Chapter 37
A Validation Study of Rehabilitation Exercise Monitoring Using Kinect

Wenbing Zhao
Cleveland State University, USA

Deborah D. Espy
Cleveland State University, USA

Ann Reinthal
Cleveland State University, USA

ABSTRACT

In this chapter, the authors present their work on a validation study of using Microsoft Kinect to monitor rehabilitation exercises. Differing from other validation efforts, the authors focus on a system-level assessment instead of the joint-level comparison with reference motion capture systems. They assess the feasibility of using Kinect by examining the enforceability of a set of correctness rules defined for each exercise, which are invariances of each exercise and hence independent from the coordinate system used. This method is more advantageous in that (1) it does not require coordinate system transformation between those of the reference motion capture system and of the Kinect-based system, (2) it does not require an exact match of the Kinect joints and the corresponding external marker placements or derived joint centers often used in reference motion capture systems, and (3) the correctness rules and their mapping for Kinect motion data analysis developed in this study are readily implementable for a real motion monitoring system for physical therapy.

INTRODUCTION

In rehabilitative health care, a carefully designed physical exercise plan could be instrumental to the recovery of a patient provided that the patient. Exercise programs are prescribed to address specific problems, and are often individually tailored by a clinician due to the presence of co-morbidities and additional impairments. It is critical that the patient perform the proscribed program correctly and with

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adequate practice repetitions (in the range of thousands) (Kleim and Jones, 2008), otherwise, the exercise may be ineffective, or even dangerous (Escamilla et al., 2009; Tino & Hillis, 2010).

Correct adherence to supplemental home exercise is essential for safe, effective, and efficient care. The lack of correct feedback during independent in-home exercise is therefore a serious concern. The use of simple counting devices helps verify the exercise repetitions. However, such simple, commercially available devices cannot fully capture all the required movements beyond the most simple, such as counting steps or recording overall amounts of activity (Wagner et al., 2012; Yang & Hsu, 2010), and are, therefore not useful for most prescribed home exercises.

The release of the Microsoft Kinect sensor, which is equipped with a depth camera capable of measuring 3 dimensional positions of the objects in its view, has triggered tremendous interest in its use to monitor in-home physical therapy exercises (Chang et al., 2013; Chang et al., 2012; Garcia et al., 2012; Gibson et al., 2012; Guerrero & Uribe-Quevedo, 2012; Huang, 2011; Zannatha et al., 2013; Pastor et al., 2012). A Kinect-based system could facilitate proper performance of the exercise or fitness program, increase patient accountability, allow the clinician to correct any errors in exercise performance, and allow program modification or advancement as needed. Hence, the Kinect sensor based system could potentially provide sufficient feedback and guidance to patients performing clinician prescribed in-home exercises, significantly minimizing costly and inconvenient trips to outpatient centers, and improving the effectiveness and outcomes of courses of treatment.

Many existing clinical trials with Kinect-based systems appear to have proceeded without comprehensive validation tests (Chang et al., 2013; Chang et al., 2012; Garcia et al., 2012; Gibson et al., 2012; Guerrero & Uribe-Quevedo, 2012; Huang, 2011; Zannatha et al., 2013; Zhao et al., 2014; Tamei et al., 2015; Ebert et al., 2015). Other studies have aimed to characterize the accuracy of the Kinect sensor; however, these validation studies have focused primarily on the movements within the frontal plane for a subset of the joints or segments (Clark et al., 2013; Obdrzalek et al., 2012; Mobini et al., 2013). In this article, we report our validation study on using a Kinect-based system for physical therapy exercise monitoring. Instead of comparing the joint positions or angles formed by key segments with respect to a (usually far more expensive) reference system, we take a completely different approach by focusing on the feasibility of using such a system to assess the correctness rules for a few common exercises in physical therapy. The correctness rules are readily implementable in a computer program for real-time motion tracking and feedback.

Due to space limitation, we only present results for two exercises, namely hip abduction and toe touch. In the standing hip abduction exercise, one leg is moved into hip abduction without any additional sagittal plane hip flexion/extension or transverse plane hip rotation. The pelvis, knee, and ankle remain stationary. In the standing toe touch exercise, the trunk bends forward and the arms reach to touch the floor. Motion occurs primarily as sagittal plane spine and hip flexion with concurrent shoulder flexion. When done correctly, there is minimal movement of the elbows, wrists, knees and ankles. We show that, although the Kinect-based system is capable of assessing many correctness rules for these exercises, it fails in the presence of significant self-occlusion, especially for the toe-touch exercise.

BACKGROUND

Microsoft Kinect was initially released as an add-on device for the Xbox 360 game console. Kinect enables a person to interact with a game using gestures and voice commands via what is referred to as