Spanning two decades, these studies have led to the development of simulated human figures that are both anthropometrically accurate and useful in a variety of applications.

A Progression of Human Figures Simulated by Computer Graphics

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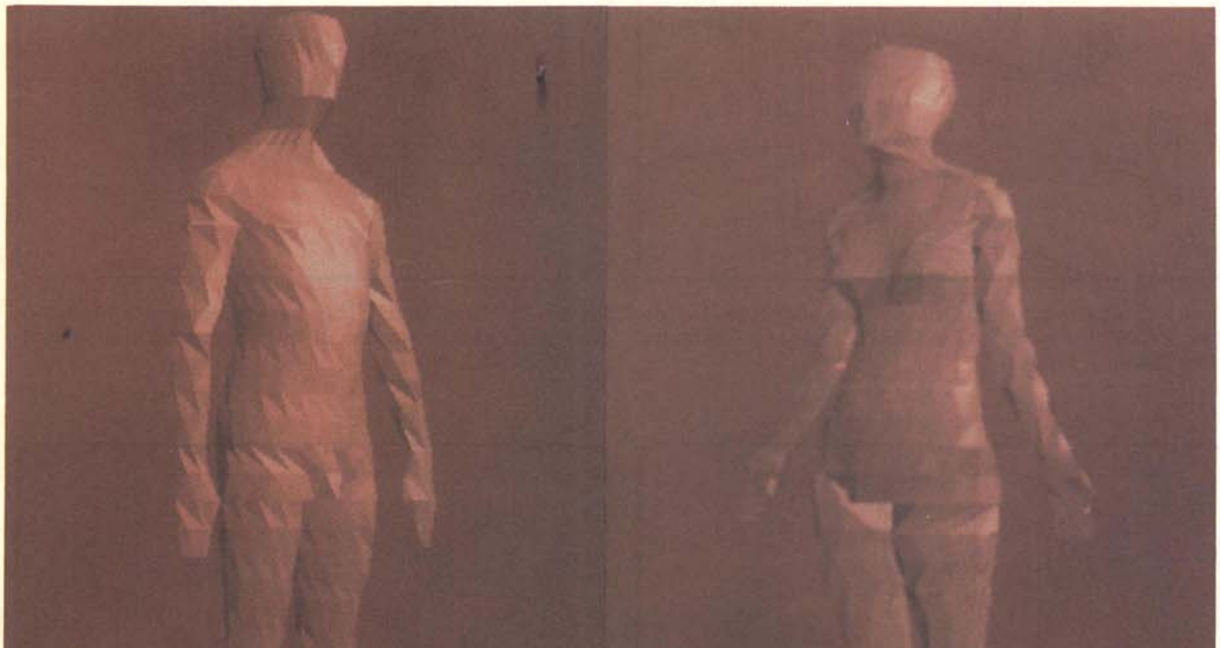

There has been a long-standing need in certain computer graphics applications for human figure simulations that, as descriptions of the human body, are both accurate and, at the same time, adaptable to different user environments.

This article describes a progression of figure simulations developed by the author over the last 20 years in an attempt to meet this need. Emphasizing graphic design as the proper direction for technical developments, the work chronicled below was accomplished in a computer graphics system framework in which the human figure was but a single element of the overall research effort.

The figures accompanying this article illustrate the four stages of this progression of human figure simulations. A number of the simulations and applications were firsts[1] at the time, meeting their original objectives and stimulating other researchers, who often commanded greater technical resources.

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"First Man" and "Second Man"

In 1959, the author's most fundamental work leading to human figure simulation was the development of computer perspective animation—a project proposed to and authorized by Verne L. Hudson, chief of preliminary design at the Wichita Division of the Boeing Airplane Company.[2] It was Hudson who probably coined the term *computer graphics.*

The first human figure simulated by means of a computer may have been the "Landing Signal Officer" illustrated in Figure 1. LSO was a fixed database we developed to give the location and scale of the landing signal officer on the CVA-19 class aircraft carrier for a motion picture that simulated cockpit visibility during landing.[3] Viewed from the flight path, the figure was a 12-point silhouette with the lines representing two-dimensional edges only.

For queueing theory studies, however, 30 straight-line connected points defined the figure in a block form, and the lines represented the right-angle block edges. These figures were moved down the aisles of simulated commercial aircraft to predict passenger movement.

