A SPORTS ANALYSIS SYSTEM:
A BIOMECHANICAL WORKSTATION

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The concept of a biomechanical workstation can provide a unique environment for students, teachers, and coaches to analyze sport motion. The sport analysis workstation, appropriately named SASAI (Sport Analysis System via Altered Images) combines video images of sport technique and sophisticated software to provide a visually oriented, extremely user friendly vehicle. Through the "rubber banding" software, which allows for the dynamic interplay of joints and segments, the user can be taught what biomechanics of motion is inherently about--the visual and analytical dynamics of sport movement. This level of understanding of motion has been a very elusive skill to pass on to our students in biomechanics.

The basis for SASAI reflects a belief in synergistic biomechanics and implies the complementary nature of dichotomies such as qualitative and quantitative views of data. By combining polar opposites, such as visual phenomena and numerical data, a new entity is created which is more than the sum of each part and different from either. To borrow Leonard's (1975) analogy of hard and soft eyes as we look at the world around us, the traditional biomechanical "hard images" based on precise coordinate data can be paired with "softer images" that utilize more abstraction and the essence of the motion through a graphic image.

A technology, or at least the beginnings of one, is finally available that might just make this synergistic biomechanics concept possible. Apple's Macintosh™ computer with its desk top metaphor appears to be an exciting vehicle for the creation of a visually oriented, biomechanical workstation. User friendly has an entirely new meaning with a familiar desk top from which users can proceed with human intuition through their own programs,such as the digitizing program described in this paper, and interfacing with other readily available programs that allow for drawing, sketching, and word processing.

A SPORT MOTION ANALYSIS SYSTEM

The motion analysis system incorporates two entities to accomplish the integrated (hard and soft) analysis. The first entity is the image source itself. The second is the digitizing program named BioMacDigit, which utilizes all the standard Macintosh user-interface features. With images of sport motion from any video or pictoral source the user can proceed to digitizing, analyzing, visualizing and presenting biomechanical information.

Image Sources

The computer, through the use of an inexpensive vision system, will accept any video source from a video disk, video tape or video camera. For the biomechanist this allows for significant flexibility in creating, storing and accessing images for analysis. Another device enables the user to scan any photograph, drawing or sketch that fits in the Apple's printer. Both of these software applications are readily available and described in-depth by McComb (1985). The entire system is so portable (we could refer to it as a BioMac Lab in a Bag) that it is feasible to carry it to the gymnasium or athletic field for total "on site" analysis.
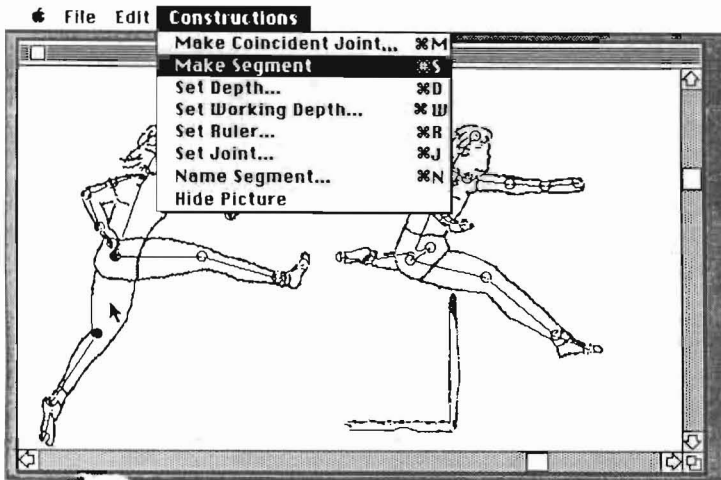
Make Coincident Joint...	⌘M
Make Segment	⌘S
Set Depth...	⌘D
Set Working Depth...	⌘W
Set Ruler...	⌘R
Set Joint...	⌘J
Name Segment...	⌘N
Hide Picture	

Figure 1. Constructions menu

🍎 File Edit Constructions

SKIER 1(SIDE)

