eBiom: Easy Biomechanics Package for Ergonomics and Clinical applications

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ABSTRACT

In this paper, we introduce a new 3D Biomechanics package, eBiom, it is being developed for clinical and ergonomics applications. The most important feature of eBiom is the simplification of the capture pipeline in order to facilitate the execution by a non technical user. Computer animation and 3D virtual models are used to guide the user during motion capture. The biomechanics models have been designed from many years of clinical experience. High precision in computing markers position and real-time data process makes eBiom a very useful tool for research and motion evaluation applications. The experience in many years of Biomechanics

Keywords

Motion Capture, Camera Calibration, Working Postures, Body Joints Motion.

INTRODUCTION

We present a new application aimed to the study of biomechanics properties with ergonomics and clinical applications. eBiom, name that stands for easy Biomechanics, has been designed for using in clinical laboratories or working environments without need of a technical user. It is well known [5] that most of the biomechanics equipments usually are painful to use because of both user knowledge and too long time data process. eBiom tries to overcome both problems. An easy interface has been designed for guiding the user step by step to create a final report with the significant parameters and most important data plots that can be completed by the expert clinician with his personal interpretation.

The first step is always to identify the present worker or patient which implies an appropriate data base running in background and record enough information to identify the present study. With this data base, every capture is properly recorded and classified according to different prefixed items. Second step is to choose the type of study being planed to perform, eBiom incorporates a wide set of the most important clinical models. A virtual human model is used to guide the user in positioning the markers associated to the model following the most standard protocols, see [5], [7].

Different type of data can be captured for a model, usually 3D motion capture from images and emiography data signals are used but, the application is designed to be scalable for incorporating other kind of data if needed.

eBiom uses infrared light which is invisible for human eyes, this is completely different from using regular spotlight and people feel more comfortable in order to perform motion in a natural way. The size and placement of markers is also designed with a double goal: to facilitate person's motion and to decrease possible occlusions from the cameras.

The eBiom interface has been designed to be user configurable. Different looking appearances, language and other setup defaults can be modified by the user according his preferences.

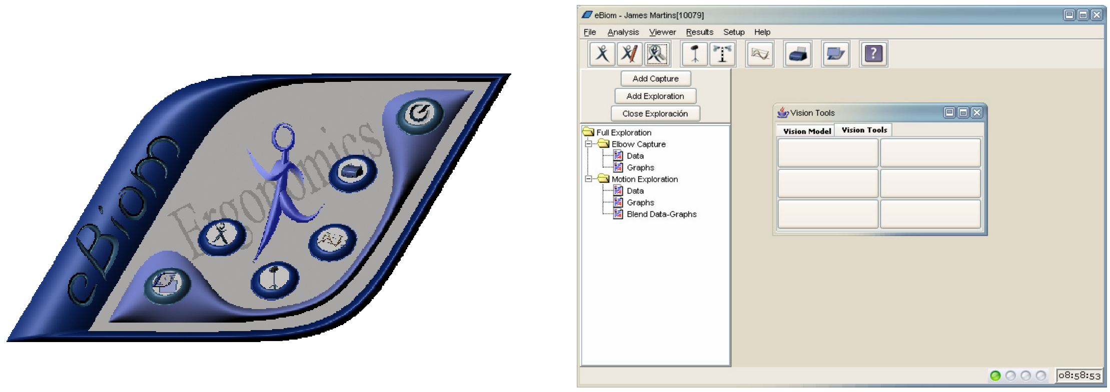

Figure 2. eBiom easy interface (left) and full technical interface (right).

SETUP OF THE SYSTEM

eBiom is essentially a 3D optical system and is designed for capturing data from the images send by a set of high frequency cameras (60/100 Hz). The number of cameras is scalable it can be and even number 2, 4, 6,… We have used four cameras in our experiments achieving real-time image processing and tracking, if the number of cameras is greater than 8 another strategy has to be taken and system performance can not be maintained.

As every other 3D system application, the calibration procedure is one of the most important steps to assure a precise final result. The intrinsic and extrinsic camera parameters are estimated from a pinhole camera model taken into account lens distortion (see fig.1), epipolar geometry and noise. A non-linear optimization procedure is used to obtain a precise estimation of all parameters. We have also designed a calibration pattern that tries to cover the maximum allowed capture volume. It is well known that precision during motion capture is improved if a calibration marker has been used in this part of the capture volume. We use a vertical calibration stick 2.0m high with markers positioned optionally every 10cm (we use every other position), eBiom automatically identify and label markers according to the number of markers visible from this position. This allows as covering a non-cubic capture volume which is much closer to the real vision pyramid associated to each camera.

