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CALCULATING THE CENTERS OF MASS RMS ERROR OF BODY SEGMENTS OBTAINED THROUGH KINECT™ FOR WINDOWS™

Calculando o erro RMS dos centros de massa dos segementos corporais obtidos através do Kinect Windows(R)

Fabio S. F. Vieira[1,4] ; Adriano G. M. dos Santos[1,3] ; Anderson E. da Silva[1,4] ; Claudio Novelli[1,4,6] ; Felipe Silvestre[1,3] Gustavo C. Martins[1,3] ; Heleise. F. R. de Oliveira[1,2] ;Joaquim J. F. Pereira[1,3] ; Leandro B. de Camargo[1,4] ; Pedro Domotor[1,3] ; Raul M. Casagrande[1,5] Guanis B. Vilela Junior[1,4,6]

ABSTRACT

Due to the importance of both developing and validating new low cost analysis, diagnosis and intervention devices for several areas, since rehabilitation until high performance training environments. The objective of this study is to determine the value for RMS error of the CM of body segments. Methods: anthropometric data were collected from a volunteer standing still in orthostatic position. Using Kinect™ for Microsoft™, the X, Y and Z coordinates were acquired. From there on, values of reference and values calculated by the device were taken into consideration. Results: the values calculated by the device demonstrated to be consisting through the different moments over data collects as well as RMS error values were satisfactory due to their low percentage, favorably subsidizing the usage of such device as a tool for analysis, diagnosis and intervention over several health care areas, such as physical education, physiotherapy and medicine among others.

Keywords: RMS; Human Movement; Center of Mass.

RESUMO

Devido à importância do desenvolvimento e validação de novas ferramentas para análise, diagnóstico e intervenção com custos menores nas mais diversas áreas que atendem desde os ambientes de reabilitação até o treinamento de alta performance, o objetivo do presente estudo é determinar o valor do erro RMS do CM dos segmentos corporais. Métodos: Foram coletados dados antropométricos de um voluntário que permaneceu em posição ortostática, e com o uso do Kinect® da Microsoft™ foi realizada a aquisição as coordenadas de X, Y e Z. A partir de então foi levado em consideração os valores de referência e os valores calculados pelo instrumento. Resultados: Os valores calculados pelo instrumento demonstraram consistência nos diferentes momentos das coletas, assim como os valores do erro RMS apresentaram-se satisfatórios pelo seu baixo valor percentual, o que torna subsidio favorável para a utilização do instrumento como ferramenta de análise, diagnóstico e intervenção nas mais variadas áreas da saúde, como por exemplo educação física, fisioterapia, medicina entre outras.

Palavras chave: RMS; Movimento Humano; Centro de Massa

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
6- Metrocamp Devry do Brasil

Autor de correspondência

Fabio S. F. Vieira
Curso de Doutorado em Ciências do Movimento Humano - Unimep Rod. do Açucar Km 56, Campus Taquaral Bloco 7, Piracicaba - SP
E-mail: vieira.fsf@gmail.com

INTRODUÇÃO

Given the importance of developing and validating low cost instruments for analysis, diagnosis and intervention on the several health care sciences, such as physiotherapy, orthopedics, neurology, and physical education among others, the hardware Kinect™ has allowed a promising researches front. Its Windows™ version, in comparison to the previous Xbox one, presents considerable improvements, as shown in Table 1.

Table 1. Table comparing Kinect® 360 with Kinect for Windows®

	Kinect® 360	Kinect for Windows®
Method to calculate depht of objects in scene	Structured light	Time of flight
Resolution	480 Pixels	1080 Pixels
Numbers of skeletons tracked	2	6
Skeleton joint defined	20 joints	26 joints
Bone orientations	No	Yes
Forces at body joints	No	Yes
Muscle Simulation	No	Yes
Recognizing expressions	No	Yes
Face Tracking	Yes	Yes
Measuring heart rate	No	Yes
Color camera	640 x 480 @30fps	1092 x 1080 @30fps
Depht Camera	320 x 240	512 x 424
Max Depth Distance	~ 4.5m	~ 4.5m
Min Depth Distance	40cm in near mode	50cm
Horizontal field of view	57 degrees	70 degrees
Vertical field of view	43 degrees	60 degrees
Tilt motor	yes	no

We can observe the resolution increased over 120%. Concerning the number of skeletons tracked, the increase reached 200%; 30% for skeleton joint defined; 71% for color camera; 60% for depth camera; 25% for min depth distance; 23% and 40% for horizontal and vertical field of view, in that order. Those confirm Kinect™ for Windows™ has a great potential for usage on environments attended by human movement sciences and health care in general, both for academic-scientific and daily practices on health clubs, hospitals and others.

