Research on Admittance Control Simulation Based on Simechanics
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Abstract. Firstly, the kinematics of the robot and the principle of admittance control are analyzed. Then, the kinematics model and spatial contact model of 2R robot are established. Furthermore, the robot model and admittance controller are established in Simechanics. Finally, the model is simulated and validated in simulink, and the influence of admittance control parameters on control effect is studied by using control variable method. The results show that the force at the robot end can quickly stabilize to the given force. The mass and damping parameters in admittance control have a great influence on the response speed of the system. The stiffness parameters determine the static error of the system.

Introduction

With the development of industrial robots, the control of robots has gradually extended from position control to force control. In recent years, many researchers have studied how to control the contact force between the robot end and the environment. Raibert et al. [1] proposed the hybrid force/position control which controls the force in some directions and the position in others. Hogan [2] put forward the concept of impedance control. The essence of the concept is that the external environment is equivalent to admittance, the robot is equivalent to impedance, and the impedance is adjusted to control the contact force between the robot end and the environment.

Impedance control requires precise dynamic modeling of the robot, which is more complex to achieve. Indirect force control schemes such as hybrid force/position control cannot solve the problem of changing the position of the operating target. Admittance control is a control scheme which makes the robot end show the desired dynamic system characteristics under a certain force. This paper will do simulation research on admittance control based on Simechanics [3].

Admittance Control of Robot

Kinematics Transform of Robot

There are geometric method, algebraic method and D-H method for solving kinematics of robots. In this paper, the kinematics equation is solved by geometric method. The planar two-link structure is a typical 2R robot, and its structure is shown in Fig. 1.
The forward kinematics equation of the two-link structure can be obtained as follows:

\[
\begin{align*}
  x &= l_1 \cos \theta_1 + l_2 \cos(\theta_1 + \theta_2) \\
  y &= l_1 \sin \theta_1 + l_2 \sin(\theta_1 + \theta_2)
\end{align*}
\]  

(1)

\[\theta_2\] can be solved by cosine theorem:

\[
\theta_2 = \arccos\left(\frac{x^2 + y^2 - l_1^2 - l_2^2}{2l_1l_2}\right)
\]  

(2)

Then the values of \(\psi\) and \(\beta\) can be obtained:

\[
\begin{align*}
  \beta &= A \tan 2(y, x) \\
  \psi &= \arccos \frac{x^2 + y^2 + l_1^2 - l_2^2}{2l_1 \sqrt{x^2 + y^2}} \\
  \theta_1 &= \beta \pm \psi
\end{align*}
\]  

(3)

When \(\theta_2 < 0\), Eq. 3 takes "+", when \(\theta_2 > 0\), Eq. 3 takes "-".

Admittance Control Principle

The admittance control model is shown in Eq. 4. \(e\) is the relative displacement between the colliding objects, \(F\) is the contact force, \(M\) is the expected mass matrix, \(C\) is the expected damping matrix, \(K\) is the expected stiffness matrix [4].

\[
F = (Ms^2 + Cs + K)e
\]  

(4)

As shown in Fig. 2, the admittance control adjusts the displacement of the robot end according to the actual feedback force of the robot end, so as to achieve the purpose of adjusting the contact force.

Simulation Model Based on Simechanics

In order to verify the control effect of admittance control and the influence of control parameters on the control effect, the above two-link model is built in simulink/Simechanics, as shown in Fig. 4.
The Env module is used to set up the simulation environment. The mechanical part is composed of Root Ground, Revolute and Body. The electrical part is composed of Joint Actuator, position Sensor and velSensor.

The initial parameters of the two-link model and the inherent parameters of the system are shown in Table 1.

Table 1. Two-link model parameters.

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<tr>
<td>$l_1$</td>
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<td>$l_2$</td>
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<td>$\theta_1$</td>
<td>90[°]</td>
<td>$\theta_2$</td>
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The admittance control model of two-link system is established according to Fig. 2 and the kinematics equation of the two-link system, as shown in Fig. 5.

The parameters of the simulation experiment are set as follows: stiffness in X direction is 1000N/m, stiffness in Y direction is 0N/m, target force is 500N.

### Simulation Experiment

The admittance control parameters of the simulation experiment are as follows: $M=[100,0;0,100]$, $B=[400,0;0400]$, $K=[0.01,0;0.01]$. The response trajectory and contact force of the robot end are shown in Fig. 6.
Figure 5. The response trajectory and contact force of the robot end.

Fig. 6 shows that the initial position of robot end is (1,1). At this time, the contact force is zero. The controller controls the motion of the robot according to the deviation between the contact force and the target force. Finally, the position of the robot end is stable at (1.5,1) and the force is stable at 500N.

The control variable method is used to study the influence of admittance control parameters on the control effect. The system response is shown in Fig. 7.

As can be seen from Fig. 7 with the increase of M parameter, the response of the system becomes faster, but there will be overshoot at the same time. When the B parameter is too large, the system shows over-damping, slow response and long time to reach stable state. The K parameter has a great influence on the static error of the system. When K is small, the static error of the system is small. With K increasing, the static error of the system increases gradually.
**Conclusion**

In this paper, the admittance control in the field of force control is studied theoretically and simulated experimentally. Firstly, the kinematics transformation and admittance control principle of the robot are studied, and the admittance control model of the robot is obtained. Then a robot model is built based on Simechanics, and the admittance control is simulated and validated by simulink. The experimental results show that the admittance control has fast response speed and strong robustness. Among the admittance control parameters, the mass parameter and the damping parameter have a greater impact on the response speed of the system, while the stiffness parameter has a greater impact on the static error of the system. Subsequently, the application of impedance control in self-piercing riveting and other scenarios will be studied.

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**References**


