TECHNICAL NOTE

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Presenting Three-Dimensional Forensic Facial Simulations on the Internet Using VRML*

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ABSTRACT: Advances in graphical computing have led to the development of computerized simulation models for forensic facial reconstruction in three dimensions. As well as being rapid and repeatable, computerization also offers a flexible means of presenting finished reconstructions. Here we describe the presentation of virtual images of plastic reconstructions on the Internet using virtual reality modeling language (VRML) and the enhancement of the final images using a commercially available three-dimensional editing program. The Internet offers an additional medium for presenting images to the public which will complement the traditional methods. International round-the-clock accessibility to images is gained, combined with the facility to interact freely with the reconstruction in three dimensions. Use of the Internet will also facilitate an efficient internationally available service for computerized forensic facial reconstruction.

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

Advances in graphical computing have lead to the development of computer systems for three-dimensional facial reconstruction which use the traditional tissue depth data (1–3), and to research into the collection of new tissue depth datasets at the traditional landmark sites from ultrasound (4) and computed tomography scanners (3,5). Our current research (3) has two emphases: the first is the collection and direct application of volume craniofacial data from medical imaging in facial reconstruction—leading to the abandonment of the traditional landmarks in favor of a matrix of tissue depths collected at *circa* 256 × 256 co-ordinates on the skull; the second is the presentation of 3-D facial simulations via the Internet using the virtual reality modeling language (VRML) standard. It is the latter aspect of our research which we describe below.

Materials and Methods

Pending the outcome of research into volume tissue depth data collection from CT/MR and the development of algorithms for its application to "unknown" skulls in forensic cases, we used computerized "virtual images" of plastic reconstructions as equivalents. Plastic reconstructions of typical male and female archaeological skulls, produced using published "obese" and "emaciated" tissue depth data (6), 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). A 360° image of a forensic craniofacial reconstruction produced from a male skull using mean tissue depths (6) was captured with the scanner and the void generated at the apex of the head was filled using the *toupee* command in *Echo.* Scans (180°) of the anterior half of the head were produced from reconstructions of male and female archaeological skulls and cropped at the hair line using the *crop* 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. Low resolution co-ordinate matrices of 40 × 40 were chosen for images of the forensic reconstruction. To enable comparison of images at different resolutions, both 40 × 40 and 151 × 151 matrices and were produced from the archaeological reconstructions. *Open Inventor* (.iv) files were transferred to a Silicon Graphics O_2 workstation running IRIX 6.2 and converted to VRML 2.0 (.wrl) format via VRML 1.0 using IRIX command line data conversion utilities *ivToVRML* and *vrml1ToVrml2,* which are supplied by Silicon Graphics under the Varsity Program licence. The reconstruction of a female archaeological skull produced using the "obese" tissue depth data and represented by 151 × 151 co-ordinates was loaded into *Cosmo Worlds*™, Silicon Graphic's VRML editor, and a point light source was added. The VRML 2.0 files were loaded onto our departmental research Internet site (http://forensic.shef.ac.uk/jfs) for viewing.

Results

Images of female and male facial reconstructions in VRML format loaded onto our departmental Internet site and viewed using *Cosmo Player* are shown in Figs. 1 and 2. The low resolution computerized version of a plastic reconstruction of a forensic male skull and a photographic image of the original are shown for comparison in Fig. 3. Point-lit images of one of the reconstructions are shown with the light source in different positions (Fig. 4).

Discussion

The images produced from male and female archaeological reconstructions illustrate the varying quality of the same image

