摘 要

手势作为一种自然直观的交互方式，在人机交互的诸多场景中展现了巨大的应用前景。但全手行为跟踪技术仍存在运动导致的误差累积的问题，同时基于姿态的手势交互技术也面临 MidasTouch 等问题。因此，本文开发手部约束特性以优化全手行为追踪技术，设计区分交互意图用户实验以探究更自然的空中手势交互方法。

本文主要工作如下：

1）研究了一种全手行为跟踪优化方法。首先，本文依据传感器姿态估计方法，构建全手行为跟踪算法。其次开发手部约束特性，将手部约束作为先验知识融合进全手行为跟踪算法中，作为全手行为跟踪优化算法。最后通过实验验证在对 PIP 姿态求解中优化算法相较于未优化算法的$q_3(F_{1,33}=396.4，p<0.001，\eta^2=0.46)$和$q_4(F_{1,33}=396.3，p<0.001，\eta^2=0.46)$误差存在显著差异，表明姿态优化方法结果更加贴近真实手部姿态。

2）通过以用户为中心的方法设计基于姿态的手势集，并提出了空中手势交互中的坐标映射方法与手势实现方法，最后通过设计实验，提取用户震颤信息以识别用户交互意图，为空中手势交互中的 MidasTouch 问题提出一种解决方法。实验结果表明，通过提取的震颤特征在区分用户有无交互意图行为的准确率达到了 97%，通过震颤特征区分用户交互意图强弱的准确率达到了 76.8%。

3）设计并实现了基于姿态的空中手势交互系统 iInteractiveGloves。在该交互系统中，实现了空中手势交互的五类基本功能：平移、选择、抓取、旋转和缩放，并且针对该空中手势交互系统设计了无线传输数据手套，为基于姿态的空中单手手势交互提供支持。

本研究面向基于姿态的全手行为跟踪与手势交互技术，通过开发手部约束特性，提出一种全手行为跟踪优化算法；其次按照以用户为中心的方法设计用户实验，提出一种基于姿态的手势集合；最后对震颤与交互意图进行分析，设计用户实验并利用震颤特征识别用户行为中的交互意图，结果表明这种方法具有可行性。由于人体生理约束空间的广泛性，本研究所提方法可扩展到更多的约束维度，最终提高姿态估计系统的性能和可用性，同时本研究通过探究震颤特征识别用户交互意图，可以辅助交互系统获取更多信息，提交空中手势交互的自然性，这对于全手行为跟踪技术以及空中手势交互技术具有参考意义。

关键词： 人机交互；手势交互；手部姿态；行为跟踪；交互意图

Abstract

As a natural and intuitive way of interaction, gesture has shown great application prospect in many human-computer interaction scenes. However, the problem of motion-induced error accumulation still exists in the whole hand behavior tracking technology, and the gesture-based interaction technology also faces MidasTouch and other problems. Therefore, this paper develops the hand constraint feature to optimize the whole hand behavior tracking technology, and designs user experiments to distinguish the interactive intention to explore more natural air gesture interaction methods.

The main work of this paper is as follows:

1) a whole-hand behavior tracking optimization method is studied. Firstly, the whole-hand behavior tracking algorithm is constructed based on the sensor attitude estimation method. Secondly, the hand constraint is fused into the whole-hand behavior tracking algorithm as a prior knowledge and used as the optimal algorithm of whole-hand behavior tracking. Finally, the experimental results show that there is a significant difference between the optimal algorithm and the non-optimal algorithm $q_3(F_{1,33} = 396.4，\ p < 0.001，\ \eta^2 = 0.46)$ and $q_4(F_{1,33} = 396.3，\ p < 0.001，\ \eta^2 = 0.46)$.

2) the user-centered method is used to design the gesture set based on the gesture, and the coordinate mapping method and the gesture implementation method in the air gesture interaction are proposed. Finally, the user experiment is designed to use the extracted tremor information to identify the user interaction intention, and a solution to the MidasTouch problem in air gesture interaction is proposed. The experimental results show that the accuracy of the extracted tremor features is 97% , and the accuracy of the extracted tremor features is 76.8% .

3) the air gesture interactive system iinteractive gloves based on gesture is designed and implemented. In this interactive system, five basic functions of air gesture interaction are realized: translation, selection, grasping, rotation and zooming, and a wireless data transmission glove is designed for the air gesture interaction system, which provides support for air gesture interaction based on posture.

In this study, we propose an optimal hand tracking algorithm for gesture-based whole-hand behavior tracking and gesture interaction by developing hand constraint characteristics, finally, the user experiment is designed and the interaction intention in

user behavior is recognized by using the feature of vibration, the results show that this method is feasible. Due to the wide range of human physiological constraint space, the proposed method can be extended to more constraint dimensions, and finally improve the performance and availability of attitude estimation system, at the same time, this research can help the interactive system to get more information and submit the naturalness of air gesture interaction by exploring the feature of tremor to identify the user's interactive intention, it has reference significance for whole-hand behavior tracking technology and air gesture interaction technology.

Key words: Human-Computer interaction;Gesture recognition; Hand attitude; Motion tracking; Interaction intention