The Kinect Versus The Proficio: Measuring Hand Position During Exercise Monitoring

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ABSTRACT

Motion capture technology has recently found a new application in physical therapy. The advantages of the *Microsoft Kinect* and similar devices have motivated researchers to focus on how to leverage the capabilities of motion capture technology to provide therapists with new tools for therapy sessions. Although the *Kinect* seems to be an affordable, convenient and therapeutic solution, more investigation is required to confirm its accuracy. In this paper, we evaluate the performance of the *Kinect* to capture the trajectory of the hand in different exercises by comparing it to the trajectory of the same movement recorded by the *Proficio* robotic arm. The arm provides us with accurate values for the position of the hand during the exercise which serves as a ground truth for the comparison. In our experiment, we trained the *Proficio* with different exercises and captured the trajectories from the *Kinect* in different backgrounds and relative orientations between them. Our results show acceptable error in trajectories obtained from the *Kinect*. We also observed dependence on the margin of the error on the relative position between the *Kinect* and the *Proficio* and the direction of the exercise motion.

CCS Concepts

•Human-centered computing → Interaction devices; Interaction techniques;

Keywords

Proficio robotic arm, Microsoft Kinect, Motion Capture Technology, Dynamic Time Warping (DTW)

1. INTRODUCTION

Technology-assisted physical therapy has been proposed for rehabilitation of individuals with physical disabilities. The Kinect interface by Microsoft can be incorporated in physical therapy sessions to create an engaging environment for people seeking physical exercises. It is capable of capturing body joint information of the person exercising in front of it. This information is beneficial for therapists to analyze the performance of their patients doing the exercises.

An extensive review [6] examined works regarding the use of the Kinect in rehabilitation. Multiple systems have been designed based on the Microsoft Kinect to assist in physical therapy. Bao et al. [2] reported the overall improvement in the motor function test scores of the patients in their experiment using the Kinect. Sin and Lee [7] showed significantly greater improvement in the functional and behavioral measures of people with physical disability if their conventional treatment were accompanied by the Kinect-based treatment.

The validity of the designed systems hinges on the accuracy of the Kinect to measure exercise performance. Thus, researchers have focused on quantitatively evaluating the performance of the Kinect by comparing its results with the results extracted from other sources [3, 4, 5]. In order to measure the accuracy of the Kinect for arm tracking, Gieser et al. [3] compared the skeleton data obtained by a Kinect with data obtained by a VICON system. Kurillo et al. [4] have examined the accuracy of the Kinect by comparing its results to the results of a marker-based motion capture system used simultaneously by ten individuals with no physical disability. A fabricated model of upper body was suggested in another work [5], as the ground truth for measuring the accuracy of the Kinect.

In this paper, we have quantitatively evaluated the performance of the Kinect by comparing hand trajectories recorded by it with the ground-truth trajectories obtained from the Proficio robotic arm. Proficio is a 3-degree-of-freedom robotic arm designed for individuals with physical disabilities to do exercises with their arms [1]. In addition, we investigated the dependence of the results on the background and the relative orientation between the Kinect and Proficio.

2. METHOD

In order to compare two trajectories captured from two different sources, we first mapped the coordinate axes of the two systems and made sure that they are aligned in time as well.

- The measurement rate of the Proficio robotic arm is 2 sets of points per millisecond, while the rate of the Kinect is on average 30 frames per second. Given that the measurement rates differ, we used Dynamic Time Warping (DTW) to align the two trajectories and mitigate error due to misalignment of time.

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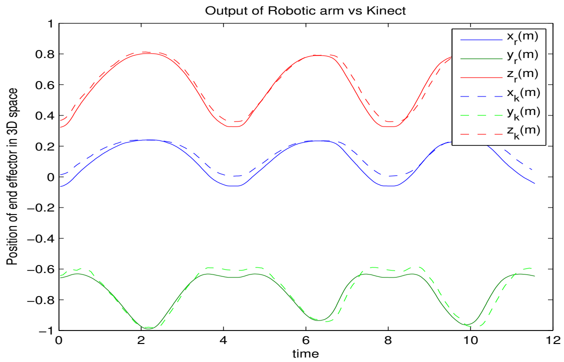

Figure 1: Comparison of trajectories obtained from the Proficio robotic arm and the Kinect. The blue, green and red curves represent X, Y and Z axes respectively. Solid lines indicate the trajectory obtained from the Proficio and dashed lines show their corresponding values obtained from the Kinect. The error for this pair of trajectories is 2.145 cm/#pts

- The origin and direction of coordinate axes for the Proficio and the Kinect are not the same. Mapping the coordinates might cause offset to the error of the compared trajectories, thus in addition to the root mean squared error, the variance should be taken into consideration.

2.1 Experiment

In our experiment, we used the standalone version of the Kinect for Xbox One for Microsoft Windows 10, released in July, 2014. We utilized the depth sensor and the video camera to track the X, Y and Z coordinates of the user's hand in a 3D scene using the Kinect SDK 2.0. We first trained the Proficio with three different exercises; the first exercise was a combination of vertical and horizontal movements of the hand, the second covered vertical movements and movements away-from and toward the person's body (depth), and the third a combination of horizontal movement and movement in depth. Each of these designed exercises was then repeated nine times in three categories with three samples each. First, the Proficio was placed approximately 2 m far from the Kinect cameras such that the optical axis of the Kinect was pointing to the chest of the user. In the second case, the Proficio arm is fixed, and the Kinect is placed such that the relative orientation between the robot and the Kinect is about 60 degrees. Then the Proficio was turned toward the Kinect which creates the same relative orientation as the first exercise, but with a different background.

2.2 Results

We measured the error between the designed trajectory of the Proficio and the measured trajectory from the Kinect. Figure 1 shows an example of two trajectories obtained from the Proficio robotic arm and the Kinect for the same arm movement. The normalized root mean squared error for this pair is 2.145 cm per number of points, which is considered acceptable due to adequate similarity of two trajectories. Table 1 indicates the average of root mean squared error through three similar cases. As stated earlier, minor displacement in the mapping of axis coordination causes extra offset error, thus the distribution of measurement error should not have any significant peak far from zero to reflect the true value of error. It should be also mentioned that in two of the cases, the Kinect was mistakenly tracking part of the Proficio as the arm of the user which lead to a high error and is excluded from the result of the experiment.

Table 1: Average of Root Mean Squared error between trajectory obtained from the Proficio and the Kinect through three similar cases. The error is normalized to the number of samples in each trajectory. The unit for the values in the table in cm/#pts.

-	Case1	Case2	Case3
Exercise 1	3.345	1.789	2.255
Exercise 2	8.609	6.794	5.182
Exercise 3	1.245	7.109	6.629

3. CONCLUSIONS

The differences in the error can be attributed to different factors; the Kinect performs differently depending on the exercise, background and the relative orientation between the Kinect and the Proficio. Occlusion is still the main problem that affects the performance of the Kinect significantly. However, there exists a great potential in the Kinect that needs further investigation in order to minimize the adverse effect of these factors and obtain the best performance.

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