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VERTICAL JUMP ANALYSIS USING THE MICROSOFT KINECT SENSOR

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Abstract. *The aim of this study was to validate the vertical jump analysis, in terms of the height estimation, obtained by Microsoft Kinect. The Microsoft Kinect sensor, placed frontally to the human subject, enable the acquisition of the three-dimensional coordinates of human body joints and the representative body segment vectors. With this information, it is possible to calculate the human body center of mass in any situation, as in a jump performance, and its trajectory. To validate the vertical jump analysis, a series of sixty attempts was quantified by two instruments, the Kinect and the force platform (golden measure). The two measures of jump height were compared using the Mann-Whitney test ($p < 0.05$). The comparison did not show sensible differences ($p = 0.873$). Furthermore, was attested that 80 % of errors were below 1.6 cm. In this way, the viability of use the Kinect sensor as a low-cost alternative was substantiated.*

Keywords: *Vertical Jump, Microsoft Kinect, Center of Mass, Force Platform, Biomechanics*

1. INTRODUCTION

Recent advances in video game technology have nourished a proliferation of low-cost devices that can sense the user's motion. As shown by Microsoft (2010) on this category of Natural User Interface (NUI) systems resides the widely spotlighted Microsoft Kinect, which had made it possible to sense the full-body pose for multiple users without the use of markers or handheld devices. The Microsoft Kinect is a peripheral device that consists of a multi-array microphone, a RGB camera, a monochrome CMOS camera, and an infrared projector. The last two being the core of the depth sensing technology. The projector produces a structured infrared light pattern in the scene, which is imaged by the CMOS camera. The displacement of the CMOS camera relative to projector results in computing the distance to objects in the scene using triangulation. One of the core results, of this distances calculation is the depth-map stream of predefined joints (head, shoulders, elbows, wrists, chest, hips, knees, ankles, and feet) that constitute a wireframe skeleton of a moving user. Besides embedded hardware particularities, previous information is made available by drivers and processing algorithms libraries. At the moment, of this writing, there are three major projects with freely available libraries that can be used to collect and process data from a Kinect sensor – OpenKinect, OpenNI, and Kinect for Windows SDK. The launching of those libraries and the low cost made the use of the depth field technology available with the Kinect sensor in a range of fields. For instance: as a tool in the help of elderly, physical rehabilitation, hear and visual impaired, , biometrics, biomechanics as a NUI controller medical assistance, education aid.

According to Microsoft (2010), Kinect performs the body analysis in two stages. First, Kinect uses Structured light technique to create a depth map. It also uses some others Computer Vision techniques like Depth from Focus and Depth from Stereo. Structured light is the process of projecting a known pattern of pixels on to a scene. The way that the pixels deform when striking surfaces allow vision systems to calculate the depth and surface of objects in the scene. Kinect uses an infrared projector with infrared sensor to apply the Structured light. At the second stage, already with the depth map, the Kinect driver uses machine learning algorithms to find objects, patterns and human bodies in the scene. Some examples of scenes with a body were used to teach the algorithm what to look for; It was simulated by Microsoft's super computers. A decision tree is created with this data and with a depth map it can return if there is and the position of a human body at the scene.

Motions of the center of body mass are commonly used to indicate movement performance and stability during standing activities, like jumps, says Adrian (1995). The center of mass trajectory is usually calculated by video analysis, also called kinematics analysis. As the kinematics analysis needed a time for video editing and analysis, turns out to be impractical for clinical use.

During walking, running or jumping, forces are exerted on the floor. These forces can be measured by a force plate. With the force plate technique, for example, the knowledge of the intensity, time and place where forces are applied allows an estimate of height reached by the center of mass.

2. METHODOLOGY

During the work, two Kinect sensors were employed, although in the majority of experiments only one was required. A notebook computer connected by cable with the sensor were used to process the data. The OpenNI driver was previously installed in the computer. For data processing and comparison were used: a force plate, retroreflective markers, an image editing software, Matlab and GNU Octave.

First, some body joints were automatically captured by the Kinect. On the other hand, some joints and body points were not identified by the OpenNI driver. In this case, some coding was developed to obtain all the required body data. The code available within the OpenNI driver allows separation of the body and the surrounding ambient. Fig. (1) illustrates the detachment: in the left, the whole captured scene and in the right, the body data isolated from the ambient.

