BIOMECHANICS OF AIRBORN TWISTING SOMERSAULTS

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The mechanics of twisting somersaults have received considerable attention from scientists in recent years. It has been shown that the function of an asymmetrical arm swing pattern is to cause the body to leave the salto rotation plane, thereby creating a component of angular momentum around the longitudinal axis of the body. A newly defined "Coriolis Index" has been developed for computer diagnostic evaluation of arm swing patterns in airborn twisting somersaults (Liu and Nelson, 1983). The purpose of the present study was to devise an interactive computer graphics technique by which the complex mechanical features of twisting somersaults could be shown visually and thereby assist coaches and athletes in their understanding of this movement.

METHODOLOGY

Five Penn State University divers were filmed by two 16 mm cameras as they performed twisting somersault movements from a 1 meter springboard. An on-line film analysis method produced three dimensional coordinates of the joints of the body at points throughout the airborn movement. These data were used to calculate the following parameters: 1) angular velocity of the salto rotation, 2) twist angle of the trunk, 3) linear velocity of the arm motions relative to the longitudinal axis of the trunk and 4) "Coriolis Index" (C.I. = Vz * Ws * cos B). Figure 1 shows the coordinate system fixed on the trunk.

A computer program was written which provided a multi-picture sequence of stick figures of the diver and curves of the biomechanical parameters. These were displayed on an Evans and Sutherland Multi-Picture Graphics System in concert with a PDP-11/34 minicomputer. Figure 2 shows The Evans and Sutherland system hardware which consists of the MPS graphics engine, a 21-inch calligraphic display, keyboard, and a number of interactive devices including extended function switches, analog control dials, a three axis joystick, and data tablet. The

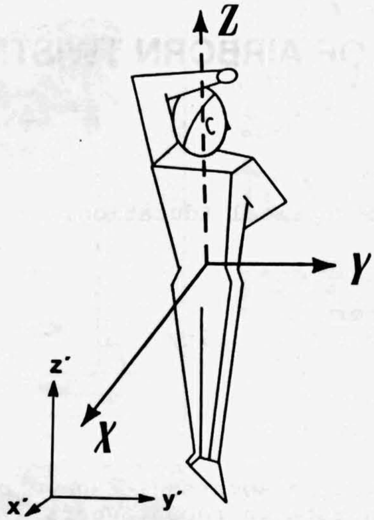


Figure 1. Fixed and Relative Coordinate systems.

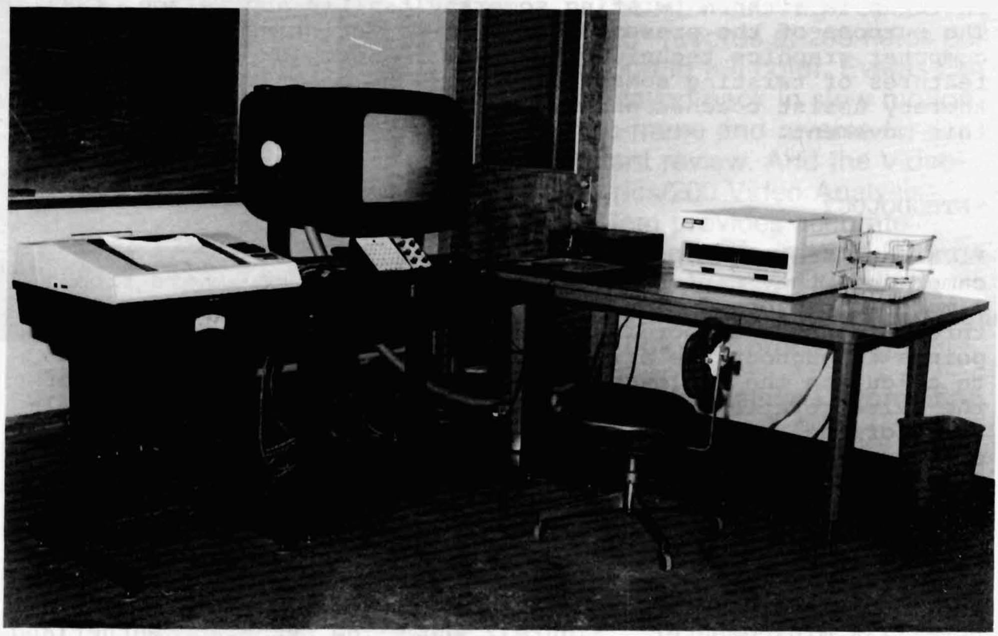


Figure 2. The Evans and Sutherland Hardware system.

high-resolution of the display is 4096 by 4096 and images of over 20,000 vectors can be refreshed 30 times a second to provide smooth continuous motion. Eighteen line modes and textures are available in any of 64 intensities. Graphic transformations, which include rotation, scaling, translation, windowing and perspective projection, are performed by the hardware of the graphics engine. This engine contains 64 K words of display memory plus 128 K words of extended memory suitable for storing untransformed display lists, coordinate data and display segments. A versatec V-80 printer/plotter is available for listings (at 1000 lines per minute) and for producing hardcopy of selected positions appearing on the screen display (the resolution is 0.005 inch).

The schematic diagram in Figure 2 demonstrates the interaction between PDP-11/34 minicomputer and Evans and Sutherland Multi-Picture System and their input and output relationships.

This made possible a dynamic, interactive display of the stick figures and biomechanical parameters in real time. The input data can be modified and the effects on the movement observed. Control of the stick figures, two Coriolis Indices and two curves of the center of gravity of the arms is accomplished by manipulating three dials and four extended function switches. The figures can be rotated along the X, Y, and Z axes, thus making it possible to view the figure from any position desired. The arm motions can be observed in two or three dimensions, while the two Coriolis Index curves and centers of the gravity of the arms, representing characteristics of the arm swing, are simultaneously displayed. The scale size of the figure and the speed of its arm motion can also be altered.

