3D RECONSTRUCTION ACCURACY OF TWO MOVING MOTION ANALYSIS SYSTEMS: PRELIMINARY RESULTS

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The purpose of this study was to compare the 3D reconstruction accuracy, through a rigid bar test, provided by two moving systems, optoelectronic cameras (MOCAP) and action sport cameras (ASC). The cameras were fixed in the same rolling rigid structure (4.4 × 4.0 × 2.5 m) and the data were acquired simultaneously by the two motion analysis systems. Algorithms were previously developed to perform the roto-translation of the global coordinate system from reference points arranged on the floor, while the cameras and the structure were moving (40 m, antero-posterior direction). The mean inter-markers distance was 598.93 mm and 585.27 mm, and the standard deviation was 6.20 mm and 2.23 mm, by ASC and MOCAP. Despite the ASC had a performance almost 3 times worse than the MOCAP, the ASC is a more portable system and less expensive.

KEY WORDS: accuracy analysis, video cameras, 3D motion analysis, moving camera system.

INTRODUCTION: Human motion assessments are performed by kinematic analysis systems. These systems are composed of fixed cameras, optoelectronic (Eichelberger et al., 2016) or video (Bernadina et al., 2017). Both systems have low reconstruction errors, but are limited to the acquisition of movements in restricted volumes. In contrast, some human movements are characterized as cyclic movement and require a displacement of the body, therefore, cyclical movements are studied for few cycles. An alternative to this limitation is to use ergometers (treadmill - et al., 2007, cycle ergometer - Bini et al., 2010, rowing ergometer - Steer et al., 2006), however, the use of such equipment cannot reproduce the real movement because it limits the movement of the subject and this requires the familiarization of the subject with the equipment.

In this sense, some researchers evaluate the feasibility of systems that put the cameras in motion, following the subject and allowing the capture of several cycles of movement. For 3D kinematic analysis, this type of acquisition was tested with optoelectronic cameras (Colloud et al., 2008; Colloud et al., 2009; Bergon et al., 2009), however, some new cameras technologies allows a more portable configuration. The action sport cameras are an example, since they are wireless, small, slight and resistant. In this paper, we compare the 3D reconstruction accuracy provided by two moving motion analysis systems, one previously proposed using optoelectronic cameras (MOCAP) and the second one composed by action sport cameras (ASC).

METHODS: Two types of cameras were compared: optoelectronics and video. For this we used four cameras ViconMX40 (Motion capture system - Vicon, Oxford Metrics Ltd., UK) and four Action Sport Cameras (GoPro, Hero3 +, Black Edition® / USA). The image resolution of ViconMX40 and GoPro were 2353 x 1728 and 1280 x 720 pixels, respectively. The acquisition frequency of 120 Hz was used for both systems. Since the optoelectronic cameras use retro reflexive markers (passive markers of ∅: 14.0 mm), a custom accessory composed of white high-bright LED lamps (power: 4W, 1W each) was fixed around each ASC lenses. With this lighting it was possible to increase the contrast of the markers with the background. The cameras were fixed in a rigid structure (4.4 x 4.0 x 2.5 m) at a height about 2.30 m in relation to the ground. The data acquisition occurred simultaneously. The ASC were synchronized by the Wi-Fi remote control of the ASC. A light signal, at the beginning of each acquisition, was used to synchronize the two motion analysis systems. The camera calibration procedure was performed using the tools and procedure recommended by Vicon. Initially, the calibration tool (T-shaped with five markers) was acquired by moving through an acquisition volume limited by the cameras view, while the rigid structure, together with the cameras, remained static. Subsequently, the calibration tool was put on the ground in the center of the volume to define the global coordinate system. On the other hand, the ASC parameters were initially calculated based on the epipolar geometry (Cerveri et al., 2001). Then, the four cameras were calibrated according to a non-linear method (Cerveri et al., 1998).

To take into account displacement of the cameras with respect to the global coordinate system, markers were put on the ground in two parallel lines. Each line was composed of forty-one reflective markers arranged along the length of the volume. Each of these markers was positioned on the ground with a distance of 1 m between them. Algorithms were developed to translate and rotate the global coordinate system from the three reference points on the ground as the cameras moved. The roto-translation of the reference system happened during all the movements execution path. The detailed procedure for the movement reconstruction can be checked in Bergon et al (2009).

The evaluations of the 3D reconstruction accuracy for the ACS and MOCAP systems were performed. For this, we acquired the kinematics of two markers put on a rigid bar (inter-markers distance: 584.00 mm). This rigid bar was moved through the 40 m of the track runner followed by the rigid structure that carried the cameras. The accuracy evaluation defined by the mean value of the inter-markers distance and the standard deviation of this distance distribution. The videos acquired by the ASC were converted to AVI format. The image processing with tracking markers was performed on a platform developed in software MatLab® 2015 (Mathworks, Natick MS).

