UNIVERSITI PUTRA MALAYSIA

DESIGN AND DEVELOPMENT OF A TWO-DEGREE OF FREEDOM SERIAL BALL AND SOCKET ACTUATOR WITH ADAPTIVE LEARNING CONTROL ALGORITHM

HAYDER M. A. ALI AL-ASSADI

FK 2008 49

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By

HAYDER M. A. ALI AL-ASSADI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

April 2008

Dedication

TO MY DAUGHTER LAYLA, MY WIFE, MY FATHER, MY FAMILY, AND MY COUNTRY IRAQ

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for the degree of Doctor of Philosophy

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HAYDER M. A. ALI AL-ASSADI

April 2008

Chairman: Associate Professor Datin Napsiah Ismail, PhD

Faculty: Engineering

The implementation of robot for various applications has increased dramatically and this attributed to the rise in demands and development in fundamental components. Two types of joints are commonly found in serial robot manipulator, revolute joints (provide rotation motion) and prismatic joints (provide translation motion). These joints are restricted to one degree of freedom, to simplify the mechanics, kinematic, dynamic, and control of the manipulator.

For more complex articulation such as human arm shoulder or leg hip joints, two revolute joints are required. The shoulder or hip joint; in biomedical literature, are usually considered as a ball and socket joint. In engineering the ball and socket joint is the mechanical connection used between parts to provide some relative angular motion in virtually all directions.

This study presents the development and implementation of a two degree of freedom serial ball and socket actuator controlled by an adaptive learning algorithm. The ball and socket actuator has been proposed as an alternative actuator to the conventional one degree of freedom revolute actuator. The actuator is fabricated from ball and socket joint powered by two electro-hydraulic cylinders. An electronic board, transistor relay driver circuit, is designed for the purpose of establishing communication interface between the computer, adaptive learning algorithm and the actuator mechanism.

Artificial Neural Network (ANN) is the adaptive learning algorithm for controlling the ball and socket actuator. ANN is well-known algorithm that simulates the human brain ability of learning and predicting sets of information. In this approach, ANN will learn the controlling parameters to obtain the operation condition, for the mechanical and power elements, of each individual movement of the end effector rod without any prior knowledge of the actuator.

In addition, kinematic and dynamic simulation models of the ball and socket actuator were derived and modeled. These models represent the kinematic and dynamic relationships, implemented by using MATLAB/SIMULINK software package. In these models, full kinematic and dynamic simulations are achieved. All realistic factors such as position, velocity, acceleration, reactions, and forces, required to represent the real system accurately are incorporated.

The results from manually operating the ball and socket actuator are collected and analysed to demonstrate the performance of the newly actuator. The analysis includes the end effector dynamic behaviour for both the Cartesian and Spherical coordinates. The manually collected experimental controlling datasets had been provided for ANN to learn in off-line mode. Training process is carried out to build controlling knowledge. The result of implementing the build controlling knowledge for on-line operating the ball and socket actuator shows a fully obeyed actuator end effector to the desired kinematic behaviour within the workspace. Finally, the results extracted from operating the kinematic and dynamic simulation are compared to the manual operation results for the both models validation technique.

The fabricated actuator has successfully achieved the two degree of freedom actuator to be implemented in a serial robot manipulator. Overall performance of the new ball and socket actuator shows an effective obey to the instruction from the adaptive learning algorithm. Thus, the adaptive learning algorithm as a controlling algorithm can adopt any modification in the actuator mechanism and hydraulic power system, without any changes in the controlling algorithm, through updating the controlling knowledge. Therefore, the two degree of freedom serial actuator powered by hydraulic system could add improvement to the serial robot manipulator for more degrees of freedom, flexibility and high load for any new applications.

