THREE-DIMENSIONAL ANALYSIS OF CLOSED-LEG CIRCLE A COMPARISON BETWEEN TWO METHODS

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INTRODUCTION

The growing diffusion of video systems and the reduced availability of cinematographic ones gives rise the need of systems capable of analyzing 3-D motion starting from magnetic tapes. In this paper a new system of this type, devised by one of the authors, is introduced.

To validate the system, we made a quantitative comparison between the model obtained by the new system (MIRACLE) and the equivalent model obtained by means of a well known 3-D cinematographic system: the KWON3D, devised by Young-Hoo Kwon (The Penn State University).

Two couples of shots were made, one with motion-picture cameras and the other with video-cameras, Prom view points close to each other. A closed-leg circle has been analyzed, by raking into account a whole loop.

METHOD

The equipment used for both the cinematographic study (ARRIFLEX motion-picture camera, LW INTERN. projector) and the video one (IKEGAMI video-camera , SONY videorecorder) are commercial devices. A 386-class IBM-compatible personal computer equipped with a NUMONICS digitizer (film) and a SONY video-overlay card (video) were used. The study was carried out in the biomechanic laboratory of ISEF - Rome.

The shots were made from couples of view points close to each other, with a view field of about 4x6 m. To calibrate the position of the cameras a set of gravity threads were acquired before filming; their positions were measured using a theodolite. Both motion-picture and video cameras were fixed during filming.

During filming we simulated environment conditions similar to competition: no markers, no optimal lighting, some parts of the motion were covered. We made this choice because top level performances are not obtained on laboratory condidon, but during competition, when films can be taken only respecting the requirements of either athletes, public and organizers.

Both softwares use the same method, i.e. a DLT (Direct Linear Transformation). Both systems use a digital filtering technique (FFT, Fast Fourier Transform). MIRACLE-includes an algorithm to compensate the length of those body segments defined as "rigid", i.e. with constant length. It allows to move the video cameras during filming, in both directions (horizontal and vertical) and in closing up.

To validate the video system a closed-leg circle has been digitized on both systems by two operators, so that four comparisons were available: same operator with different systems and same system with different operators.

The comparison was made through examining the kinematics of left tip toe, which makes a wide motion. The average distance between the 3-D coordinates for each couple of models was calculated for the four above mentioned cases. The optional parameters of both softwares (speed, cut frequency) were tuned as close as possible.

RESULTS AND DISCUSSION

The results are shown in the figures 1-4. The plots were made in the XY (horizontal) plane.

The following table shows the average distances and the maximum distances calculated as above.

case	constant	comparison	avg D	max D
a	KWON3D	EC/LM	0.09 m	0.14 m
b	MIRACLE	EC/LM	0.06 m	0.09 m
c	LM	KWON3D/MIRACLE	0.12 m	0.17 m
d	EC	KWON3D/MIRACLE	0.08 m	0.12 m

Table **1.**

There are few references about the DLT method accuracy. The study more closely relating to ours comes from Angulo-Dapena (1991). It shows that the average error on digitizing points that are fixed and well in sight is of 28 mm (film) and 39 mm (video).

Our study shows that on less favourable conditions (no markers, moving points) the accuracy is lower than the above mentioned one. For MIRACLE models the accuracy is similar to that reported from Angulo-Dapena for video systems with points external to the control field **(39** mm vs 40 [model LM] / 50 [model LM]). No such evaluation is available for KWON3D models.

Table 1 shows that both systems show similar accuracy irrespective of the operator and - conversely - that the result are similar when considering both operators regardless of the system. As far as MIRACLE models are concerned, starting from the average distances of both models (40 mm [LM] and 50 mm [EC]), it is possible to calculate the average distance between the models using the following equation:

$$d_m^2 = d_1^2 + d_2^2$$

The result (0.064 m) is very similar to the value reported in the table (0.06 m).

