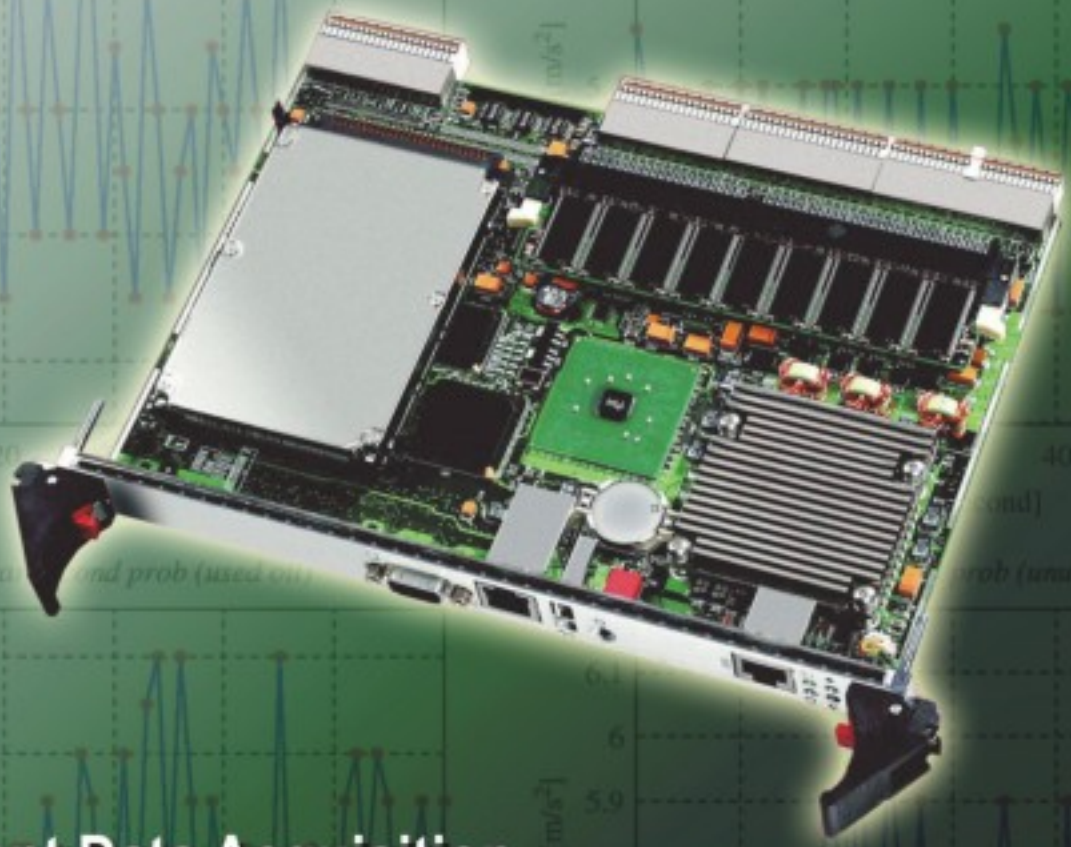
ISSN 1726-5479

vol. 19
Special
2/13

SENSORS & TRANSDUCERS



Intelligent Data Acquisition and Information Process Technologies and Their Applications. Part II

International Frequency Sensor Association Publishing

IFSA

Printed in the USA.

Sensors & Transducers

Volume 19, Special Issue
February 2013

www.sensorsportal.com

ISSN 1726-5479

Sensors & Transducers Journal

Contents

Volume 19
Special Issue
February 2013

www.sensorsportal.com

ISSN 1726-5479

Research Articles

The Fourth International Conference on Sensor Device Technologies and Applications

SENSORDEVICES 2013

25 - 31 August 2013 - Barcelona, Spain

Tracks: Sensor devices - Ultrasonic and Piezosensors - Photonics - Infrared - Gas Sensors - Geosensors - Sensor device technologies - Sensors signal conditioning and interfacing circuits - Medical devices and sensors applications - Sensors domain-oriented devices, technologies, and applications - Sensor-based localization and tracking technologies - Sensors and Transducers for Non-Destructive Testing

