PROPORTIONAL AND DERIVATIVE CONTROL SYSTEM TO REDUCE THE COMPUTATIONS OF TRANSFORMATION BETWEEN DIFFERENT SPACE REFERENCE FRAMES OF SCARA SERIAL MANIPULATOR

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Abstract: A proportional and derivative servo control system model for a three degree of freedom SCARA serial manipulator has been developed and simulated. The first two joints are revolute joints and the third one is a prismatic joint. Simulated error for the models is introduced into the robot kinematic model, dynamic model and camera projection model in order to test the feasibility of the proposed method. The proportional and derivative servo control system integrated with the joint sensor based control could increase the reliability and fault tolerance of the SCARA serial manipulator. The non-contact measurement and the overview of the manipulator/environment obtained from vision system could help with the decision procedure for the safe operation of the manipulator.

1.0 INTRODUCTION

Robots are being various industrial and domestic applications [1-16]. Vision sensors have been applied extensively in robotic research labs and in industrial environments. A vision system not only can realize non-contact position measurement, but also supplies more flexibility for a robot, such as performing cooperative work between robots and other machines. Visual servo control is a technology that incorporates the vision information directly into the task control loop of a robot [17-20]. In some visual servo control applications, the vision system recovers the actual position information of the robot end effector.

In this paper, the position information of every joint of the SCARA robot will be obtained directly from the vision system, so the control signal, which is calculated in image feature space, can be directly sent to the controller of every joint in order to reduce the computations of transformation between different space reference frames. Simulated error for the models is introduced into the robot kinematic model, dynamic model and camera projection model in order to test the feasibility of the proposed method.

2.0 SIMULATION MODEL

The simulation model of the visual servo control system used for a SCARA robot is shown in Figure 1, which gives the relationship among the models.

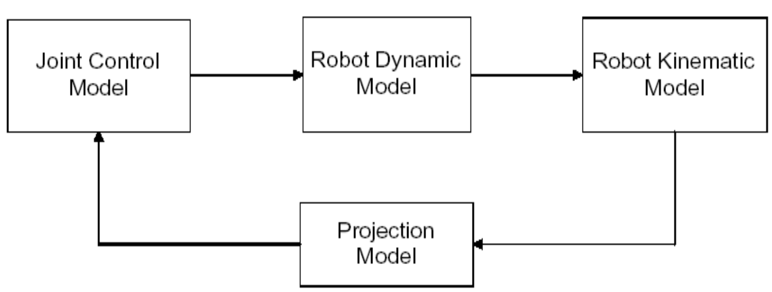

Figure 1 A visual servo control model

2.1 KINEMATIC MODEL

The robot considered in this paper is a simplified SCARA serial manipulator with three degrees of freedom (DOF), the structure of which is shown in Figure 2. The first two joints are revolute joints and the third one is a prismatic joint. The kinematic parameters with Denavit - Hartenberg representations are given in Table 1.