Several researches[1, 2, 3, 4, 5, 6, 7] reveal the elevated Kinect™ reliability on three dimensional kinematic analysis of the human movement through positioning data captured on X, Y and Z axes, besides studies aiming to verify its errors, accuracy and precision[8, 9, 10, 11, 12, 13, 14].

The errors related to methods and instruments during measurements are classified as systematic, meanwhile those related to the statistical nature of the mediation process are classified as random and cannot be totally eliminated. It is common to find the term *real measure* in the literature.

However, it is valid to highlight, despite of the obvious, that the ideal usage, according to Goldemberg[15] and Vieira et al.,[8], remains on the expression referential measure.

It is important to remind that accuracy and precision are terms usually mixed up one to each other, even though those are not the same. To use the expression "accuracy and precision" is redundant, once precision is inserted into accuracy. We understand accuracy embraces systematic and random errors, while precision is exclusively associated to random errors[8].

The assessment of relative and absolute errors is valid for the instruments validation process, even though the most indicated method consists in RMS (Root Mean Square), which utilizes both referential values as calculated ones by a device under testing[16,17].

The center of gravity (CG) is a point of a body over which gravity force plays its attraction, also known as barycenter. The center of mass (CM), which consists in this study's object, is a fix point in a body or bodies cluster system that behaves as if all of the total amount of mass was concentrated on it, and can be calculated through the equation [18]:

$$CM=(\sum(Ri \times Mi)/(\sum Mi)$$

Where: CM = Center of Mass; Ri = distance of each point of the segment perpendicularly to its longitudinal axis; Mi = mass composing the body segment.

By definition, CM and CG concepts are not synonymous. Otherwise, they might match when it is a homogeneous body, which is not the case for the human body, one composed by different densities biomaterials[19].

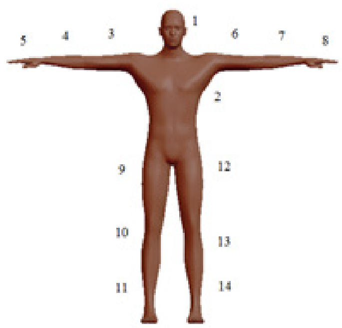
The objective of this study was to calculated Microsoft™ Kinect™ RMS error of CM for different body segments.

METHODS

Specific software for the CM acquisition on each body segment has been developed with C# programming language, through the softwares Visual Studio 2013™ and Kinect for Windows™ SDK 2.0.

The minimal requirements for the software utilization are Windows 8 or above. However, the recommended configuration consists in a dual-core 64bits (x64) processor, 3.1 GHz or above, 4GB RAM memory or above, USB 3.0 port dedicated to Kinect for Windows™ connection or to Kinect V2 (which requires an adaptor).

The hardware Microsoft™ Kinect® was placed on a three feet stand, its lens was parallel to the floor, far 0.75m from it, and the room was satisfactory lighted up for the footage capturing. One male volunteer, 1.87m height, 1.75m wingspan and 101.100kg body mass has been positioned facing Kinect™ optical axis at 3.60m from it, in orthostatic position, performing shoulders abduction, sustaining upper limbs in horizontal position for the CM positioning standardization on each body segment analyzed[20], according Figure 1:



(1) Head – C7-T1 to ear canal;
(2) Trunk – Greater trochanter to glenoumeral joint;
(3) Upper Arm Right (6) Upper Arm Left – Glenoumeral joint to wrist center;
(4) Forearm Right, (7) Forearm Left – Elbow to wrist center;
(5) Hand Right, (8) Hand Left – Wrist center to knuckle II of third finger;
(9) Thigh Right, (12) Thigh Left – Hip to knee center;
(10) Leg Right, (13) Leg Left – Knee to ankle center;
(11) Foot Right, (14) Foot Left – Ankle to ball of foot.

Three data collects were performed under a 30Hz data acquisition, matching Kinect™ native frequency. This very research has been submit and approved by the Ethics and Research Committee of the Methodist University of Piracicaba, protocol #49/2014, and the volunteer signed a Free and Clarified Consenting Term.

