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DEVELOPMENT OF A LOW COST MOTION CAPTURE SYSTEM DESTINED FOR THE DETERMINATION OF HUMAN'S KINEMATICS

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Abstract. *The motion capture is a main tool for quantitative motion analyses, developed in several systems since the XIX century, for applications in biomechanics, animations, games and movies. A precise human motion analysis requires knowledge from distinct fields, being necessary to use didactics tools and methods for research and learning. The motion capture devices currently found on the market presents drawbacks for didactical practice, such as difficulty of transportation, high cost and limited freedom of data acquisition. Therefore, quantitative motion analysis requires highly complex laboratories. To counteract these problems, this work presents the development of a cheap, light, portable, freeware and handy motion capture system for didactic use. This design includes the selection of the device and software development. One device was selected and two softwares were developed, in different developing environments, first in Microsoft Visual Studio C++¸ for integration with the hardware and recording the motion, another in Qt Creator (due its large number of programming tools and visualizations) on order to process and represent the motion capture. Both programs aim to have a handy graphical user interface for classrooms and to aid the dialogue between health field and engineering about kinesiology. The system requires the Microsoft Kinect hardware, a computer with Windows 7, and the here presented softwares.*

Keywords: *kinesiology, Kinect, motion caption*

1. INTRODUCTION

The motion caption is a main tool with application in biomechanics, characters animation for games and movies, clinical analysis, and motion study for biomimicry, or machines functions. This kind of study started in the 1860 decade and dramatically increased along XX century, for the new systems of capture used in entertainment industry according to Gomide *et al.* (2011).

A motion capture system includes a device, a processor center and an analysis method. There is a great diversity of these systems, but their cost, size, installation and transporting complexity disable their use in small clinics and students access shown by Phoenix (2012). In spite of that, the motion analysis is underlying for professional formation of physiotherapists, physical educators, biomedical engineers, sportsmen and others who need the knowledge of mechanics, kinesiology and anatomy combined.

For motion analysis, the knowledge of different areas is fundamental, but to dialogue between the various professionals, and to teach them the same multidisciplinary subject, didactic tool are desirable. This work aims to propose a motion capture system for didactic use, which must be cheap, full body caption, easy transportation, accessible commercially and connected to a computer.

Along with the device, a software for its use must also exist with the capability of read the data acquired by the device, display mechanical and kinesiology information, and videos from the caption.

2. METHODOLOGY

2.1 Device selection

Among several devices available in the market, the one that fits all of the requisitions is the *Microsoft Kinect*, developed for natural interaction with video games; this device uses infrared projection to acquire tree-dimensional data and neural networks to recognize human bodies.

The *Kinect*'s size (Fig. 1) and weight are main reasons for its choice, when bought without its console (*Xbox 360*) it includes a cable with USB and energy power connections, needed for computer integration. The distributor also offers its libraries and codecs for computer use, basics documentations and samples provided by Microsoft (2011).

An infrared projector and a camera set up for the same frequency are responsible for generate a deformed standard, this allows the software to calculate distances between the hardware and the scene. This is called depth stream, with this data, the software runs algorithms to recognize human bodies and specifics joints that composes the skeleton stream.

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Figure 1. Kinect for Xbox 360 Dimensions

2.2 Softwares

This work presents two applications for the system, the first uses the Microsoft libraries and codecs (Kinect Software Development Kit, SDK), coded in C++, compiled in Microsoft Visual Studio, for integration between the computer and the device, responsible for capture and storage of motion data. The second reads the data from the first and presents it graphically, tree-dimensional and numerically.

2.2.1 Caption

The User Interface (UI) was developed with the Windows Forms Tool, generating common interface forms such as buttons and textboxes, although, this tool does not provides native OpenGL forms, needed for image rendering, hence they were customized from native window form, creating a new object for modeling the UI.

A separated section of the code access the device, searches for it, identifies it and sets it for usage. When a Kinect connects to the computer it starts to capture with both cameras, one for color stream and other for skeleton stream, the skeleton data comes from the depth data acquired. Depending of computer's efficiency, the program may start caption in less than ten seconds.