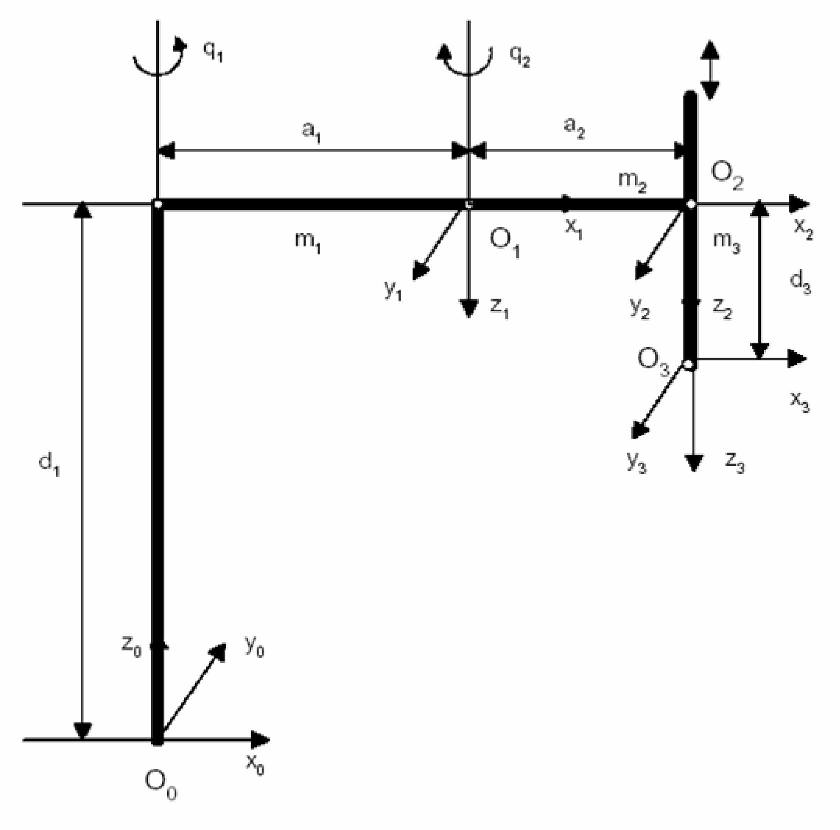

Figure 2.Three-DOF SCARA serial manipulator

Table 1 Kinematic parameters of the example manipulator.

θ	**d**	**a**	**α**
q_1	d_1	a_1	180^0
q_2	**0**	a_2	0^0
0	$d_3 = q_3$	**0**	0^0

2.2 DYNAMIC MODEL

According to Lagrange-Euler dynamic model, the dynamic model of a robot can be represented as

$$\boldsymbol{\tau} = \mathbf{M}(\mathbf{q})\ddot{\mathbf{q}} + \mathbf{N}(\mathbf{q}, \dot{\mathbf{q}}) \qquad (1)$$

where **q** , $\dot{q}$, and $\ddot{q}$ are the vectors of joint positions, velocities and accelerations; **τ** is the vector of the joint torques and forces; **M** is the inertia matrix and **N** represents the effects of friction, gravity and Coriolis and centrifugal force.

2.3 PROJECTION MODEL

From the overhead, the ideal image of the top planes of the joints is shown in Figure 3. The circles on the top plane represent the joints, where each joint can be considered as a cylinder. The centers of the circles can be assigned as origins of the joint coordinate frames. One camera will be placed overhead so that the image plane is parallel to the link plane, then the scaled orthogonal projection model is applied:

$$[u \quad v]^T = s[x \quad y]^T \qquad (2)$$

where $[u, v]^T$ are the coordinates of the observed points in camera frame, which are the centers of the circles shown in Figure 3. Considering the digitization process, equation (2) will be:

$$[u \quad v]^T = s[x \quad y]^T = [(I - I_0)\Delta u \quad (J - J_0)\Delta v]^T \qquad (3)$$

where *(I, J)* are the image coordinates of the points in the digital image; Δu and Δv are decided by the resolution of the image and the optical distortion of the camera along different directions; *s* is a fixed scale factor, which is decided by the focus length and the distance between the image plane and the object. Hough Transformation [3] will be a good method for recognizing those circles.

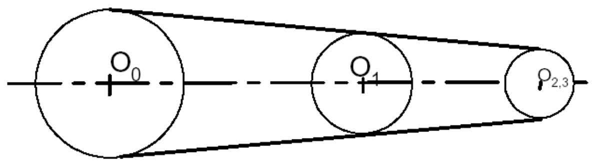

Figure 3 Overhead view of manipulator from the camera

The displacement of the prismatic joint will be recorded by another camera, which will recognize a mark at the end of the cylinder. The mark could be a circular line around the pistol of the prismatic cylinder. The vertical position of this line represents d_3 which is the third joint variable.

2.4 CONTROL MODEL

In some visual servo control systems, the vision system has been used to recover the position information of the robot end effector and then transform it into the joint space by inverse kinematics computations. However in this paper, position information of every joint will be obtained directly from the vision system. The control signal, which is calculated in image feature space, can be directly sent back into the controller of every joint. In the simulation PD (proportional and derivative) control strategy was used in the joint controller.

