# 摘 要

上肢外骨骼机器人应用于康复训练领域可以帮助上肢运动功能受损的患者完成功能性活动和日常活动，为此本文设计了一款基于 STM32 的上臂外骨骼机器人仿生运动控制系统，它能够感知患者主动运动意图并驱动外骨骼执行与运动意图相适应的仿生运动动作，为脑卒中患者的的康复训练提供一定的技术支持。本文的主要内容包括以下几个方面：1）上臂外骨骼机器人仿生运动机理分析。通过分析人体上肢解剖结构和人体上肢运动的产生机制并将其与外骨骼机器人的本体机械结构相对照，确定了外骨骼机器人各关节的运动属性和活动范围，并且使用 D-H 法对外骨骼机器人进行运动学分析，计算其完成仿生运动所需的关节角位移；2）上臂外骨骼机器人控制系统总体设计。根据机器人控制系统在触发信号、通讯模块和安全性方面的需求，完成了本控制系统的总体设计，主要包括人体上肢动作模式识别和上臂外骨骼仿生运动实现两部分内容，其中，模式识别作为触发信号，在经过通讯模块传输后用于控制上臂外骨骼仿生运动；3）患者运动意图识别。根据人体上肢完成不同类型动作产生的表面肌电信号，使用 Pytorch 建立了卷积神经网络进行不同人体上肢动作的识别和分类，并依据实验采集的数据对卷积神经网络进行了训练和测试，测试结果表明，该卷积神经网络的分类正确率为 98.15%，能够有效识别到表面肌电数据下蕴含的动作类型信息；4）上臂外骨骼机器人仿生运动控制系统设计。首先，根据上臂外骨骼机器人仿生运动的控制需求，完成了控制系统元器件（步进电机、步进电机驱动器、减速器、电源等）的选型和连接，然后根据控制系统的软件需求，进行了患者运动意图识别模块、运动指令传输模块、上臂外骨骼仿生运动驱动模块的软件设计，最后，进行了系统软硬件的集成。5）上臂外骨骼仿生运动控制实验。根据控制系统的软硬件设计，建立了 STM32 的上臂外骨骼机器人仿生运动实验平台，进行了离线识别患者运动意图并驱动外骨骼机器人运动的实验，实验结果表明，本控制系统识别准确率为 99.07%且外骨骼机器人重复 16 次仿生运动动作不发生失步。

**关 键 词**：表面肌电信号；模式识别；STM32；运动学分析；控制系统

# ABSTRACT

The upper- limb exoskeleton robot used in the field of rehabilitation training help patients with impaired upper limb function complete functional and daily activities. Therefore, a STM32-based upper-limb exoskeleton robot bionic motion control system which can sense patients' movement intentions is studied. The intention of the movement decide the bionic movement type of the exoskeleton. The control system can provide certain technical support for the rehabilitation training of the stroke patients. The main contents of this paper include the following aspects: 1) Analysis of the bionic motion mechanism of the upper-limb exoskeleton robot. By analyzing the anatomy of the upper limbs and the mechanism of the upper limb movement of the human body and comparing it with the mechanical structure of the exoskeleton robot, the motion properties and range of motion of the joints of the exoskeleton robot are determined, and the exoskeleton robot is analyzed by D-H method for calculating the joint displacement required to complete the bionic movement; 2) The overall design of the upper-limb exoskeleton robot control system. According to the requirements of the robot control system in terms of trigger signal, means of communication, safety, the overall design of the control system is completed, which mainly contains upper-limb motion pattern recognition and the exoskeleton bionic motion. Among the control system, pattern recognition works as a trigger for the upper-limb exoskeleton; 3) the patient's motion intention identification. With regard to the sEMG signals generated while human upper-limb moving, Pytorch was used to establish a convolutional neural network to identify different upper-limb movements. The convolutional neural network was trained and tested. The test result shows that the classification accuracy of the convolutional neural network is 98.15%, which means the method offered can effectively identify the movements. 4) Design of the bionic motion control system of the upper-limb exoskeleton robot. Firstly, according to the requirements, the selection and connection of the control system components (stepping motor, stepping motor driver, reducer, power supply, etc.) are completed. Secondly, code is written for the control system which has three main parts: motion intent recognition module, the motion instruction transmission module and the upper-limb exoskeleton bionic motion module. Finally, the integration of software and hardware was carried out. 5) Upper-limb exoskeleton bionic motion control experiment. According to the software and hardware design of the control system, a STM32 based upper-limb exoskeleton robot bionic motion experimental platform was established. The experiment of offline recognition of patient's motion intention and the exoskeleton movement is carried out. The experimental results show that the control system has a recognition accuracy rate of 99.07 % and can repeat 16 times of one kind of bionic motion action without loss of synchronization.

**KEY WORDS**: SEMG signal; Pattern recognition; STM32; kinematics' analyzomg ; control system

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