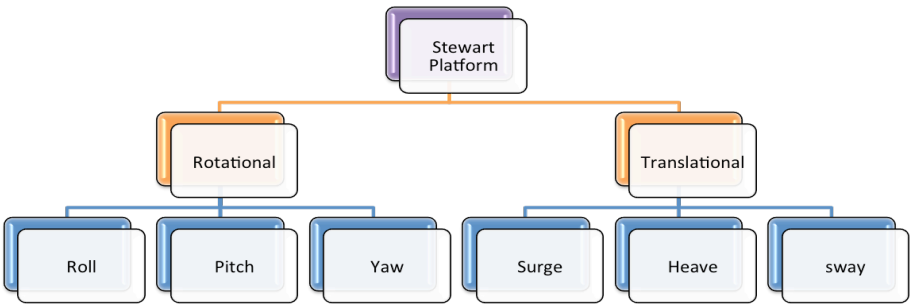


Figure 1.1: Steward Platform Motion

Stewart Platform conventional manipulator has six (6) extendable legs and a very rigid hence kinematic structure [1]. Compared to the kinematic manipulator series, a Stewart platform has the desirable characteristics of high load capacity and rigidity.

## 1.2. Problem Statement

The problem statement of this study can be written as follows:

i. The 6-DOF is not always required for many practical applications and less applies 3RRS in system.

ii. Most of the recent system applies with hydraulic for the actuation that is low in response and slow movement.

iii. Higher DOF involves more actuators and increase the total cost in manufacturing and operations.

## 1.3. Research Objective

The followings are the objectives of this research.

i. To apply a kinematic mathematical model for 3RRS system.
ii. To apply an experimental structure of active-motion platform model with 3 DOF 3RRS systems that is actuated by micro servomotor.
iii. To simulate and analyse the model in SimMechanics and validate with experimental structure.

## 1.4. Scope of Work

This followings are the scopes of the research.

i. 3 degree of freedom of parallel platform will be applied.
ii. The 3RRS prototype will be equipped with micro servomotor 9g with its specification for model development.
iii. The experiment works will be performed in simulation environment using MATLAB/Simmechanics.

### 1.5. Contribution of the Work

From the literature work conducted, it is obvious that there are significant issues related to the identification and that need to be investigated further. Several contributions can be made in Simmechanics based on the problem statements discussed. The main research contributions from this study are as follows:

i. Study a kinematics mathematical model of 3RRS system.
ii. Apply the 3RRS kinematics using Simmechanics by simulate the model.

### 1.6. Organization of the Project Report

Chapter 2 presents the literature review of the related works regarding the research topic. The chapter will start with discussion on the kinematics model. Next, the parallel platform with consist 6-DOF, 3-DOF and 3-RRS. At the end of chapter, the possible to apply the kinematics in Simmechanics in this research.

In chapter 3, methodology approaches used in this research are presented. Overall system setup, which explains the workbench, data acquisition method and components used, are discussed in detail. Then, the kinematics mathematical modelling are using. This chapter explained the simulation on Simmechanics.

Chapter 4 presents the results and discussion on the simulation works and real-time experimental works conducted in this research. First, the result obtained from kinematics mathematical modeling. The model that can represent by the micro servomotor system. This chapter also presents the result for simulation in Simmechanics.

Chapter 5 summarizes the research findings and the recommendation of future research based on this study.

## REFERENCES


[1] Gough, V. E. (1956–1957). "Contribution to discussion of papers on research in Automobile Stability, Control and Tyre performance". Proc. Auto Div. Inst. Mech. Eng.: 392–394.

[2] Stewart, D. (1965–1966). "A Platform with Six Degrees of Freedom". Proc. Institution of Mechanical Engineers (UK). Vol 180 (Pt 1, No 15).

[3] Lazard, D.; Merlet, J. -P. (1994). "The (true) Stewart platform has 12 configurations". Proceedings of the 1994 IEEE International Conference on Robotics and Automation. p. 2160. doi:10.1109/ROBOT.1994.350969. ISBN 0-8186-5330-2.

