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Advanced Control Methodologies in Parallel Robotic Systems

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Introduction

Recent demands in robotics accelerated the growth of high precision technology using parallel mechanism in various applications such as medicine, environmental investigations, industry, inteligent systems etc. Maintaining the desired dynamic behavior of systems in the face of perturbations and other uncertainties has become the ultimate goal in stability of robotic systems, [1]. In some robotic systems the external disturbances cannot be accurately predicted. However, the appropriately chosen parameters can be kept inside acceptable boundaries.

The parallel robotic platform (or Stewart mechanism), widely known as hexapod, is a parallel kinematic structure that can be used as a basis for controlled motion with six degrees-of-freedom (DOF), [2]. Parallel robots have several advantages comparing to serial robots, mainly related to stiffness, accuracy, flexibility and high speed. The detailed overview of such robotic mechanisms [3-4], included both theoretical and practical considerations. The parallel robotic mechanism belongs to a group of the parallel manipulator. These types of robotic systems consist of a moving top platform connected by extendable legs. The mobile upper platform is connected to a stationary base via six legs mounted on universal joints. To control the motion of the upper platform, the solution of inverse kinematics was used to compute the angles for the desired position of the moving platform. Dynamics of parallel robotic platform has been demanding and challenging task. An algorithm for solving direct kinematics was suggested in [5]. Based on the principle of virtual work and the concept of link Jacobian matrices, a methodology for deriving the dynamical equations of motion (inverse dynamics) has been developed [6]. The comprehensive study and the dynamic equation of the Stewart platform manipulator has been analyzed in [7]. Using an external laser measuring device to determine the actual accuracy of a parallel robotic platform, a practical and simple leg length compensating calibration method [8] was used to improve the accuracy of the system.

Control Methodologies

The control problem for the parallel robotic platform was rigorously analyzed in the robotic community. Widely used PID control usually provides sufficiently good results. However, for the practical applications sometimes is necessary to deal with the different uncertainties or nonlinearities. Hence, the significant research on the control of parallel robotic platforms was done by analyzing adaptive, robust and predictive control approach.

The adaptive robust control approach was introduced with an idea to combine the advantages of these two approaches during the control task [9]. In [10] a novel robust controller was proposed to minimize the errors during the robust tracking procedures. Article [11] presents the controller synthesis for a highly accurate system of a 3-DOF micro parallel positioning platform. A double servo system for high precision that govern the platform was developed. A method of robust control of 6-DOF hydraulic parallel robot was presented in [12]. The information about the friction was used to reduce the high frequency motions. The non-linear dynamics method and robust multi-input multi-output (MIMO) controller [13] guaranteed system stability. The control tasks were performed on a linearized system model. Further work on L2 robust controller was conducted in [14]. The purpose of the nonlinear controller was to reduce the vibrations of the system. Another robust MIMO controller [15] which solved the tracking problems for the high precision systems. The friction signal was used as an uncertainty that needs to stay within the predefined limits. The presence of uncertainty remained in focus of the authors of the robust controller for tracking tasks [16]. The proposed control was developed based on Lyapunov second method. The sulution of inverse kinematic problem [17] was given for the adaptive robust control of parallel robotic platform. The Lagrange energy method was used in [18] to solve forward dynamics problem and to model the Stewart system. Another solution for vibration problems of the parallel robotic platforms was presented in [19]. The nonlinear robust controller was proposed with the previously developed system dynamics using the Newton-Euler method.

Several reported studies related to the use of the robust controllers together with some other control methodology. The robust control approach was sometimes used as a dual control together with regular feed-forward force control, as in [20]. Furthermore, the predictive model and robust control was used in [21] for position tracing tasks of a parallel manipulator. The task space equations of motion were developed to control the Stewart platform using combined robust and adaptive controller. The developed equations were obtained using the virtual work approach, [22]. A control scheme combining the dynamics disturbance force forward feed with μ synthesis was suggested in [23]. The parallel platform governed by hydraulic system showed high disturbance force during the tracking motions. In this case, the robust controller eliminated the influence of known uncertainties. A new mathematical method [24] used an identification transfer matrix for parallel system dynamics analysis. Article [25] focused on deriving a robust back-stepping control methodology to solve the active vibration isolation problem of the parallel robotic system. The solution of a control problem where the robotic system was loaded with asymmetric payloads was presented in [26]. The examples of different variation of robust controller, such as robust sliding-mode control were analyzed in [27]. The method solved the motion problem with uncertain dynamical behavior in presence of non-linearity. A regulation control of the parallel robots was introduced in [28]. The control schema was applied in the double input/double output (DIDO) subsystems. A novel non-linear adaptive control method, using the robust observer was reported in [29]. A robust-based control algorithm assures the system's