Abstrak thesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

REKABENTUK PEMBANGUNAN DUA-DARJAH KEBEBASAN BEBOLA BERSIRI DAN SOKET DENGAN ALGORITHMA KAWALAN

By

HAYDER M.A. ALI AL-ASSADI

April 2008

Chairman: **Professor Madya Datin Napsiah bt Ismail, PhD**

Fakulti: **Kejuruteraan**

Implementasi robot untuk pelbagai aplikasi telah meningkat dan menyebabkan peningkatan permintaan dan perkembangan komponen-komponen asas. Terdapat dua jenis penghubung yang biasa dijumpai pada pemanipulasi robot iaitu penghubung berputar (pergerakan berputar) dan penghubung prismatik (pergerakan translasi). Penghubung-penghubung ini terhad kepada satu darjah kebebasan untuk menerangkan mekanik, kinematik, dinamik dan kawalan pemanipulasi.

Bagi pergerakan yang komplek contohnya seperti lengan (bahu) manusia atau penghubung peha, dua penghubung berputar diperlukan. Penghubung tangan (bahu) atau kaki; dalam literasi biodemik biasanya dianggap sebagai bebola dan penghubung soket. Dalam kejuruteraan, bebola dan penghubung soket adalah penghubung yang digunakan antara bahagian-bahagian untuk menghasilkan pergerakan dalam pelbagai arah maya.

Penyelidikan ini adalah tentang perkembangan dan implementasi bebola dan soket dua darjah kebebasan yang dikawal oleh pemadan pembelajaran algorithma. Bebola dan soket telah dicadangkan sebagai alatan penggerak alternatif bagi alatan

penggerak berputar satu darjah pergerakan bebas. Alatan penggerak dihasilkan daripada bebola dan penghubung darjah kebebasan soket dan dikuasai oleh dua silinder elektro-hidraulik. Papan elektronik, litar transistar pemacu berganti dihasilkan untuk tujuan mengembangkan komunikasi antara komputer, menggerakkan kawalan pemadan pembelajaran algorithma dan mekanisma alatan penggerak.

Rangkaian sarat tiruan merupakan pemadan pembelajaran algorithma untuk mengawal bebola dan soket. Rangkaian sarat tiruan merupakan algoritma yang terkenal untuk mensimulasikan keupayaan pembelajaran bagi otak dan menganggarkan informasi. Dalam kajian ini, rangkaian sarat tiruan akan belajar mengawal parameter bagi memperoleh operasi untuk unsur mekanikal dan kuasa, setiap pergerakan batang pengesan tanpa pengetahuan asas mengenai alatan penggerak.

Tambahan lagi, model-model simulasi kinematik dan dinamik bagi alatan penggerak bebola dan soket telah dihasilkan. Model-model ini akan melambangkan hubungan kinematik dan dinamik, diimplementasi menggunakan perisian MATLAB/SIMULINK. Dalam model-model ini, simulasi kinematik dan dinamik yang lengkap dapat dicapai. Semua faktor realistik diperlukan untuk melambangkan sistem sebenar yang tepat. Faktor-faktor ini adalah seperti posisi, halaju, pecutan, tindakbalas dan daya yang dikira dalam simulasi.

Keputusan daripada operasi manual alatan penggerak bebola dan soket diperolehi dan dianalisa untuk demonstrasi keupayaan alatan penggerak baru. Analisa ini

merangkumi ciri-ciri dinamik hujung lengan bagi kedudukan kartesian dan polar. Data kawalan manual yang dikumpul untuk rangkaian sarat tiruan bagi mempelajari mod bukan dalam talian. Proses latihan dijalankan untuk menghasilkan pengetahuan tentang kawalan.   Keputusan daripada implementasi operasi dalam talian untuk alatan penggerak bebola dan soket menunjukkan batang pengesan penggerak menurut arahan sepenuhnya bagi ciri-ciri kinematik yang diingini dalam kawasan kerja. Akhirnya, keputusan pengoperasian simulasi kinematik dan dinamik dibandingkan dengan keputusan operasi manual untuk bagi kedua-dua model. .

Alatan penggerak yang direka telah berjaya mencapai dua darjah kebebasan alatan penggerak untuk diimplementasi dalam robot manipulator bersiri. Keseluruhan pencapaian untuk alatan penggerak bebola dan soket baru menunjukkan keberkesanan mematuhi arahan daripada pemadan pembelajaran algorithma. Oleh yang demikian, pemadan pembelajaran algorithma sebagai algoritma kawalan dapat menerima apa-apa pengubahsuaian dalam mekanisma alatan penggerak dan sistem kuasa hidraulik tanpa apa-apa perubahan dalam algoritma kawalan, melalui kemaskini pengetahuan kawalan. Oleh itu dua darjah pergerakan bebas yang dikuasakan oleh sistem hidraulik dapat menambah perkembangan kepada pemutar robot bersiri bagi lebih banyak darjah pergerakan bebas, fleksibel dan beban tinggi bagi aplikasi-aplikasi yang baru.

