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三轴式无人旋翼飞行器及自适应飞行控制系统设计

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A Design of Triaxial Unmanned Rotor Aircraft and Its Adaptive Flight Control System

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摘要

设计了一种操控简便的三轴式无人旋翼飞行器,由三组共轴双旋翼组成,各旋翼由直流电机直接驱动,只需调节各电机转速就能控制旋翼飞行器运动姿态和轨迹。为使三轴式无人旋翼飞行器飞行控制系统设计得到有效验证,研究了旋翼飞行器的飞行动力学非线性建模,运用叶素动量理论建立了共轴双旋翼变转速旋翼载荷计算方法,分析了旋翼入流分布对共轴双旋翼气动载荷模型的影响,通过试验验证了共轴双旋翼气动载荷计算模型的正确性。由于旋翼飞行器飞行动力学模型的非线性及未建模动力学的影响,难于建立非常精确的数学模型,给飞行控制系统设计带来了挑战。本文根据旋翼飞行器飞行动力学非线性模型推导出了旋转动力学模型逆和平移动力学模型逆控制器,利用神经网络在线自适应修正模型逆误差,采用线性PD或PI控制器调节指令跟踪误差,应用由向心回转和垂直上升组合的机动科目进行了仿真验证,给出了具有外界阵风干扰模拟的仿真结果,表明所设计的飞行控制系统具有自适应性和鲁棒性,能实现精确的轨迹跟踪控制。

关键词： 无人飞行器 共轴旋翼 多旋翼 气动特性 动态逆 神经网络自适应控制 机动科目仿真验证

Abstract:

A tri-axial unmanned rotor aircraft consisting of three sets of coaxial rotors is designed. The control mechanism of the unmanned rotor aircraft is very much simplified. The rotors are directly driven by DC motors. The speed of each motor is the only regulating variable which could control the attitude and trajectory of the aircraft. In order to verify the design of the flight control system for the triaxial unmanned rotor aircraft, a nonlinear dynamic model of the aircraft is investigated. A computing method of the rotor aerodynamic loads is established by means of the blade element momentum theory. The effect of the rotor inflow characteristics on the rotor aerodynamic load is analyzed. The validity of the rotor aerodynamic load model for the co-axial rotor is tested by experiments. Due to the influence of nonlinearity and un-modeled dynamics, it is quite difficult to establish a very accurate mathematical model, which makes it a challenge to design a flight control system. In this paper, a rotational dynamical model inverse controller and translational dynamical model inverse controller are deduced according to the nonlinear model of the aircraft. The model inverse error is adaptively compensated with an online neural network. The command following error is regulated with a PD/PI controller. A combined maneuver flight mission task element is applied to simulation validation, which included pirouette and vertical maneuvers. A demonstration is conducted to validate the flight control system of the tri-axial unmanned rotor aircraft. Simulation results including an imitation of gust disturbance are provided. The demonstration shows clearly that the designed flight control system has adaptability and robustness, and that it can implement accurate command following control.

Keywords: unmanned aerial vehicle coaxial rotor multi-rotor aerodynamic characteristic dynamic inversion neural network adaptive control maneuver flight simulation verification

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