
UNIVERSITI PUTRA MALAYSIA

# EMULATION OF THE SPACE ROBOTICS SYSTEM ON EARTH

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By

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Thesis Submitted in Fulfilment of the Requirement for the
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*TO MY DEAREST FATHER, MOTHER AND BROTHER*

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science.

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Present and future, without the sophisticated and highly automated mechanisms, it is impossible to fulfil the humanity's destiny in space. Thus to determine the success of ambitious space missions of the future, the humans and space robots have to form an excellent integrated team. Generally space robotic systems are designed, developed and operated to assist or replace humans in accomplishing tasks that are dangerous, costly or simply impossible for humans. The nature and operation of space systems are totally different from on earth such as zero gravity environments, have made the modifications of design and usage of robotics in space very important. This research comprises an analytical and experimental study of space robot locomotion.

The main objective of this research work is to build a test-bed for space robot emulation that operates in the "zero gravity" situation. To experimentally study the locomotion of space robot in the laboratory, one has to create a "zero gravity" or "less gravity" environment. In order to perform simulations of partial or microgravity environments on earth requires some method of compensation for the earth's gravitational field. To

achieve this, gravity-less 2 Degrees-Of-Freedom robot with an unique instrumental arrangement was considered to compensate the gravity force.

The space robot kinematics and dynamics formulations are studied, especially the Denavit-Hartenberg (D-H) parameters and Newton-Euler formulation. The feedbacks of the robot's arms are detected by encoders at the servomotors and transducers around the robot and sent to the computer through PC interface card. The space robot dynamic algorithms were tested in simulation and as well as in practical. The data especially the torque values, the joint positions and angular velocities of the robot's arm in the "zero gravity" environment as well as with gravitational effect were taken from the experimental and simulation. The simulation comprises the combination of mechanical simulation and virtual prototyping software, Mechanical Desktop and MSC Working Model. The graphs were plotted from data by using Excel. The Mathematical software package, Mathematica is used to derive the equations of motion. Finally all the trend graphs were plotted using Excel. The results were compared and analyzed with derived equations to prove that the "zero gravity" condition is achieved. Moreover this instrumental setup for emulation of space robot system can be used for various algorithms study based on robotics, control and other areas.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

**PENGIKUT JEJAK SISTEM ROBOTIK ANGKASA LEPAS ATAS BUMI**

Oleh

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Pada masa kini dan masa depan, cita-cita manusia dalam mengeksplorasi angkasa lepas tidak akan berjaya tanpa peralatan mekanisma automasi yang sangat canggih dan sofitikated. Oleh itu, manusia dan robot angkasa lepas perlu membentuk satu pasukan bersepadu yang sempurna untuk menentukan kejayaan dalam cita-cita misi angkasa lepas untuk masa hadapan. Secara amnya, sistem robot angkasa lepas direka, dibangun dan dioperasi untuk membantu dan mengganti manusia dalam melaksanakan kerja yang berbahaya, mahal atau mustahil bagi manusia. Sifat dan operasi bagi sistem angkasa lepas adalah jauh berbeza daripada di bumi kerana angkasa lepas mempunyai persekitaran tanpa graviti. Dengan itu, adalah sangat penting untuk mengubahsuai rekaan dan kegunaan robot dalam angkasa lepas. Penyelidikan ini merangkumi analisis dan eksperimentasi tentang gerakan robot angkasa lepas.

Objektif yang terpenting dalam penyelidikan ini ialah membina satu tapak ujian untuk pengikut jejak robot angkasa lepas yang beroperasi dalam keadaan tanpa graviti. Persekitaran tanpa graviti atau kurang graviti mesti diadakan untuk membuat

eksperimen tentang gerakan robot angkasa lepas dalam makmal di bumi. Cara-cara bagi mengimbangi graviti bumi diperlukan untuk menjalankan simulasi dengan persekitaran sebahagian atau mikrograviti atas bumi. Robot 2 *Degree-Of-Freedom* dengan cara pasangan peralatan yang unik dipertimbangkan untuk mengimbangi daya graviti seterusnya menjayakan penyelidikan ini.

Formula kinematik dan dinamik robot angkasa lepas dipelajari, terutamanya parameter Denavit-Hartenberg(D-H) dan formular Newton-Euler. Maklumbalas tangan robot yang dikesan oleh *encoder* di dalam *servomotor* dan *transducer* di sekeliling robot dihantar ke komputer melalui *PC interface card*. Algoritma robot angkasa lepas diuji dalam simulasi dan juga dalam praktikal. Data terutama nilai tork, kedudukan sambungan dan laju putaran tangan robot dalam keadaan tanpa graviti dan juga dengan graviti diperolehi daripada eksperimen dan program simulasi. Program simulasi terdiri daripada simulasi mekanikal dan perisian prototaip sebenar, *Mechanical Desktop* dan *MSC Working Model*. Perisian Matematik, *Mathematica* digunakan untuk mendapatkan persamaan. Ahkir sekali, semua bentuk graf diperolehi dengan mengguna Excel. Keputusan dibandingkan dan dianalisiskan dengan persamaan untuk membuktikan keadaan tanpa graviti telah dicapai. Tambahan pula, persiapan peralatan untuk pengikut jejak sistem robot angkasa lepas ini boleh digunakan untuk pelbagai algoritma berasaskan robotik, kawalan dan bidang yang lain.

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