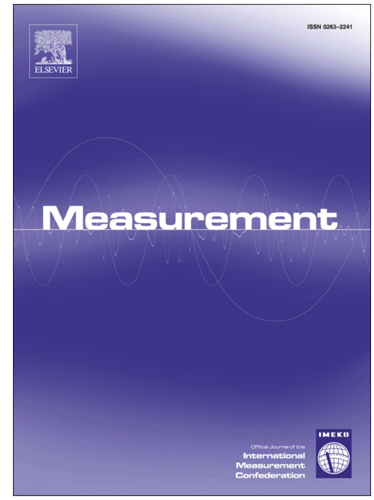
Accepted Manuscript



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PII: S0263-2241(14)00242-5
DOI: http://dx.doi.org/10.1016/j.measurement.2014.05.021
Reference: MEASUR 2868

To appear in: *Measurement*

Received Date: 1 March 2013
Revised Date: 23 April 2014
Accepted Date: 15 May 2014

Please cite this article as: D.U. Guanglong, P. Zhang, Human-Manipulator Interface Using Hybrid Sensors With Kalman Filters and Adaptive Multi-space Transformation, *Measurement* (2014), doi: http://dx.doi.org/10.1016/j.measurement.2014.05.021

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Human-Manipulator Interface Using Hybrid Sensors With Kalman Filters and Adaptive Multi-space Transformation

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Abstract— **This paper utilizes a human-robot interface system which incorporates Kalman filter (KF) and Adaptive Multi-space Transformation (AMT) to track the pose of the human hand for controlling the robot manipulator. This system employs a 3D camera (Kinect) to determine the orientation and the translation of the human hand. We use Camshift algorithm to track the hand. KF is used to estimate the translation of the human hand. Although a KF is used for estimating the translation, the translation error increases in a short period of time when the sensors fail to detect the hand motion. Therefore, a methodology to correct the translation error is required. What's more, to be subject to the perceptive limitations and the motor limitations, human operator is hard to carry out the high precision operation. This paper proposes an Adaptive Multi-space Transformation (AMT) method to assist the operator to improve the accuracy and reliability in determining the pose of the robot. The human-robot interface system was experimentally tested in a lab environment, and the results indicate that such a system can successfully control a robot manipulator.**

Index Terms—**robot teleoperation, human-robot interface, Kalman filter (KF), adaptive multi-space transformation (AMT).**

I. Introduction

HUMAN intelligence is required to make a decision and control the robot especially when it is in unstructured dynamic environments. Thus, robot teleoperation is necessary in this situation especially when objects are unfamiliar and shapeless. There are some human-robot interfaces (Keum-Bae Cho.[1]) like joysticks (Postigo et al.[2]; Hirche S et al.[3]; Takeshi Ando et al.[4]), dials and robot replicas, and they have been commonly used. However, for completing a teleoperation task, these contacting mechanical devices always require unnatural hand and arm motion.

There is another way to communicate complex motions to a remote robot and it is more natural compared with using contacting mechanical devices. This method uses inertial sensors, contacting electromagnetic tracking sensors, gloves instruments with angle sensors, and exoskeleton systems (Kazuo Kiguchi et al. [5]) to track the operator hand-arm motion which completes the required task. However, these contacting devices may hinder natural human-limb motion.

Because vision-based techniques are non-contacting and they seldom hinder the hand-arm motion. Vision-based methods often use physical markers which are placed on the anatomical body part (Kofman et al.[6]; Jae-Han Park.[7]; GuangLong Du et al.[8]). There are a lot of applications (Peer A.[9]; Borghese and Rigiroli[10]; Kofman et al.[6]) using this marker-based tracking method. However, because body markers may hinder the motion for some highly dexterous tasks, operators may get occluded. Thus, this marker-based tracking method is not always practical. Due to this reason, a markerless approach seems better for many applications.

Compared to image-based tracking method which uses markers, markerless method not only is less invasive, but also eliminates problems about marker occlusion and identification (Verma [11]). Thus, for remote robot teleoperation, markerless tracking may be a better approach. However, existing markerless human-limb tracking techniques have a lot of limitations so that they may be difficult to use in robot teleoperation applications. Many existing markerless-tracking techniques capture images and then compute the motion later (Yinghong et al. [12]; Peng K.C.C. et al. [13]; Suau, X. et al. [14] Rosales and Jing-Ming Guo [15]). Thus, the robot manipulator can be controlled by continuous robot motion using the markerless tracking method. To allow the human operator to perform hand-arm motions for a task in a natural way without any interruption, the position and orientation of the hand and arm should be provided immediately. Many techniques can only provide 2D image information of the human motion (Khezri M et al. [16]; Dardas N.H [17]), thus the tracking methods cannot be extended for accurate 3D joint-position data. An end-effector of a remote robot requires the 3D position and orientation information of the operator's limb-joint centers. How to identify human body parts in different orientations has always been a main challenge (Peng K.C.C. et al. [13]; Yinghong et al. [12]; Varkonyi-Koczy A.R. [18]).

Some limited research towards markerless human-tracking has been done for robot teleoperation. Some use a human-robot interface based on hand-gesture recognition to control the robot motion. (Fong et al. [19]; Ueda E. et al. [20]; Jianwei Zhang [21]). Ionescu et al. [22] developed markerless hand-gesture recognition methods which can be used for mobile robot

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