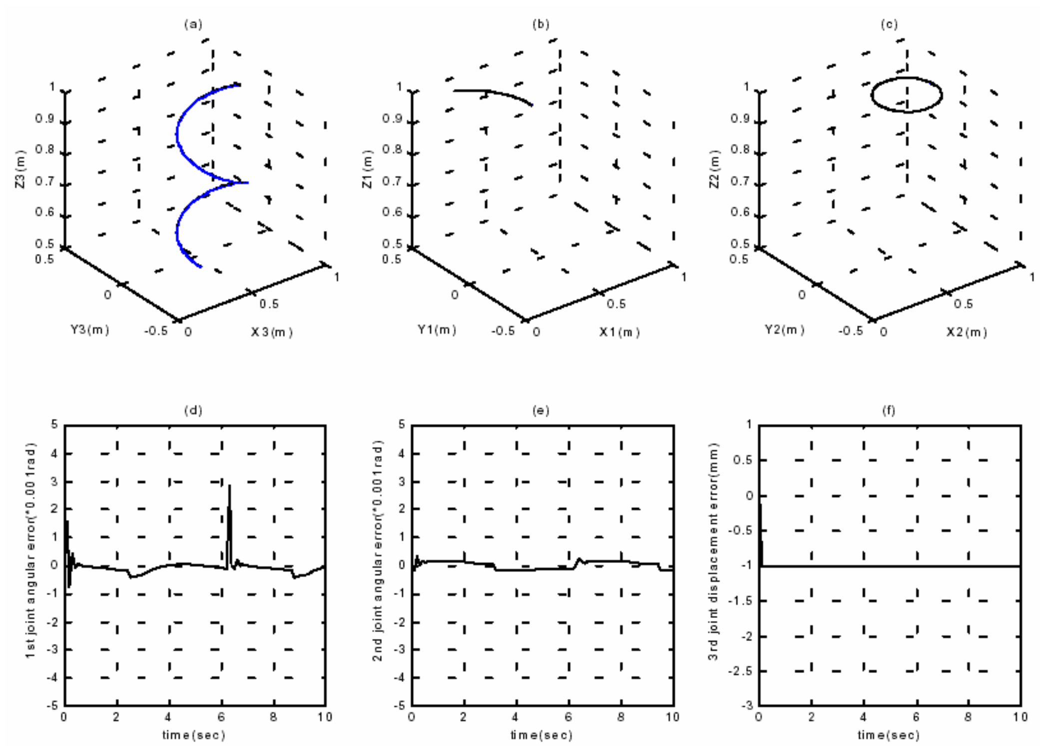

Figure 4 Simulation results with ideal camera model

3.0 SIMULATION RESULTS AND DISCUSSIONS

In this simulation, the robot is required to follow various trajectories in order to test the performance and feasibility of the visual servo control model. Due to the space limitation, the model parameters are not given here. Figure 4 shows the simulation results. No error has been introduced into the kinematic model and camera projection model. Figure 4a shows the desired trajectories of the endpoint of the third joint. Figures 4b and 4c show the desired of the origins of the first and second joints, respectively. Figures 4d, 4e and 4f show the position error of the first, second and third joints, respectively.

In Figure 4, the effect of the digitization due to image processing is obvious. The maximum angular error is 0.003 rad. The error along z_3 axis is less than 1.000 mm. So the results will show a constant error, which might be compensated for according to a “teaching” procedure. The constant errors can also be compensated for by applying calibrating a more precise camera model. The effects of the kinematic dynamic disturbance on the visual servo control model have also been simulated, but are not given here due to the space limitation.

4.0 CONCLUSION

A proportional and derivative servo control system model for a SCARA serial manipulator was developed and simulated. The simulation results of the tracking prove that this system model is feasible. If the delay in the tracking task is not very important, the simulation shows good performance for point -to- point tracking. For simulation purpose other error models could also be investigated and tested.

The proportional and derivative servo control system integrated with the joint sensor based control could increase the reliability and fault tolerance of the SCARA serial manipulator. The non-contact measurement and the overview of the manipulator/environment obtained from vision system could help with the decision procedure for the safe operation of the manipulator.

