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MICROSOFT KINECT™ ACCURACY IN THE KINEMATIC ANALYSIS OF THE HUMAN MOVEMENT

Acurácia do Microsoft Kinect® na análise cinemática do movimento humano

Fabio S. Ferreira Vieira[1,4]; Adriano G. Marques dos Santos[1,3]; Anderson Evaristo da Silva[1,4]; Claudio Novelli[1,4]; Felipe Silvestre[1,3]; Gustavo C. Martins[1,3]; Heleise F. R. Oliveira[1,2]; Joaquim J. Fantin Pereira[1,3]; Kelmerson Henri Buck [1,4]; Leandro Borelli de Camargo[1,4]; Pedro Domotor[1,3]; Raul Marcel Casagrande[1,5]; Guanis de Barros Vilela Junior[1,4]

ABSTRACT

The lack of low cost devices apt to collaborate both researches and clinical intervention s quality for health promotion is quite significant, peculiarly in developing countries. The objective of this study consisted in calculating the accuracy of the hardware Kinect™ by Microsoft™. **Methods**: anthropometric data were collected from a subject in orthostatic position, at four different distances from the optical axes of the hardware, on X, Y and Z. The normality and the variances homogeinity of the data were stated through Kolmogorov-Smirnov and Barlett's tests, in this order. It has been adopted a significance $P < 0.05$ for all the statistical tests, and the size effect for all of the spatial coordinates (in the four different placements) exceeded 0.80. **Results**: the relative error presented no significant differences in all of those distances in the three spatial axels and the accuracy averaged 0.047m; such result allows to conclude that the hardware presents satisfactory both scientific and clinical applicability, embracing potentially human movement investigations and interventions, as well as orthopedics, physiotherapy, physical education, and sports among others.

Keywords: Accuracy; Kinematics Analysis; Human Movement.

INTRODUCTION

One of the biggest methodological challenges for the human movement sciences is developing and validating usable devices for a wide range of needs in human health area. Such instruments are potentially useful beyond academic matters, in clinics, hospitals, rehabilitation centers, and physical training centers, among many others. Microsoft Kinect™ hardware has been originally developed for the Xbox™ videogame. It has been utilized, even though embryonically yet, on health researches, especially its second version released for Windows™, presenting a considerable and representative precision in comparison to the previous one, as reported by the manufacturer.

Modern technology hardwares and softwares utilized on health, including scientific research, are expensive and often imported under sieve of exorbitant customs taxes. This scenario makes hard inserting Brazil in the circuit of front

Autor de correspondência

Fabio S. F. Vieira
Universidade Metodista de Piracicaba
Rodovia do Açúcar Km 156, Bloco 7, Sala32
Taquaral 13400-911 - Piracicaba, SP – Brasil

E-mail: vieira.fsf@gmail.com

1- Núcleo de Pesquisas em Biomecânica Ocupacional e Qualidade de Vida / CNPq
2- Universidade Estadual de Ponta Grossa – UEPG
3- Cetus Informática Ltda.
4- Centro de Pesquisas Avançadas em Qualidade de Vida – CPAQV
5- Hospital São Vicente de Paula – Jundiaí - SP

end science producers. That fact brings deleterious impacts on health practices, at where only a privileged minority have access to those technologies. Such an argument justifies the relevance of studies in this area.

ERRORS AND ACCURACY

Errors are usually classified as Systematic and Random. The first ones relate to methods and devices utilized during measurements, meanwhile the second ones refer to the statistical nature of the measurement process and cannot be totally eliminated. When there is a small systematic error, the outcome presents a better accuracy. When there is a small random error, the outcome presents a better precision. Therefore, the better the accuracy and precision, the better the measurement. Despite being obvious, it is worth noting there is no real measurement, but reference measurement instead [(1)].

Accuracy embraces systematic and random errors. In turn, precision exclusively associates to random errors. Then, the expression "accuracy and precision" is obviously redundant, once the last inserts itself in the first.

Thus, the objective of this work is to asses Kinect™ Microsoft™ accuracy on human movement kinematics analysis.

