COMPARISON BETWEEN MS KINECT AND A TRADITIONAL MARKER-BASED SYSTEM FOR SHOULDER AND ELBOW KINEMATIC RECONSTRUCTION

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Abstract: Motion tracking systems are commonly used for movement analysis in the field of Biomechanics. Marker based systems like BTS help to evaluate patients' movements and detect modifications with respect to normality. As this kind of system is expensive and unmanageable, the markerless motion capturing system Kinect™ seems to be an interesting possibility to avoid time wasting calibration and preparation procedures, as well as the opportunity for patients to perform home rehabilitation. This paper presents a comparison of the precision in tracking shoulder and elbow angle using both systems simultaneously. The results show reasonable errors in elbow flexion/extension and shoulder adduction/abduction angles while, for shoulder flexion/extension, errors were larger. The mean segment lengths during a measurement show remarkable differences between Kinect and BTS. Although both systems work with infrared light, no interferences between the signals could be recognized.
Keywords: BTS, Kinect, motion tracking, home rehabilitation

Introduction

In 2010 Microsoft unveiled Kinect for the game console Xbox360 [1]. Their new innovation enabled the gamer to use the console simply by motion control. They integrated depth and color sensors to track the user's movement and translate them into motions of virtual characters.

The low price of Kinect made it attractive for game developers which induced Microsoft to provide Software Development Kits and Drivers for Notebooks additionally [2]. But Kinect did not only awaken the interests of game developer, it also seemed to be a rentable application for the purpose of home rehabilitation [3]. Kinect generated a wide variety of new research in hand gesture recognition and control [4], 3D surface reconstruction [5] and natural user interface [6]. Over the past years, over 3000 papers related to Kinect have been published. A state-of-the-art report by researchers of University of Oxford gives an overview of the publications and possibilities using Kinect out of its original context [7].

In the present paper the application of the markerless system Kinect for Data Acquisition with the traditional marker-based system BTS [8] was investigated. As a possible application the system could enable patients with shoulder injuries to improve their symptoms with special software developed for Kinect, which can be used at home. The current work is therefore principally concerned with movement analysis of the upper extremities.

Materials and methods

This work has been approved by the University Hospital Ethics Committee. A healthy subject (male, age 29) was recruited and fixed with markers according to figure 1. A physiotherapist was asked to place the markers on the anatomical landmarks in order to avoid incorrect placement for joint reconstructions.

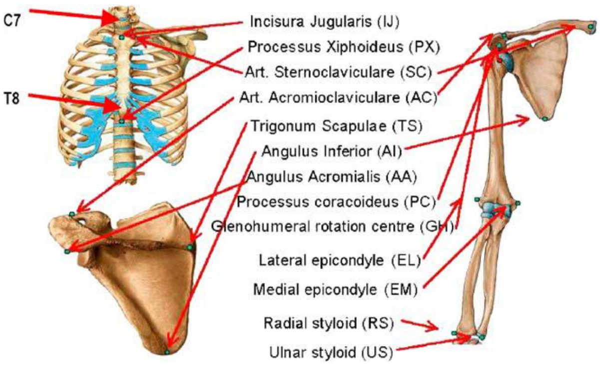

Figure 1: Landmarks and local coordinate system of the thorax, clavicle, scapula and humerus [9]

The subject was placed 2 meters in front of Kinect and in the middle of the working area surrounded by the BTS cameras. In order to obtain every degree of freedom in shoulder and elbow joints of the right upper extremity he was asked to perform a movement as follows, starting in anatomical neutral position: 90° elbow flexion – 90° shoulder Abduction – 90° shoulder flexion – 90° shoulder extension – 90° shoulder Adduction – 90° elbow extension. This motion sequence enabled to predict angle curves for the validation of Kinect and the BTS system.

