Computer Graphics Human-Figure System Applicable to Transportation

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A study of improved graphic representation that has usefulness for transportation research is presented. Applications that parallel the transportation design process in the variety of levels of detail required are emphasized. For example, a human figure represented by a single point can be useful in overview plots of population density and consumer areas. A crude 10-point figure can be applied to studies of queuing theory and the simulated movement of groups. A 100-point figure can be animated to scale in a design showing different overall body shapes, including male and female figures. A 1000-point figure, similarly animated, can be used in anthropometrics for work-station designs, gross body movements, and occupant motion in vehicle crashes. Extrapolations of this order-of-magnitude approach should ultimately result in very complex data bases and a program that automatically selects the correct level of detail.

The need exists in transportation research to clearly display information about the human figure—information ranging from large numbers for population and other demographic studies to single figures for studies of occupant safety, all accessible in a single system (6). Many computer simulations and modeling systems are under development. Program output is often already in machine-readable form that can drive improved graphic displays. The ability to relate different research results may be simplified and made more coherent by adopting some graphic conventions of the human figure (3).

Figure 1 shows the limited graphic quality of some research software (3, 5). Quality improvements in graphics are sometimes deferred in current research because the specialists must concentrate on the functional aspects of their particular fields of study. When graphic output is used, the means of achieving an improved display are not always readily available. In addition to animation capability, management of graphic parameters is needed so that end products have quality and consistency (5).

The wider communication capability required to reach specialists in rapidly subdividing technologies often calls for reliance on graphics to help translate or bridge specialized jargon. There is a relatively new, growing need to communicate simultaneously with other disciplines and with the public, which also suggests more reliance on graphics. A consistent conceptual framework applicable to transportation research is needed in which data may be accessed and displayed in controlled degrees of detail.

HUMAN-FIGURE COMPUTER MODELING

Problem

The problem is how to develop a computer graphics system, for independent use or for use in work by other researchers, which is applicable to an array of man-machine research and application purposes including transportation. Development of a comprehensive program and anthropometric data bases must ensure a widely used language in a straightforward data format. The program must be reliable and provide relatively easy manipulation of three dimensionally defined data in a number of basic projections including map projections. The data must be developed to accommodate many levels of detail and, ultimately, easily calculated costs.

The system capabilities must be complete enough for relatively independent direct applications. A transportation-related example is population mapping of a mass transit system, enlarged to figures to display queuing through a station, then enlarged again to indicate space requirements in vehicles by means of many figures occupying a single car. Detailed studies of car occupants during decelerations should also be possible.

The system should be relatively convenient for display of other ongoing research. For example, existing data on spatial needs related to anthropometry should be assimilated and graphically portrayed. Another use is the translation of existing biomechanical dynamic models into more easily communicated, animated predictions.

Research

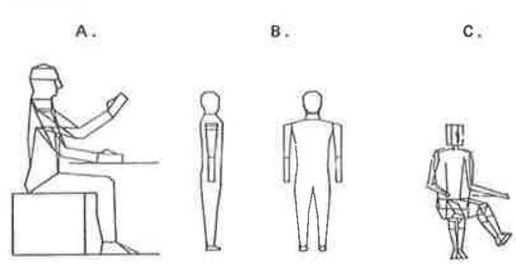
Research in computer models of the human figure is often principally involved in functional aspects of biomechanical modeling in which only modest attention is paid to display; such work is addressed to a very specific research area or relies on the capabilities of specific computer hardware-software systems.

Some of the work that has emphasized body functions includes that of Springer and Katz of the Boeing Company's personnel subsystems development for the Joint Army-Navy-Air Instrumentation Research (JANAIR) program (Figure 2). Other extensions of the Boeing work are proceeding at the Naval Air Development Center. Computer models have been developed by, among others, Kilpatrick (3) and Reed and Garrett (5).

Work that addresses very specific research areas is exemplified by studies at the University of Utah and the Naval Aeromedical Research Laboratory. Parke (4) has developed advanced specialized representations of the human figure; equations have also been developed that express possible variations in leg movements. Naval researchers have done voluminous studies of the biomechanical effects of head-neck motion.