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asymptotic stability and it is based on Lyapunov methodology. A simple robust auto-disturbance rejection controller (ADRC) in link-space [30] was used to realize high precision tracking control of a 6 (DOF) Stewart platform.

Medical Robotics-A Profitable Challenge

Medical robotics is an exciting and relatively new field. Robotics plays an important role in medical engineering. Medical robots were initially used in the 1980s, in the field of urology. Robotic arms were developed and used for prostate resection. They can also be highly specialized and assist in diagnosing and treating patients. While there is still much more work to be done, using robots can enhance medical treatments in terms of both the quality and accessibility of care. Using robots can help reduce human error and bring highly specialized information to remote areas without requiring physicians' direct intervention [31].

For instsance, in radiation therapy, high-energy radiation from x-rays, gamma rays, neutrons, and other sources has been used to kill cancer cells and shrink tumors. Radiation may come from a machine outside the body (external-beam radiation therapy), or it may come from radioactive materials placed in the body near cancer cells (internal radiation therapy, implant radiation, or brachytherapy). The usage of robotic systems to improve the cancer treatment outcome is a new field. This field overlaps with electronics, computer science, artificial intelligence, mechatronics, nanotechnology, and bioengineering.

For this purpose, paralle robotic systems can be used in medical facilities to perform different tasks such as delivering radiation sources, real-time tracking during radiation delivery or external beam delivery. In recent years, the investigation of various aspects of motion management and tracking in medicine, using parallel robotic systems, leaded to development of tools to deliver precise dose to moving target [32]. Consequently, there are strong reasons to believe that medical robotic systems, including parallel manipulators, will continue to attract significant attention in the scientific community.

