Assessment of Microsoft Kinect in the Monitoring and Rehabilitation of Stroke Patients

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Abstract. Telerehabilitation is an alternative way for physical therapy of stroke patients. The monitoring and correction of exercises can be done through the analysis of body movements recorded by an optical motion capture system. This paper presents a first study to assess the use of Microsoft Kinect in the monitoring and rehabilitation of patients who have suffered a stroke. A comparative study was carried out to assess the accuracy of joint angle measurement with the Microsoft Kinect (for Windows and for Xbox One) and Optitrack™. The results obtained in the first experiment showed a good agreement in the measurements between the three systems, in almost all movements. These results suggest that Microsoft Kinect, a low cost and markerless motion capture system, can be considered as an alternative to complex and high cost motion capture devices for the monitoring and rehabilitation of stroke patients.

Keywords: Monitoring · Rehabilitation · Stroke · Joint angle · Motion capture · Microsoft Kinect · Optitrack™

1 Introduction

The stroke rehabilitation process requires that patients perform intensive physical therapy with the help of physiotherapists, which may become an exhaustive task. The long therapy sessions often lead to a lack of motivation in performing exercises due to the high number of repetitions [1]. Therefore, this brings negative effects to the rehabilitation process and may delay the clinical recovery. One possible approach to overcome this issue is the introduction of "serious games" as a stimulus to practice the exercises and to encourage the patient to the therapy. Moreover, this allows that the therapy can be carried out at home. When playing games, the patients stimulate the accomplishment of specific movements, which enables the development of motor skills of the affected limbs (arms and legs) important to their recovery process, while making the therapy sessions less tedious and more fun. To make the rehabilitation effective it is

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necessary to monitor the correct execution of exercises. A possible approach is the analysis of body movements recorded by an optical motion capture system.

The objective of this study is to validate the accuracy of Microsoft Kinect to measure the movement of upper limbs performed by stroke patients in therapy exercises. The joint angular variation data of five movements, obtained with the two Kinect versions were compared with the data captured with the Optitrack™ Flex 3 with 6 cameras. The Optitrack™ is used as a reference system for its high accuracy.

2 Background

Patients who survive strokes suffer from cognitive, motor or visual losses that depend on the length and location of the damaged brain tissue [6]. Virtual reality games are very appealing to a wide variety of individuals, as this type of technology is very immersive and motivating. By developing games as rehabilitation tools, we can achieve the motivation associated with the games. In these environments, users are focused on the game and not so much in the exercise they are doing [7]. Several projects have explored the use of new technologies for patient motivation and allow doing the exercises at home [8–10]. These telerehabilitation systems offer users and therapists new possibilities for treatment using the Microsoft Kinect. These devices make use of an avatar that plays the exercises performed by the patient based on data captured by the Kinect [11]. Using the Kinect numerous motion detection games were created, which have proved very appealing and not for the sole purpose of entertainment, but also to promote health and rehabilitation.

The Microsoft Kinect device offers a flexible solution with a low cost for rehabilitation, not requiring any kind of markers. This allows its installation at the patients' homes with an affordable cost. The major disadvantage of this device is its precision. Thus, it is only possible to use it for cases where a high accuracy is not required. However, previous studies showed that clinical rehabilitation monitoring and correction can be performed without extreme precision [4]. On the other hand, optical systems with reflectors markers are commonly used for motion capture for its accuracy, but they have some drawbacks: it requires the placement of markers in the body for performing a high quality data acquisition; comprises several cameras; requires a large space in order to capture the volume needed for data collection [2, 3]; and has a very high cost, making the installation at patients' home unaffordable.

3 Methods

The Microsoft Kinect has a huge potential for motion capture usage on rehabilitation. We have performed a study involving one subject performing well known rehabilitation movements and gathering the motion data with three different motion capture devices to identify the Microsoft Kinect limitations.

3.1 Participants and Materials

A male participant without any pathologies (20 years, 170 cm tall, 65 kg weight), volunteered to participate in this experience. For the analysis of the movements, the participant was equipped with a special suit fitted with 34 reflective markers.

Three systems were used for motion capturing: Optitrack™ Flex 3 with 6 cameras and the two Microsoft Kinect devices (for Windows and for Xbox One). The Optitrack™ (Fig. 1B) records the movement at 100 Hz and requires the use of reflective markers mounted on a special suit (in our case we used 34 markers) placed on major joints (Fig. 1A and C), so a relatively large space is required to capture the high volume and ensuring the fluidity of movements and ability to obtain not one but several bodies in the capture. The Optitrack™ was considered a reference system in this study because of its high precision.

