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ACCURACY ANALYSIS OF A NON-COMMERCIAL 3D KINEMATIC ANALYSIS SYSTEM (DVIDEO) USING STANDARD AND INDUSTRIAL CAMERAS

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SUMMARY

The accuracy of a non-commercial 3D kinematic analysis system (DVideo) was evaluated using two different cameras. The first setup used standard cameras (Nikon Coolpix AW100) and the second setup used industrial (Basler A602fc) CCD cameras. Both sets of cameras were located and oriented in a similar way and recorded simultaneously the same movement of a rigid bar with reflective markers fixed on it, in the working volume (3x2.5x1 m^3). The accuracy in the rigid bar test was measured, among other variables, by the mean absolute error of the distance between markers and reached 0.58 mm for the setup 1 and 0.61 mm for the setup 2. Further analyses were performed such as the analysis of the possible effect of object position in the working volume and the velocity variation on the accuracy measurements. The results indicated that both setups can provide highly accurate outcomes, similar to those reported by commercial systems.

INTRODUCTION

The 3D motion analysis systems are widely used to study human movement in different domains, as sport science [2, 5, 7, 8], rehabilitation engineering [6] and biomechanics [3, 4, 9]. Commercial systems (BTS Engineering, Milan, Italy; Vicon, Oxford, UK) normally use the industrial cameras with an infrared filter in the lenses and high accuracy results were reported (0.5mm to 2.3mm [3]).

The recent evolution of video technology incorporates some extremely useful features for biomechanics, such as high speed record and high resolution images, in some very low cost and widely spread commercial cameras. Besides, the same technological development allowed the computer vision industry to launch products for industrial inspection based on CCD cameras that also incorporate characteristics of interest for biomechanics.

Since 1999, a non-commercial 3D kinematical analysis system (DVideo, Campinas, Brazil; [1, 4] has been used for researching in many fields of Biomechanics [2, 8, 9]. The system consisted of a software able to load/capture AVI files, calibrate cameras, tracking markers or special features, and reconstruct trajectories. Different camera configurations can be used. Therefore, it is important to evaluate whether the use of such non-dedicate setup can compromise the accuracy of the results. Thus, the aim of the present work is to evaluate and compare the accuracy of the DVideo system using standard and industrial cameras. The accuracy analysis was also performed aiming to investigate the possible effects of object position and velocity in both camera setups.

METHODS

The data acquisition was performed in a controlled environment using the DVideo kinematic analysis system [1, 4]. The setup 1 consisted of four gen-locked Basler area scan cameras (A602fc) connected in a single personal computer for online data acquisition. The cameras were set with monochromatic images, with a resolution of 656 X 490 pixels, a pixel size 9.9 X 9.9 µm, and optical sensor size of ½ inch (6.49 X 4.86 mm). The focal length was set to 6 mm (wide angle C-mount lenses). The setup 2 consisted of four Nikon compact digital cameras (Coolpix AW100) recording on 32Gbs memory cards. Video files were transferred after the data collection to be measured in the DVideo system. They were set with color images, with resolution of 1280 X 720 pixels, a pixel size of 1.8 μm^2 and the optical sensor size of 1/2.3 inch (6.2 X 4.6mm). Both camera setups were synchronized by the same event in the images (interfield synchronization) and the frame rate set up to 60 Hz. In order to equalize the possible effect of camera location, the cameras of both setups were located side-by-side in pairs. In order to avoid the possible effects of the reference points of calibration in the comparison, both setups used the same six plumb lines with 25 markers in each one as reference points. The working volume was 3 x 2.5 x 1 m^3. A non-linear calibration was used and this method is based on the DLT to estimate the initial parameters. In order to refine the intrinsic and distortion parameters of each camera the straight lines of the plumb line were exploited. In order to model the distortion we used the equations proposed by [10] where the radial, decentering and thin prism parameters can be determined. Since the cameras had different lenses the distortion model adopted in the calibration procedure was different, for the Nikon cameras just the radial distortion was taken into account and for the Basler cameras all the distortion parameters were taken into account. The accuracy of each system was assessed considering the same sequence, containing 600 frames (10 sec), of a rigid bar with two reflective markers. The rigid bar was moved in the working volume and their markers were automatically tracked in the DVideo system. The distance between markers (nominal value D: 284.85 mm) was obtained as a function of time. From the curves of distance between the markers along time for both setups, the mean, the standard deviation and the mean absolute error were calculated. The accuracy was assumed to be the norm of the difference between the real and obtained value (error). Firstly, the error was evaluated as a function of the rigid bar 3D position in the working volume, in terms of their coordinates (X-transversal, Y-vertical and Z-longitudinal directions). Secondly, the error was evaluated as a function of the velocity variation of the rigid bar movement, in terms of their coordinates.