21213

TRUNK

LOWER LEG

Ruler

Clipboard

4 SEGMENTS
0 FREE JOINTS
2.3333 1.6944 0
1.3472 2.0556 0
TRUNK
1.9722 .79167 0
1.5694 .79167 0

1.5694 .79167 0
1.9861 1.625   0
LOWER LEG
1.9861 1.625   0
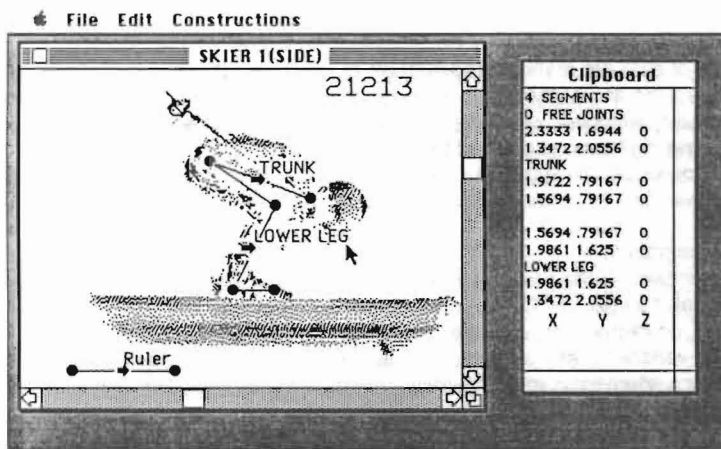1.3472 2.0556 0
   X   Y   Z

Figure 2. Digitizing and naming joints

The Digitizing Program

BioMacDigit adheres to and takes advantage of all the standard user-interface features such as mouse driven interaction, pull-down menus, multiple layers of windows, and cut-copy-paste of data to and from the clipboard. At any time during the program, sketching and word processing programs can be accessed. Images and geometry data may then be altered as desired. These altered images may themselves be treated as original documents for further digitizing and analysis. The joint and segmental data that is generated by this program can be automatically read by other programming languages (such as Basic and Pascal) in order to perform extended analyses. The key to this unique approach to digitizing and analyzing biomechanical data is the dynamic interaction capability provided for the researcher. Not only can one superimpose images and geometry, but moving, orienting and stretching segments through the use of rubber banding become the basis for a new look at biomechanical analyses. Some of the specific features of the program are presented below.
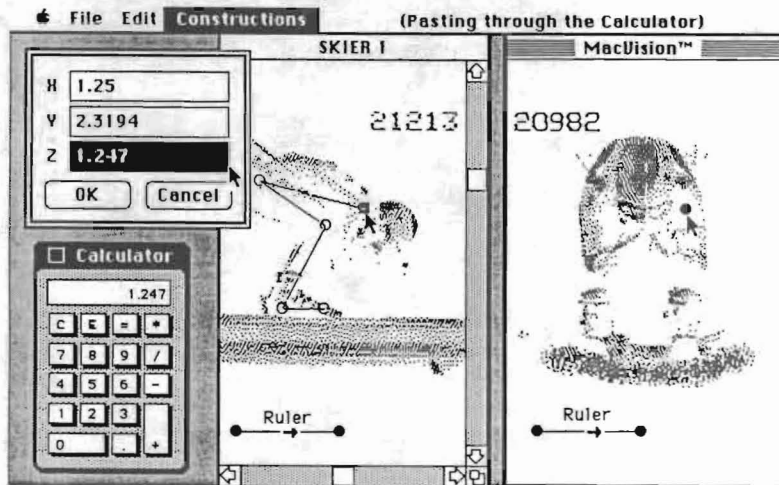
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Figure 3.   The third dimension

Windowing

Data is operated on through rectangular areas of the screen called windows. In the program several types of data are manipulated through its windows: (1) image windows, which are for creating and editing any of the video, scanner or hand drawn images that are stored as documents, and (2) geometry windows, which display the graphic and textual output (stick figure information) produced during digitization such as the ruler, joints, segments, and segment names. Image and geometry windows can be superimposed or separated at will by special commands. Additionally, the clipboard window will show any type of data that is copied to the clipboard.