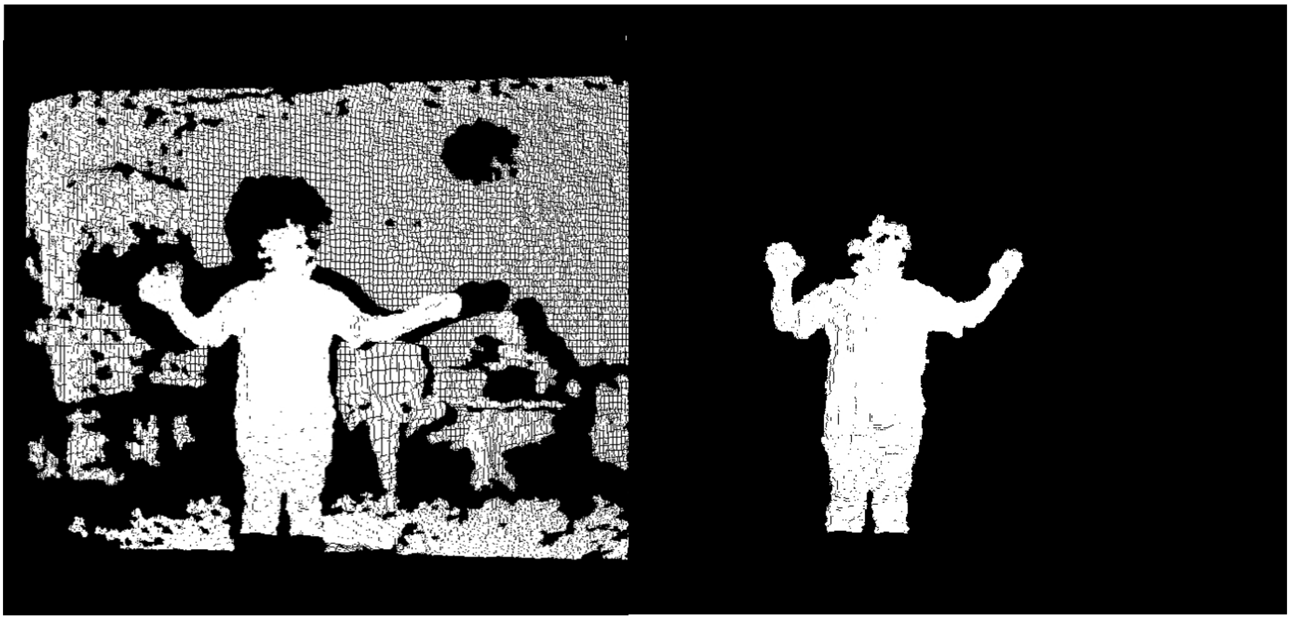

Figure 1. Human body representation as captured by the Kinect

Identification of the human body in a scene is fundamental for a biomechanical analysis. Moreover, the OpenNI driver encompasses an algorithm for joint capture, as shown in Fig. (2).

With the detected joints, as shown on the left of Fig. (2), body segments and motion properties can be calculated. For instance, angles and angular velocity, as shown on the right of Fig. (2)

The angle between joints were calculated using the relation from the scalar product:

$$(1)\quad \theta = \arccos \frac{\mathbf{A} \cdot \mathbf{B}}{\|\mathbf{A}\| \, \|\mathbf{B}\|}$$

In Fig. (2), **A** is the vector corresponding to the segment from the shoulder to the elbow and **B** is the vector from the wrist to the elbow.

