Evaluation of Kinect Skeletal Tracking in a Virtual Reality Rehabilitation System for Upper Limb Hemiparesis

G Tao, PS Archambault, MF Levin
School of Physical & Occupational Therapy
McGill University
Montréal, Canada

Interdisciplinary Research Center in Rehabilitation
Jewish Rehabilitation Hospital
Laval, Canada
gordon.tao@mail.mcgill.ca, philippe.archambault@mcgill.ca, mindy.levin@mcgill.ca

***Abstract*— This study evaluated the kinematic validity of Microsoft Kinect skeletal tracking for use with an upper limb virtual reality rehabilitation system. We determined the extent to which Kinect tracking of hand position, elbow angle, and trunk position matched that recorded by a motion tracking system over a range of Kinect camera positions. The optimal Kinect camera position was between 1.45m and 1.75m from the user at 0.15m left or right. Tracking error of the Kinect should be considered when the system is used in the clinical setting.**

Keywords—virtual reality; motor; rehabilitation; Kinect; stroke; upper limb; low cost

I. Introduction

Mounting evidence suggests that recovery from upper limb disabilities [1], such as arm paresis, due to stroke can continue well into the chronic stage [2], [3]. These late improvements may be accessed via sensorimotor learning and adaptive plasticity by practicing a variety of related tasks [4], [5] in a rich training environment that incorporates cognitive challenges [6], [7]. Using virtual reality (VR) is one method of creating such a training environment.

This study evaluated the kinematic validity of using the Microsoft Kinect (for Windows) camera's skeletal tracking system as part of MediJin (MJ), an upper limb (UL) VR rehabilitation system developed by Jintronix (Montreal, Canada). MJ uses the camera's markerless tracking system as an interface for UL activities. In the MJ games, participants are seated and tasked with reaching and manipulating virtual objects in a variety of scenarios. This study focused on determining the extent to which the Kinect camera is useful for the purposes of UL rehabilitation.

II. Methods

We determined the accuracy and precision of the Kinect camera in the tracking of hand position, trunk position, and elbow angle, over a range of camera positions: a 5x5 grid with 15cm intervals at minimum distance 130 cm in front of the participant. As the gold standard comparison for UL kinematics, we used an Optotrak (NDI, Canada) 3D motion capture system with tracking markers placed at the forehead, sternum, both shoulders, both hands, right elbow, and right wrist. One healthy participant performed right-hand reaching movements to each of 6 targets, trunk leaning forward/backward, and complete elbow flexion/extension; each movement was repeated 3 times in succession. This task was performed for each camera position. The 6 reaching targets were transparent squares numbered in black ink suspended by a wooden frame and translucent wire directly in front of the participant. The Kinect camera was fixed at a height of 135 cm.

III. Results

Tracking data from both systems were recorded simultaneously and compared after frame of reference matching. The root mean square difference between Kinect and Optotrak data was taken as error for the Kinect. For hand-reaching movements, constant error averaged 6.3 cm and variable error 2.4 cm, discounting 3 extreme cases (Fig. 1). For those positions, constant error was less than 9.8 cm, 95% of the time. Trunk movement mean error was 3.9 cm (constant) and 2.5 cm (variable), excluding the farthest and nearest rows where error jumped to over 12 cm. Elbow angle mean error was 26.7º (constant) and 6.2º (variable). Constant error for the elbow was likely due to modeling limitation of the Kinect; this data closely matched Optotrak data after the bias was removed.

IV. Conclusions

The Kinect camera should be located within a 30x30cm square at a distance of between 1.45 and 1.75 m from the user, and at either 0.15 m to the left or right. Target locations should be calibrated using the Kinect according to predetermined hand, elbow and trunk positions to account for bias errors. Variable error of Kinect tracking should be accounted for when setting clinical

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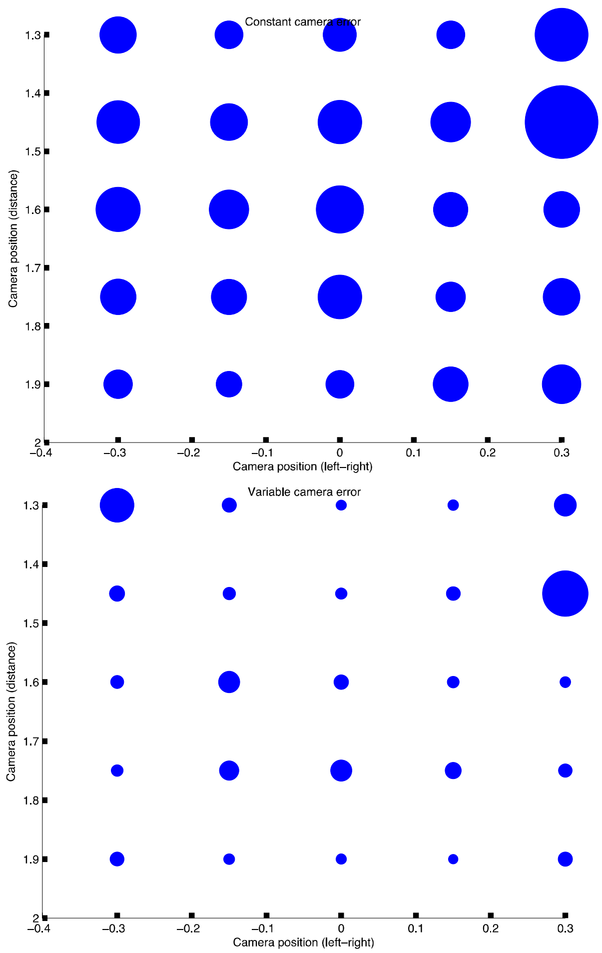

Fig. 1. Constant (top) and variable (bottom) error of the Kinect tracking for the right hand. The error is shown as an average for each of the 25 camera positions, with the upper row being the closest to the participant. The size of each circle is proportional to the average error, constant or variable, at that camera position.

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