Much of the work described in the examples above relies on widely available computer systems—the University of Utah being at least one notable exception. In many cases, plotters, a growing number of which access computer output microfilm (COM) or interactive cathode ray tube (CRT) displays, are the extent of graphic communication hardware. It appears that the system under development could be a useful aid to a number of these systems in communicating research results.

Figure 1. Limited graphic quality of some research software.



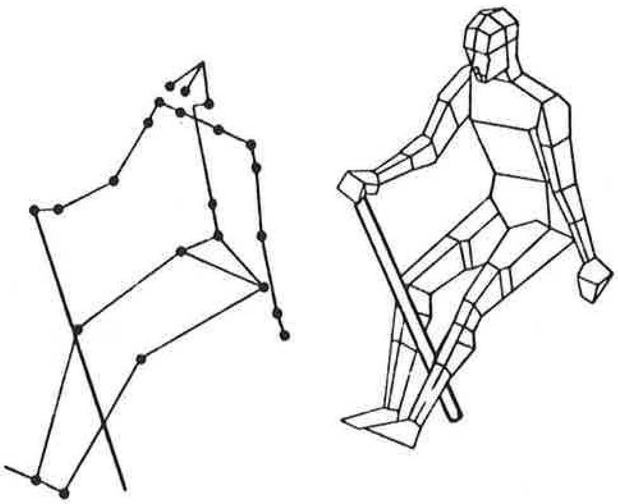
THE STUDY

Background

Earlier developments by Fetter in human-figure computer graphics occurred in an industrial setting at the Boeing Company where it was important to produce meaningful anthropometric contributions to the design process, to reduce such research to profitable practice, and to bring about reliable results and multipurpose graphics output (2). An eight-step system was developed to integrate graphic and technical qualities:

1. Aims definition to set goals,
2. Communication design to provide early visualization of the end product,
3. Data transcription to encode data,
4. Computing-programming to manipulate the data,
5. Automatic drawing to produce the essential image,
6. Final rendering to complete a master copy,
7. Reproduction to produce further copies, and
8. Distribution to ensure the communication reached the audience.

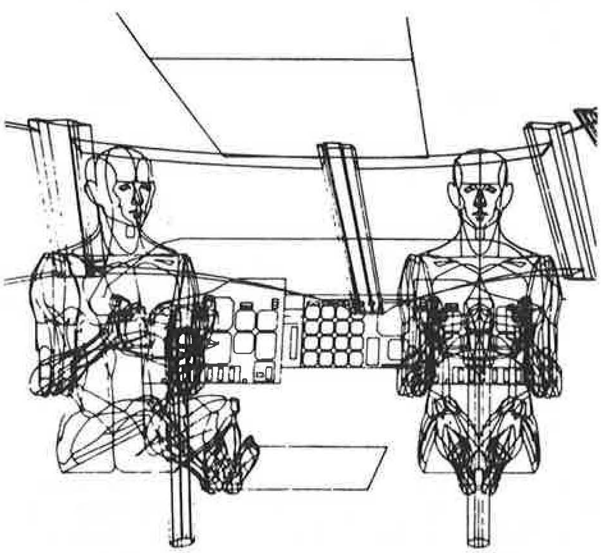
Figure 2. Sample of graphics for a joint military study.



The visual module system permits one image to be immediately useful in a number of communication media without costly reworking. The most common media in use have been document illustrations, presentation charts, 35-mm slides, 16-mm motion pictures, closed-circuit television, and interactive CRT displays. This system has demonstrated its usefulness in industry.

Human-figure work originally centered around male, variable-percentile representations of airline pilots. A rendition of a landing signal officer was used in early carrier landing simulations. Figure 3 shows the first articulated model, known as the "first man," which involved the use of seven systems. The "second man" (using 19 systems) was then developed for more complete articulation and applied to a number of aircraft design projects and cockpit evaluation studies.

Figure 3. Seven-system man-in-cockpit studies emphasizing graphic modeling.