Deadline for papers: 30 March 2013

http://www.iaria.org/conferences2013/SENSORDEVICES13.html

The Seventh International Conference on Sensor Technologies and Applications

Deadline for papers:
30 March 2013

SENSORCOMM 2013

25 - 31 August 2013 - Barcelona, Spain

Tracks: Architectures, protocols and algorithms of sensor networks - Energy, management and control of sensor networks - Resource allocation, services, QoS and fault tolerance in sensor networks - Performance, simulation and modelling of sensor networks - Security and monitoring of sensor networks - Sensor circuits and sensor devices - Radio issues in wireless sensor networks - Software, applications and programming of sensor networks - Data allocation and information in sensor networks - Deployments and implementations of sensor networks - Under water sensors and systems - Energy optimization in wireless sensor networks

http://www.iaria.org/conferences2013/SENSORCOMM13.html

The Sixth International Conference on Advances in Circuits, Electronics and Micro-electronics

CENICS 2013

25 - 31 August 2013 - Barcelona, Spain

Deadline for papers: 30 March 2013

Tracks: Semiconductors and applications - Design, models and languages - Signal processing circuits - Arithmetic computational circuits - Microelectronics - Electronics technologies - Special circuits - Consumer electronics - Application-oriented electronics

http://www.iaria.org/conferences2013/CENICS13.html

Sensors & Transducers, Vol. 19, Special Issue, February 2013, pp. 64-67

www.sensorsportal.com

Sensors & Transducers

ISSN 1726-5479

http://www.sensorsportal.com

Design and Optimal Control of Parallel Robot

[1] Ying Sun, [2] Yuesheng Gu and [1] Hegen Xiong

[1] College of Machinery and Automation, B.O.X 242, Wuhan University of Science and Technology, Wuhan, 430081, China,

[2] Department of Computer Science, Henan Institute of Science and Technology, Xinxiang 453003, Henan, China

+86-027-68862283,wustsunying@126.com

Received: 2012 /Accepted: 15 January 2013 /Published: 19 February 2013

Abstract: As a completely new-type of robot, the parallel robot possesses a lot of advantages that the serial robot does not, such as high rigidity, great load-carrying capacity, small error, high precision, small self-weight/load ratio, good dynamic behavior and easy control, hence its range is extended in using domain. The current status of research on the parallel robot is described in this paper, including the introduction and the characteristics of the parallel robot, current status of research, classification of parallel robot, kinematics analysis, dynamics analysis, singular configuration analysis and workspace analysis in parallel robot and so on. Then the actual state and development trends of parallel robot, some problems and challenges in parallel robot industrialization of our nation are expounded .In order to adapt to machine industry development, the prospect of parallel robot is presented in the end. *Copyright © 2013 IFSA.*

Keywords: Parallel robot, Kinematics, Dynamics, Singular configuration, Modular design.

1. Introduction and Characteristics of Parallel Mechanism

Stewart of German invented six degrees of freedom parallel mechanism in 1965 and it was used to train pilot as flight simulator [1]. Famous mechanism Professor Hunt of Australian put forward that parallel mechanism was used to robot arm in 1978[2]. Subsequently Maccallion and Pham D. J. designed this mechanism as operating device for the first time and Stewart mechanism was successfully used to assemble product line, which indicated the birth of real parallel robot and promoted history of parallel robot development from then on. Typical Stewart parallel robot was described as Fig. 1.

Parallel robot possessed a lot of advantages as following relative to the serial robot:

1) Compared with the serial mechanism, rigidity is high, the structure is steady;
2) The load-carrying capacity is great;
3) The precision is high;
4) Movement inertia is small;
5) When the position is solved, serial mechanism had easy positive solution, difficult inverse solution.

But parallel robot has difficult positive solution and easy inverse solutions.

Because the on-line real time calculation of parallel robot is required to calculate inverse solution, which is disadvantageous to serial mechanism, but it's easy to realize for parallel mechanism. Because of a series of advantages, the application domain of whole robot is expanded.