The OpenGL form aims to give a visual feedback of the motion caption; it shows the caption obtained by the color stream with current images of the environment of caption, simultaneously, draws the user skeleton with strait lines and circles around the captures joints, presented in Figure 2.

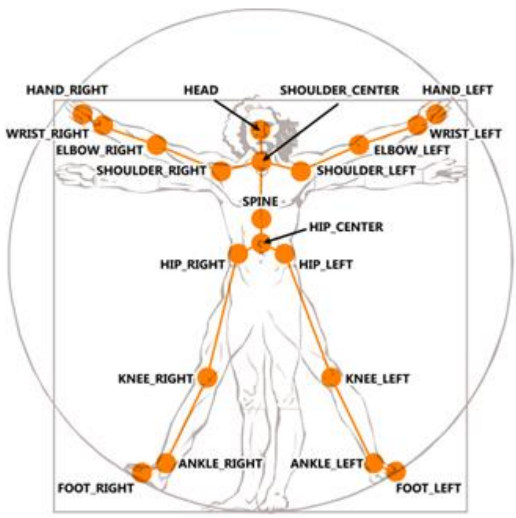

Figure 2. Human representation with highlighted joints, which Kinect recognizes.

Visual feedback combines two different types of data, with different scales; the color stream is a sequence of images, measured in pixels, while the skeleton stream is in meters. Top left pixel of color stream is zero to *x* and *y* coordinates, bottom right pixel depends on the image resolution, 640 width for 480 height in this work. Skeleton measure is relative to Kinect's position and orientation, *z* coordinate means distance, it is the perpendicular horizontal distance between the surface and the device, *x* is the parallel horizontal distance from de device, positive for the hardware left, negative for its right, finally, *y* is the vertical perpendicular distance, positive above the camera, negative below it. All the distances are in millimeters.

This software saves all the joints named in Figure 2 positions along a time defined by the user, with buttons to start and stop, the user writes the archive name in a textbox and select a folder by a usual folder chooser. File manipulation functions used belong to *fstream* library, for C++. The file also stores time past between the capture frame and the start frame, for velocity and acceleration calculation.

For a good caption, some environment conditions must be preserved, first, the luminosity, all sunlight must be avoided, sun light beans directly to the device or the surface measured can drastically distorts the acquired data, artificially lighted rooms are better places for measure. Second condition is space, the volume of caption begins by 0.80 m in front of the device and goes up to 4 m far from it, the angle of caption is 43º vertically and 57º horizontally, a total of about 5.3 m^3 pyramid body. This space must be free for movement as much it is possible, any object will interfere in movement caption or movement itself, let in this space only indispensable object. Other people must never stand between the user and the device; someone must stay behind the user for any aid or support. Third condition, the device must capture the entire body of the user.

To aid full body caption, the program automatically sets the rotation motor inside the device, when the head is not captured, it rotates up, when both feet are not in sight, it rotates down, if none can be captured it sends a message asking to user to stand further away from the hardware.

2.2.2 Processing

A second software is responsible for data reading and analysis, for its development the QtCreator application. It access the saved file trough a group of functions from the QFile object, for UI it uses several native Qt classes, such as QButton, QGLWidget and QSlider. The UI aims to simplicity, usability and intuitiveness.

OpenGL is present in the software too, also for visual feedback, with two graphic widgets, one for tree-dimensional representation of the human body, other for two-dimensional graphics. The first widget has commands for scale, rotate, translation, centering in a chosen joint and zoom, it presents and "Corner of wall" to increase the tree-dimensional sensation.

Velocity is calculated by positions chances trough time, similarly, acceleration trough velocity and time. Linear algebra relation between vectors with the same origin calculates angles, for instance, the elbow angle needs a vector for itself to the shoulder, and another from the same origin to the wrist. Other angles are more complex to measure, for the degrees of freedom of each joint, like the shoulders and hips, for they it is used vector *out* of the body, found by vectors products.

3. RESULTS

The programs developed are able to caption and analyze movements quickly, needing only a computer, the device, energy power for them and an open space with low natural light. Its acquisition cost is low, the device might be found by less than R$ 100 on internet recently, (Ebay, 2015). The software cost is undefined, probably freeware.