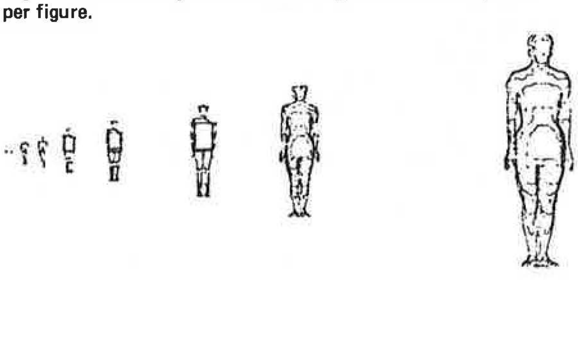
Objectives

The objectives of this study are to resolve display problems in a cost-effective, reliable system. The quality of the graphic representation of each human figure is limited in number of data points but also controlled as to size to ensure appropriate levels of completeness and finish in each representation. The visual module system is the prime mover of information, controlling visual angle, line weight, size of images, and other graphic standards for use in any media.

To achieve a number of levels of detail, a system of several data subbases, each of which increases by one order of magnitude in number of points, is under development (Figure 4). A 1-point figure can be used for statistical mapping; a 10-point figure for large crowds for, say, queuing-theory studies; a 100-point figure for gross bodily motion; a 1000-point figure for detailed motion; and so on. Ultimately, the choice of data bases will be made automatically within the system based on user requirements.

Demonstration applications under way in the field of design include population as one aspect of transportation information display. Anthropometric applications can include studies of a single-percentile comfort analysis of designed artifacts such as interior dimensions of a vehicle. [Anthropometric data used in this research are drawn from those of Diffrient, Tilley, and Bardagjy (1) (Figure 5).] Applications include display with more complicated systemic details.

Figure 4. Human-figure data for a range of number of points per figure.



Integration

By integrating the eight-step approach, including the program VIEWIT, and the visual module and the order-of-magnitude human-figure data, the following results have been achieved. [All figures are based on the 50th-percentile data of Diffrient, Tilley, and Bardagjy (1) unless otherwise noted.]

The 1-point man and woman are single points defined

Figure 5. Sample of anthropometric data now in use.

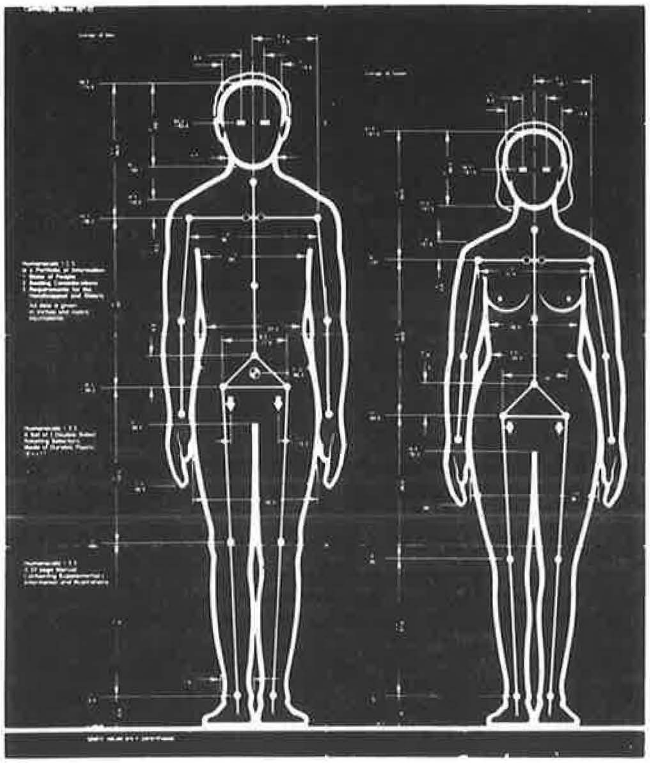


Figure 6. Male and female 1000-point figures showing motion in the male.

