TECHNICAL NOTE

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Interpolating Between Computerized Three-Dimensional Forensic Facial Simulations*

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ABSTRACT: The shape of the skull is a limited predictor of facial appearance and facial reconstruction methods can offer at best a resemblance to the individual during life. Various unknown factors in addition to those relating to age, build, obesity, ethnic group, and the varying shape of the eyes, nose, and mouth mean that a variety of facial reconstructions could be produced from any single skull. A disadvantage of both traditional "plastic" facial reconstruction methods and existing computerized equivalents is that the finished reconstruction is fixed and substantial further work is required if a modified outcome is to be presented. An advantage of computerization is that if offers a greater potential for easy revision of images. Here we describe a method for interpolating or "morphing" between virtual images of facial reconstructions produced using the "plastic" technique which enables the interactive fattening of the face in three dimensions. Morphing is achieved using *qmorf*, a demonstration program, and using the interpolator node of virtual reality modeling language (VRML).

KEYWORDS: forensic science, forensic anthropology, physical anthropology, facial reconstruction, facial reproduction, three-dimensional modeling, virtual reality modeling language

It is well known that the shape of the skull is a limited predictor of facial appearance and that facial reconstruction methods can offer at best a semblance of the individual during life (1). The influence of various unknown factors in addition to those relating to age, build, obesity, ethnic group, and the varying shape of the eyes, nose and mouth mean that a variety of facial reconstructions could be generated from any single skull. A disadvantage of both traditional "plastic" facial reconstruction methods (2–4) and existing computerized equivalents (5,6) is that the finished reconstruction is fixed and substantial further work is required if a modified outcome is to be presented. An advantage of computerization is that it offers a greater potential for easy revision of images. The use of computer graphic techniques further offers a means of making available an international service via the Internet and of increasing the flexibility of presentation of facial reconstructions. Here we present a method for interpolating or "morphing" between virtual images of facial reconstructions produced using the "plastic" technique. Morphing is achieved using *qmorf*, a demonstration program, and using the *CoordinateInterpolator* node of virtual reality modeling language or VRML (7).

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Materials and Methods

Plastic reconstructions of typical male and female archaeological skulls, produced using published "obese" and "emaciated" tissue depth data (2), were scanned using a Cyberware 3030RGB/CN color laser scanner and *Echo* software (Cyberware, Monterey, CA) running on a Silicon Graphics Indy Workstation and IRIX 5.3 operating system (Silicon Graphics, Mountain View, CA). Scans of the anterior half of the head were produced. To ensure that "obese" and "emaciated" versions of reconstructions produced from identical skulls were captured in precisely the same orientation, the reconstructions were positioned on the scanner platform in the Frankfurt plane (8), positioned at a constant height on the scanner platform using telescopic stands. As the stands were superfluous to the final image, they were covered with a black cloth—which is invisible to the laser scanner—and hence excluded. The 180° scans were originated at the dorsal margin of the right external auditory meatus and terminated at the dorsal margin of the left. Images were cropped approximately at the hair line using the *crop* command in *Echo.* Voids in the scanned image were filled using the *fill* command. Three-dimensional images in *Echo* format were converted into Silicon Graphics *Open Inventor*™ file format using *cy2iv*, an IRIX command line utility program supplied by Cyberware, which generates output in quadrilateral mesh (quadmesh) format. Co-ordinate matrix sizes of 151 × 151 were generated from *cy2iv* and the *Open Inventor* (.iv) files were transferred to a Silicon Graphics O_2 workstation running IRIX 6.2 for morphing.

Morphing was achieved using *qmorf*, a demonstration program which will interpolate between any two *Open Inventor* three-dimensional images in quadmesh format. *Qmorf* was used to interpolate between "emaciated" and "obese" reconstructions produced from typical female and male skulls. As the moving images generated by *qmorf* cannot easily be displayed via the Internet, the *CoordinateInterpolator* node of VRML 2.0 was used to create a file which will interactively display morphing between 40 × 40 co-ordinate "emaciated" and "obese" reconstructions on the Internet. The *CosmoWorlds*™ (Silicon Graphics, Mountain View, CA) VRML editor was used to render the face with a "white" skin-like surface material and add text to the model. A selection of images was captured from each morphing experiment at different stages of interpolation.