RESULTS AND DISCUSSION

The mean value of the distance curves was 285.15mm, the standard deviation was 0.65 mm and the mean absolute error was 0.58 for the setup 1. For the setup 2 the mean value of the distance curves was 284.98, the standard deviation was 0.72 and the mean absolute error was 0.61mm. As far as the effects of the object position on the error the setup 1 (values ranging from 0.007 to 2.03mm) and the setup 2 (0.004 to 1.94mm) present similar error distributions in all axis and no association with the test bar movement were found (Figure 1). These results indicated that both setups are highly accurate and presented accuracy similar to those reported by commercial systems [3].

It is important to emphasize that open systems such as DVideo require further expertise in kinematic analysis and have to be regularly tested in order to verify whether high level of accuracy were effectively reached.

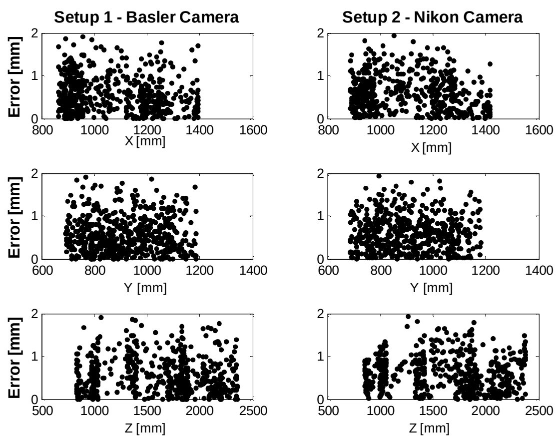

Figure 1: **3D reconstruction error as function of the rigid bar position in the working volume (transversal (X), vertical (Y) and longitudinal (Z) directions) for each system**.

The mean velocity of the rigid bar movement was 0.36m/s and the variation ranged from 0.08m/s 0.61m/s. As far as the effects of the velocity variation on the error the setup 1 and the setup 2 present similar error distributions, showing that the velocity variations have no influence on the error in both setups (Figure 2).

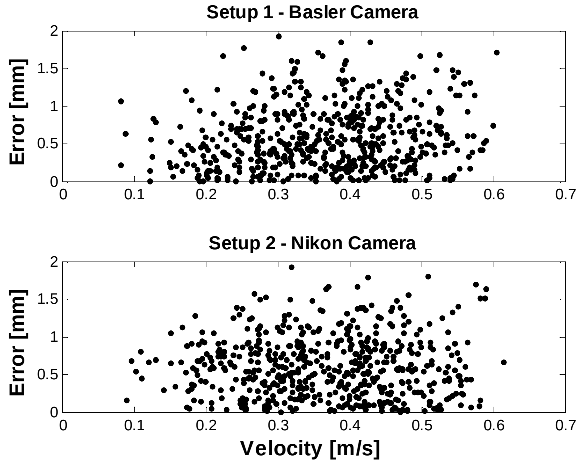

Figure 2: 3D reconstruction error as function of the velocity variation of the rigid bar in the working volume (transverse (X), vertical (Y) and longitudinal (Z) directions) for each setup.

CONCLUSIONS

This work showed that the DVideo system can be highly accurate and flexible with industrial and standard video cameras. No influence of the object position or velocity was verified on the accuracy of the measurements.

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