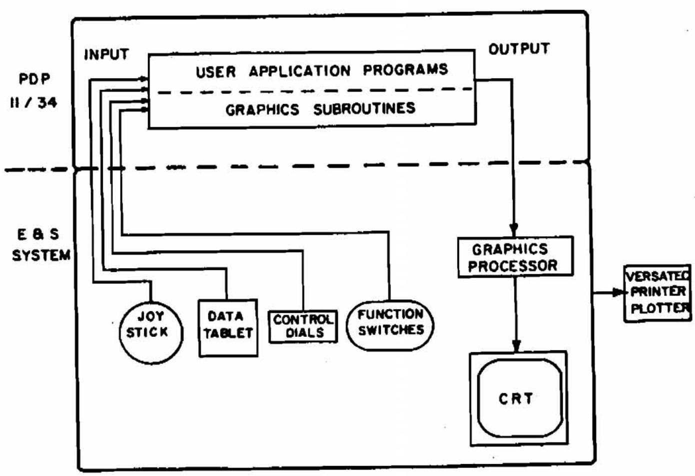


Figure 3. A schematic diagram of the Evans and Sutherland Computer Graphics system.

RESULTS

Figure 4 shows two photographic records taken from the CRT display. Each photo contains: a) the stick figure form of the diver with paths of the arm centers of gravity and the plots of the Coriolis Indices for both arms. Hard copies of any point in the movement can be obtained from the V-80 Printer/Plotter by merely depressing the appropriate switch. By observing the C.I. index curves in conjunction with the arm movement patterns it is possible to identify errors in direction and magnitude which detract from the successful completion of the dive.

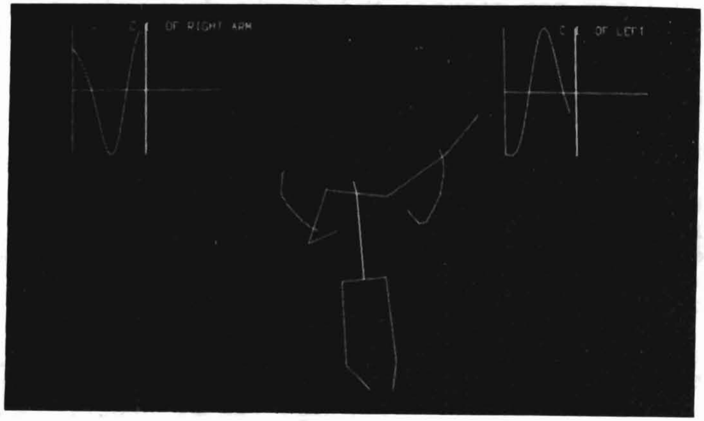


Figure 4. Photograph taken of the Computer CRT Display.

Figure 5 contains three different views of the diver stick figure. The view shown in 5b) was transformed from that in 5a) by rotating the system 90° about the longitudinal axis. The front view in 5a) was displayed in the Y-Z plane and the side

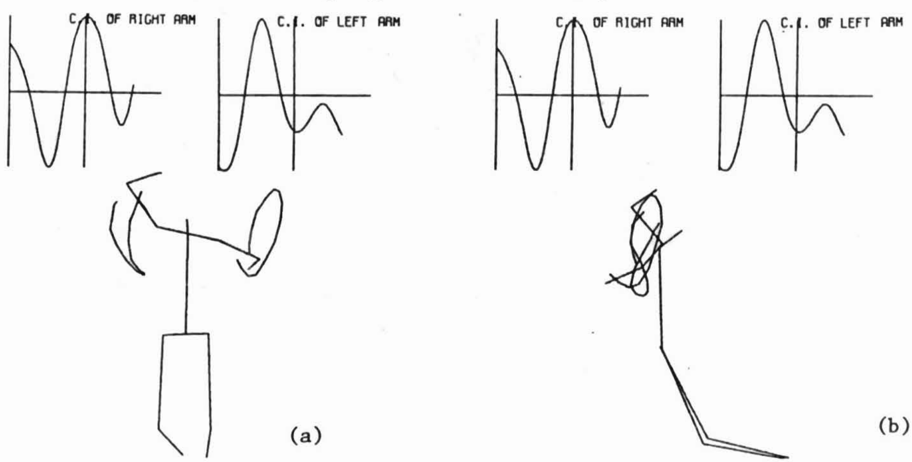
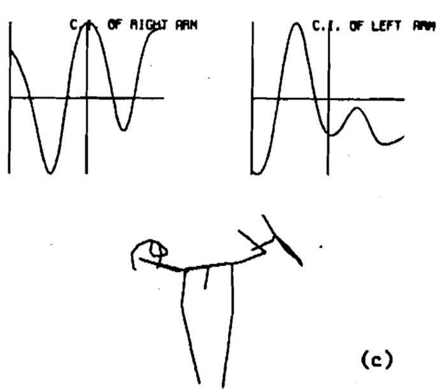


Figure 5. Examples of hard copies produced by the V-80 printer/plotter showing: (a) view of the Y-Z plane; (b) view of the X-Z plane; and (c) view of the X-Y plane.



(c)

Figure 5. Cont.

view in 5b) in the X-Z plane. The top view in 5c) which occurred slightly later in the dive, appears in the X-Y plane. These 90° rotations are easily achieved by merely depressing the correct function switch. Two speeds of graphic presentation are available. The high speed mode is best used to view the complete movement of the dive, while the slow speed is most effective for identifying specific components of the dive.

CONCLUSION

The computer graphics system presented here offers an effective method for observing and studying complex three-dimensional twisting movements which occur in sports such as diving and gymnastics.

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