2. Current Status of Parallel Robot Research

Since Professor Hunt put forward the structure model of parallel robot in 1978, a lot of scholars paid attention to the research of parallel robot. A group of scholars such as Roney, Ficher, Duffy, and Sugimoto in America, Japanese were engaged in research. Some European countries such as Britain, Germany, Russia etc were also engaged in research work. Huang Zhen Professor of Yan Shan University in China has participated in the research of this content in U.S.A. since 1982, and made a breakthrough in 1983. Up until now sample of parallel mechanism is various including level, space different degrees of freedom, different layment and super many degrees of freedom. Approximately it was used to exploit flight simulator in 1960s.Then conception of parallel robot arm was put forward in 1970s. Parallel robot machine tool began to develop in 1980s.Crame was exploited by making use of parallel mechanism in 1990s.

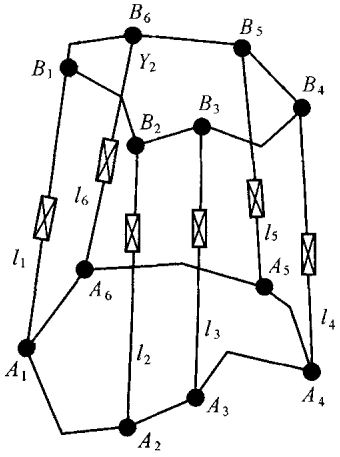


Fig. 1. The typical Stewart parallel robot.

After this, every big company of Japan, Russia, Italy, Germany and Europe introduced the parallel robot as the application mechanism of Processing tool. Our country pays much attention to research and development of parallel robot and parallel machine tool too. A lot of units such as automatic research institute in Shenyang of the Chinese Academy of Sciences, Harbin Institute of technology, Tsing-Hua University, Beijing Institute of Aeronautics, Northeastern University, Zhejiang University, Yanshan University are launching the work of studying in this respect too, and has made certain achievement.

3. Classification of Parallel Robot

No matter the structure and appearance of parallel robot got abundant development since the first parallel robot was born from institute of automation and robot in Dezhou of U.S.A. in 1993. It's divided into the following several kinds:

(1) According to the figure of degree of freedom, parallel robot can make F degree of freedom operation, so it's called as F-degree of freedom parallel robot. For example: a parallel robot has six-degree of freedom, called 6-DOFparallel robot. Redundant parallel robot, namely its degree of freedom is greater than six. Deficiency rank parallel robot, namely its degree of freedom is less than the order number of parallel mechanism.

(2) According to input form of parallel mechanism, parallel robot can be divided into: linear drive input parallel robot and rotation drive input parallel robot. Parallel robot of linear drive input was studied more than the other. Reverse solutions to position of this robot were very much easy and possessed uniqueness. Parallel robot of rotation drive input possessed more compact structure, less inertia, better load-carrying capacity compared with the linear drive input, but its input form decided that inverse solutions to position are many and complicated.

(3) According to the length of pillar, parallel robot can be divided into: parallel robots, which use variable pillar to support the upper and lower platforms and parallel robots, which use regular length pillar to support the upper and lower platforms. For example: the first kind of parallel robot of six rods was called Hexapod, its movement platform and foundations were jointed by six pillars of variable length. Both ends of each pillar were jointed by hinge between movement platform and foundation separately. The location appearance of movement platform was changed through regulating the length of pillar. Another kind of fix length parallel robot of six rods was called Hexaglide, its movement platform and foundation were jointed by six pillars of regular length. Each one of pillar's ends was jointed on the movement platform by hinge. Another end was jointed on foundation through hinge. This hinge can move along slide way fixed on foundation, so the location appearance of movement platform was changed.

4. Kinematics Analysis of Parallel Robot

Main parameters in kinematics: position, displacement, speed, acceleration and time. Kinematics analysis chiefly studies positive solution and inverse solution of parallel mechanism. Given position parameter of upper platform of parallel robot and solution to position parameter of input joints is inverse solution of parallel mechanism kinematics. Solution to position parameter of upper platform of parallel robot is positive solution of parallel robot kinematics when given position parameter of input joints of parallel robot. Reverse solution to position of parallel robot is easy and positive solution is very complicated, which is against to serial robot. There are two kinds of most general research approaches: numerical solution and analytic solution [9].

Numerical solution has simple mathematical model and can solve any parallel mechanism, but can't get all position solution of mechanism. Scholars use a lot of decrease dimension searching methods to get positive solution to position.