This first stage culminated in the production of the "First Man," shown in Figure 2. This model was composed of seven movable segments that could be articulated at the pelvis, neck, shoulders, and elbows to approximate various pilot motions. Anthropometric data already encoded in the original figure, which represented the average-sized American male (50th percentile), was digitized and mathematically transformed to smaller or larger figures. The lines now represented surface traces of minimum radii—an illustrator's economical technique of letting a single line represent the likely demarcation of shadow.

Through an agreement with the Boeing Company and Computer Graphics, Inc., the author used his First Man data for a 30-second television commercial, illustrated in Figure 3, at Graphcomp Sciences Corporation for Norelco. Modifications made to the figure database for this purpose included approximately sound-synchronous lip motion as the figure spoke. Possibly the first commercial

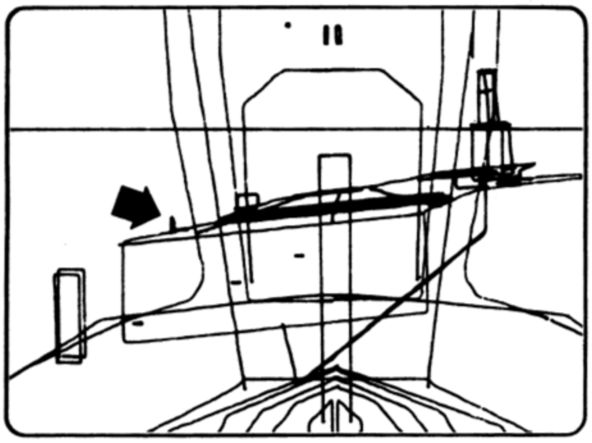

Figure 1. "Landing Signal Officer." The LSO at deck edge (see arrow) gave scale to the CVA-19 in cockpit visibility films (Boeing, 1960).

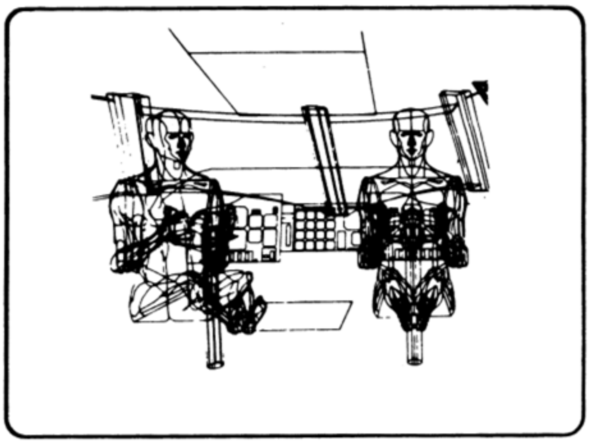

Figure 2. "First Man." This seven-segment articulated pilot was used in studies of the Boeing 747 instrument panel (Boeing, 1968).

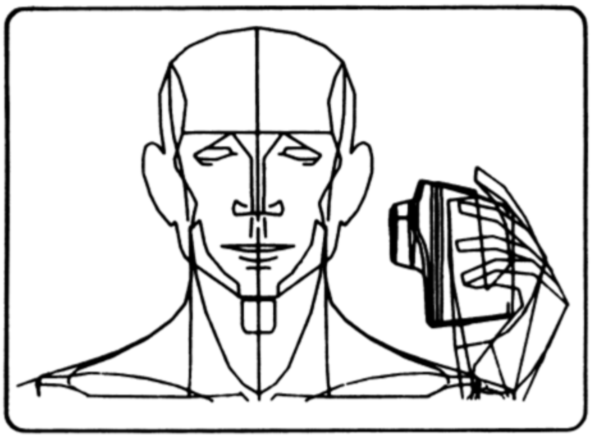

Figure 3. "Norelco TV Commercial." This may have been the first perspective computer graphics television commercial (Graphcomp/Boeing/CGI, 1970).

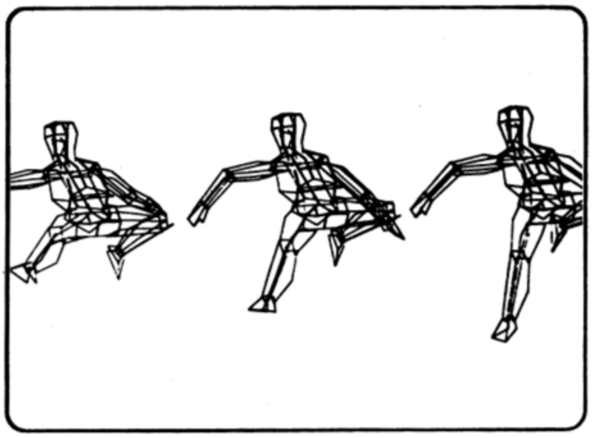

Figure 4. "Second Man." A more fully articulated 19-segment figure was developed with a temporary, simpler surface (Boeing, 1969).

to make use of computer graphics perspective, it achieved high prime-time ratings.