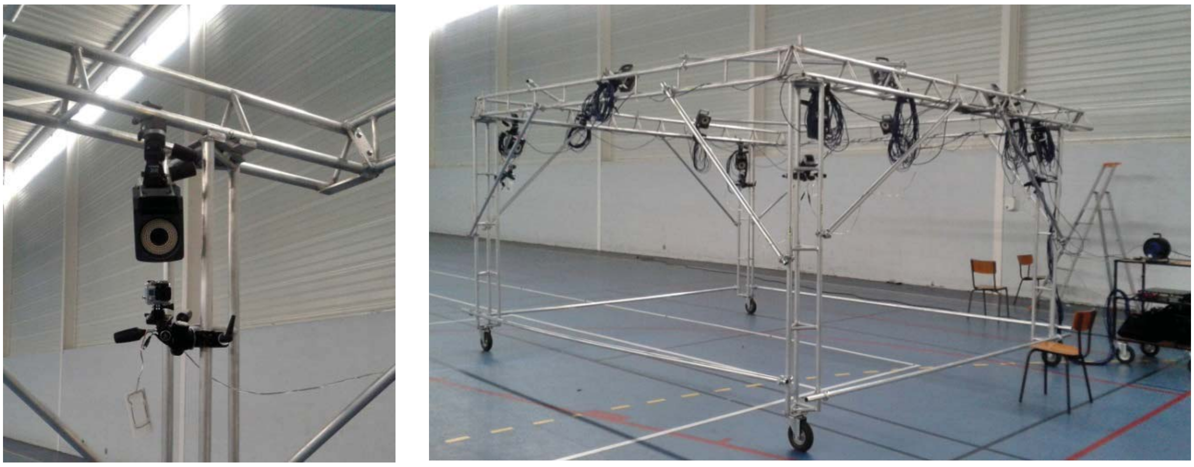

Figure 1. Cameras position (ViconMX40 and GoPro, Hero3 +) fixed in a rigid structure that moves.

RESULTS AND DISCUSSION: Studies using optoelectronic cameras have already been performed for an initial evaluation of this type of acquisition. Colloud et al. (2008) developed an algorithm to acquire the three-dimensional (3D) kinematics in a large volume and obtained results similar to regular motion analysis systems. In other studies (Colloud et al., 2009; Begon et al., 2009), this algorithm was applied for the calculation of the 3D kinematics of a human gait. It was possible to acquire the data of displacement by a corridor of 40 m of length. In this study, we investigated the use of ASC to this type of acquisition. The mean inter-markers distance was 598.93 mm and 585.27 mm, and the standard deviation was 6.20

mm and 2.23 mm, by ASC and MOCAP, respectively, during the rigid bar test (real inter-markers distance: 584.00 mm). This represents a performance almost 3 times higher in the MOCAP. This result can be explained by the fact that the MOCAP system suffer less with the marker definition and occlusion, since they not capture the image but the light reflection of the marker. The reconstruction by the ASC is difficult by the tracking markers process. This process (performed manually or semi-automatically) requires the marker to be well defined. The lack of definition of these markers can increase the measurements variation with consequent decrease of the accuracy. Despite this improved performance by optoelectronic cameras, the ASC obtained a similar result to the initial evaluation performed by Colloud et al. (2008) (standard deviation: 6.20 mm and 6.74 mm, ASC and the study cited, respectively) in the condition of movement of an object and of the structure with fixed cameras, reported in the study.

It is necessary to improve the analyses using ASC, however, these results present an initial evaluation on the 3D reconstruction using this type of camera, in motion. Despite the limitations, such as the difficulty of minimizing the occlusion of the markers, the great finding of this study is due to the possibility of capturing movements during a volume of approximately 40 m with this type of commercial camera. For future studies, it is necessary to investigate possible influences of the image resolutions, the use of a larger number of cameras, different markers size, in order to discuss how to improve the system. Further, we will investigate the use of ASC in the acquisition of 3D kinematics of human movement, for example, human gait.

CONCLUSION: The ASC, in a first evaluation, is a potential instrument to acquire kinematic data with the main focus for movements with wide displacement. The ASC offers advantages concerning to the absence of cables which make it easy to put them moving and a low prices compare to the MOCAP. However, in future research, it would be interesting to investigate other camera and acquisition configuration that would influences the performance of the system. It would be interesting, also, to use more cameras in order to minimize the limitations found in this study involving camera positioning, lighting and marker tracking, besides improving acquisition protocols and deepen the accuracy evaluation.

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