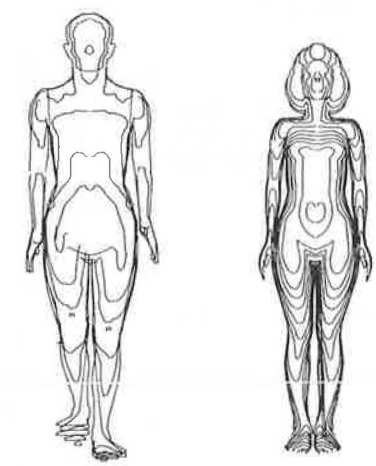


Figure 7. Frame from animated film showing human figure in a monorail design simulation.

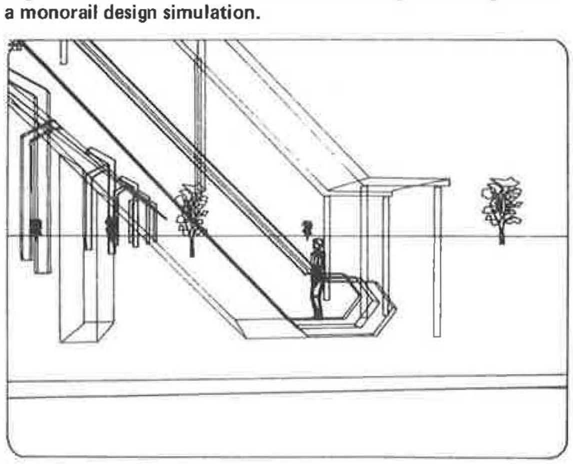
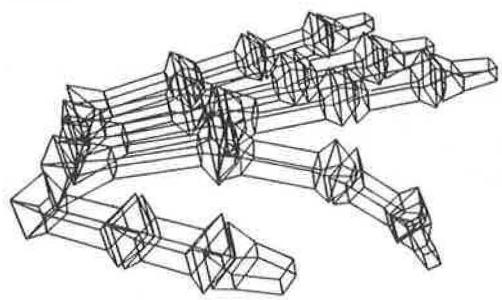


Figure 8. Skeletal hand with a high number of data points.



in three-dimensional coordinates and of a height consistent with 50th-percentile center of gravity depending on the application. Because of the distances viewed, the single point represents all figure elements.

The 10-point figures become stick-figure lines simultaneously representing the bones and the surface of the body—again, because of the thickness of lines needed in the small sizes to be used. This will give way to a polygonal form in the new data bases.

The 100-point figure has a system of 10 moveable linkages in which the data represent the exterior surface only:

1. Torso,
2. Head,
3. And,
4. Upper arms,
5. And,
6. Lower arms and hands,
7. And,
8. Upper legs,
9. And,
10. Lower legs and feet.

New polygonal data will contain surfaces and five systems.

The 1000-point figure (Figure 6) has a 10-linkage system that may be articulated. The data describe only the exterior surface, which is composed of points from a biostereometric data representation of the surface. The figures shown here are based completely on hand-drawn biostereometric contours, but tapes made available by Herron of Baylor University should allow the point definition of surfaces to be converted more readily to this system for animation with greater accuracy and ease of data transcription.

Demonstration

Demonstrations of potential applications of this system to date have included a seated figure, representation of figure scales in a monorail design simulation (Figure 7), and a motion simulation of a skeletal hand (Figure 8). In two cases, the 100-point figure has been used in exercises showing gross body motions. The process of seating the figure in a chair demonstrated the potential testing of a chair design against multiple-percentile male and female figures.

A slide and film simulation of a contemplated monorail system at Southern Illinois University permitted the inclusion of human scale in the presentation (Figure 7). The animation of a skeletal hand (Figure 8) demonstrates a biomedical training example of a figure that will contain 10 000 data points. The skeleton of the hand was simplified to the basic representative forms and data transcribed. Then the limits of motion and the hierarchical array of motion were programmed for an animation sequence demonstrating the hand motions.

Application

An important part of this effort is the constant growth of the interface between the generalized system capability and potential users. Promising areas of application are being studied to determine the best means of collecting and coding data. The completed media will be shown to others interested in this field of research so that feedback on the usefulness of the system can be obtained.

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