Numerical solution is a solution to a set of nonlinear equations. Nonlinear equations are educed from vector hoop equation by some concrete structural algebra disposal, so get the solution to position and posture of movement platform corresponding to input displacement. Because this method omits convoluted mathematical deduction, the calculating method is simple, but its speed is slow and can't guarantee that all solutions are got and the final results are related to the selection of initial value. Huang Zhen put forward one-dimension search method that can simplify parallel mechanism that has triangular platform to nonlinear equation that only has one variable in 1985. This method improves the speed of solution obviously [3]. Chen Yong of Xian Jiao Tong University put forward a new iterative method based on homotopy function, which didn't need to choose initial value and can get all solution [4]. This method can be used for getting positive solution to position of a general 6-sps parallel mechanism and all 40 groups solutions can be easily got.

Analytic method can get input-output equation that is one uncertain multinomial through elimination method eliminating unknown number of constraint equation of mechanism. This method can get all solutions. Error effect of input-output can be shown quantificationally and singular problems can be avoided, has significance in theory and application.

Rao Qing of Beijing University of technology built basic equation of positive solution by using geometry equation theory of mechanism. Then deduced a 20 order number input-output equation of unitary displacement, so the close positive solutions can be got [5].

5. Dynamics Analysis of Parallel Robot

Dynamics studies the relationship between movement and operation force of object. Parallel robot is a complicated dynamics system, and the serious nonlinearity exists. It's composed of many joints and many connecting rods, has many input and output. There are intricate coupling relationship exists between them. So very systematic method must be adopted so as to analyze the dynamics characteristic of robot. There are a lot of existing analytical methods, such as Lagrange method, Newton-Euler method, Gauss method, Kane method, spin or method (dual data) and Roberson-Wittenburg method, etc. Ficher and Merlet discussed dynamics in the early time, got dynamics equation of Stewart robot after neglecting friction of joints and inertia of connecting rod [6, 7]. Do and Yang accomplished inverse dynamics analysis of Stewart robot by using Newton-Euler method, assumpted that there is no friction in joints and each rod is asymmetric thin rod (namely the weight is at the axis and the inertia of rotating which winds the axial can be neglected) [8].

6. Singular Configuration Analysis

Jacobian matrix becomes singular matrix when robot mechanism stays some steady location, its determinant is zero and reverse solution of speed of mechanism is inexistent at this moment. This kind of location of mechanism just calls singular location. One character of parallel robot is high rigidity, however when parallel robot stays on singular displacement, many problems will cause. Because parallel robot can't bear any load in this position, its operation platform possesses excessive degrees of freedom, and the mechanism will be out of control. Therefore, while designing and using parallel robot, singular location must be excluded from working field.

Another kind of method is singular position equation, which can identify singular position by solution to the equation. Shi and Fenton confirmed singular matrix by using positive transient kinematics equation. Sefrioui and Gossellin deduced analytic expression of singular track aiming at level parallel robot of 3-DOF [10].

Ficher had found the singular position of Stewart platform mechanism: namely The position of revolves round Z axel $\pm 90°$ when movement platform parallels foundation[6].Singular position of mechanism can be got by analyzing Jacobian matrix of mechanism equals zero.

7. Workspace Analysis

Workspace analysis is primary link of designing parallel robot operation device. Workspace of robot is the job area of robot operation device and an important index of weighing the performance of robot. Workspace can be classified as accessible workspace and nimble workspace according to position characteristics of operation device while working. Accessible workspace is an assembly to accessible whole points of some reference point on operation device and it don't consider the location of operation. Nimble workspace is an assembly to accessible points from any direction of some reference point on operation device.

The maximal weakness of parallel robot is small space, which should be a relative conception. Workspace of serial robot is bigger than parallel robot when the size of mechanism is the same. When the workspace is the same, serial robot is smaller than parallel robot.

Analytic solution to workspace of parallel robot is a very complicated problem. It depends on the research achievement of solution to structural location to a great extent. So far there isn't a perfect method.