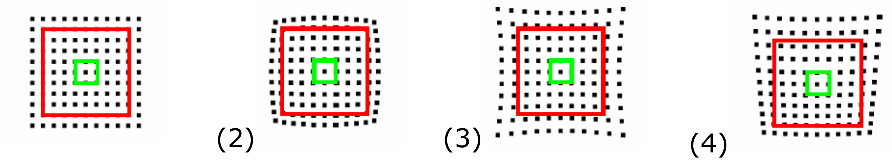

Figure 1. Different lens distortion effects: (1) reference pattern, (2)-(3) radial distortion, (4) tangential distortion.

Our calibration system is able to obtain both internal and external camera parameters, this allow our system to change hardware configuration in case it was needed. A non-linear numerical optimization method is used to compute camera parameters. Correction of radial lens distortion and possible image noise is also considered. As a result, we obtain sub-pixel precision in the calibration step which can be translate in terms of metric measures to less than 1mm, when cameras are placed at the corners of a room of 4.20x3.45x3.25m, for all the calibrated volume points included in a volume of 2.1x2.1x2m. The total calibration procedure can be done by only one person in few minutes and no recalibration is needed unless changes in the position of the cameras have been made.

Figure 2. From the original image (1), a background subtraction (2), contour detection (3) and different intensity threshold values (4) can be applied.

MOTION CAPTURE

Once the system has been calibrated, the simplified interface of eBiom guides the user in choosing which biomechanics model is the appropriate for the study he wants to make. The different movements associated for instance to a working place, are translate to angle variation of the involved joints. Every joint has a different number of degrees of freedom that can be studied placing an appropriate set of markers on the person in motion. eBiom shows the user a 3D virtual humanoid (see fig. 3) with markers positioned in the right place and, for clinical applications, it also shows with a computer animation, the motion patient is supposed to do.

Motion capture module starts after placing the markers. In the initial step, the identification of each marker in the different cameras can be automatic, if one of the clinical models is used, or manual, when a new position for the markers is used. In this last case, a manual label of each marker is required; eBiom facilitates this task using a dragger arrow which allows selecting the appropriate points in the images.

Once the initiation is finished, the system performs the tracking of each marker along the capture time. At this step, one of the critical problems is dealing with the possible occlusions of the markers when the person is moving. Position and number of cameras can help in this task. If cameras are placed covering the maximum range of volume vision this can guaranties that at least two cameras can see simultaneously each marker. In case a marker have been lost for a short period of time, inverse kinematics can be used to predict its position but capture have to be repeated when this solution is not enough.

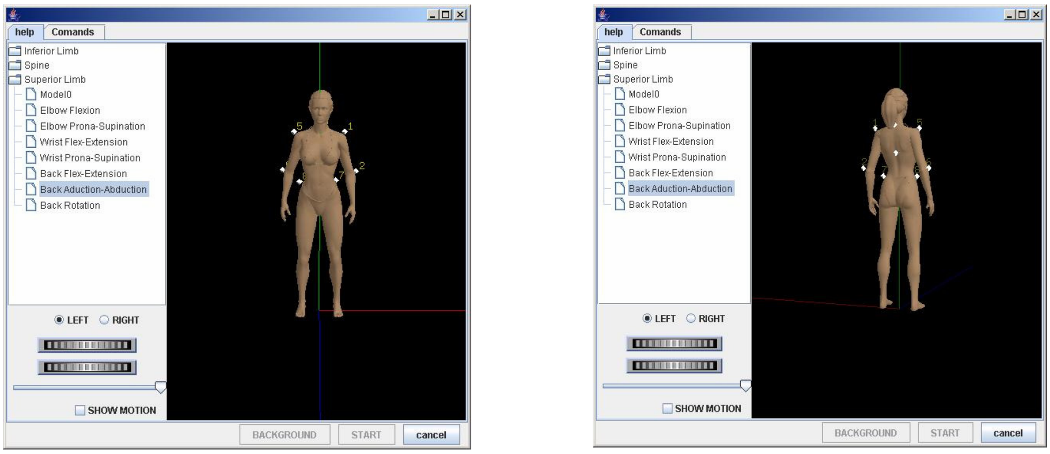

Figure 3. Markers on the Virtual humanoid. Motion is shown using computer animation

MOTION ANALYSIS

After recording the 3D data corresponding to the person's motion eBiom allows the data analysis and post process. This module is designed to analyze the video captured images together with the different plots corresponding to the kinetic measures of the joints. Plots and video are synchronized in order to allow the selection of the best portion of the captured images. Quantitative information like extreme values, rang variation, etc., is also provided. All data will be processed if no subset is specified.

