

穿刺针尖光纤力传感信号的小波变换分析

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Wavelet transform analysis of optic fiber force sensing signals at puncture needle tip

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摘要

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摘要 经皮软组织穿刺过程中,穿刺针尖会历经不同材料特性的器官组织,受到复杂变化的作用力。为了测量针尖处的作用力并鉴定穿刺路径上不同层次的软组织,研制了一种光纤力传感器,并进行了力信号分析。首先,基于法-珀干涉介绍了光纤力传感器的测量原理、光链路设计、及其与针的集成和标定方法。在穿刺力信号分析的基础上,提出利用Mallat算法对力信号进行小波变换,提取信号的特征模式,界定软组织的各层边界。最后,在猪的肝脏和肋条组织样本上进行了针穿刺实验验证。结果显示:光纤力传感器的可测力为0至3.20N,测量精度可达0.01N。得到的穿刺试验结果表明Mallat算法能够有效地区分软组织的类型。研制的光纤传感器满足穿刺力的测量范围、精度和可靠性等要求,所提出的小波变换算法可用于软组织边界的界定,有望用于机器人穿刺控制。

关键词 : 光纤力传感器, 针穿刺, Mallat算法, 分层软组织, 边界界定, 小波变换

Abstract : During a percutaneous soft tissue puncture, a puncture needle is inserted into the layered tissues with various material properties, and the interactive force at the needle tip occurs discriminately. To measure the force and identify the boundaries of the layered tissues in the puncture path, a fiber optic force sensor was fabricated, and the force data acquired with the sensor were analyzed. In terms of a Fabry-Perot interferometer, the measuring principle of the fiber optic sensor was presented, and its optical link, its integration into the needle and calibration approach were introduced. Then, based on the insertion force signal analysis, the force signals were decomposed via the Mallat algorithm into wavelets, and their patterns were recognized and used to identify the layered tissue boundaries. Finally, needle insertion tests were performed with the swine liver and belly tissue phantoms. The experimental results show that the working range of the force sensor is 0-3.20 N and the measuring resolution is under 0.01 N. Moreover, the insertion test results indicate that the Mallat algorithm is effective to the discrimination of layered tissues. It concludes that the fabricated fiber optic sensor meets the requirements of working range, accuracy and reliability to measure an insertion force. The proposed wavelet transform algorithm is able to identify the boundaries of the layered tissues and is expected to be used in the percutaneous control by a robot.

Key words : fiber optic force sensor needle insertion Mallat algorithm layered tissue boundary identification wavelet transform

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