Ficher studied workspace of parallel robot having 6 degrees of freedom by fixing three posture parameters and a position parameter of six posture parameters and let other two parameters change [6]. Gosselin identified fixed posture workspace of parallel robot having 6 degrees of freedom using crossing arc method and gave three-dimensional express of workspace. This method regards asking the border of the workspace as purpose and its efficiency is high and can compute the volume of workspace directly [11, 12].

8. Outlooks

Parallel robot has been studied for decade's years and very great progress has been made, but there are a lot of work that are needed to study further.

(1) Explore solution method of redundancy in Stewart platform robot of strength.

(2) Research on workspace and singular situation of parallel robot.

(3) Dynamics theory and experiment research of parallel robot.

(4) Modular design of parallel robot.

(5) Strengthen the research on few degree of freedom parallel robots.

(6) Kinematics optimization synthesis of Stewart robot based on well-conditioned workspace.

References

[1]. Stewart. D. A., Platform with Six Degrees of Freedom, in *Proc. Inst. Mech*, Eng. London, 1965, 180, pp. 371-386.

[2]. Hunt. K. H., Structural Kinematics of In-Parallel-Actuated Robot Arms. Frans. ASME, *J. of Mech. Trans. and Auto, In Design*, Vol. 105, 1983, pp. 705-712.

[3]. Huang Zhen, Mechanism theory and control of parallel robot, *Machine Industry Press*, 1997.

[4]. Chen Yong, Yan Jing, Homotopy Iteration method and applied to Forward Displacement Analysis Problem of 6-SPS Parallel Robotic Manipulator, *Mechanical Science and Technology*, Vol. 16, Issue 2, 1997, pp. 189-194.

[5]. Rao Qing, Chen Ningxin, Ren Shixian, Forward Displacement Analysis of 6-6 Stewart parallel robot, *Mechanical Science and Technology*, Vol. 3. 1994, pp. 46-52.

[6]. Fichter. E. F., A Stewart platform-Based Manipulator, General theory and practical construction, *Int. J. of Rob Res*, 1986, pp. 157-182.

[7]. Merlert. J. P., NRIA Research Report, 1987, 646.

[8]. Do. W. Q. D, Yang. D. C. H, *J Robot Sys.* Vol. 5, Issue 3, 1988, pp. 209-227.

[9]. Zou Hao, Mechanism and Kinematics Research of parallel robot for manufacturing, *Northeastern University*, Vol. 10, 1997.

[10]. Serfrioui. J. and Gosselin, C. M., Singularity analysis and representation of planar parallel manipulators, *Robotics and Auton, Syst.*, Vol. 10, 1992, pp. 209-224.

[11]. Gosselin, C. M., Determination of the Workspace of 6-DOF parallel Manipulators, *J. of Mech. Des.*, Vol. 112, 1990, pp. 331-336.

[12]. Gosselin. C. M. Lavoie E., Tountant P., Robotics Spatial Mechanisms and Mechanical System, *ASME-45*, 1992, pp. 323-328.

.

Aims and Scope

Sensors & Transducers is a peer reviewed international, interdisciplinary journal that provides an advanced forum for the science and technology of physical, chemical sensors and biosensors. It publishes original research articles, timely state-of-the-art reviews and application specific articles with the following devices areas:

- Physical, chemical and biosensors;
- Digital, frequency, period, duty-cycle, time interval, PWM, pulse number output sensors and transducers;
- Theory, principles, effects, design, standardization and modeling;
- Smart sensors and systems;
- Sensor instrumentation;
- Virtual instruments;
- Sensors interfaces, buses and networks;
- Signal processing and interfacing;
- Frequency (period, duty-cycle)-to-code converters, ADC;
- Technologies and materials;
- Nanosensors;
- Microsystems;
- Applications.

Further information on this journal is available from the Publisher's web site:
http://www.sensorsportal.com/HTML/DIGEST/Submission.htm

Subscriptions

An annual subscription includes 12 regular issues and some special issues. Annual subscription rates for 2013 are the following:

Electronic version (in printable pdf format): 400.00 EUR
Printed with b/w illustrations: 640.00 EUR
Printed full color version: 760.00 EUR

40 % discount is available for IFSA Members.

