A 3D COORDINATE APPROACH TO WALKING ANALYSIS

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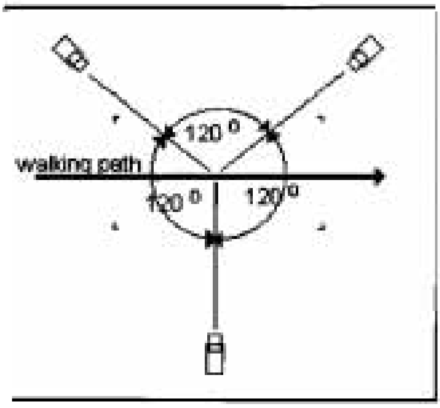
The method developed uses three video cameras (60 fields per second) to record the movement. The body segment co-ordinates are captured manually on each image. No anatomic markers are used for a 14-segment human body representation. The data extracted from the images are interpolated to calculate information for non-recorded instants. The 3D reconstruction is made using the DLT calibration procedure.

KEY WORDS: video, images, calibration, interpolation, walking analysis.

INTRODUCTION: Walking analysis is a study ordinarily performed to establish normal or abnormal walking patterns. The objective of this implementation of the method is to evaluate adolescents' behaviour while walking. To assure a natural posture and/or speed in young people it is desirable to have them free of anything that could impede a natural behaviour like cables or markers. To get the sample required for the study it is necessary to set up a gait lab in some elementary and high schools. Usually, to setup the movable gait lab a comparator structure, three tripods, three non-professional CCD video cameras and a surface of at least 200 m^2 are needed (Figure 1). This is usually the schoolyard or the gym.

METHOD: The procedures and methods are relatively common. For the implementation of this video-computerised analysis procedure, the input data are provided by a walk cycle recorded simultaneously by three video cameras. The human body representation comprises 14 straight lines called corporal segments each one of which corresponds to one of the 14 body parts. After selecting the video sequences, each of these is stored to an AVI file. This procedure and the next of converting to 60 fields per second image files involve a grabber board inserted in a personal computer. The board colour resolution is 24-bit (16.7 million colors), its input is NTSC video format, and the output consists of images with a geometric resolution of 640x480 pixels.
Human Body Representation: An ordinary procedure to extract the anatomic points' co-ordinates fmm the images is used. The 14 body parts' inertial properties are in accordance with Chandler et al. (1975).
Camera Calibration and 3D Movement **Reconstruction:** A rectangular parallelepiped (Figure 2) was constructed (x = 3 m, y = 1.5 m, z = 2 m) in order to calibrate the volume considered for a walk cycle. For this purpose, 18 1.5" diameter spheres were carefully located to cover the whole volume. Basically. the methods used are those from Abdel-Aziz, & Karara (1971) studied and analysed by other researchers (Marzan, & Karara, 1975; Shapiro, 1978; Wood, & Marshall, 1986; Gentleman, 1973; Gruen, 1996; Hatze, 1988; Woltring, 1980).
The images from the camera are synchronised by simultaneously taping a rectangular object sliding along a sloped surface.
Approximation by Cubic Splines Interpolation. To approximate the movement for times for which there is no image taped, an interpolation routine was used that calculates the values corresponding to more images per second. The method used is the cubic Beta-splines (Barsky, & Beatty, 1983; Bartels, & Beatty, 1987). The interpolation routine was adapted from those published in Smith (1983). This method provides a local curve control facility using two parameters, beta1 and beta2, which stand for bias and tension, respectively. The user is able to adjust the curve suitably.



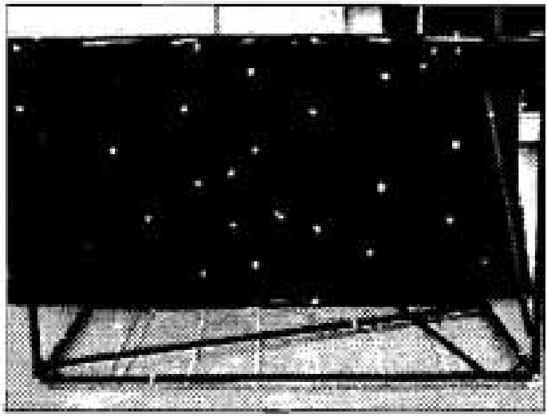


Figure 1 - View from above of the 3-camera setup.

Figure 2 - Comparator with the 18 Spheres.

Taping and Filming Methods to Validate Data Interpolation: The interpolated data were validated by the following procedure: A high velocity cinematography camera (HYCAM O'Connor Hydro-ped, Mod-102-8. 16 mm) and a non-professional CCD video camera were located as near as possible to each other. The experiment consisted of filming and taping simultaneously a young male runner. The distance to the displacement path was 12 m. Each camera's focus was adjusted to the path's midpoint. Filming was done at 240 frames per second and the non-professional taping at 30 frames per second (NTSC).

For this study the frame sequence used covered the following phases: floor support with the whole left foot, floor support with the left foot's front half, left foot floor release, body flight, floor support with the right foot's heel, floor support with the whole right foot, floor support with the right foot's front half, and right foot floor release. For this sequence, cinematography required 72 frames and video 10 frames.

The procedures for video frames were those described in Espinosa-Sanchez (1993), the coordinates' values were interpolated to eight calculated values between two actual values giving a calculated 240 frames per second. So for the 10 actual values there were 72 calculated values (Figure 3).