LITERATURE REVIEW

Three-dimensional analysis technologies become more and more popular at human movement sciences field [(2)]. Kinect™ Microsoft™ has proven itself efficient for such area although it has had been first thought as a revolutionary device for the electronic games market. This device is provided with movement sensors, allowing gamers to interact with electronic plays without any hand controls or joysticks. In other words, the spatial coordinates capture for one movements' interpretation is done without the use of any markers [(3)].

The interaction between a user and a computer interface might be understood as Virtual Reality (VR), involving a real time simulation of a determined environment, scenario or activity through several sensory channels [(4)]. In consequence, the increased reality that one observes gets amplified through one's sensorial perception by means of computational resources, allowing a more natural interface with data and image generated by the computer [(5, 6)].

Therefore, Kinect™ may offer a relevant contribution beyond electronic games. Researchers [(8, 9, 10, 11)] have been testing its technology concerning human movement capture at eagerness for its contribution on further researches. The focus is not only Quality of Life (QOL) based, but also on daily life activities (DLA) as well as several human movement ones, from rehabilitation to high performance sports [(12)]. Kinect™ holds a movement detector that enables it to identify subtle human gestures such as fingers movement, wrist twist, facial expressions, and heart rate perception. Besides that, Kinect™ infra-red sensor allows its operation either in outdoor and indoor environments. With an increased sight field in comparison to its previous version, it is possible to capture and interpret movements up to six individuals at a time. In other words, it succeeds on recognizing ones' identity, assuring a natural interface and some positioning freedom related to the distance from its optical axes, even under low lights (3).

Kinect™ has been yet shortly used in researches either in Brazil or abroad. However, the small number of researches undertaken has pointed its importance to several areas, including rehabilitation. It shows that individuals undergoing physical rehabilitation may find a better performance on their exercises during intervention phases when utilizing Kinect™ (3).

Concerning rehabilitation, some studies (4,5) mention Kinect™ relevance on gait requalification, once it may be used to create a biofeedback real time system for gait training. Besides its low cost, it is portable and do not demand any sensors connected to one's body, as happens on common laboratory tests.

Some researches (4,5,11) also mention Kinect™ validity for postural control assessment, confirming its reliability, internal consistency and excellent concurrent validity. Another Kinect™ contribution related to Quality of Life at Worksites (QOLW) concerns ergonomics, once postural recordings are very important in this area to determine workers muscle-skeleton injury risks.

Therefore, researches point the use of Kinect™ to facilitate labor images and movements capture, once cameras for this kind of assessment do not present such a great sensitivity.

In a research (6) comparing Kinect™ with another movement capture device, named Vicon, researchers found Kinect™ not only holds a bigger sensitivity concerning 3D movements capture, as its portability facilitates its utilization.

Having in mind the wide variety of Microsoft™ Kinect™ applications, it is majorly important to verify its accuracy for the human movement in an academic-scientific environment. From then on, it is necessary to highlight the accuracy (a) may be calculated in function of the odds (b), which is the difference between the sample average and the reference and the precision value (DPx), over the equation (1) (7):

$$a=b+DPx \qquad \text{Eq. (1)}$$

The Relative Error (RE) is calculated over the modular value on equation 2:

From there on, it is possible to verify Microsoft™ Kinect™ device accuracy. Kinect™ device accuracy.

METHODS

Microsoft™ Kinect™ has been positioned on a table in a way its lens optical axis was parallel to the floor, and vertical 0.75m distant from it.

The ambience was satisfactory lighted up due to optimize the device images capturing. One subject, height 1.78m, wingspan 1.74m, body mass 84.80kg, was placed facing Kinect™ optical axel in orthostatic position, with upper limbs on a horizontal line due to shoulders abduction. Four different placements were assessed: 1.80m, 2.60m, 3.60m, and 4.30m from the device optical axis.(Fig 1). Three data acquisition attempts were run to each of those placements under the native device 30Hz data acquisition rate.

