博士学位论文摘要选登

大型拼接镜面望远镜子镜装卸装置的研究

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自从 400 yr 前伽利略第 1 次使用望远镜观测天空以来，人类为了探索更深的宇宙，望远镜的口径越做越大，拼接镜面望远镜成为趋势. 本世纪初一批大口径拼接望远镜先后被研制出来，这其中包括我国的大天区面积多目标光纤光谱天文望远镜 LAMOST. 随着望远镜口径增大，子镜单元增多，子镜单元的装卸问题日益突出. 本文试图对这一问题进行探讨，设计了一套用于 LAMOST 球面主镜的子镜单元装卸装置，希望为大口径望远镜的子镜装卸提供一些思路和借鉴.

文章对目前世界上运行的大口径拼接镜面望远镜的子镜单元安装方式进行了调研，比较了多种安装方案，结合 LAMOST 球面主镜的安装特点，提出了一个多级串联、具有多个冗余自由度的子镜装卸装置设计方案.

基于该设计方案，进行了运动学理论研究，先建立了装卸装置的运动学模型，完成了机器人的正运动学和逆运动学求解，得到了实际安装 37 块子镜时，各个关节的运动曲线，使用样条曲线拟合优化实际安装过程.

第 2 章中分析了装卸机器人的动力学特性，并按照拉格朗日方法推导装卸机器人的动力学方程，分析了装卸机器人的耦合特性，使用软件分析得出了机器人各关节在运动中的受力和力矩曲线.

在理论分析的基础上，具体设计了整个装卸装置的实际结构，其中机械臂部分采用技术成熟的随车吊改造，提供大位移、高速度的粗定位；机械手部分具有 6 个自由度，在设计中对 6 个部分分别进行了校核计算，多次改进方案，最终完成了整个机械手的设计；两者使用液压推杆连接，保持机械手底面始终水平.

在第 6 章，分析了装卸装置的控制特点，提出了总体的控制方案和整个控制流程图，并在此基础上选择了控制器件.

最后总结了整个设计过程，提出了装置的进一步改进思路，为以后大口径拼接镜面望远镜的子镜装卸提供一些经验和借鉴.

A Research on the Primary Mirror Manipulator of Large Segmented-mirror Telescope

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Since Galileo firstly used the telescope to observe the sky 400 years ago, the aperture of the telescope has become larger and larger to observe the deeper universe, and the

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segmented-mirror telescope is becoming more and more popular with increasing aperture. In the early 21st century, a series of segmented-mirror telescopes have been constructed including the Large Sky Area Multi-object Fiber Spectroscopic Telescope (LAMOST) of China. LAMOST is a meridian reflecting Schmidt telescope, and the dimension of the primary mirror is about 6.7 m$\times$6 m, which is composed of 37 hexagonal sub-mirrors. However, a problem about the mirror installation appears with the increasing aperture. If there are hundreds of sub-mirrors in the telescope, it is a challenging job to mount and dismount them to the truss. This problem is discussed in this paper and a manipulator for the primary mirror of LAMOST is designed to perform the mount and dismount work.

In chapter 1, all the segmented-mirror telescopes in the world are introduced and how the sub-mirrors of these telescopes are installed has been investigated. After comparing with the serial and the parallel robot, a serial robot manipulator proposal, which has several redundant degrees of freedom (DOFs), has been chosen from a series of design proposals.

In chapter 2, the theoretical analysis has been carried out on the basis of the design proposal, which includes the forward kinematics and the inverse kinematics. Firstly the D-H coordinate is built according to the structure of the manipulator, so it is possible to obtain the end-effector position and orientation from the individual joint motion thanks to the forward kinematics. Because of the redundant DOFs of the manipulator, the inverse kinematics solution can be a very trick task, and the result may not be only, therefore a kind of simulation is carried out to get the numerical solution using ADAMS (Automatic Dynamic Analysis of Mechanical System).

In the dynamics analysis the Lagrange formulation is introduced, and the dynamic equations of the manipulator have been obtained by using the Lagrange method. Since the manipulator is a serious coupling system, the dynamic curve of the key joints is plotted by using the ADAMS software.

According to the theoretical analysis, the manipulator for the primary mirror of LAMOST is designed and fabricated. The whole manipulator consists of three parts. The first part is the mechanical arm which is used to realize the high speed and the long distance location, and it is rebuilt from a small truck crane; The second part is a serial mechanical hand which is used to realize the low speed and the short distance location. It has six DOFs including the pitch, the rotate about the vertical axis, the elevation along the vertical axis, and two horizontal translations. Subsequently the structure is analyzed in the ANSYS software to confirm that the strength is enough and the displacement is in the tolerance; The third part is a mechanical wrist, in which part a hydraulic rod is used to keep the bottom of the mechanical hand horizontal.

In chapter 6, the control characteristics of the whole manipulator are analyzed. Furthermore, the control method and flowchart are proposed. Based on this method the control device was selected.

In the end of this paper, the main work and the results of this project are summarized. Further research is prospected and it provides a reference for the future large telescope projects.