While simpler in appearance, the "Second Man" series—representing the second stage of this work—improved the articulation of the First Man figure by incorporating a greater number of joints and continuing to develop its anthropometric accuracy. Film sequences based on a photo series by Muybridge[4] demonstrated animation of the 19-joint figure. Tests of animated motions included operating an aircraft control column, running, and high jumping, as seen in Figure 4.

"Third Man and Woman"

The third model—"Third Man and Woman"—which was developed at Southern Illinois University at Carbondale's Department of Design, represented an initial attempt at a hierarchical figure series, with successive figures separated by an order of magnitude in complexity. Prior experience had shown that human figures at different scale had useful applications. We developed a progression of databases using one-point figures for demographic distribution, 10-point figures for queueing studies, and 100-point figures for anthropometrics (see Figure 5).

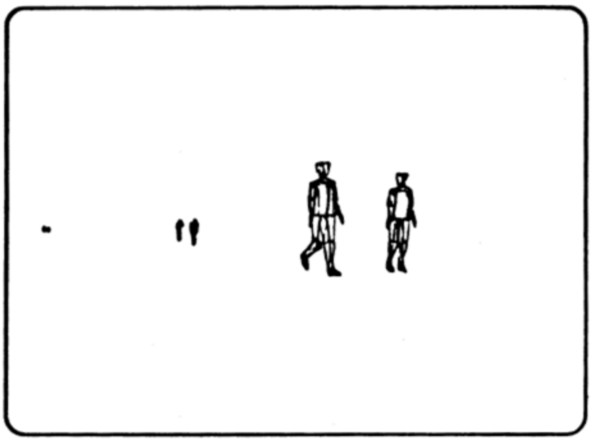

Figure 5. "Third Man System." An order-of-magnitude progression designed for use in different scales for several applications (Southern Illinois University at Carbondale, 1974).

Points located the figures' center of gravity for one-point figures only. In the 10-point figures, a single line represented an entire limb, head, or torso.

The 100-point figures were 50th percentile representations based on *Humanscale 1/2/3*, a book of anthropometry for designers.[5] They contained 10 movable body elements and could be animated—the lines represented edges of a boxlike definition of each body element. The 100-point figures were used with databases of other designed objects in display exercises where figures seated themselves in automobiles, walked in architectural environments, or rode the escalator to a monorail station,[6] as in Figure 6.

To gain more detail, we needed to be able to measure points on the body surface more precisely.[7] Existing photogrammetric plots of human figures had considerable asymmetry, so the author redrew them to obtain a symmetrical and aligned 1000-point figure that would simplify motion. The lines now represented contours connecting points on the surface equidistant from a plane within the coordinate system (see Figure 7).

As we developed and reviewed the more detailed, 1000-point figures, we realized that ultimately not only surface but also internal elements would have to be defined. Using the same baseline perspective animation program with a slightly different hierarchy of elements, we digitized a simplified skeletal structure of the hand and animated the fingers. Here, as shown in Figure 8, the lines represented edges of a blocklike description of the bones.

We had successfully achieved the progression of detail we sought with the one-, 10-, 100-, and 1000-point figure series, but in each system the lines represented different elements. This variance compelled us to look for a more consistent presentation of the figures, despite changes in their level of complexity.

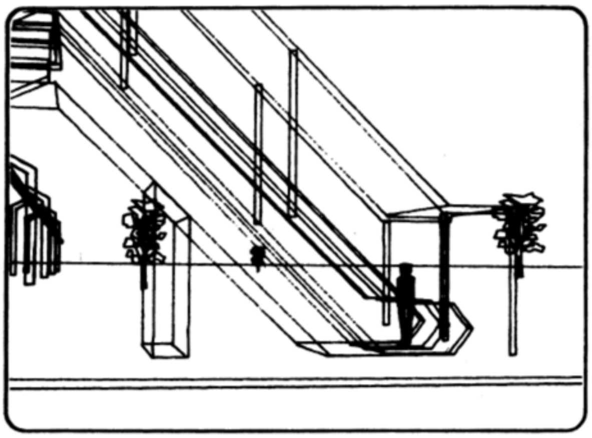

Figure 6. "Monorail Film." The 100-point figure using an escalator was employed in a film simulating a monorail system (Southern Illinois University at Carbondale, 1975).

