多指仿人机器人灵巧手的同步控制研究

一、本文概述

Overview of this article

随着科技的不断进步和的深入发展，仿人机器人技术已成为当今研究的热点领域。作为仿人机器人的重要组成部分，灵巧手的设计与控制技术直接决定了机器人的操作能力和实用性。多指仿人机器人灵巧手，作为模拟人类手部功能的重要装置，其在精细化操作、抓取稳定性以及适应性等方面具有显著优势。本文旨在研究多指仿人机器人灵巧手的同步控制技术，以提高其运动协调性和操作精度，为仿人机器人技术的发展提供理论支持和实践指导。

With the continuous progress and in-depth development of technology, humanoid robot technology has become a hot research field today. As an important component of humanoid robots, the design and control technology of dexterous hands directly determine the operational ability and practicality of robots. The multi finger humanoid robot dexterous hand, as an important device for simulating human hand functions, has significant advantages in fine operation, grasping stability, and

adaptability. This article aims to study the synchronous control technology of multi finger humanoid robot dexterous hands, in order to improve their motion coordination and operational accuracy, and provide theoretical support and practical guidance for the development of humanoid robot technology.

文章首先介绍了多指仿人机器人灵巧手的基本结构和特点，包括手指数量、关节配置以及驱动方式等。随后，阐述了同步控制在多指仿人机器人灵巧手操作中的重要性，以及现有同步控制技术的不足和挑战。在此基础上，文章提出了一种新型的同步控制策略，该策略结合了现代控制理论和机器学习方法，旨在实现更快速、更准确的灵巧手运动控制。

The article first introduces the basic structure and characteristics of a multi finger humanoid robot dexterous hand, including the number of fingers, joint configuration, and driving mode. Subsequently, the importance of synchronous control in the dexterous hand operation of multi finger humanoid robots was elaborated, as well as the shortcomings and challenges of existing synchronous control technologies. On

this basis, the article proposes a novel synchronous control strategy that combines modern control theory and machine learning methods, aiming to achieve faster and more accurate control of dexterous hand movements.

本文的研究内容主要包括以下几个方面：对多指仿人机器人灵巧手的运动学模型进行建模和分析，为后续的同步控制算法设计提供理论基础；设计并实现了一种基于优化算法的同步控制策略，以提高灵巧手在运动过程中的协调性和稳定性；再次，通过仿真实验和实际应用测试，验证了所提同步控制策略的有效性和可靠性；对研究结果进行了总结和展望，提出了未来研究方向和潜在应用领域。

The research content of this article mainly includes the following aspects: modeling and analyzing the kinematic model of the dexterous hand of a multi finger humanoid robot, providing a theoretical basis for the subsequent design of synchronous control algorithms; A synchronization control strategy based on optimization algorithms has been designed and implemented to improve the coordination and stability of dexterous hands during movement; Once again, the effectiveness and reliability of the proposed synchronization control

strategy were verified through simulation experiments and practical application tests; A summary and outlook of the research results were presented, and future research directions and potential application areas were proposed.

通过本文的研究，不仅为多指仿人机器人灵巧手的同步控制提供了新的思路和方法，也为仿人机器人技术的发展和应用推广奠定了坚实基础。

Through the research in this article, not only does it provide new ideas and methods for synchronous control of multi finger humanoid robot dexterous hands, but it also lays a solid foundation for the development and application promotion of humanoid robot technology.

二、多指仿人机器人灵巧手的结构与特点

The structure and characteristics of a multi finger humanoid robot dexterous hand

多指仿人机器人灵巧手是机器人技术领域的重要分支，其设计灵感来源于人类手部的复杂结构和功能。这种灵巧手的设计初衷是模拟人类手部的多指结构和灵活性，以实现更精细、更复杂的操作任务。

Multi finger humanoid robot dexterous hands are an important branch of robotics technology, and their design inspiration comes from the complex structure and function of human hands. The original intention of the design of this dexterous hand is to simulate the multi finger structure and flexibility of the human hand, in order to achieve more precise and complex operational tasks.

结构上，多指仿人机器人灵巧手通常由多个指节和关节组成，每个指节都可以进行独立的弯曲和伸展动作。这样的设计使得灵巧手能够模仿人类手指的精细动作，如抓取、捏取、握持等。为了增强灵巧手的稳定性和适应性，许多设计还会配备传感器，如力传感器和触觉传感器，以便在操作过程中实时感知外界环境和力量变化。

Structurally, a multi finger humanoid robot dexterous hand typically consists of multiple knuckles and joints, each of which can perform independent bending and stretching movements. This design enables dexterous hands to mimic the fine movements of human fingers, such as grasping, pinching, and gripping. In order to enhance the stability and adaptability of dexterous hands, many designs are also equipped with sensors, such as

force sensors and tactile sensors, to sense the external environment and force changes in real time during operation.