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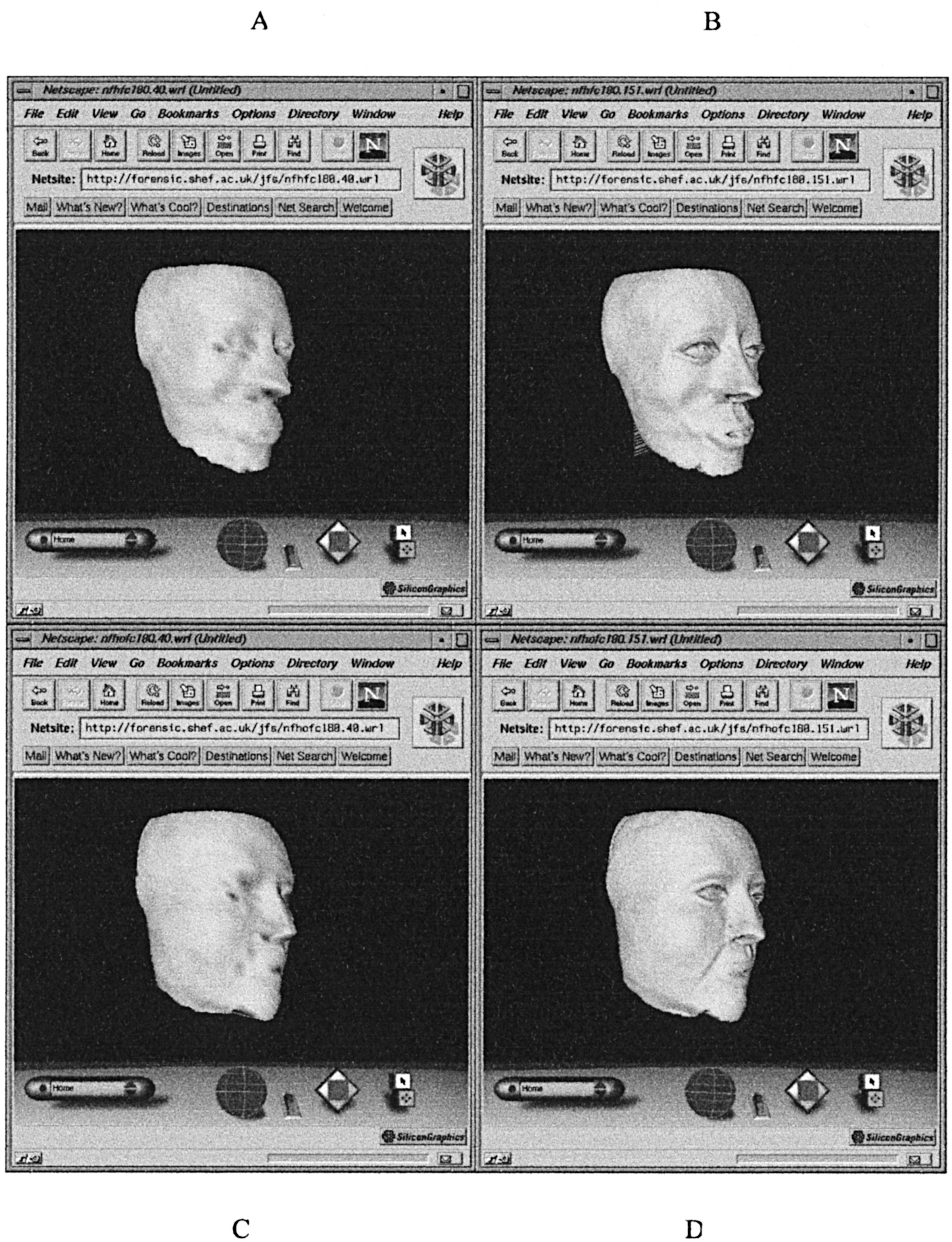
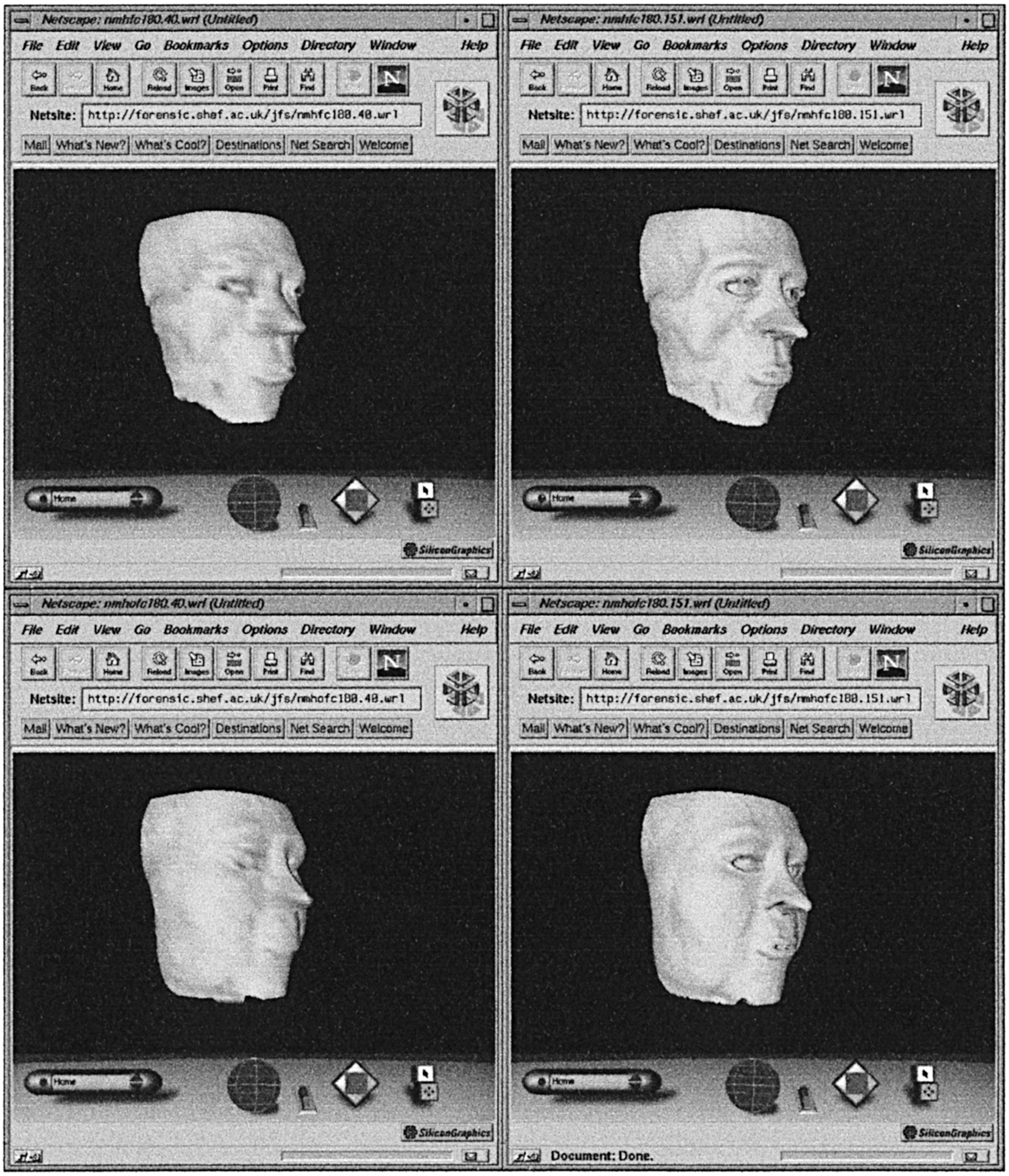