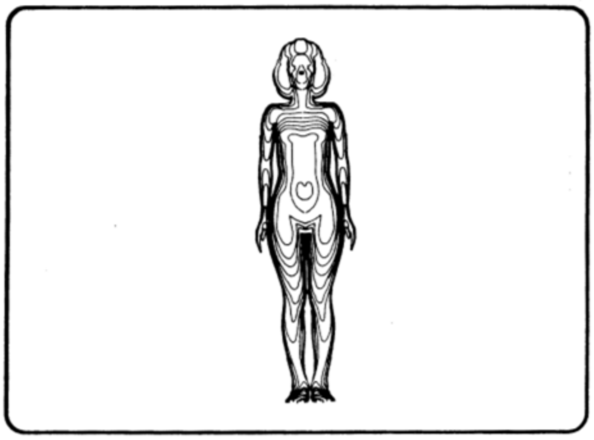

Figure 7. "Third Woman." A 1000-point contour figure based on redrawn photogrammetric plots planned for 10 movable segments (SIU-C, 1975).

"Fourth Man and Woman"

This research continued in 1977 in the newly formed Southern Illinois Research Institute, where the author decided to access biostereometric tapes—a more accurate and manageable starting point[8] for the fourth stage of his work in human figure simulation. At the Bellevue, Washington, office called Siroco, we defined horizontal contours and began searching for a program to construct polygons between these contours in addition to varying the numbers of contours for figures at different levels of complexity.

In writing software to restructure data from the biostereometric tapes, we developed a program that contained options for selecting contours, selecting desired numbers of points along the contours, and dividing the points evenly along each contour.[9] A range of levels of detail was then possible. Decisions on the number of polygons were based on factors such as line weight, image size, and—particularly—viewing distance. Thus, we can generate a progression of figures that appear to have about the same mass of lines for plotters and about the same polygon size for raster displays even when the actual complexity per figure varies considerably (see Figure 9).

The "Fourth Man and Woman" line plots developed at Siroco have been useful in testing geometry and exploring the visual effects of hemispheric projection[10]—an area of research originally demonstrated by the author in the 1960's with the display of information on the inner surface of a hemisphere. Hemispheric projection totally immerses the viewer in a visual environment for perspective scenes or other information displays. The databases used in preparing Fourth Man and Woman plots demonstrate correct geometry when properly projected inside a hemisphere, even though a slide in its original flat form appears distorted, as in Figure 10.

In demonstrating the appearance of the Fourth Man and Woman on raster displays, surface normals of each polygon are calculated to determine surface visibility, amount of hue, and the highlights necessary to render the figures with shading and color. The Fourth Man and Woman figures prior to error corrections and smoothing are shown on the title page of this article. The facets of the polygons can be smoothed with the additional calculation

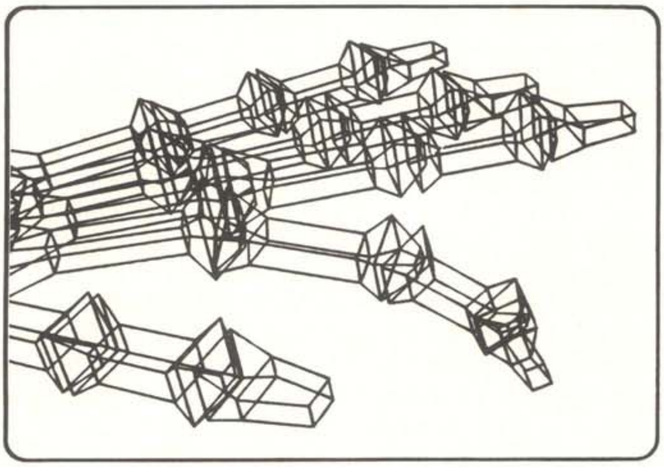

Figure 8. "Skeletal Hand." One frame from an animated study of an envisioned 10,000-point figure (Southern Illinois University at Carbondale, 1976).

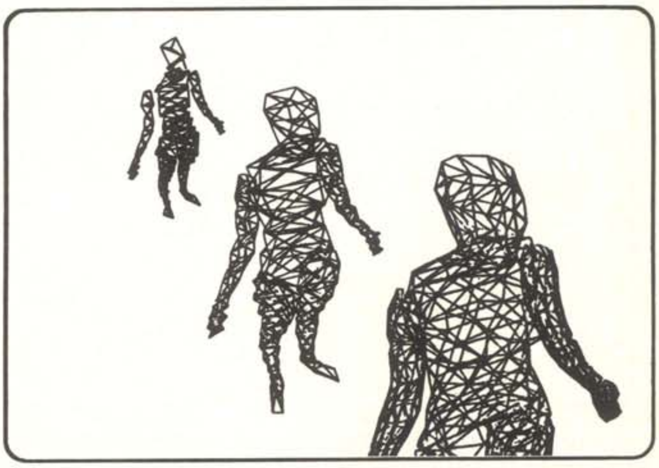

Figure 9. "Polygonal Progression." From a biostereometric tape, several levels of detail were generated as a function of distance (SIRI-US, 1977).