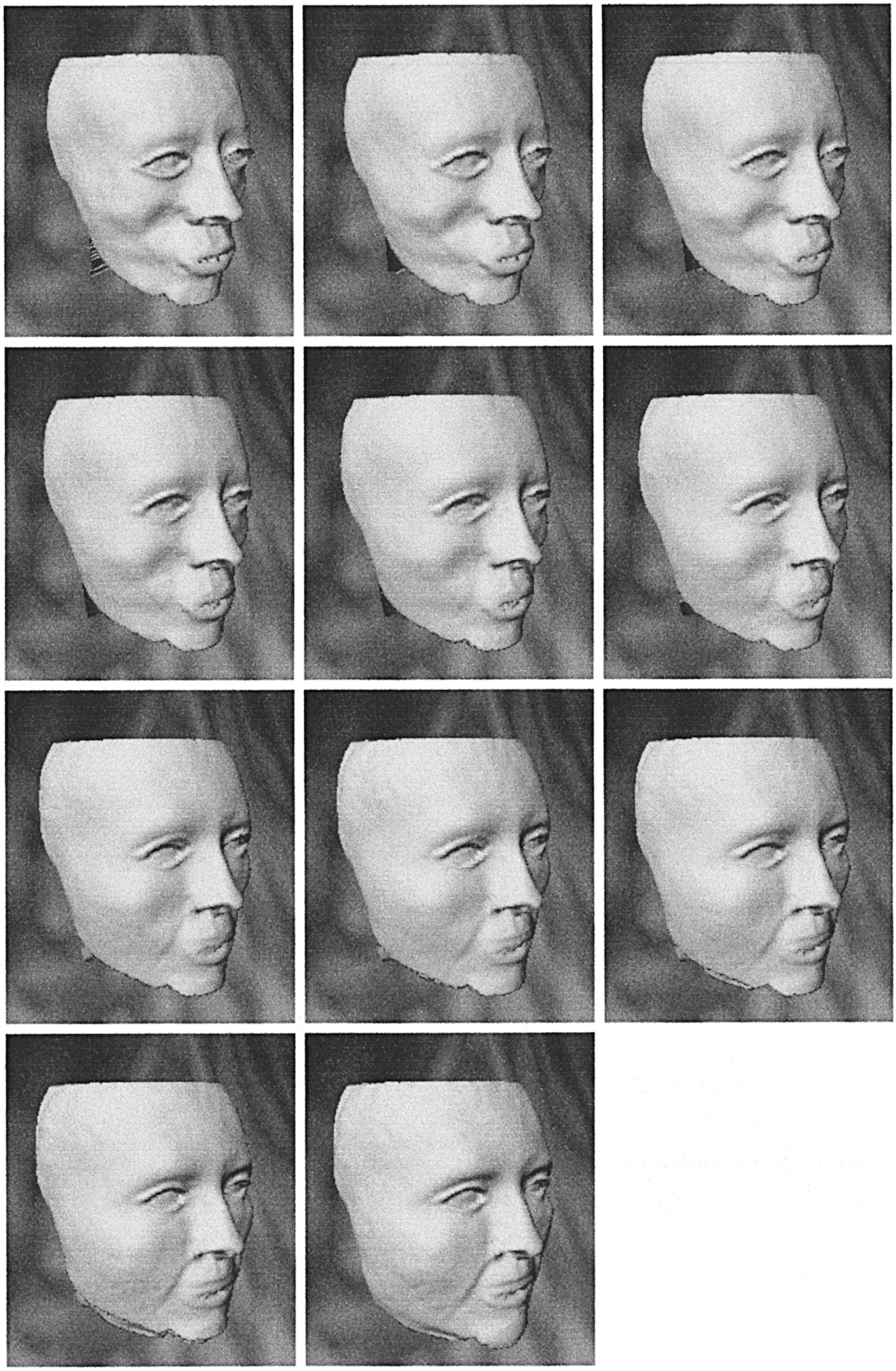

FIG. 1—*Images showing* qmorf *interpolation between two reconstructions from a female archaeological skull produced using the "emaciated" and "obese" tissue depth data.*