特点上，多指仿人机器人灵巧手具有以下几个显著优势。首先是灵活性高，其多指结构和独立控制的关节使得它能够执行各种复杂的操作任务。其次是适应性强，通过配备各种传感器，灵巧手可以感知并适应不同的环境和物体形状。最后是精度高，通过精确控制每个指节的运动和力量，灵巧手可以实现高精度的操作，如装配零件、书写等。

In terms of characteristics, multi finger humanoid robot dexterous hands have the following significant advantages. Firstly, it has high flexibility, as its multi finger structure and independently controlled joints enable it to perform various complex operational tasks. Secondly, it has strong adaptability. By equipped with various sensors, dexterous hands can perceive and adapt to different environments and object shapes. Finally, high precision is achieved through precise control of the movement and force of each finger joint, allowing dexterous hands to perform high-precision operations such as assembling parts and writing.

然而，多指仿人机器人灵巧手的设计和控制也面临一些挑战。例如，由于结构复杂，其运动学和动力学模型也更为复杂，这给控制算法的设计和实现带来了难度。为了实现精确的同步控制，还需要解决多指之间的协调和运动规划问题。

However, the design and control of multi finger humanoid robot dexterous hands also face some challenges. For example, due to its complex structure, its kinematic and dynamic models are also more complex, which brings difficulties to the design and implementation of control algorithms. In order to achieve precise synchronization control, it is also necessary to solve the coordination and motion planning problems between multiple fingers.

多指仿人机器人灵巧手作为一种模拟人类手部的机器人装置，在结构和特点上都具有独特的优势和挑战。未来的研究将集中在如何进一步提高其灵活性、适应性和精度，以满足更广泛的应用需求。

The multi finger humanoid robot dexterous hand, as a robot device that simulates human hands, has unique advantages and challenges in structure and characteristics. Future research will focus on how to further improve its flexibility,

adaptability, and accuracy to meet a wider range of application needs.

三、同步控制策略与算法

Synchronous control strategy and algorithm

同步控制是多指仿人机器人灵巧手实现精细、协调操作的关键技术。为实现多指仿人机器人灵巧手的同步控制，本文提出了一种基于运动学逆解和动力学优化的同步控制策略，并设计了相应的算法。

Synchronous control is a key technology for achieving precise and coordinated operation of multi finger humanoid robot dexterous hands. To achieve synchronous control of multi finger humanoid robot dexterous hands, this paper proposes a synchronous control strategy based on inverse kinematics and dynamic optimization, and designs corresponding algorithms.

通过运动学逆解算法，根据目标物体的形状、大小和姿态，计算出多指仿人机器人灵巧手各手指的关节角度，以实现对手指姿态的精确控制。该算法基于几何学和运动学原理，通过建立手指与目标物体之间的空间关系，求解出各手指关节的最优角度，从而保证多指仿人机器人灵巧手能够准确地抓取和操作目标物体。

By using inverse kinematics algorithm, the joint angles of each finger in the dexterous hand of a multi finger humanoid robot are calculated based on the shape, size, and posture of the target object, in order to achieve precise control of finger posture. This algorithm is based on geometric and kinematic principles. By establishing the spatial relationship between fingers and the target object, the optimal angles of each finger joint are solved, ensuring that the multi finger humanoid robot dexterous hand can accurately grasp and operate the target object.

为了实现多指仿人机器人灵巧手的动力学优化，本文采用了一种基于优化算法的动力学模型。该模型考虑了多指仿人机器人灵巧手的惯性、重力、摩擦等动力学因素，通过优化算法对动力学模型进行求解，得到各手指关节的最优运动轨迹和力/力矩输出，从而实现多指仿人机器人灵巧手的平稳、协调运动。

In order to achieve dynamic optimization of the dexterous hand of a multi finger humanoid robot, this paper adopts a dynamic model based on optimization algorithms. This model takes into account the dynamic factors such as inertia, gravity,

robot. Through optimization algorithms, the dynamic model is solved to obtain the optimal motion trajectory and force/torque output of each finger joint, thereby achieving smooth and coordinated motion of the dexterous hand of a multi finger humanoid robot.

为了实现多指仿人机器人灵巧手的同步控制，本文采用了一种基于时间同步的控制算法。该算法通过设定一个统一的时间基准，对各手指的运动轨迹和力/力矩输出进行同步控制，从而保证多指仿人机器人灵巧手各手指之间的协调性和同步性。

In order to achieve synchronous control of the dexterous hand of a multi finger humanoid robot, this paper adopts a control algorithm based on time synchronization. This algorithm synchronizes the motion trajectory and force/torque output of each finger by setting a unified time benchmark, ensuring coordination and synchronization between the fingers of a multi finger humanoid robot dexterous hand.

本文提出的基于运动学逆解和动力学优化的同步控制策略及算法，能够有效地实现多指仿人机器人灵巧手的同步控制，提高多指仿