The twenty joints captured along the body allows a full scanning for one user in a proper environment, with an amplitude of moves unlimited by markers. However, quick moves are hard to capture with the device maximum caption rate, which is around 30 frames per second (Fig. 3).

The analysis program allows up to six graphics of movement quantities trough time, position, velocity, acceleration, joint angle, joint angle velocity, joint angle acceleration, and position, velocity and acceleration between two joints, for instance, you may choose to present the displacement among the feet (Fig. 4). Open a file is simple like any common software; it searches for the format set in the caption software (.mck).

The programs separation intend to change only part of the project for a new device, only the caption software need several change, while the analysis one need only minor changes, avoiding long debugs.

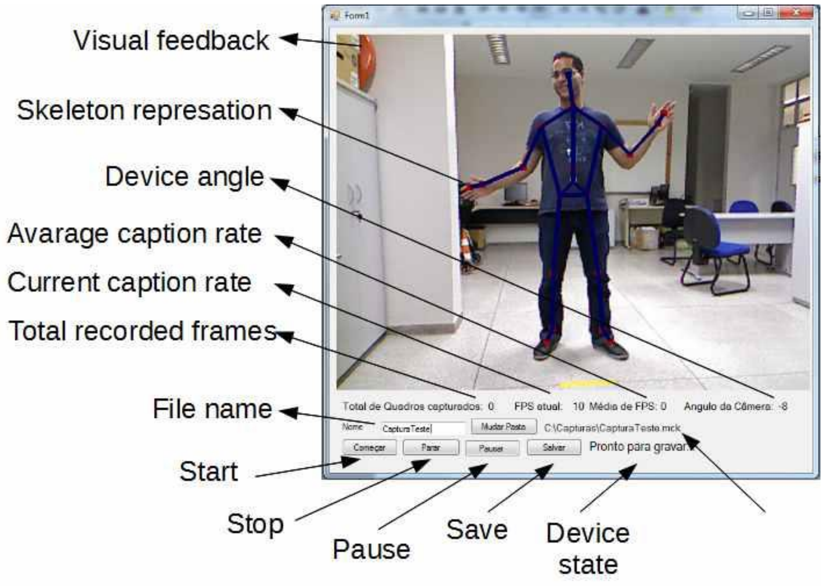

Figure 3. Caption Software User's Interface along a setting up process.

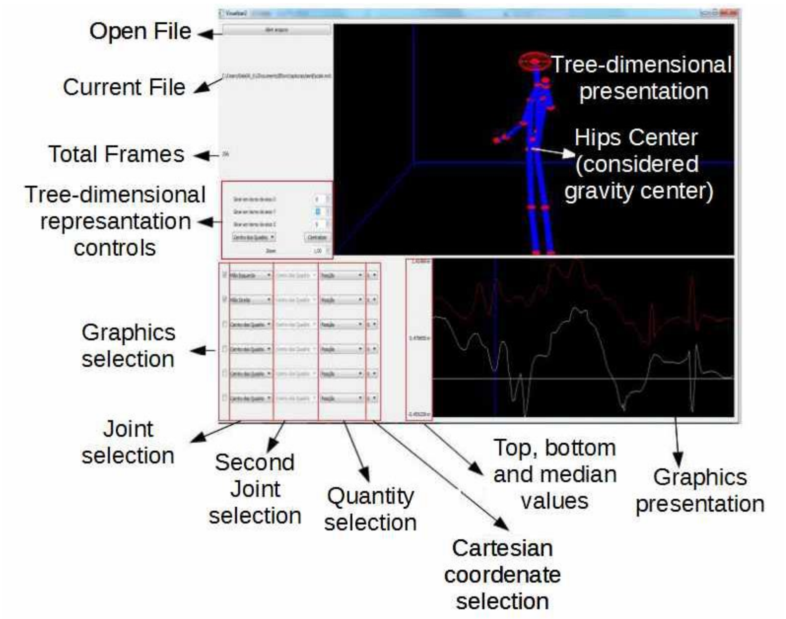

Figure 4. Analysis software's User Interface with two graphics

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