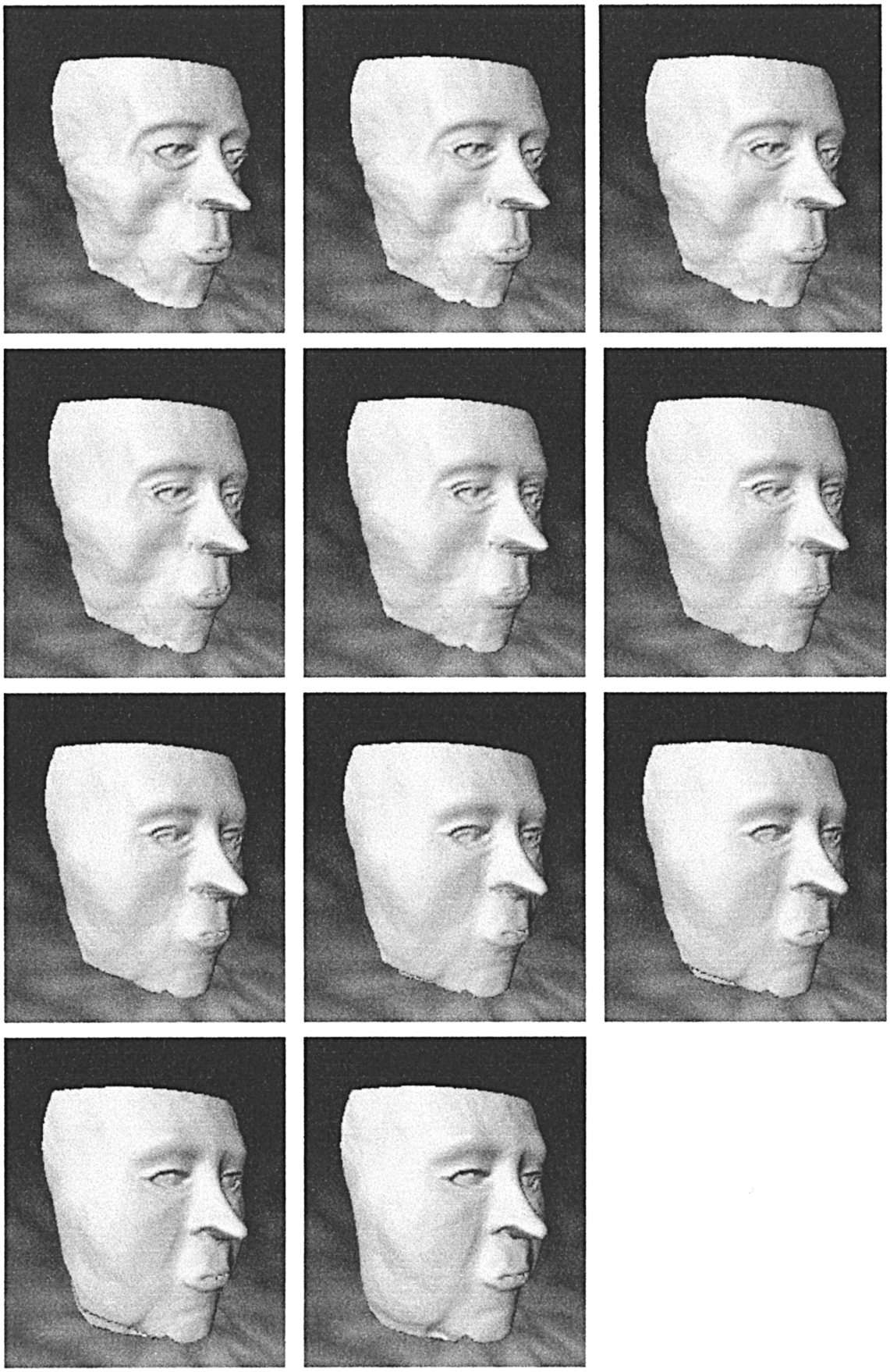

FIG. 2—*Images showing* qmorf *interpolation between two reconstructions from a male archaeological skull produced using the "emaciated" and "obese" tissue depth data (http://forensic.shef.ac.uk/jfs/fatten.mov).*

Results

Images showing the results of *qmorf* morphing between "emaciated" and "obese" extremes for reconstructions of a female and a male skull are shown in Figs. 1 and 2, respectively. Images of a VRML 2.0 file loaded into a VRML browser (Silicon Graphics' *Cosmo Player*™) and showing interpolation between "emaciated" and "obese" extremes of a female reconstruction are shown in Fig. 3. Movement through a series of three preset viewpoints is also shown in this figure.

Discussion

When supplied with files representing "emaciated" and "obese" reconstructions from the same skull, *qmorf* will interpolate smoothly between the extremes. The same result can be achieved in a simple VRML model. The images can be examined interactively in three dimensions. As well as generating images of the reconstruction at different levels of obesity, the mean tissue depth dataset is also represented. The time taken to morph automatically between two 151 × 151 co-ordinate datasets is three seconds. In *qmorf*, a slider control allows the user to manipulate the interpolation process manually or to stop at any particular point in the process.

