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三自由度驱动冗余并联机构动力学建模与试验

Dynamics modeling and experiments of 3-DOF parallel mechanism with actuation redundancy

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中文摘要:

对于农业机器人而言，其动力学模型是进行动力学特性分析的基础，是实现动力学优化设计及高精度操作的前提。该文针对一种新型驱动冗余并联机构进行了动力学建模，该机构的动平台通过2个PRRR支链和1个PPRR支链与静平台相连，拥有2个转动自由度和1个平动自由度。在分析并联机构组成的基础上，充分考虑各构件惯性力的影响，建立基于Lagrange方程的工作空间完整动力学模型，并运用最小2范数法实现驱动力优化；通过分析给定路径下并联机构各主要组成构件对驱动力的影响，提出针对上述完整动力学模型的简化方案。结合并联机构应用特点，进行了仿真及试验。结果表明，非冗余驱动情况下第1，2轴向驱动力的最大值为15 N，施加冗余驱动后，最大值降为10 N，各驱动力峰值降低约33%；机构位姿角β达到57.6460o时，各驱动力均发生急剧变化，经验证可知该点为奇异点，在实际应用中应避开该点。机构末端轨迹跟踪结果显示，在Y，Z和β方向的最大跟踪误差分别为0.8 mm，0.6 mm和0.068o，因此，基于本文所建立的简化动力学模型的机器人控制系统具有良好的跟踪特性。该研究可为冗余并联机构的动力学控制方法设计提供重要参考。

英文摘要:

Abstract: Dynamics modeling plays an important role in the application of agricultural robots, which is the key to analyze the dynamic characteristics and achieve high-precision operation. This paper addressed the issue of deriving the dynamic formulation of a novel 3-DOF redundantly actuated parallel mechanism. The structure of the parallel mechanism is composed of a moving platform attached to a fixed platform through two identical PRRR kinematic chains and one PPRR chain. The parallel mechanism has two translational degrees and one rotational degree. Firstly, inverse kinematic solution of the parallel mechanism was studied by analyzing the structure property and the constraint equation; Secondly, according to the kinematics of the redundant mechanism and considering fully the impact of inertial force for each component, the inverse dynamic equation was formulated in the task space by using the Lagrangian formalism, and the driving force was optimized by utilizing the minimal 2-norm method. By investigating the contribution of each term in the dynamic model to the driving force, a simplified strategy of the dynamic model for real-time control application was proposed. Simulation and experimental results showed that the maximal value of the driving force for the parallel mechanism without actuation redundancy was 15N, but that of mechanism with actuation redundancy was 10N andthe driving force peak was reduced by 33%. It is noted that the point β=57.6460° was the singularity which should be avoided in practical application. Additionally, the maximal tracking errors for the end-effector were 0.8mm, 0.6mm and 0.068° in Y, Z and β direction, respectively. Thus the parallel mechanism system based on the proposed dynamic model can achieve good tracking performance. This research provides technology reference for further study of high precision real-time control of parallel mechanism.