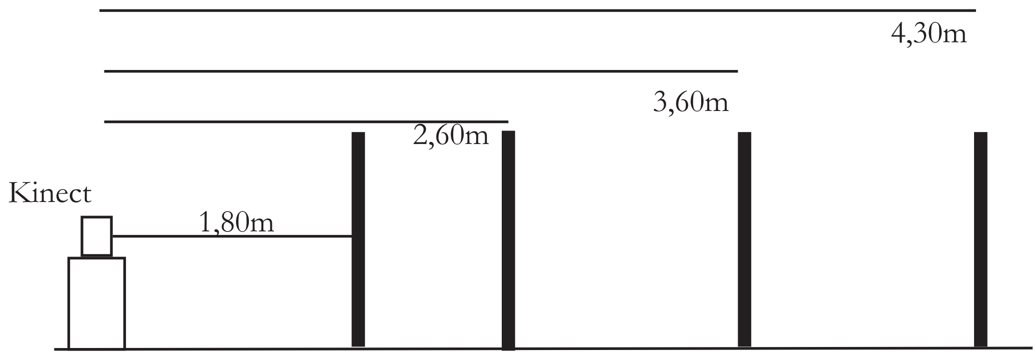

Fig 1 - Subject's positions in relation to Kinect

It is important to highlight that the distances adopted were established accordingly the device sight field. Being the closest 1.80m and the furthest 4.30m, those were the limits for the subject to be integrally viewed by the device. This research has been submitted and approved by the Research Ethics Committee CEP-UNMIEP under protocol #49/2014, and the subject signed a Free Will and Clarified Consent Term.

Both softwares SPSS 20.0 and Origin 9.0 were used for the statistical analysis. ANOVA Two Way was used to compare the measures among the three different moments of the data acquisition, under Scheffé's post-hoc test at 5% significance. The data normality and the homogeinity variances were supported through Kolmogorov-Smirnov and Barlett's tests, in this order. There was a 0.80 power test to minimize type II errors events (7).

The effect size (ES) has been calculated accordingly Levine's equation (3):

$$ES= (\omega_1 - \omega_2)/SDc$$

Where, ω are the averages of each data acquisition and SDc is the combined standard deviation. Thus, ES has been calculated thrice for each of the coordinates (X, Y, Z): X1 e X2; X1 e X3; X2 e X3; the same for Y and Z.

SDc was obtained over the equation (Eq.4):

$$SDc= sqrt((SD_1)^2.(n_1-1)+(SD_2)^2.\ (n_2-1))/(n_1+n_2-2)$$

When ES > 0.80, it is considered big; 0.50, moderate; and 0.20, small (7). For all the distances verified (1.80, 2.60, 3.60, and 4.30m), there was ES >0.80.

The sample average x has been calculated, as the sample precision (the samples standard deviation), and the average precision (SDx), since we assumed not knowing the device precision.

RESULTS

From the three data acquisition for each of the four established distances, through the equations, all the necessary data were calculated due to determine both accuracy and errors supplied by Kinect™. Table 1 shows averages and standard deviations related to distance for each axis over the three data acquisition

Table 1. Averages, standard deviations and variables spotted with asterisks (*) do not present significant differences among each other at ANOVA Two-Way test.

Dist.	1,80m	2,60m	3,60m	4,30m
Coord.	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
X_1^*	-0,566(0,001)	-0,608(0,018)	-0,532(0,010)	-0,578(0,000)
X_2^*	-0,569(0,000)	-0,613(0,003)	-0,538(0,006)	-0,577(0,002)
X_3^*	-0,571(0,001)	-0,609(0,001)	-0,537(0,008)	-0,577(0,001)
Y_1^*	0,608(0,001)	-0,571(0,002)	0,624(0,006)	0,553(0,001)
Y_2^*	0,607(0,002)	-0,566(0,003)	0,620(0,002)	0,547(0,001)
Y_3^*	0,607(0,001)	-0,567(0,001)	0,621(0,003)	0,546(0,000)
Z_1^*	1,892(0,001)	2,758(0,008)	3,652(0,001)	4,133(0,005)
Z_2^*	1,891(0,001)	2,766(0,004)	3,647(0,001)	4,307(0,002)
Z_3^*	1,892(0,003)	2,758(0,002)	3,649(0,001)	4,306(0,001)

* Variables not presenting statistical significant differences.

At equation 2, for verification of the Relative Error (RE), it is necessary to check the reference value and the device under testing obtained value. After that, the RE will be found, as displayed on Table 1, as follows.