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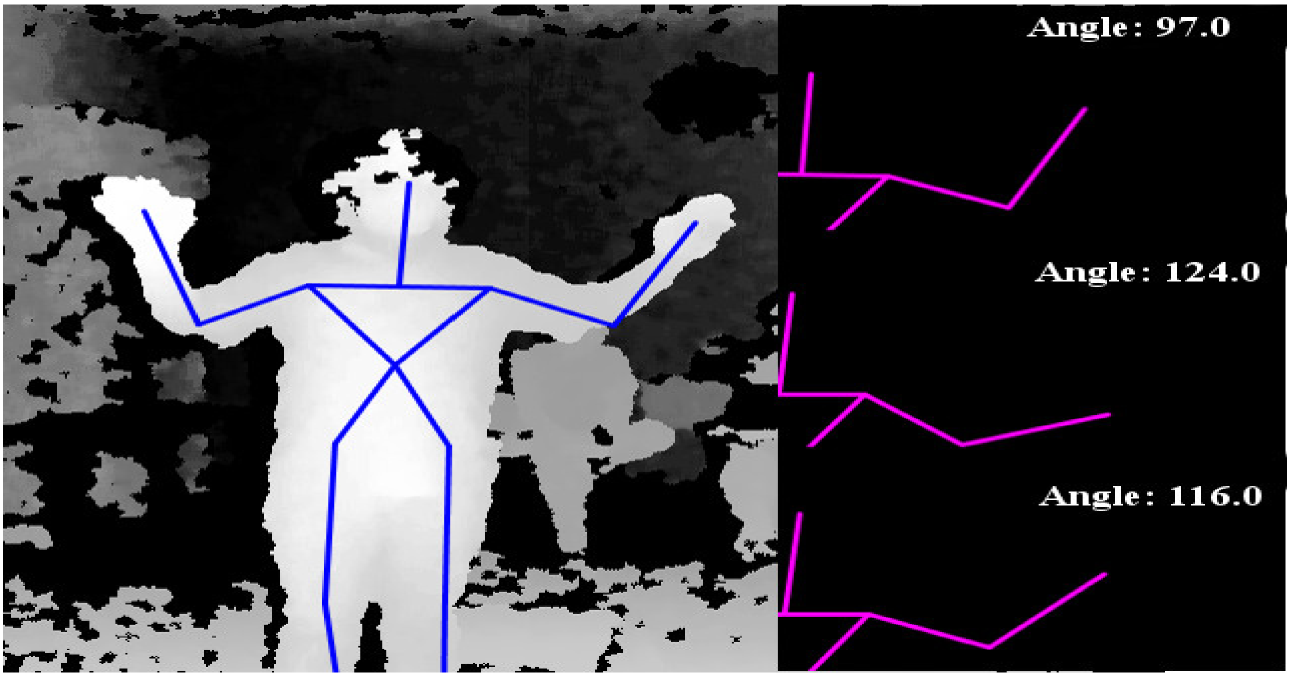

Figure 2. Segments calculated by Kinect and elbow's internal angle.

According to Preer (2012), center of mass is the averaged position of the particles that constitutes a given body or object. Motion of the body center of mass is commonly employed as a measure of performance, motion and stability in physical activities, e.g., jumps. The center of mass trajectory is calculated from video analysis, also known as kinematic analysis. By his turn, the kinematic analysis can be time-consuming and not adequate for clinical trials.

One of the most-used ways to identify an individual´s center of mass is by segmentation. In the segmentation the coordinates from the body segments is obtained from an image. Next, the knowledge of the segments center of mass is used. For instance, according to Charles (1969), arm center of mass is located 51.3 % far from the elbow and 48.7 % far from the shoulder.

Knowing the center of mass for the segments, the next step is to obtain the whole-body center of mass. This is done multiplying the coordinates of the center of mass of the segments by his relative weight. This product corresponds to the force momentum of the segment weight. The location of the center of mass is the quotient between the sum of segment's momentum and the whole body weight.

The above procedure is accomplished using the Kinect and a computer. Fig. 3 depicts the segment's center of mass and the body center mass using the procedure.