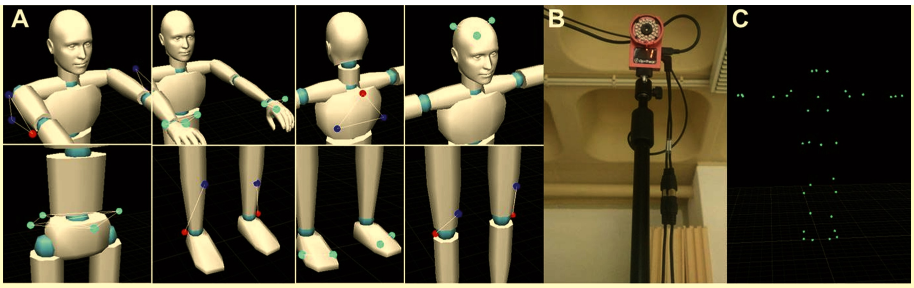


Fig. 1. (A) Skeleton that shows the body positions where the markers should be placed; (B) One of the six cameras used by the Optitrack™ system; (C) 3D Markers positions.

Microsoft Kinect is a motion sensor developed for the Windows/Xbox 360 (Kinect I) and Xbox One (Kinect II). These sensors use a frequency of 30 Hz and have four key features: RGB camera (Red, Green, Blue) that allows the body recognition; sensor (Infra-Red), which allows the recognition of the environment around in three dimensions; issuer (Infra-Red), which emits laser pulses, measuring the time they take to reflect and to be detected by the sensor IV, through the Kinect software will determine the depth in 3 dimensions; and its own processor and software [12]. The major differences between the two versions of the sensor are presented on Table 1 [13, 14].

3.2 Procedure

For the initial position, it was asked of the participant in the study to stand upright in his natural posture and to look straight ahead with both hands down at his sides. In addition, the participant was asked to wear a special suit coated with spherical markers [15, 16]. During tasks, kinematic data was recorded simultaneously by the three motion capture systems. Both Microsoft Kinect devices were placed in front of the subject at a distance of 2 m. The Optitrack™ cameras cover the capture volume with multiple views. No particular instructions were given about speed or amplitude to reach.

Table 1. Technical specifications of Kinect I and Kinect II.

	Kinect I	Kinect II
Field of view $(H \times V)$	$57.5° \times 43.5°$	$70° \times 60°$
Camera resolution $(H \times V)$	640×80 @ 30 fps	1920×1080 @ 30 fps (15 fps with low luminance)
Depth resolution $(H \times V)$	320×240	512×424
Maximum depth range	6 m	4.5 m
Minimum depth range	40 cm	50 cm
Depth technology	Triangulation between near infrared camera and near infrared laser source (structured-light)	Indirect time of flight
Tilt motor	Yes	No
USB standard	2.0	3.0
Supported OS	Win 7, Win 8	Win 8

Five movements from upper body commonly used in physical therapy of stroke were performed by the participant with ten repetitions of each one [17]. The following movements were chosen (Fig. 2): elbow flexion (flexion of the elbow keeping the forearm in the anatomical position), shoulder abduction (raising the arm in the coronal plane), frontal arm elevation (raising the arm in the sagittal plane), horizontal arm abduction (moving the arm in the transverse plane) and neck flexion (flexion of the neck in the sagittal plane). The selection criteria for these movements was the most referenced movements in the rehabilitation therapies [5].

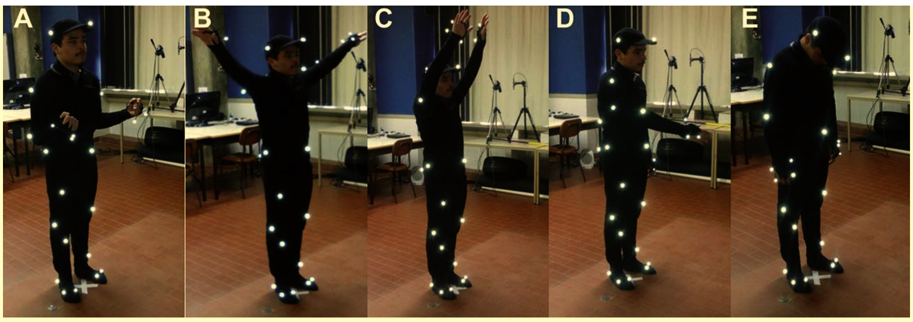


Fig. 2. (A) Elbow flexion movement; (B) Shoulder abduction movement; (C) Frontal arm elevation movement; (D) Horizontal arm abduction movement; (E) Neck flexion movement.

3.3 Data Analysis

The sampling frequency of Optitrack™ system was set to 100 Hz, while the Kinect was set at 30 Hz. In order to compare the data captured by the two motion capture systems, running at different capture (sampling) rates, custom MATLAB code was developed to down-sample the 100 Hz OptiTrack™ data into a 30 Hz data set. The positions of the markers were expressed in a coordinate system that is positively driven to the right in the side vector of the individual (X axis), upward in the vertical vector (Y-axis) and backward in the sagittal vector (Z axis) [18]. The markers positions estimated by both systems suffered some noise. Due to this problem, we used a Butterworth low pass filter of the 4th order with a cut-off frequency of 8 Hz to eliminate high frequency noise. After filtering the data, joint angles were calculated for all the three systems at the neck, elbow and shoulder, in the three motion planes.