Prices include shipping costs by mail. Further information about subscription is available through IFSA Publishing's web site: http://www.sensorsportal.com/HTML/DIGEST/Journal_Subscription.htm

Advertising Information

If you are interested in advertising or other commercial opportunities please e-mail sales@sensorsportal.com and your enquiry will be passed to the correct person who will respond to you within 24 hours. Please download also our Media Planner 2013: http://www.sensorsportal.com/DOWNLOADS/Media_Planner_2013.pdf

Books for Review

Publications should be sent to the IFSA Publishing Office: Ronda de Ramon Otero Pedrayo, 42C, 1-5, 08860, Castelldefels, Barcelona, Spain.

Abstracting Services

This journal is cited, indexed and abstracted by Chemical Abstracts, EBSCO Publishing, IndexCopernicus Journals Master List, ProQuest Science Journals, CAS Source Index (CASSI), Ulrich's Periodicals Directory, Scirus, Google Scholar, etc. Since 2011 *Sensors & Transducers* journal is covered and indexed (including a Scopus, Embase, Engineering Village and Reaxys) in *Elsevier* products.

Instructions for Authors

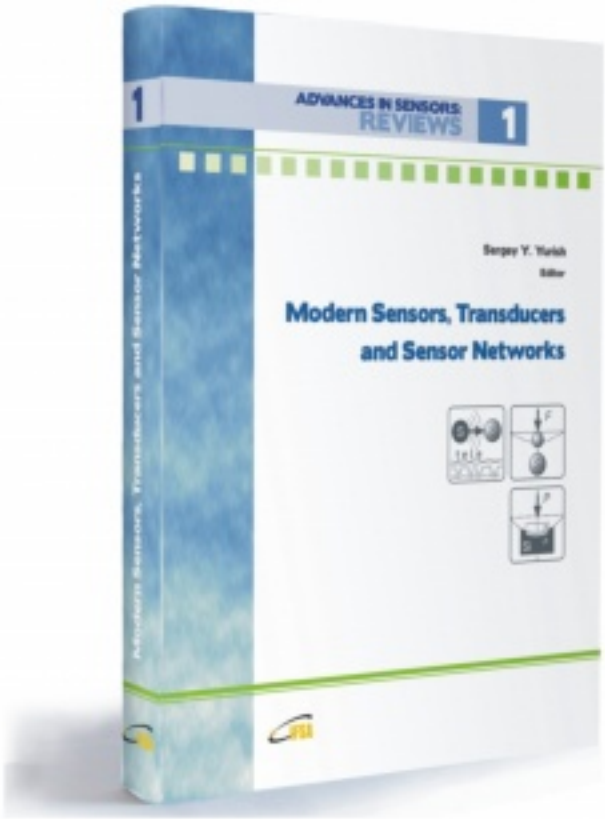
Please visit the journal web page http://www.sensorsportal.com/HTML/DIGEST/Submission.htm Authors must follow the instructions very carefully when submitting their manuscripts. Manuscript must be send electronically in both: MS Word 2003 for Windows (doc) and Acrobat (pdf) formats by e-mail: editor@sensorsportal.com

International Frequency Sensor Association Publishing

ADVANCES IN SENSORS: REVIEWS 1

Sergey Y. Yurish
Editor

Modern Sensors, Transducers and Sensor Networks



Modern Sensors, Transducers and Sensor Networks is the first book from the Advances in Sensors: Reviews book Series contains dozen collected sensor related state-of-the-art reviews written by 31 internationally recognized experts from academia and industry.

Built upon the series Advances in Sensors: Reviews - a premier sensor review source, the *Modern Sensors, Transducers and Sensor Networks* presents an overview of highlights in the field. Coverage includes current developments in sensing nanomaterials, technologies, MEMS sensor design, synthesis, modeling and applications of sensors, transducers and wireless sensor networks, signal detection and advanced signal processing, as well as new sensing principles and methods of measurements.

Modern Sensors, Transducers and Sensor Networks is intended for anyone who wants to cover a comprehensive range of topics in the field of sensors paradigms and developments. It provides guidance for technology solution developers from academia, research institutions, and industry, providing them with a broader perspective of sensor science and industry.

Order online:
http://sensorsportal.com/HTML/BOOKSTORE/Advance_in_Sensors.htm

www.sensorsportal.com