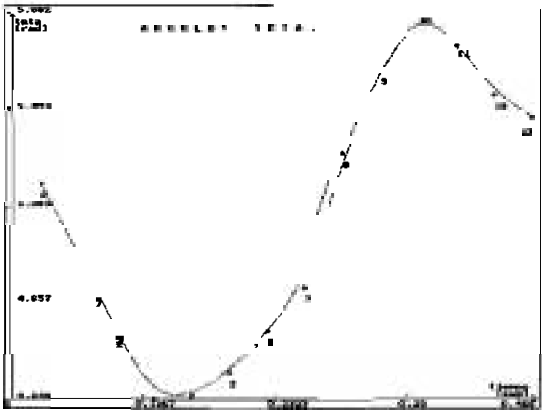


Figure 3 - Interpolated values of a sprint runner's run cycle right thigh instantaneous angles.
Numbered points are the original data.

ANABIO3D Software Characteristics: Figure 4 shows the system's modules, some of which concern instrument use. Locating and marking with the mouse, in every digitised image capture the source information, the point coordinates that limit the 14 segments. The complete capture of an image requires marking 19 points. This capture generates a file with the movement information.

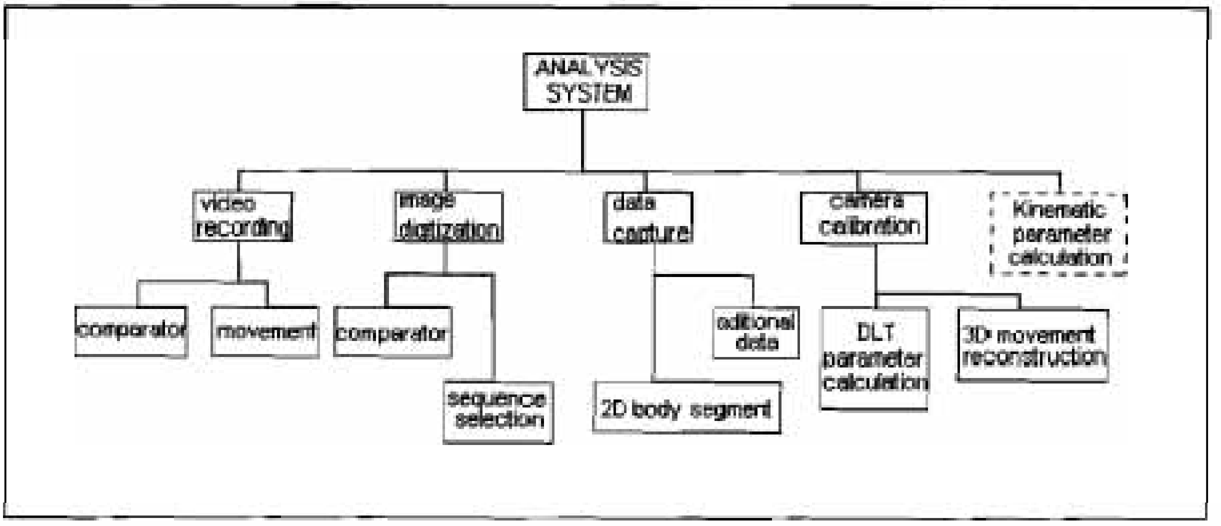


Figure 4 - Implemented analysis system diagram.

RESULTS: Results are reported for the cinematography data (Table 1)(Figure 5):

1. Displacement of the body's centre of gravity. The correlation coefficients were obtained; the displacement correlation in the x-axis is acceptable, but not in the z-axis. However, the result is not significant, since the values' variation range, up to 5 %, is comparable with the measurement error. This percentage is the mean value of a repeated point localisation on the same image (Espinosa-Sanchez, 1993).
2. Right arm-forearm (a-f) flexion-extension angle variation. The correlation results are in this case acceptable.

Table 1 Correlation Coefficients

X	0.999
Z	0.754
Right a-f	0.917
Left a-f	0.928

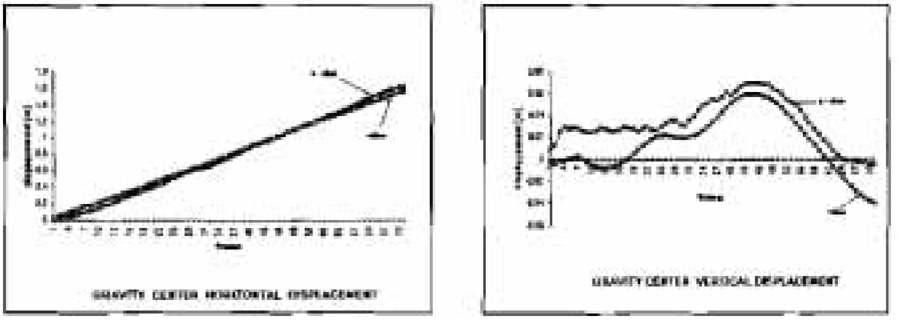


Figure 5 - Gravity centre displacement and right arm-forearm angle curves.

DISCUSSION: Error source: The manual segment capture is the main source of error. This depends on the image quality and on the skill of the person who locates the anatomic points on the screen.

The interpolation procedure is adequate for the walking analysis purposes. The DLT is a reliable and sufficiently studied method successfully adapted to this video-computerised implementation.

Main Disadvantages: The capture of 19 coordinates on each of the three view images is an overwhelming task.

Main Advantages: Taping with no markers is easy and fast. Natural walking is possible.

CONCLUSION: Taking into account the equipment and software costs, the transportation of equipment, the requirement that the subjects walk naturally, and size of the required sample (approximately 500 teenagen), it was decided that the above method was the best choice.

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