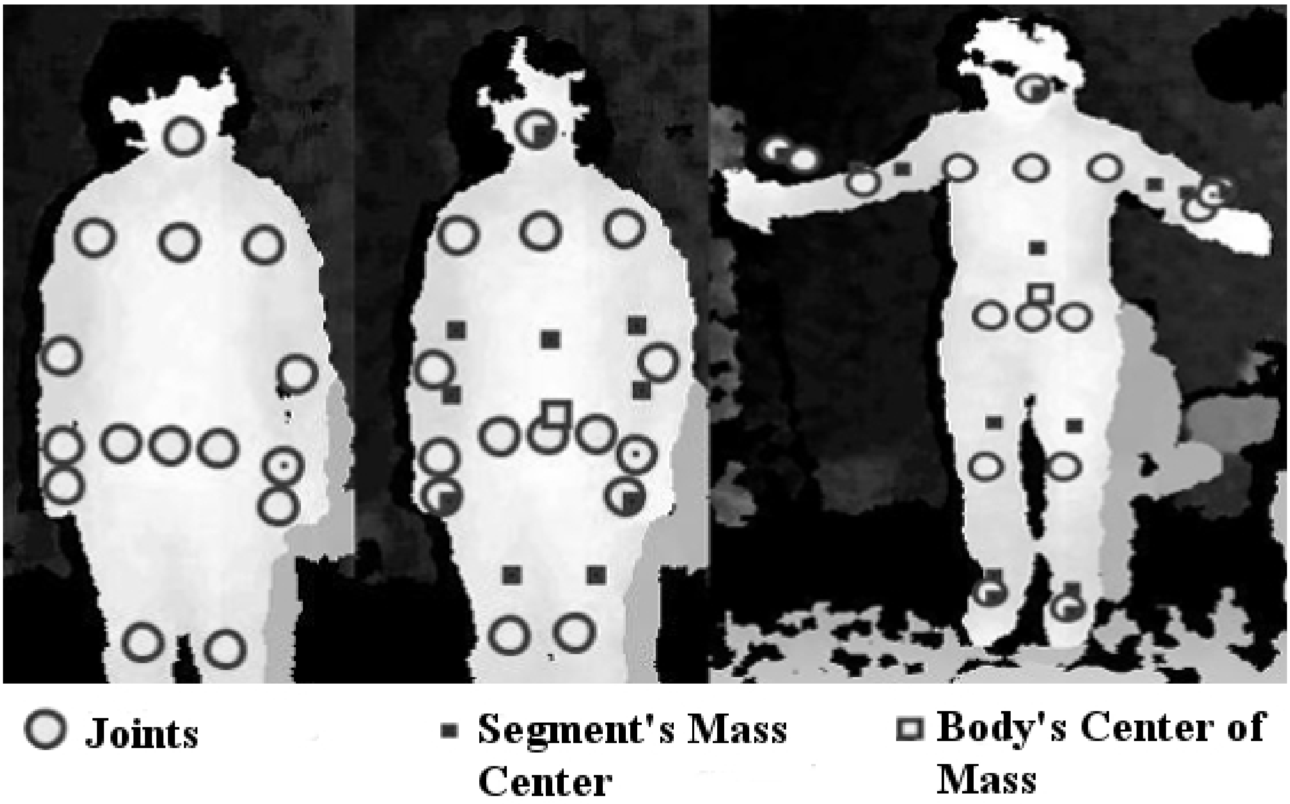

Figure 3. Location of the center of mass of the human body by the Kinect.

In the Fig. (3), from left to right, is presented the joints (unfilled circles), segment's center of mass (filled squares) and calculated body center of mass (unfilled square). It should be noticed the calculated center of mass was closer to the anticipated location, near the lower trunk.

For jump analysis was employed in concomitance two systems: the Kinect sensor and the force platform (BIOMEC400, EMG System do Brasil); During the acquisition session, the subject was positioned on the platform and performed 60 jumps. The subject was oriented during the jumps to work at a quite vertical trajectory. A time lapse during the jumps was used to adequately record the data for the two systems. The jump height was informed by the native software from the force platform, whereas, for the Kinect system was employed the vertical amplitude for the center of mass trajectory.

The force plate method is based on the forces exerted during gait or jump. These forces are measured by the platform. For instance, using the flying time estimated by the plate allows it is possible to obtain the center mass during the jump.

In Table 1 is presented the errors for the jump heights.

Table 1: Error distribution.

Error (cm)	Absolute Frequency	Relative frequency (%)	Cumulative frequency(%)
0.0000 |-- 0.0300	17	28.33%	28.33%
0.0300 |-- 0.5525	18	30.00%	58.33%
0.5525 |-- 1.0750	5	8.33%	66.66%
1.0750 |-- 1.5975	8	13.33%	79.99%
1.5975 |-- 2.1200	3	5.00%	84.99%
2.1200 |-- 2.6425	6	10.00%	94.99%
2.6425 |-- 3.1650	2	3.33%	98.32%
3.1650 |-- 3.6875	1	1.68%	100%

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In Fig. 4 is presented the data from height of the center of the mass height during the jumps. The data was collected from a sixty series of vertical jumps. The results were obtained from the Kinect methodology and the force plate. The plate results were identified as the golden measurements.