A plastic facial reconstruction can take up to a week to produce, although the process can be reduced to one or two days in an emergency. If the reconstruction has to be amended some hours or days further work can be required. Amendments to finished three-dimensional reconstructions in VRML or using morphing programs such as *qmorf* can be achieved in seconds. The same approach can be used to age the face, to move between typical female and male tissue depth datasets—in the case of a robust female, gracile male or un-sexed skulls, for example—or to morph between typical datasets for the major ethnic categories where a skull cannot be clearly placed in one or other group. Since important features of fa-

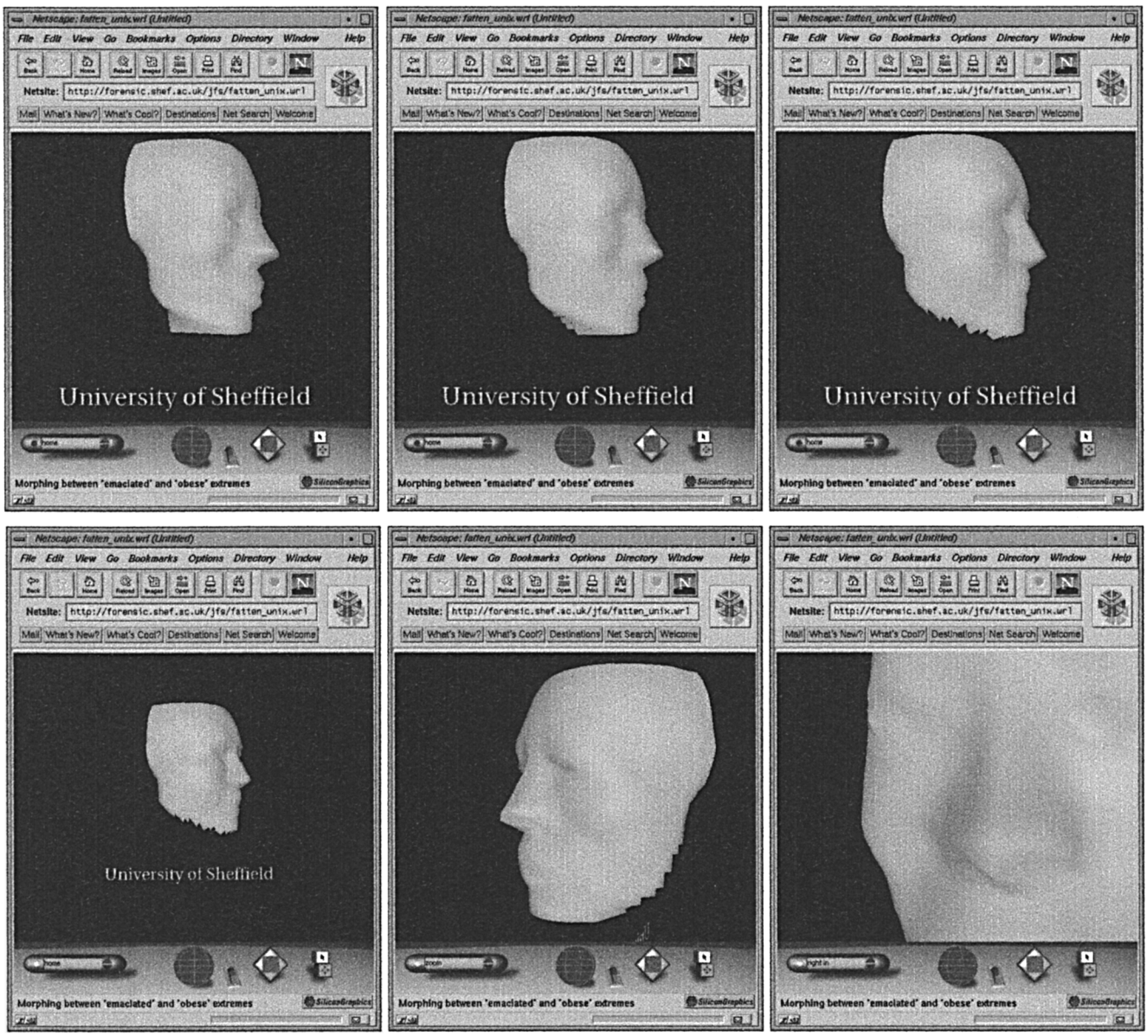

FIG. 3—*Images produced using a VRML model to interpolate between "emaciated" and "obese" reconstructions from a female archaeological skull, as displayed on the Internet (http://forensic.shef.ac.uk/jfs/fatten.wrl). Movement through three preset viewpoints is shown in the bottom half of the figure.*

cial appearance—the shape of the eyes, tip of the nose and the lips—cannot be predicted from the skull, VRML or programs such as *qmorf* can be used to allow the user to select from a variety of shape options.

Since *qmorf* performs a simple linear interpolation between the start and end co-ordinates, future research is directed at the development of VRML models and Java algorithms for non-linear interpolation which more appropriately reflect the anatomical processes underlying the fattening of the face.

Acknowledgments

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