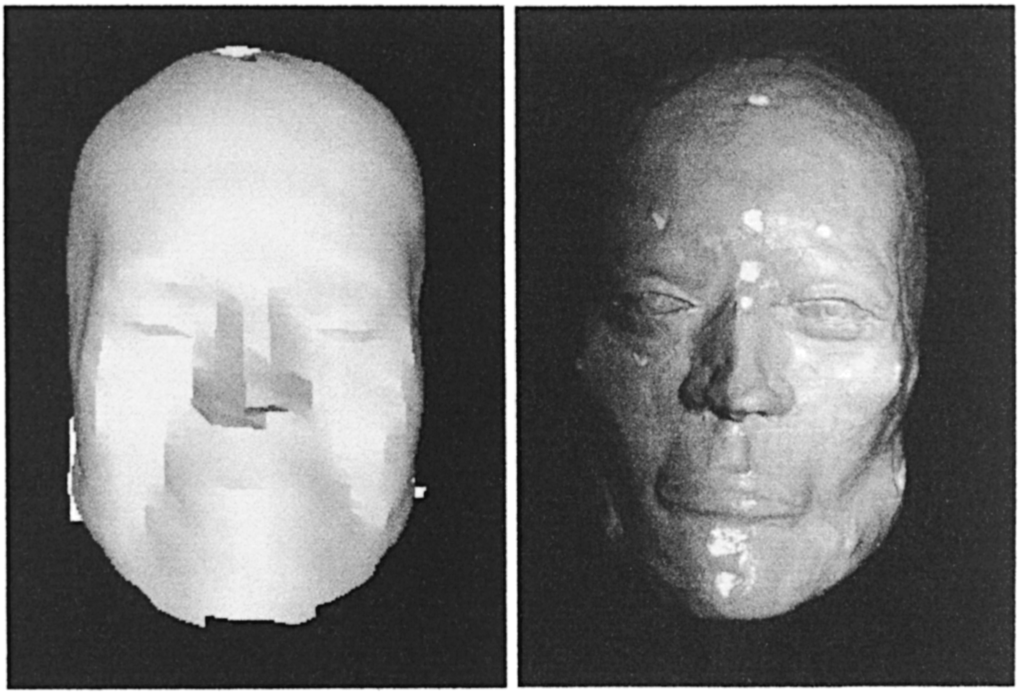
FIG. 1—*Image of a reconstruction of a female archaeological skull produced using:* (a) *the 'emaciated' tissue depth data, represented by 40 × 40 co-ordinates (../nfhfc 180.40.wrl);* (b) *'emaciated' tissue depth data, represented by 151 × 151 co-ordinates (../nfhfc180.151.wrl);* (c) *'obese' tissue depth data, represented by 40 × 40 co-ordinates (../nfhofc180.40.wrl); and* (d) *'obese' tissue depth data, represented by 151 × 151 co-ordinates (../nfhofc180.151.wrl).*