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REFERENCES:

4. A. Chennakesava Reddy, B. Kotiveerachari, and P. Ram Reddy, Dynamic trajectory planning of robot arms, Journal of Manufacturing Technology, v3, n5, pp.15-18 (2004).

5. A. Chennakesava Reddy, B. Kotiveerachari, and P. Ram Reddy, Finite element analysis of flexibility in mobile robotic manipulators, Journal of Institution of Engineers, v85, n2, 27-31, (2004).

6. A. Chennakesava Reddy,P. Ram Reddy, and B. Kotiveerachari, Optimization of robot arm path planning without collision in its workspace using genetic algorithm, International Conference on Emerging Technologies in Intellectual System and Control, Coimbatore, January 2005.

7. A. Chennakesava Reddy,P. Ram Reddy, and B. Kotiveerachari, Studies on the effect of vibration of robot links on the end point trajectory path using CAD, International Conference on Recent Advances in Material Processing Technology, Kovilpatti, February 2005.

8. B. Rajasekhara Reddy, and A. Chennakesava Reddy, Obstacle avoidance of planar redundant manipulators for pick-and-place operations using real-coded genetic algorithm, National Conference on Advances in Manufacturing Technology, Palghat, February 2003.

9. B. Rajasekhara Reddy, and A. Chennakesava Reddy, Dynamic modeling of two-link robot arm driven by DC motors using linear graph theory and principles of mechanics, National Conference on Trends in Mechanical Engineering, Warangal, August 2003.

10. A. Chennakesava Reddy,P. Ram Reddy, and B. Kotiveerachari , Two methods for computing reduced-form dynamics of closed – chain mechanism, National Conference on Trends in Mechanical Engineering, Warangal, August 2003.

11. B. Kotiveerachari, and A. Chennakesava Reddy, Kinematic and static analysis of gripper fingers using reciprocal screws, National Conference on Computer integrated Design and Manufacturing, Coimbatore , November 2003.

12. A. Chennakesava Reddy,and P. Ram Reddy, Hazard detection for multi - agent reactive robotic system using on - line software analysis of safety constraints, National Conference on Computer integrated Design and Manufacturing, Coimbatore , November 2003.

13. B. Kotiveerachari, and A. Chennakesava Reddy, Non-linear finite element modeling for dynamic trajectory controlling of robotic manipulators with flexible links, National Conference on Advanced Materials and Manufacturing Techniques Hyderabad, March, 2004

14. A. Chennakesava Reddy, and P. Rami Reddy, Elastic rigid-body dynamic modeling of planar parallel robot actuated by servomotors, National Conference on Advanced Materials and Manufacturing Techniques, Hyderabad , March 2004.

15. A. Chennakesava Reddy, P. Ram Reddy, and B. Kotiveerachari, Optimization of path dependent trajectory for an arm - like serial chain robot using genetic algorithm, National Conference on Recent Trends in CAD/CAM, Bidar, July 2004.

16. A. Chennakesava Reddy, P. Ram Reddy, and B. Kotiveerachari, Optimum trajectory path planning for 3-dof planar robot with minimum joint disturbances, National Conference on Advances in Manufacturing Technology in the Era of Globalization, Pune, January 2005.

17. A. Chennakesava Reddy, P. Ram Reddy, and B. Kotiveerachari, Generation of RPR and RRR planar parallel robots using computer program, National Level Technical Symposium Nalgonda , March 2005.

18. J. T. Feddema and O. R. Mitchell: "Vision-Guided Servoing with Feature-Based Trajectory Generation", IEEE Trans. Robotics Automatio*n*, v5, n5, pp. 691-700 (1989).

19. G. Hager, S. Hutchinson, and P. I. Corke: "A Tutorial on Visual Servo Control", IEEE Trans. Robotics Automation, v12, n5, pp. 651-670, (1996).

20. V.F. Leavers, Shape Detection in Computer Vision Using the Hough Transform, Springer-Verlag (1992).