MS Kinect data were recorded with the Image Acquisition Toolbox by Matlab. It includes the possibility to capture information such as skeleton tracking by defining 20 different body points and provides x, y and z coordinates of their position in space. By creating vectors with this coordinates, the angles of shoulder and elbow joint can be easily calculated using simple trigonometry formula

$$\cos(\theta) = \frac{\mathbf{u} \cdot \mathbf{v}}{|\mathbf{u}| \cdot |\mathbf{v}|} \qquad (1)$$

Elbow rotation is the angle between the vectors wrist to elbow and elbow to shoulder and can be easily determined as the angle between two 3D vectors. For shoulder Abduction/Adduction angle, vectors from left to right shoulder point and right shoulder to elbow are calculated, whereas shoulder Flexion/Extension angle is created out of the vectors from spine to right shoulder and right shoulder to elbow, as can be seen in Figure 2.

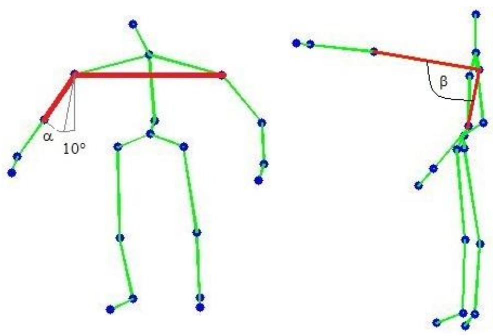

Figure 2: Shoulder angle calculation of Kinect with vectors between body joints; left: Abduction/ Adduction, right: Flexion/Extension

In both angle calculations for the shoulder joint 3D coordinates are first transformed into 2D coordinates. Additionally, 10 degrees for shoulder Adduction/Abduction were considered to obtain realistic angle curves. Shoulders internal/external Rotation and lower arm Supination/Pronation position are not possible to detect with Kinect since information about body joints orientation are missing.

The protocol for Marker-based data processing with BTS is based on a recommendation on definition of joint coordinate systems, as well as the way to calculate coordinate system for each body segment [9]. The BTS System tracks the position and trajectory of each Marker attached on anatomical landmarks, but does not supply directly information about joint centers.

Joint centers of elbow and wrist are estimated as the midpoint between both epicondyles and styloid processes, respectively. The only joint which cannot be captured directly is the glenohumeral rotation center. Therefore a regression equation coefficient to estimate its position is used, obtained from scientific literature [10]. [11].

As both BTS and Kinect data are recorded manually, the time axes of both data need to be synchronized. Therefore the peaks of both angle curves are determined, time periods between the minima are compared and finally the curves are superimposed to see differences in curve shapes. Furthermore, after starting to record data with Kinect, a time delay of a few seconds needs to be considered as well as the different frame rates of the systems.

As the recording from the depth map is noisy and from lower quality than the BTS data, the motion capture data from Kinect must be filtered to create usable data. Hence a fourth-order low-pass Butterworth filter with cut-off frequency of 6Hz was applied to Kinects signals to smooth the noise.

Results

From both Kinect and BTS data angle trajectories were calculated and adjusted to evaluate Kinect's effectiveness as a motion capture system. In Figure 4.2 the curves are superimposed, blue presents Kinect data and red BTS data.

