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基于阻抗内环的新型力外环控制策略

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Novel Explicit Force Control Strategy Based on Impedance Inner Control

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摘要 对于空间装配等与环境进行交互的任务，迫切要求空间机器人具有力控制的能力。利用机器人的关节力矩传感器，提出了一种新型的基于阻抗内环的力外环控制策略。在该方法中，内环采用阻抗控制代替传统的位置控制。阻抗控制内环使机器人具有一定的柔顺性，力外环通过期望力与实际力的误差对内环的参考轨迹进行修正，实现了机器人的力跟踪控制。另外，为了验证利用关节力矩传感器间接测量末端接触力的效果，机器人末端安装了一个高精度的JR3腕力传感器用来直接测量实际接触力。在基于位置内环和阻抗内环的力外环控制方式下，进行了机器人接触刚度变化较大环境（海绵、泡沫和铁块）的力跟踪实验。实验表明，当环境刚度变化较大时，相对于传统的力外环方法，本文提出的方法能够实现稳定的力跟踪性能。尤其对于铁块这种刚度很大的环境，该方法的有效性更加明显。

关键词： 力控制 力矩控制 力外环控制 空间机器人

Abstract: The ability of force control for space robots is crucial for tasks which require robots to interact with the environment, such as space assembling. Utilizing joint torque sensors of the manipulator, in this article, a novel explicit force control strategy based on impedance inner loop control is proposed in which an impedance controller is selected as the inner loop instead of the traditional position controller. The impedance inner loop controller guarantees the compliance of the robot and the outer loop modifies the reference trajectory of the inner loop based on force errors between the desired and actual forces, thus realizing force tracking control. Furthermore, in order to validate the contact force of the end effector measured indirectly by joint torque sensors, a high precision wrist force/torque sensor mounted on the manipulator is used to measure the real contact force directly. Force tracking experiments of contacting various stiffness environments of sponge, foam, and iron surfaces have been performed under both position inner loop control and impedance inner loop control. Experimental results show that the proposed method exhibits more stable force tracking performance while contacting different environments. The effectiveness of the proposed method is especially obvious for high stiffness environment, such as iron material.

Keywords: force control torque control explicit force control space robot

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