References

1. Buzurovic IM, Debeljkovic DL (2012) Robust Control for Parallel Robotic Platforms. International Symposium on Intelligent Systems and Informatics.
2. Jakobovic D, Budin L (2002) Forward kinematics of a Stewart platform mechanism. International Conference on Intelligent Engineering Systems.
3. Dasgupta B, Mruthyunjaya TS (2000) The Stewart Platform Manipulator: A Review. Mech Mach Theory 35: 15-40.
4. Fichter EF (1986) Stewart Platform-based Manipulator: General Theory and Practical Construction. Int J Robot Res 5: 157-182.
5. Husty ML (1996) An Algorithm for Solving the Direct Kinematics of General Stewart-Gough Platforms. Mech Mach Theory 31: 365-379.
6. Tsai LW (2000) Solving the Inverse Dynamics of a Stewart-Gough Manipulator by the Principle of Virtual Work. J Mech Des 122: 3-9.
7. Lebret G, Liu K, Lewis FL (1993) Dynamic Analysis and Control of a Stewart Platform Manipulator. Journal of Robotic Systems 10: 629-655.
8. Chai KS, Young K, Tuersley I (2002) A Practical Calibration Process using Partial Information for a Commercial Stewart Platform. Robotica 20: 315-322.
9. Ghobakhloo A, Eghtesad M, Azadi M (2006) Adaptive-Robust Control of the Stewart-Gough Platform as a Six DOF Parallel Robot. World Automation Congress.
10. Oh SR, Mankala K, Agrawal SK, Albus JS (2004) Dynamic Modeling and Robust Controller Design of a Two-Stage Parallel Cable Robot. International Conference on Robotics and Automation.
11. Seo TW, Kang DS, Kim J (2008) Synthesis and Comparison of Fine Actuator Controllers for a 3DOF Micro Parallel Positioning Platform. 10th International Conference on Control, Automation, Robotics and Vision.
12. Xing J, Peng L, Lv B (2008) Vibration Reduction of 6-DOF Hydraulic Parallel Robot Based on Robust Control. International Conference on Computer and Electrical Engineering.
13. Lei L,Ping WG,Ren KX, Li WB(2011) Dynamic Modeling and Robust Active Isolation Control of Stewart Platform. Journal of Astronautics 32: 1231-1238.
14. Yang T, Ma J, Hou Z, Jing F, Tan M (2009) Nonlinear L2 Robust Control of an Active Vibration Isolation Platform Based on Stewart Parallel Mechanism. Jiqiren/Robot 31: 210-223.
15. Fu S, Yao Y, Shen T (2006) Nonlinear Robust Link Space Control for an Electrical Stewart Platform. World Congress on Intelligent Control and Automation.
16. Kang JY, Kim DH, Lee KI (1996) Robust Tracking Control of Stewart Platform. IEEE Conference on Decision and Control.
17. Fu SW, Yao Y, Shen T (2007) Non-linear robust Control Design with Inverse Dynamic Compensation for Stewart Platform Manipulator. Int. J. Modelling Identification and Control 11: 88-92.
18. Tang J, Yuan L, Zhao K (2008) QFT Robust Control of Hydraulic Driven Stewart Platform using Dynamics Real-Time Compensation. World Congress on Intelligent Control and Automation.
19. Yang T, et al. Nonlinear Robust Control Method for Active Vibration Isolation using a Stewart Platform. Proc. of IEEE International Conference on Robotics and Biomimetics (ROBIO), 2008:1059-1064.
20. Peng LK, Xing JF, Zhu SJ, Xiao ZQ (2007) Robust Control of Vibration in Hydraulic Stewart Platform. Journal of System Simulation 19: 5246-5268.
21. Lara-Molina FA, Rosário JM, Dumur D (2011) Robust Generalized Predictive Control of Stewart-Gough Platform. IEEE 9th Latin American Robotics Symposium and IEEE Colombian Conference on Automatic Control.
22. Yime E, Saltaren R, Diaz J (2010) Robust Adaptive Control of the Stewart-Gough Robot in the Task Space. American Control Conference.
23. Lin TJ, Laing DY, Ding ZK (2009) μ Synthesis Control of Hydraulic Stewart Platform Based on Dynamics Disturbance Feed Forward. Journal of Jilin University - Engineering and Technology Edition 39: 662-667.
24. Liu L, Wang B (2008) Multi Objective Robust Active Vibration Control for Flexure Jointed Struts of Stewart Platforms via H8 and μ Synthesis. Chinese Journal of Aeronautics 21: 125-133.
25. Yang T, et al. Robust Backstepping Control of Active Vibration Isolation using a Stewart Platform. Proc. of IEEE Int Conference on Robotics and Automation, 2009:1788-1793.
26. Iqbal S, Bhatti AI, Ahmed Q (2008) Determination of Realistic Uncertainty Bounds for the Stewart Platform with Payload Dynamics. IEEE International Conference on Control Applications.
27. Iqbal S, Bhatti AI (2007) Robust Sliding-Mode Controller Design for a Stewart Platform. International Bhurban Conference on Applied Sciences and Technology.
28. Wen FUS, Yui Y, Lei Han (2009) Selection of Uncertainty Weighting Function for Decentralized Subsystems of an Electrical Stewart Platform. Control Theory and Applications 26:415-419.
29. Dongguang X, Yanliang D, Shenglin W, Bo W, Keding Z (2007) Nonlinear Adaptive Controller Design for the Stewart Platform by Hydraulic Driven. Chin J Mech Eng 43: 223-234.
30. Su YX, Duan BY, Zheng CH, Zhang YF, Chen GD, et al. (2004) Disturbance-Rejection High-Precision Motion Control of a Stewart Platform. Ieee T Contr Syst T 12: 364-374.
31. Buzurovic IM, Podder TK, Yu Y (2012) Robotic Systems for Radiation Therapy. In: Dutta A (2012) Robotic Systems – Applications, Control and Programming, InTech.
32. Buzurovic I, Huang K, Yu Y, Podder TK (2011) A Robotic Approach to 4D Real-time Tumor Tracking for Radiotherapy. Phys Med Biol 56: 1299-1318.

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