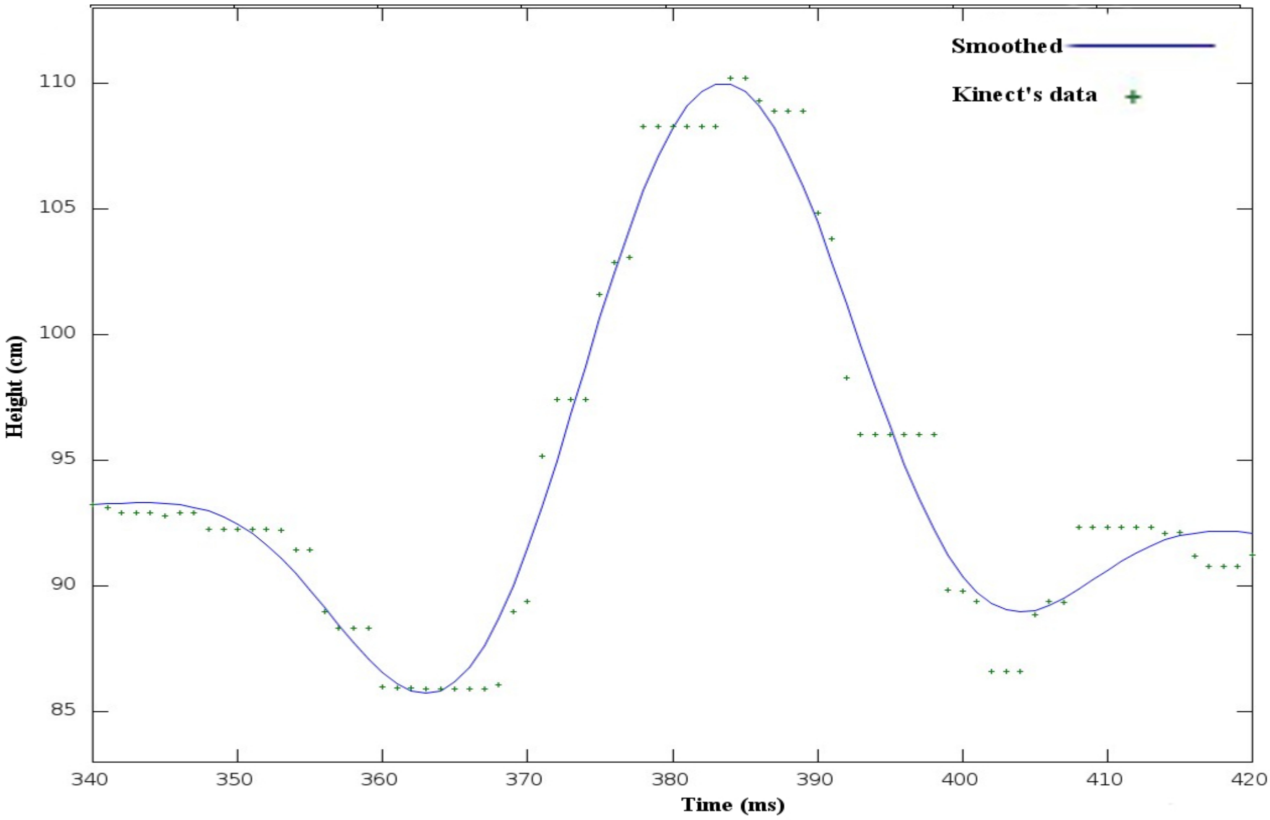

Figure 4. Center of mass height during the jumps.