Tabela 2. Valores do Erro Relativo (ER) de acordo com a distância do avaliado em relação à lente do hardware para cada eixo.

Dist.	1,80m	2,60m	3,60m	4,30m
Coord.	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
X_1^*	1.325 (0,00)	1.349 (0,00)	1.305 (0,00)	1.332 (0,00)
X_2^*	1.327 (0,00)	1.352 (0,00)	1.309 (0,00)	1.331 (0,00)
X_3^*	1.328 (0,00)	1.350 (0,00)	1.308 (0,00)	1.331 (0,00)
Y_1^*	0.555 (0,00)	0.583 (0,00)	0.544 (0,00)	0.594 (0,00)
Y_2^*	0.556 (0,00)	0.586 (0,00)	0.546 (0,00)	0.597 (0,01)
Y_3^*	0.556 (0,00)	0.586 (0,00)	0.546 (0,00)	0.598 (0,01)
Z_1^*	0.051 (0,00)	0.061 (0,00)	0.014 (0,00)	0.034 (0,12)
Z_2^*	0.050 (0,00)	0.064 (0,00)	0.013 (0,00)	0.033 (0,13)
Z_3^*	0.054 (0,00)	0.060 (0,00)	0.013 (0,00)	0.033 (0,12)

*Variables not presenting any significant statistical differences.

The Relative Error did not present any significant statistical differences on the four analyzed placements for the three axes (X, Y, Z), showing measurements consistency.

The average values (in meters) for odds, precision and accuracy are presented in Table 4, for each one of the axes (X,Y and Z), to every distance placement assessed.

Distance	Coordinate	Odds	Precision	Accuracy
1,80	X	0.112	0.000	0.112
1,80	Y	0.012	0.002	0.014
1,80	Z	0.094	0.002	0.092
2,60	X	0.090	0.000	0.090
2,60	Y	0.051	0.002	0.054
2,60	Z	0.161	0.005	0.156
3,60	X	0.154	0.008	0.162
3,60	Y	0.002	0.004	0.002
3,60	Z	0.050	0.003	0.046
4,30	X	0.101	0.000	0.101
4,30	Y	0.068	0.014	0.081
4,30	Z	0.127	0.563	0.691

It has been observed that odds, precision and accuracy present satisfactory results, revealing how accurate the device is for the distances forementioned.

DISCUSSION

Utilizing Kinect™ as a three-dimensional analysis device for human movements has been show effective for academic-scientific matters, even understanding that this tool has been first created as a videogame joystick, what may illustrate its wide range of applications [13, 14]. Being an individual in orthostatic position with upper limbs elevated due to shoulders abduction, it was possible capturing X, Y and Z axes coordinates utilizing Microsoft™ Kinect™. From there on, acquired data were statistically analyzed aiming to verify the device accuracy.

Concerning variables and theirs gross measurement values, for each of the data acquisition em each of the distances and all of the axes, as those can be observed in Table 1, it is noticeable that in 100% of the cases there was not presented any statistically significant difference under comparison, suggesting results were similar on the three data acquisition attempts, as found on previous researches [13, 15, 17].

By analyzing the Relative Error, it is noticeable the results are in agreement with other studies, once the significant differences percentage found is too low [17, 18].

The odds, precision and accuracy analysis for all the axes (X, Y, Z) and the four different considered distances support Yang [17] and Khoshelham [18, 19, 10] studies.

The values obtained through the analysis on this research, both related to accuracy and the gross values of the coordinates for the different distances to the assessed individual, all of them present conformity to the findings from previous studies [13, 16, 17, 20].

It shall be highlighted that Microsoft™ Kinect™ has been shown a satisfactory performance for those demands to which it has been tested on academic scenario, besides the easiness of its transportation and low cost, meeting the needs for developing and validation of devices in health sciences domain, as testified by Shingade [3], Dutta [4], Adamovich [5], Chang [9], and Caurin [12] studies.

FINAL CONSIDERATIONS

It was concluded that the accuracy demonstrated by Microsoft™ Kinect™ is enough satisfactory for utilization in kinematics analysis by the human movement sciences, orthopedics, physiotherapy, rehabilitation, sports, neurology and correlate areas.

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