실시간 제어를 위한 2 DOF 병렬 로봇 시스템 개발
Development of a 2 DOF parallel robot system for real-time control

* 이진용 [1], #강희준 [2], 서영수 [2], 노영식 [2]

*Tien Dung Le[1], #Hee-Jun Kang(hjkang@ulsan.ac.kr)[2], Young-Soo Suh[2], Young-Shick Ro[2]

[1] 울산대학교 전기공학부대학원, [2] 울산대학교 전기공학부

Key words: Parallel robot, real-time control, robotic manipulators.

1. Introduction

A general parallel robot is a closed-loop kinematic chain mechanism whose end-effector is linked to the base by several independent kinematic chains [1]. Over the last few years, parallel robots have been under increasing developments from a theoretical view point as well as for practical applications. They have good features such as high payload, high stiffness and high speed.

The objective of this paper is to present the development process followed to obtain a 2 DOF parallel robot system for real-time control. The development process includes following steps: First, the geometric dimensions are determined using optimum design methods [2-4]. With these geometric parameters of robot, a maximum usable workspace is obtained. In this usable workspace there is no singularity configurations, and good dextertiy is satisfied. Second, the robot's motion and path control solutions are developed based upon the robotics and feedback control systems theories. The performance of the control system model is analyzed by using Matlab and Simulink software. Third, the system hardware is implemented. The system hardware consists of mechanical parts of the robot, a computer including PCI-bus multifunction cards, and two sevor motors including drivers and encoder sensors. Finally, the real-time control solutions for the robot system are implimented. As a result, the designed 2 DOF parallel robot control system is able to real-time control the actual robot joints and move the end-effector along any specified path within the robot workspace. In the paper, the kinematics model of the 2 DOF parallel robot is presented on section 2. The functions of the hardware and sofware components used in the control system testbed are introduced in section 3. And the conclusion is given in section 4.

2. Kinematics model of the parallel robot

The kinematics of the 2-DOF parallel robot is illustrated in Figure 1. The 2 DOF parallel robot is actuated by two active joints, A_1 and A_2, which are fixed on the base. Three passive revolute joints of the five-bar planar parallel manipulator are P_1, P_2 and E which are free to move.

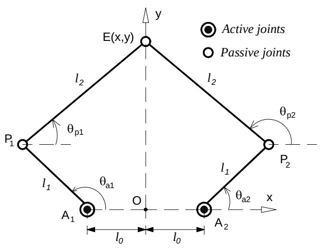

Fig. 1 The 2 DOF parallel robot kinematics.

The link parameters of the five-bar manipulators are: l_1 = 0.102m, l_2 = 0.18m, l_0 = 0.066m. These geometric parameters are obtained by using optimum design methods. With these geometric parameters of robot, a maximum usable workspace is obtained. In this usable workspace there is no singularity configurations, and good dextertiy is satisfied.

From Figure 1, the coordinates of the end-effector E(x,y) can be computed by:

$$x = -l_0 + l_1 \cos\theta_{a1} + l_2 \cos\theta_{p1} \quad (1)$$

$$x = l_0 + l_1 \cos\theta_{a2} + l_2 \cos\theta_{p2} \quad (2)$$

and:

$$y = l_1 \sin\theta_{a1} + l_2 \sin\theta_{p1} \quad (3)$$

$$y = l_1 \sin\theta_{a2} + l_2 \sin\theta_{p2} \quad (4)$$

With the given dimensions above, the 2 DOF parallel robot has a symmetrical structure.

3. System hardware and software

The schematic diagram of the 2 DOF parallel robot system is shown in Figure 2.

The rotating torques of tow active joints are generated by 2 servo motors which are controlled by two servo drivers in torque mode. The personal computer (Intel core i7 professor) calculates the control inputs and through the D/A board Advantech PCI-1720 sends the analog control signals $U_1(t)$ and $U_2(t)$ to the servo drivers. The D/A board Advantech PCI-1720 changes the digital signals from personal computer (PC) to analog voltage $U_1(t)$ and $U_2(t)$.

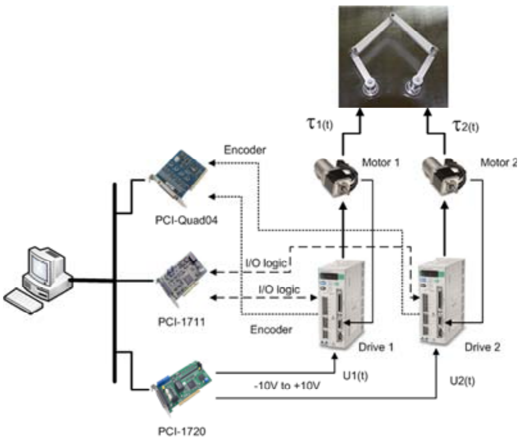

Fig. 2 Schematic diagram of the 2 DOF parallel robot system.

The multifunction board Advantech PCI-1711 controls the servo drivers through input and output logic signals. These logic signals include the commands of start/stop, emergence stop, limited positions,... The active joint angles θ_{a1} and θ_{a2} are detected by rotary endcoders which are integrated inside the servo motors. These active joint angles are fed back to the computer through a 4-channel quadrature encoder board PCI-quad04 which changes digital pulse signals to joint angles values.

The software control algorithm of the closed-loop system is coded in C-mex program code and run in Real-Time Windows Target (RTWT) of Matlab-Simulink environment. RTWT is a PC solution for prototyping and testing real-time systems. RTWT sofware uses a single PC as a host and target. On this PC, we use the Matlab environment, Simulink software, and Stateflow software to create a feedback control algorithm using Simulink blocks and Stateflow diagrams. After creating a model and simulating it using Simulink software in normal mode, we can generate executable code with Real-Time Workshop code generation sofware, Stateflow Coder code generation software, and Open Watcom C/C++ compiler. Then we can run the applications in real time with Simulink external mode.

4. Conclusion

The design project for a 2 DOF parallel robot system for real-time control is presented in this paper. The integration between the servo motor hardware system and Real-Time Windows Target software in Matlab-Simulation environment allows us to control the robot system in real time. The testbed system is very useful for analyzing and verifying the control designs of 2 DOF parallel robots.

References

1. Merlet, J.P., *Parallel Robots*. Second ed. 2006: Springer.

2. Liu, X.-J., J. Wang, and G. Pritschow, *Performance atlases and optimum design of planar 5R symmetrical parallel mechanisms.* Mechanism and Machine Theory, 2006. **41**(2): p. 119-144.

3. Liu, X.-J., J. Wang, and G. Pritschow, *Kinematics, singularity and workspace of planar 5R symmetrical parallel mechanisms.* Mechanism and Machine Theory, 2006. **41**(2): p. 145-169.

4. Tian, H., et al., *Optimal kinematic design of 2-DOF parallel manipulators with well-shaped workspace bounded by a specified conditioning index.* Robotics and Automation, IEEE Transactions on, 2004. **20**(3): p. 538-543.