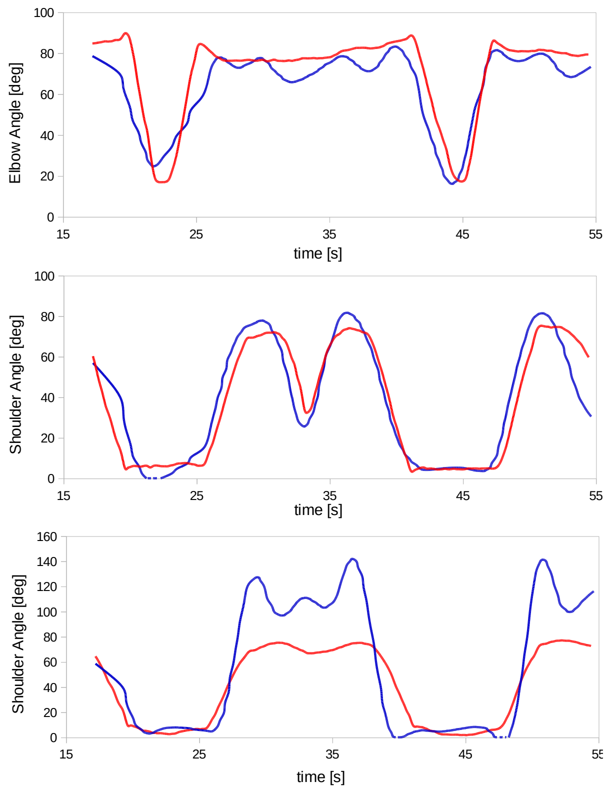

Figure 3: 1. Elbow Flexion/Extension; 2. Shoulder Abduction/Adduction; 3. Shoulder Flexion/Extension (blue – Kinect, red – BTS).

The mean error of elbow Flexion/Extension angle, shoulder Abduction/Adduction angle and shoulder Flexion/Extension angle are 11.07°, 13.07° and 33.89° respectively.

The subject's anthropometry of upper extremities, forearm, upper arm and the shoulder joint distance were measured with tape measure to compare mean distance and deviation of both systems within one track with reference values. The results are shown in Table 1 in [mm]. The left column shows the mean segment length of all frames captured during one measurement and the right column the standard deviation.

	Forearm		**Upperarm**		**Shoulder Dist.**	
	mean	*std*	*mean*	*std*	*mean*	*std*
BTS	285,42	16,10	293,47	5,98	328,11	11,35
Kinect	218,39	57,13	210,81	53,11	301,34	73,23
Anthrop.	270,00		280,00		320,00	

Table 1: Results of segment length of the right upper extremity compared with anthropometric data

Discussion

Kinect seems to be an attractive alternative for at home rehabilitation, although Kinect also presents limitations.

The most important advantage of Kinect compared with common optical motion capturing systems lies undeniably in its price and portability. Moreover it is easier to track motions of more than one subject, without any preparation with markers or calibration of the system. For Home Rehabilitation marker-based systems are unsuitable, which make markerless systems like Kinect essential in this field. Promising results of Kinect in the field of movement analysis were also shown in early work, e.g. for hand and elbow movements [12], to evaluate gait velocity [13] and anatomical landmark displacement and trunk angle [14] when compared to 3D marker-based systems.

On the other hand, marker-based systems are more precise in detecting joint position and movement sequences, as can be seen in Table 4.3. BTS Data are consistent with anthropometric data measured with tape, while Kinect Data not only show a great standard deviation of segment length within the recording, but also a great deviation from BTS and anthropometry data. The variance of segment length prefigure to noisy signals of the body points captured by Kinects skeleton toolbox.

The great deviation of BTS and Kinect Data in Shoulder Flexion/Extension is possibly caused by the different ways to calculate shoulder angle and may be optimized in future work. Shoulder Abduction/Adduction and elbow Flexion/Extension follow the same pattern in curve shape and peak high. As physiotherapists control the range of motion visually, the deviation of both curves around 10-15 degree seems to be acceptable.

Kinect also has a limited viewing angle which makes it difficult for gait analysis, but sufficient enough in the use of upper extremity motion analysis. Fast movements are detected inadequately by Kinect due to its frame rate of 30fps. In this work interferences of infrared radiation caused by the use of BTS and Kinect simultaneously could not have been detected.

Conclusion

MS Kinect may have the potential to be used in Home Rehabilitation, but needs further researches. As it is important to know the correct shoulder position in case of shoulder injuries, there should be a reflection on how to implement other tools like acceleration sensors to receive more accurate results for shoulder movements.

It has been shown in this paper the possibility of BTS and Kinect working together without noticeable interferences.

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