Joints and segments

The nuts and bolts of the program are the joints and segments, and these are activated through use of the mouse and a special " Constructions" menu. (See Figure 1.) The joints are actually the control points, while the segments are treated as three-dimensional vectors and are the program's mathematical vehicle for any analyses or transformations. The first body position on Figure 1 illustrates how a segment is made. (Notice that the " Make Segment" command is highlighted.) The arrow points to the position on the upper left leg where the segment will be created between the two darkened joints. The second body position is completely digitized and all the joints and segments are in place. It should be noted that if the motion is planar (as in the right leg position of the hurdler,) segment length can be maintained throughout the digitized sequence by selecting (highlighting) the segment. This should prove helpful in checking one's consistency.

Up to this point techniques have been improved but they have not been radically different from traditional digitizing procedures. By utilizing a standard feature, we are able, for example, to zoom in on joints or segments that are difficult to see. Joint markings may be greatly enlarged so the researcher can make more accurate judgements about placement, particularly in the situation where two joints are close together.

Moving and orienting joints and segments

By positioning an arrow cursor anywhere along a segment and moving the mouse, one can displace the segment while maintaining its orientation (its angle remains constant). A practical use of this feature, for example, is when one wants to compare the right leg positions of two subsequent "frames." By copying the previously digitized segments and moving their hip joint with the mouse to a common position, the angular displacement of the right leg is readily visible and calculable.

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Another unique feature of the program is called "rubber banding." A selected joint (for example, the knee) can be positioned precisely with respect to other joints and segments by dragging the joint with the mouse. If any (unselected) segments are attached to the joint being moved, they will stretch and remain attached to the joint. (Remember, selected segments' lengths will remain constant.) This is a very useful procedure for "fine-tuning" the placement of joints and segments. The "Constructions" menu also provides a command for naming the segments. These names (see Figure 2) are part of the data base and will follow the segments as the data is moved between files or other programs. On the right hand side of this figure the joint coordinates and the segment names of the skier are printed on the clipboard.

Three-dimensional digitizing

From the two orthogonal views of the skier in Figure 3, three-dimensional analyses can be made. The side view of the skier shows a coincident joint at the shoulder. (Displayed as a square.) Incidently, the figure of the skier in the egg position was taken from a video disk and the gray scale inverted by a single command. In order to obtain the actual Z value of the left shoulder, make the front view of the skier active and establish the X value (1.247) in this view. This is the actual Z value of the skier's left shoulder. By copying the X value and pasting it in the Dialog Box for Z, the three dimensional values (X,Y,Z) of this joint are now set. The value is shown in the calculator window only to show that any value can first be copied to the clipboard for any desired computation before copying over to the Dialog Box.

DISCUSSION

It is hoped that SASAI will prove to be a very unique and useful research environment because of its ease of use, its visual orientation and its mathematical underpinnings, but this remains to be proven with usage. However, its use as a creative teaching device for budding motion analysts , its portability allowing one to take the workstation to the athletic field, and its utilization of "off the shelf" video images should prove very useful to students, teachers, coaches and athletes.

To emphasize the most unique features of this system's software, remember that in every digitizing sequence you only have to lay down the coordinates once. As you digitize and move from frame to frame ("freezing" segment lengths along the way,) you are displacing the body by visually pushing and pulling on the joints and segments, and flushing out all of the analytical information (velocities, accelerations, etc.) in a very intimate way. In fact, "massaging the data " can be given a much more literal meaning in the context of this system. Isn't this what the study of motion is all about?

In conclusion, the synergistic viewpoint implies an interplay of opposites such as numbers and pictures, and hard and soft images. Therein lies the strength of the system described in this paper. One might look at SASAI as one of the softer tools ever to come to us from an engineer's tool box!

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