The analysis of the captured data allows including all significant values and plots in a final report. These reports can have a standard format or a free one. Usually when a prefixed model is chosen the final report is assumed to be standard but, in any case, the final file can be always edited or modified by the user.

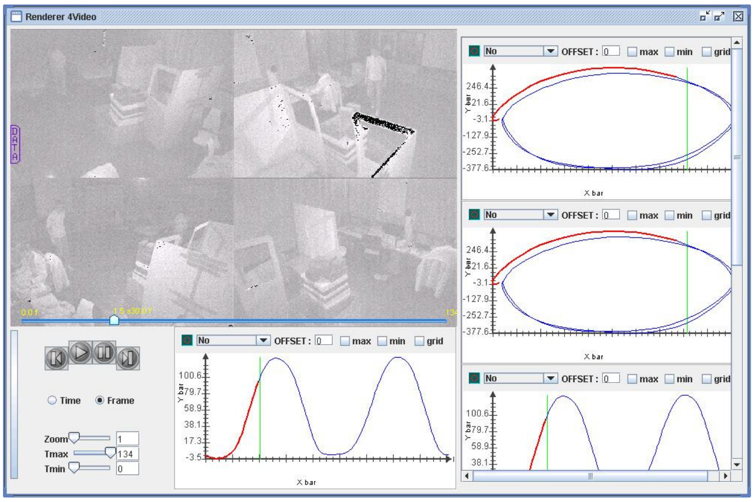

Figure 4. Motion analysis interface tool.

PRESENT AND FUTURE WORK

eBiom is almost finished in his clinical version but the ergonomics one is still under development. The difference between clinical and ergonomics applications is the design of the biomechanical model to be applied. In a clinical environment the movements of the patient can be predetermined and, therefore, the study protocol and the models are almost fixed. As a consequence, a complete automation of the process can be reached.

When a working place is being studied, the similitude with the previous situation is that a body motion is involved and the interesting parameters, like joint angles, speed of motion, etc., are the same. On the other hand, the main difference is that movements can not be standardized because they are forced, in some sense, by the task involved to the working place. This means that no previous planning can be assumed and we are forced many times to readapt a previous model to the present one.

Our developing tasks now are aimed to facilitate the users this readapt process. The idea is to start the application with a small questionnaire or similar, in order to introduce in the program sufficient qualitative information that allows choosing the better model prediction. Once the model is presented to the user, he can validate if the model fulfills the study requirements and if it is appropriate for the real physical environment. This last premise is the one that can change a lot although the movements can be very similar and makes difficult a complete automation.

Figure 5. Some frames of a carrying loads motion.

One of the possible applications of the eBiom package is the study of the movement in a working place. In our laboratory we simulate a manual carrying of loads and try to compute the values of the angle between different parts of the body. The idea was to evaluate the advantages of using our package. The position of the markers shown in figure 5 was chosen for computing the flexion-extension angle for elbow and knee in the sagittal plane, the trunk bending backward and forward can also be computed.

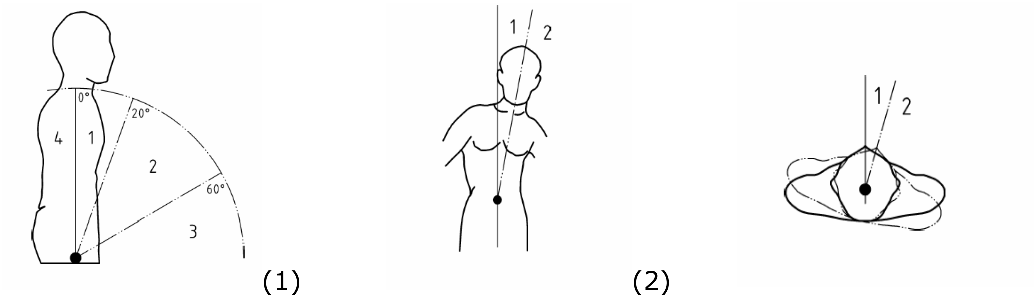

Figure 6. Trunk motion classification according to the European standard evaluation of working postures and movements in relation to machinery. For (2)-(3) region 1 is 10º.

Another application we are starting to develop is the automation of the study of a working grasp task. According to [4] the type of motion and the frequency of worker's hands can be quantified giving an overall risk level. We are studying how to place optical markers that allow eBiom to track automatically hand position during time. Camera location has to be defined according the real working place.

Figure 7. Handling of low loads task and the corresponding hand markers.

ACKNOWLEDGMENTS

We would like to thank Dr. J.L. Parreño for his advice and his experience on defining the biomechanical clinical models. We also thanks the team of Prevention and Ergonomics Center (CEP) for their support.

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