[4]Jongwon Kim, Young Man Cho, Frank C. Park, Jang Moo Lee (2003). "Design of a Parallel Mechanism Platform for Simulating Six Degrees-of-freedom General Motion Including Continuous 360-degree Spin". CIRP Annals - Manufacturing Technology (Impact Factor: 2.54). 01/2003; 52(1):347-350. DOI: 10.1016/S0007-8506(07)60598-8.

[5] Jianfeng Li, Jinsong Wang, Wusheng Chou, Yuru Zhang, Tianmiao Wang and Qixian Zhang (2001). "Inverse Kinematics and Dynamics of The 3-RRS Parallel Platform'. International Conference on Robotics & Automation.

[6] Tiberiu Itul and Doina Pisla (2010). "Three Degree of Freedom Parallel Structure Used for the TV Satllite Dish Orientation". International Conference on Robotics & Automation.

[7] Ioannis Davliakos, Evangelos Papadopoulos (2007). "Impedance Model-based Control for an Electrohydraulic Stewart Platform". European Journal of Control (2009)5:560–577 # 2009 EUCA DOI:10.3166/EJC.15.560–577

[8] C. C. Ng, S. K. Ong, A. Y. C. Nee (2006). "Design and development of 3–DOF modular micro parallel kinematic manipulator". The International Journal of Advanced Manufacturing Technology. November 2006, Volume 31, Issue 1-2, pp 188-200

[9] Merritt, "H. Hydraulic Control Systems". (1967) New York: John Wiley Sons, Inc.

[10] Sameer A. Joshi, Lung-Wen Tsai, (2002), "Jacobian Analysis of Limited-DOF Parallel Manipulators". Journal of Mechanical Design ASME, Vol. 124

[11] Hou Jingwei, Zhao Ying, Zhao Dingxuan, Ni Tao, (2011), "Numerical Simulation Research On Hydraulic Stewart Platform Motion Simulator". IEEE

[12] Yangjun Pi, Xuanyin Wang (2011), "Trajectory tracking control of a 6-DOF hydraulic parallel robot manipulator with uncertain load disturbances", Control Engineering Practice 19 (2011) 185–193

[13] Xiang Chen, Xin-Jun Liu, FuGui Xie and Tao Sun (2013), "A Comparison Study on Motion/Force Transmissibility of Two Typical 3-DOF Parallel Manipulators: The Sprint Z3 and A3 Tool Heads", nternational Journal of Advanced Robotic Systems

[14]Josef Schadlbauer, Dominic R. Walter and Manfred L. Husty (2011), "A Complete Kinematic Analysis of the 3-RPS Parallel Manipulator", 5th National Conference on Machines and Mechanisms

[15] GuoSheng and FangYueFa (2004), "A structural synthesis method for 3-DOF translational parallel manipulators avoided platform singularities", 2004 8th International Conference on Control, Automation, Robotics and Vision Kunming, China, 6-9th December 2004.

[14] J. Cazalilla, M. Vallés, V. Mata, M. Díaz-Rodríguez, A. Valera (2014), "Adaptive control of a 3-DOF parallel manipulator considering payload handling and relevant parameter models" , obotics and Computer-Integrated Manufacturing 30 - 468–477

[16] Marco Ceccarelli, Erika Ottaviano, Gianni Castelli, "An Application of a 3-DOF Parallel Manipulator for Earthquake Simulations", 22nd International Symposium on Automation and Robotics in Construction ISARC 2005 - September 11-14, 2005, Ferrara (Italy).

[17]A. Rahmani Hanzaki, E. Yoosefi, "An Improved Dynamic Modeling of a 3-RPS Parallel Manipulator using the concept of DeNOC Matrices" , 15th National Conference on Machines and Mechanisms, 2011.

[ 18] Chifu Yang, Qitao Huang, Junwei Han , "Computed force and velocity control for spatial multi-DOF electro-hydraulic parallel manipulator" , Mechatronics 22 (2012) 715–722

[19] O. Ibrahim and W. Khalil , “Kinematic and dynamic modeling of the 3-RPS parallel manipulator”, 2th IFToMM World Congress, Besançon (France), June18-21, 2007