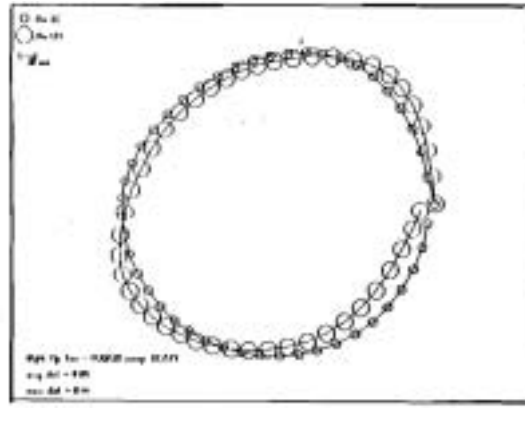

Fig.1. Comparison of left tip toe trajectories between KWON3D models. Operators LM and EC. Horizontal plane view.

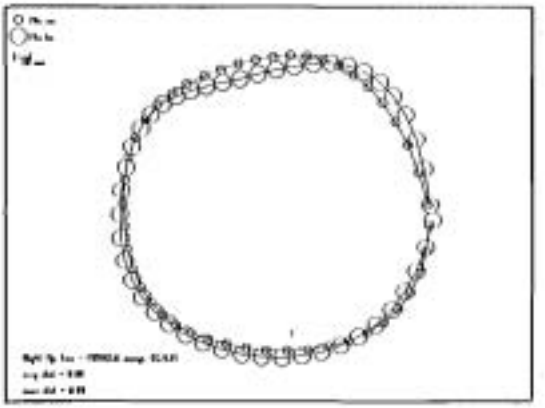

Fig.2. Comparison of left tip toe trajectories between MIRACLE models. Operators LM and EC. Horizontal plane view.

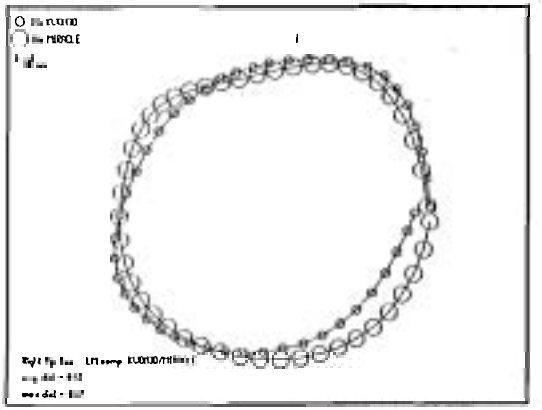

Fig.3. Comparison of left tip toe trajectories between LM models. Software KWON3D/MIRACLE. Horizontal plane view.

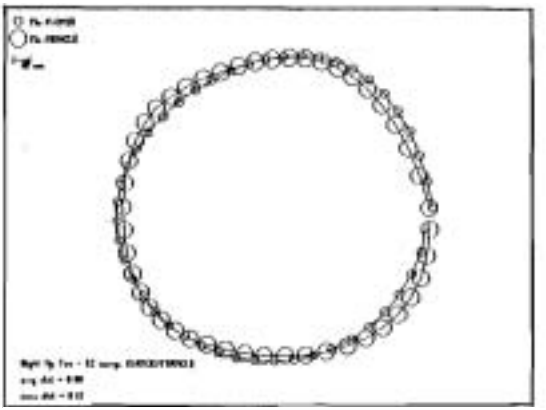

Fig.4. Comparison of left tip toe trajectories between EC models. Software KWON3D/MIRACLE. Horizontal plane view.

For video models it is possible to estimate the maximum accuracy in ideal conditions. Since the vertical extension was about 4 m, while the vertical resolution of VGA cards is of 480 pixels, the minimum element (1 pixel) is 4000/480 = 8 mm. With video images it is not possible to recognize a reference point better than +/- 2 pixels, so that the error from video resolution is about +/- 16 mm.

CONCLUSION

This paper showed that the errors for cinematographic and video systems are similar. Whenever filming conditions are not at the best, but close to competition environment, the accuracy is lower than under laboratory conditions, where cinematographic systems are anyway more accurate.

The evolution in video tecnique allows to predict that, in a short time, the resolution limit will be enhanced, even if it will still be worse than film resolution.

To compensate the negative effect of the low resolution, it is necessary to look at the athlete in full screen, following him/her by rotating the camera (horizontally and vertically) and closing up. If not, in wide motions the field bccamcs so large that the identification errors grows up too much.

REFERENCES

- Angulo, R.M. and Dapena J. (1991) Comparison of film and video techniques for the estimation of three-dimensional coordinates within a large field. International Journal of Sport Biomechanics