3D VIDEO DIGITIZING AND MOTION ANALYSIS

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INTRODUCTION

Nowadays the video digitizing analysis systems became useful helps for kinematic motion analysis in various fields, in ergonomics, medical sciences, sport sciences. These systems offer perfect, exact information about the examined motion process, and help the user to understand the motion and to improve it. This shows clearly, that these systems are needed in research and in education as well. Unfortunately these tields are not as well supported as they should be. Especially in Hungary, where biomechanics is regarded to be a young science it is not easy to enlarge the number of equipments' of a biomechanical laboratory. The only way to manage this is to crcate own systems which can be otherwise easily fitted to the special aims. These special aims always occurs, and most of the professional systems are not able to cope with special needs.

Our first step in the evolution of our own motion analysis systems was a microcomputer (Commodore 64) aided video digitizing system with an overlay card. The results were published in several conference proceedings (Barton & Barton, 1986, 1988, 1991). Meantime Shapiro et al. (1987) gave the idea how to put together the system.

'This 2D method was used mainly in education and it is still an easily understandable example for the beginners. Evolution never stops, so we have got the support of the TEMPUS scheme, and in Liverpool Polytechnic Biomechanics Department (head: prof. A. Lees) we could crcate the 3D version of the previous system on IBM PC.

METHOD

For 3D vision generally two synchronised detectors are needed. A good example is the human sight. The two eyes receive two pictures about the subject, but there are slight differences between the pictures, what results a 3D image in the central nerve system. Most of the 3D systems use the same theory, two synchronised cameras are recording the motion, and the computer creates the 3D image.

Pseudo-3D vision can be carried out with one eye. In this case the central nerve system has to operate using other rules. What is closer, it is larger, some parts of the subjects cover each other, tilted distances seem to bc shorter, and so on. This means, if we keep the rules, 3D image can be created by the computer in spite of the fact, that we have only one camera. On one hand this reduces the costs (only one camera, no synchronising hardware), on the other hand more "brainwork" is needed during digitizing.

The main rules are well known from spatial geometry, but Riley et al. (1978) applied them in motion analysis. Figure 1 shows the way how to calculate the third co-ordinate **(z)** of a segmental endpoint if the original length (1) is known. The co-ordinate system is modified, because we use X for the horizontal, Y for the vertical and Z for the sagittal axis. The reason for this is that on the monitor X and Y are the horizontal and vertical axis, so Z can be the sagittal axis.

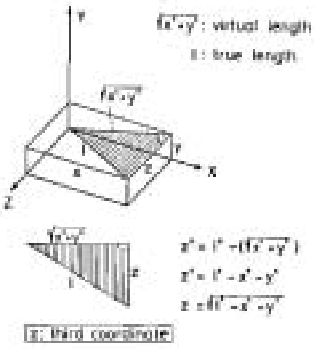

Figure 1. The way how to calculate the third co-ordinate (z)

If on a frame I see a distance to be shorter than it's original length, then it can be the result of shifting the segment parallel backwards. The other explanation for the shortening is that the segment is tilted. If we use single camera it is impossible to handle "shifting" and "tilting" at the same time as explanations of shortening. If we declare that shortening means lilting in the sagittal plane, than we have to declare that one endpoint of the segment is fix in space, otherwise the shortening could be the result of shifting as well (Fig. 2).

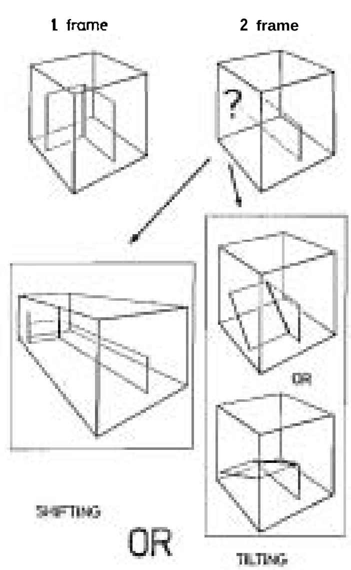

Figure 2. Shortening means shifting or tilting

The equation provides a magnitude, it can't determine whether that segment is oriented so that it points toward or away from the camera. Although it is extremely difficult to program the computer to make intuitive judgements, the human mind is exceedingly adept at making such decisions, so the computer shows the two "guesses" and the operator has to choose.

One point of the body must be fix in space. This seems to be a restriction of the method caused by the fact of using single camera, but in most of the movements there are phases, when the foot or hand touches the ground, or is in contact with a subject, and usually these phases are the most important moments during the motion.

The hardware configuration is the following: a Panasonic SVHS VW-SHS1 video camera, a Panasonic AG-7330-E video recorder, and an IBM AT compatible PC with a MicroEye 2C (Digithurst) real-time Image Capture Card. I used Turbo Pascal 5.5 for software processing.

The digitizing procedure starts with signing the two endpoints of the meter scale moving a mouse on the composite picture, made of the video and PC screen. This makes possible to calculate all the physical parameters in SI.

The second step is to digitize the reference figure. While making the video film, we have to ask the person to stand straight for a while so that his arms, legs and trunk can be seen in their original lengths. During the motion the distances between the segmental endpoints seem to be equal or less then the original length.

The next step is to digitize the fix point - let's say the right tiptoe. After this the operator has to find the following points on the body, the operator has to choose between the two guesses (see above) which can be seen from all views.

In this way a stick figure is created on the screen. When I try to find the second point, the first point is the fix point, and the computer calculates the three co-ordinates of the second point, which will be the fix point during digitizing the third point, and so on until the last point of the body. The software uses the modified Dempster (1955) human body model with three trunk segments (Barton, 1984).

This procedure has to be repeated until the last frame of the motion sequence. The maximal number of figures is 250, which is a reasonable number, because usually 10 seconds are enough for analysis (0.04 s * 250 = 10 s.)

The animation function shows the moving stick figures from all views, around a defined origin the motion can be rotated, magnified etc.

Single points can be chosen from the 35 estimated or calculated points, and the trajectory of this point can be examined from all views. The pathway of the point can be rotated, so it can be seen from any angle.

Velocity as a vector has projections on the **X,** Y and **Z** axes, **XY, YZ** and **ZX** planes, so altogether 6 projections + the magnitude of the total velocity vector can be examined against time.

The software uses one of the simplest smoothing methods (3PMA - 3 point moving average) suggested by Lees (1980) optionally.

DISCUSSION

3D video motion analysis with one camera gives the opportunity to analyse the physical parameters of any motion, where one point of the body is fix. The advantage is the low price comparing to other 3D systems, so this can be an intermediate step for those, who want to have 3D information about motion, but can't afford an expensive 3D system.

Comparing our method to the one that Riley et al. use, the main difference is, that they transfer a previously created 2D data base into 3D. Our method gives immediately 3D result, the figure "comes alive" on the screen in 3D.

CONCLUSIONS

3D video digitizing and motion analysis uses one video camera, a VTR with "frame-by-frame" possibility, an IBM AT compatible PC with an overlay card, and the software. The third dimension of a segmental endpoint can be calculated if we know the original and the actual (shortened) length of the segment. All the physical parameters can be examined in 3D.

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