光学 精密工程
OPTICS AND PRECISION ENGINEERING
核心期刊
主管：中国科学院
主办：中国科学院长春光学精密机械与物理研究所
中国仪器仪表学会
主编：曹健林

光学精密工程 2012, 20(1) 131-139 ISSN: 1004-924X CN: 22-1198/TH

微纳技术与精密机械

心脏动脉旁路手术中手术辅助机器人的模型跟随控制

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摘要： 为了使非体外循环心脏动脉旁路移植(CABG)手术中的手术辅助机器人能快速、准确地跟踪心脏表面手术点的运动,消除心脏与手术工具的相对运动,提出了心脏运动信号的自适应时变线性回归模型,将对心脏信号的跟踪问题转化为对心脏运动信号模型的运动跟随问题。应用卡尔曼滤波器动态估计手术辅助机器人系统的运动状态,并结合最优跟踪理论实现了基于心脏运动模型的随动跟踪控制。实验结果表明,与以往的相动运动消除算法相比,运用模型跟随控制算法的机器人系统能将相对运动消除能力提高30%,跟踪误差减小0.25 mm。因此,基于心脏运动自适应模型跟随算法能够进一步消除CAGB心脏手术中的相对运动,大大减小了动态跟踪误差。

关键词： 手术辅助机器人 跟踪控制 自适应心脏运动模型 模型跟随控制 卡尔曼滤波器

Model-following control of assisted robotics in CABG surgery

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Abstract: In the Off Pump Canary Artery Bypass Graphed (CABG) surgery, a robot is usually used to dynamically track the Point of Interest (POI) on the beating heart. To achieve better tracking performance and cancel the relative motion of the heart and the assisted robotics,an adaptive Auto-regessive (AR) linear model of heart motion was built to convert the complicated heart motion tracking problem to a dynamic model following problem. The Kalman filter was used to estimate the motion state of the assisted system and the linear quadratic optimal tracking theory was used to implement the model-following method. The results show that the model-following method which provides estimated future reference enables the robot to improve the relative motion cancellation ability by 30% and decrease the tracking error by 0.25 mm. The comparison tracking result on 3D test bed Phantom robotics is reported, which proves that the model-following method enhances the ability of dynamic relative motion cancellation during the CABG sugary.

Keywords: surgical assisted robotics tracking control adaptive heart motion model model-following control Kalman filter

收稿日期 2011-07-20 修回日期 2011-09-14 网络版发布日期 2012-01-25

基金项目:

中美联合培养博士生项目(No.2008602077);美国NSF CISE IIS-0222743项目

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