Before analysis all unsuccessfully tracked trials and outliers were removed from the data set, remaining five trials in each movement. The time-series data were normalized to 100 data points, spaced of 1% at 1%, to construct ensemble averages for each movement. Joint angles were calculated for each movement. For each movement comparisons of Microsoft Kinect I, Kinect II and Optitrack™ were made derived angles using several statistical metrics such as maximum amplitude, minimum amplitude, range of motion and root mean square error. All these results are presented at Table 2.

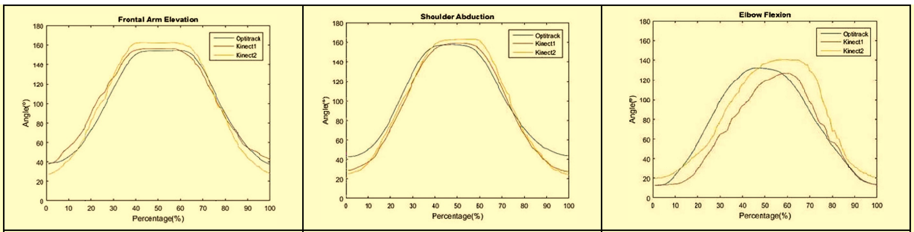
Table 2. Mean results expressed in degrees (MAX = maximum amplitude, MIN = minimum amplitude, ROM = range of motion); RMSE = Root mean square error.

	MAX (°)			MIN (°)			ROM (°)			RMSE	
	Optitrack	Kinect 1	Kinect 2	Optitrack	Kinect 1	Kinect 2	Optitrack	Kinect 1	Kinect 2	Optitrack – Kinect 1	Optitrack – Kinect 2
Elbow flexion	132,38	127,36	141,31	12,73	12,70	19,27	119,65	114,67	122,04	18,75	18,22
Shoulder abduction	157,66	159,07	163,62	42,09	26,40	23,05	115,57	132,67	140,57	9,57	11,01
Neck flexion	50,81	43,74	47,59	23,29	5,58	5,05	27,52	38,16	42,54	8,18	7,2
Frontal arm elevation	154,53	157,00	163,77	37,34	37,49	26,01	117,19	119,51	137,76	7,85	8,65
Horizontal arm abduction	119,83	118,85	115,69	81,36	49,30	41,82	38,47	69,56	73,87	29,15	34,75

Illustrative examples of movement traces are given in Fig. 3. Each plot contains the average joint angle across the five trials obtained with the three capture systems.

4 Results

In this study we can argue that the precision obtained in measuring the angles of joints with the Microsft Kinect is sufficient for most of the prescribed exercises for post stroke rehabilitation. This type of pathology affects the upper limbs and the head in particular, therefore, only movements of these parts of the body were evaluated. The five selected movements were recorded simultaneously by both Kinect devices and the reference system, the Optitrack™.



A B C

Fig. 3. Average joint angle for the movements: (A) Frontal arm elevation. (B) Shoulder abduction. (C) Elbow flexion.

Thus, it was possible to draw the necessary conclusions to perform statistical calculations such as RMSE and obtain the ROM. Moreover, it was possible to verify that the values of maximum, minimum and ROM are similar between Kinects devices, despite the Kinect I data is closer to the reference system. By analysing the data, the movements that can be considered more accurately are the Frontal Arm Elevation, Shoulder Abduction and Neck Flexion, showing such movements, low RMSE values (9,57 and 11,01 to Shoulder Abduction, 7,85 and 8,65 to the Frontal Arm Elevation, 8,18 and 7,2 to the Neck Flexion). Also for these three movements, we found that the range of values of the system used as a reference and Microsoft Kinect have relatively similar values that respect to the maximum, minimum and ROM, especially the level of the maximum amplitude values. Moreover, the movements of the Elbow Flexion and Horizontal Arm Abduction present higher RMSE values (18,75 and 18,22 to the Elbow Flexion, 29,15 and 34,75 to the Horizontal Arm Abduction), despite presenting similar relative maximum values. Consequently, this does not verify the same for minimum values and,, for the ROM. The movement of Elbow Flexion presents very similar values of maximum, minimum and ROM.

5 Final Remarks

This study evaluated the accuracy of Kinect motion capture device, which proved to be able to measure and evaluate movements with the necessary precision for post stroke rehabilitation therapies. The results showed that the precision of the Kinect is lower than that of the reference system, however for the analyzed movements it proved to be suitable, as observed in previous studies [19–21].

The Kinect has a set of advantages that make it very attractive for telerehabilitation systems: price, portability and markerless. Thus, in future work, there is the possibility of using this technology in the creation of rehabilitation systems with many advantages over traditional methods, as previously mentioned. This kind of system has some weaknesses. Further research is necessary to improve the capture of lower amplitude and magnitude movements. These information can be used as a reference for future work related to motion capture using the Microsoft Kinect.

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