In order to minimize the occurrence of type II errors, the power test was 0.80. Levine´s equation has been utilized to verify the effect size.

At last, RMS has been calculated using the equation proposed for Allard et al[16] and Figliola and Beaskey[17].

The descriptive statistics were run from the CM positions related to the three axes (X, Y and Z). The existence of differences among the three data collects was assessed over ANOVA two-way. The significance level adopted was pre set at 5%.

RESULTS

From our findings over the methodological sequence of the study, it was possible to verify the effect size values above 0.80 on each CM analyzed, what is considered a large effect[21].

Results concerning CM behavior on each body segment during assessments are expressed on Table 2.

Table 2. Descriptive Statistics of the CM to each body segment

	X(m)		Y(m)		Z(m)	
	Mean	SD	Mean	SD	Mean	SD
Head	0.0583	0.0002	1.0359	0.0003	3.5534	0.0005
Trunk	0.0329	0.0001	0.4109	0.0001	1.8593	0.0002
Upper Arm Right	0.1010	0.0000	0.3281	0.0001	1.4790	0.0002
Upper Arm Left	-0.0485	0.0001	0.3285	0.0001	1.4916	0.0001
Forearm Right	0.2422	0.0001	0.3754	0.0001	1.7718	0.0002
Forearm Left	-0.1682	0.0001	0.3652	0.0002	1.8103	0.0002
Hand Right,	0.7974	0.0006	0.7634	0.0003	3.3845	0.0001
Hand Left	-0.7094	0.0002	0.6990	0.0007	3.5250	0.0004
Thigh Right	0.0592	0.0003	0.0986	0.0001	1.3913	0.0002
Thigh Left	-0.0050	0.0002	0.0963	0.0002	1.3967	0.0001
Leg Right	0.0825	0.0001	-0.0634	0.0002	1.4600	0.0001
Leg Left	-0.0228	0.0000	-0.0757	0.0001	1.4688	0.0001
Foot Right	0.2379	0.0004	-0.6392	0.0030	3.5293	0.0038
Foot Left	-0.0759	0.0001	-0.6396	0.0001	3.5551	0.0002

On Table 2 it is possible to verify the CM behavior of each body segment analyzed, reminding the volunteer was orientated to remains in orthostatic position during all the time of the data collect.

RMS error is reported as average percentage for each body segment CM on each of the axes (X, Y and Z), according Table 3.

Tabela 3. RMS error % for CM of each body segment on three axes

	X(%)	Y(%)	Z(%)
Head	0.02	0.19	0.66
Trunk	0.04	0.11	0.96
Upper Arm Right	0.13	0.25	1.12
Upper Arm Left	0.03	0.08	0.37
Forearm Right	0.40	0.47	2.15
Forearm Left	0.11	0.14	0.71
Hand Right.	0.71	0.69	3.05
Hand Left	0.21	0.21	1.06
Thigh Right	0.06	0.08	1.19
Thigh Left	0.02	0.05	0.91
Leg Right	0.03	0.04	0.49
Leg Left	0.03	0.04	0.49
Foot Right	0.07	0.19	1.00
Foot Left	0.01	0.12	0.63

Since RMS error is one of the most utilized parameters for instruments validation process, the table above reflects values favorable to that assessment with low percentages.

DISCUSSION

From our results, it was possible to

verify they reveal significant low values, beyond consistent maintenance over the three collects. The volunteer has been conditioned to an intermediate distance between the minimal and maximal ones which allowed Kinect™ to capture one's body entirely.

ANOVA two-way has confirmed that RMS error values do not present significant differences, reflecting reliability parameters for the Microsoft™ Kinect™ device for such ends.

Having in mind that the instrument accuracy has been tested in other researches[2, 8, 11, 12], this very study shall contribute for the device consolidation as a high potential tool for the human movement biomechanics analysis. Nevertheless, from there on it is possible to imply some details are not resolved yet concerning the present situation.

It is possible to consider the values related to RMS error, which is the most indicated one to verify this valence, were very low, and it reflects the consistency for the use of Microsoft™ Kinect™ as a wide range analysis tool in the human movement analysis.

FINAL CONSIDERATIONS

Facing such results obtained from the orthostatic position, we highlight further research on diverse motion situations is necessary.

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