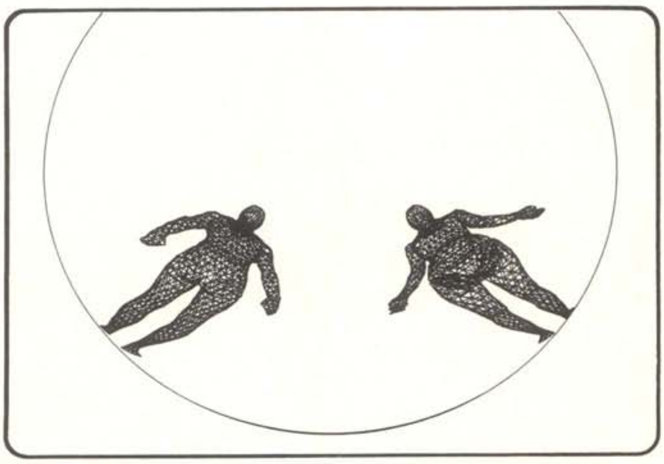

Figure 10. "Fourth Man and Woman." A hemispheric plot as it appears before projection (Siroco, 1980).

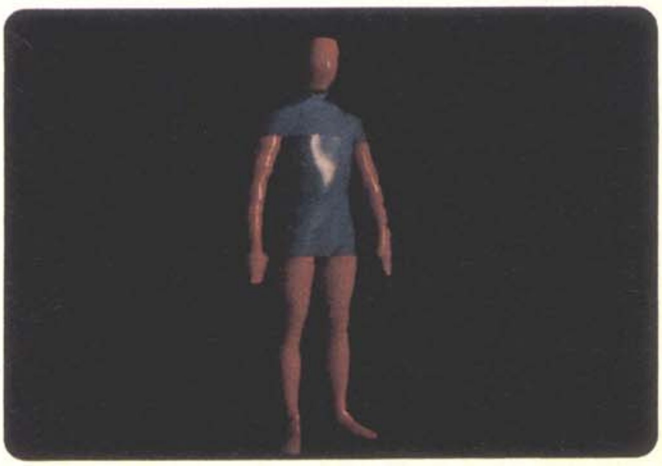

Figure 11. "Fourth Man." Figure with simulated clothing and polygon smoothing (Siroco, 1982).

of averaged normals for each polygon vertex[11] (see Figure 11).

While the levels of detail selected are still a result of the designer's or programmer's experience, a planned feature in new software is the automatic selection of contours and polygons based on viewing distance, physical screen size, available raster resolution, and any storage limitations of the system. Integration of this work with motion systems by other researchers is also planned.[12]

Both the First Man and Second Man models achieved line definition and motion at Boeing, an aerospace environment ideal for this type of research because both the technical resources and the application to demonstrable needs are closely linked and visible to participants. On the other hand, in the SIU-C academic environment the opportunity existed to explore hierarchical databases and surface treatment strategies. And at SIRI/Siroco, in a research institute environment—where some advantages of both other environments exist—raster scan, color, shading, and highlights are now part of the Fourth Man and Woman series. ■

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At SIU-C, student designer/programmers were Albert Allen, Frank Crow, Richard Rovens, John Virruso, Larry Evans, Lewis Wright, Dennis Andrews, Todd Nickle, Frank Juzwik, and Frank Stemm. Southern Illinois University at Carbondale Research and the National Science Foundation provided support, and the biostereometric tapes were available courtesy of Robin Herron.

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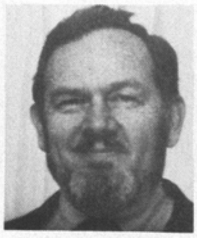

William A. Fetter has been the research director for Siroco (the Bellevue, Washington, office of Southern Illinois Research Institute US) since 1977. In 1970, he began conducting research and teaching in the Department of Design, Southern Illinois University at Carbondale, and served for two years as department chairman. Prior to that, starting in 1959, he pioneered in the initiation, organization, and application of computer graphics at the Boeing Company.

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