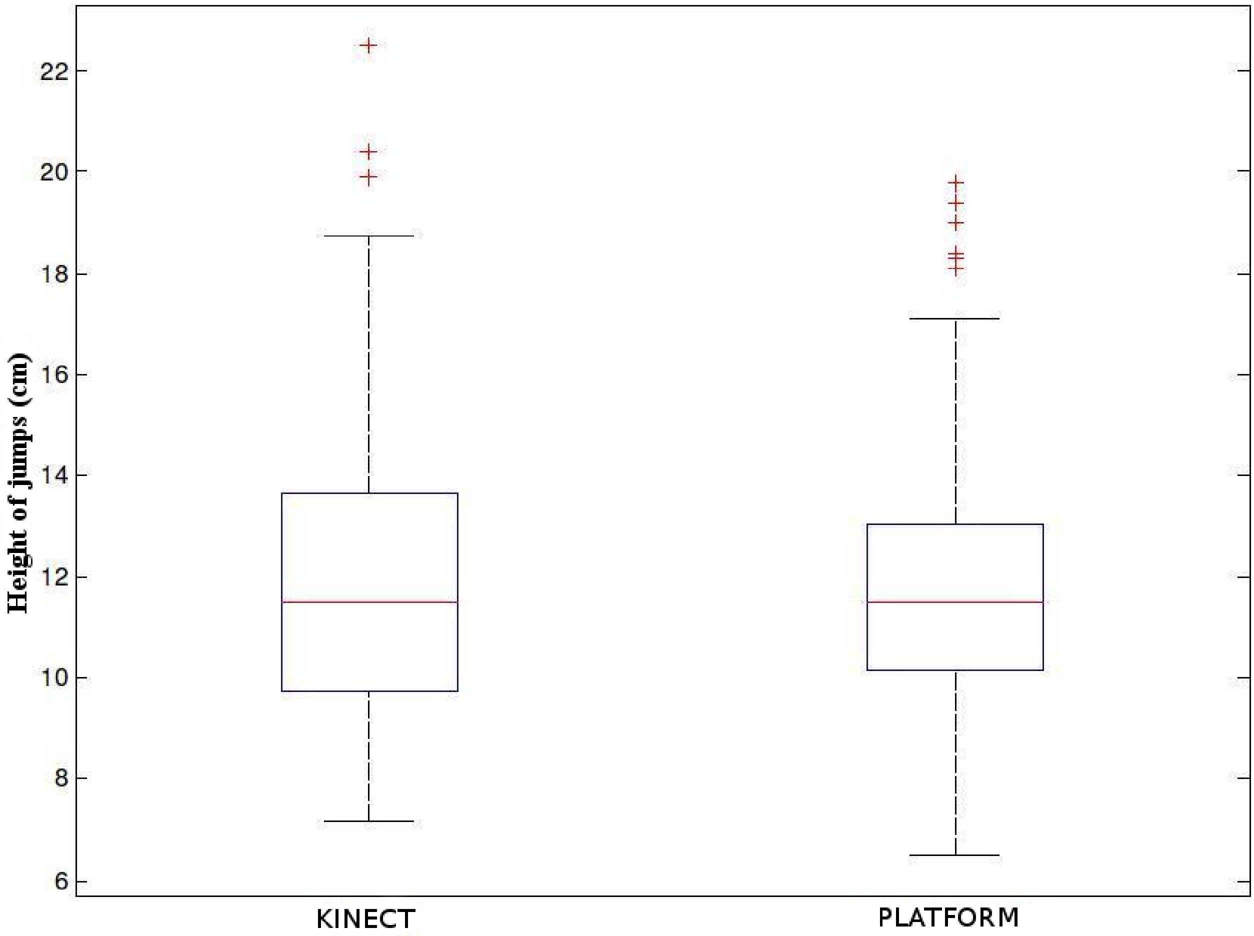

Figure 5. Box plot of the data obtained by both techniques. The left data from Kinect and the right data obtained from the force platform.

In Fig. (5) we present a boxplot analyzes with data from the Kinect and the analysis with the force platform. We can see that the median of both techniques are quite close. The value of the lower jump has a small error, however, it can be seen that the result of higher heels had a greater difference between the two measurements.

After verifying the data non-normality by the Shapiro-Wilk test, the two jump's heights, obtained respectively employing the Kinect and the force platform., were compared using the Mann-Whitney test ($p<0.05$). The comparison showed no significant differences ($p=0.873$). Also, can be noticed that 80 % of the errors are below 1.6 cm. In this sense, the Kinect sensor can be used as a tool for biomechanical analysis of jumps and center of mass location.

One of the shortcomings of the Kinect verified during the experiments is the distance from the sensor to the object, limited to four meters. For a given application this can discard the Kinect as a useful tool. A solution tested was to use two Kinects connected in a computer server. We verified that this solution can improve distance and precision.

3. CONCLUSION

During this work, a code was developed allowing to test the feasibility of Kinect as a tool for biomechanical analysis. The data obtained from Kinect were also compared with other techniques. The results point to the convenience of Kinect for some analysis, for instance, during the analysis of the motion of the center of mass. However, the Kinect had less efficacy during determination of fast changing angles. The last limitation can be credited to noisy data.

In summary, the employment of Kinect can be bounded by the needed precision in a given biomechanical application. By his turn, the data-acquisition speed and processing using the Kinect was superior in comparison with other techniques for angle calculation and center of mass analysis. The Kinect was revealed as a cheap and mobile alternative for vertical jump analysis when compared with the use of a force plate device. The low price and easy mobility can be considered an advantage during performance improvement for sports. At time of this writing, a new version of Microsoft Kinect sensor with USB 3.0 compatibility, allowing a better spatial resolution is to be released on the market by the end of the year.

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5. RESPONSIBILITY NOTICE

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