ACKNOWLEDGEMENTS

All praise to supreme almighty Allah swt. the only creator, cherisher, sustainer and efficient assembler of the world and galaxies whose blessings and kindness have enabled the author to accomplish this project successfully.

The author gratefully acknowledges the guidance, advice, support and encouragement he received from his supervisor, Associate Professor Datin Dr. Napsiah Ismail who keeps advising and commenting throughout this project until it turns to real success.

Great appreciation is expressed to Associate Professor Dr. Ishak Bin Aris and Professor Dr. Abdel Magid Hamouda for their valuable remarks, help advice and encouragement.

Appreciation also to the Faculty of Engineering for providing the facilities and the components required for undertaking this study.

I certify that an Examination Committee met on (April, 30 2008) to conduct the final examination of Hayder M. A. Ali Al-Assadi on his Doctor of Philosophy thesis entitled “Design and Development of A Two-Degree of Freedom Serial Ball and Socket Actuator with Adaptive Learning Control Algorithm” in accordance with University Pertanian Malaysia (Higher Degree) Act 1980 and University Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

Megat Mohamad Hamdan Megat Ahmad, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Shamsuddin Sulaiman, PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Abd Rahman Ramli, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Mohd Marzuki Mustafa, PhD
Professor
Faculty of Engineering
Universiti Kebangsaan Malaysia
(Independent Examiner)

HASANAH MOHD GAZALI, Ph.D.
Professor/Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 22 July 2008

This thesis was submitted to the Senate of University Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

Napsiah Ismail, PhD
Associate Professor
Faculty of Engineering
University Putra Malaysia
(Chairman)

Ishak Aris, PhD
Associate Professor
Faculty of Engineering
University Putra Malaysia
(Member)

Abdel Magid Hamouda, PhD
Professor
Faculty of Engineering
University of Qatar
(Member)

AINI IDERIS, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 14 August 2008

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

HAYDER M. A. ALI AL-ASSADI

Date: 30 June 2008

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LIST OF ABBREVIATIONS

ANN	Artificial Neural Network
3D	Three Dimensional
DC	Direct Current
I/O	Input/Output
CPU	Central Processing Unit
TTL	Transistor Transistor Logic
ROM	Read-only Memory
RAM	Random-Access Memory
MOS	Read-Write Memory
PC	Personal Computer
LPT	Line Print Terminal
BIOS	Basic Input Output System
SPP	Standard parallel port
EPP	Enhanced Parallel Port
ECP	Extend Capability Port
MLPN	Multilayer Propagation Network
ANNNA	Artificial Neural Network Nonlinear Adaptive
USB	Universal Serial Bus

CHAPTER ONE

INTRODUCTION

1.1 Background

Robot manipulators play a leading role in almost all manufacturing processes. The effect of any enhancement will improve both the manufacturing process and the production rate. However, robots have the advantages of being deployed in dangerous environment, working for a longer period of time, and maintaining a high level of quality when completing task of a repetitive nature (Pryor, 2002).

Robotic systems are a class of dynamic systems which are closely parallel to a human's range of tasks. A robotic manipulator is composed of joints and links. Joints denote the prime mover and its respective axis of motion. The actuated motion may be revolution around the axis or a translation along the axis. These joints are known as revolute and prismatic joints, respectively. Links are connected by these joints.

The revolute joint has one Degrees Of Freedom (DOF) and because of its simplicity, it is by far the most used joint in robotics. Consequently, serial robot manipulator requires an individual revolute joint for each rotational degree of freedom. To imitate the shoulder or hip joint in human, two revolute actuators are required to provide the necessary 2 DOF motions. The present revolute actuator powered by electrical motor has some limitations, will be detailed in the problem statement.