A B



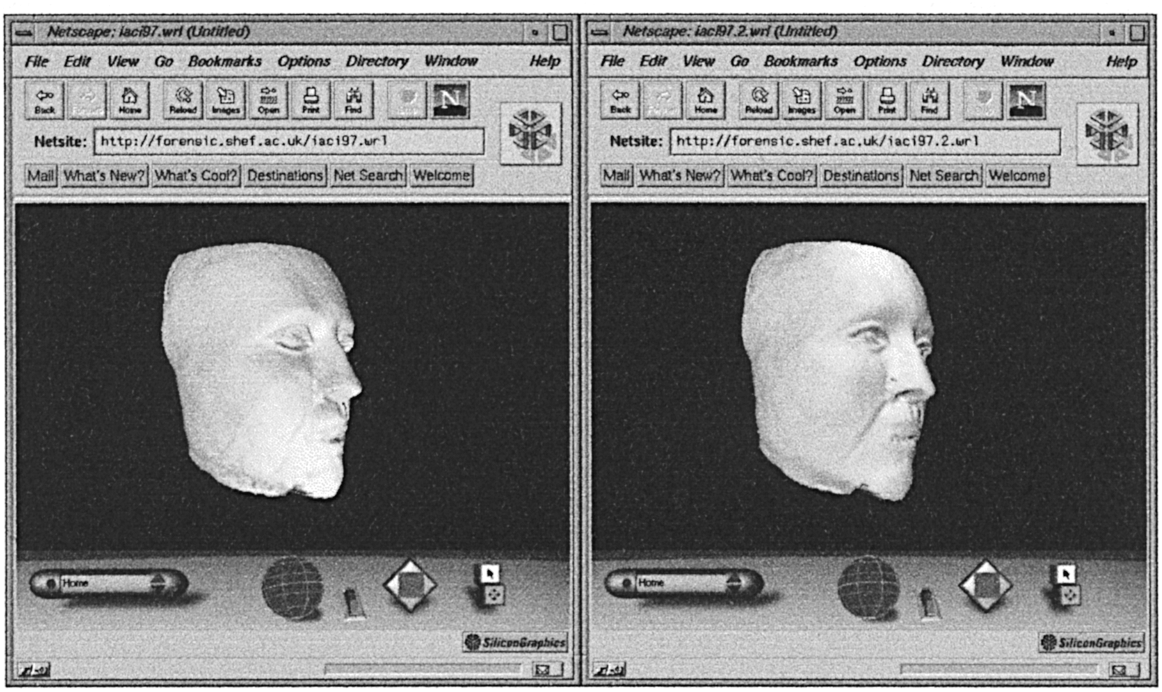
C D

FIG. 2—*Image of a reconstruction of a male archaeological skull produced using:* (a) *the 'emaciated' tissue depth data, represented by 40 × 40 co-ordinates (../nmhfc180.40.wrl);* (b) *the 'emaciated' tissue depth data, represented by 151 × 151 co-ordinates (../nmhfc180.151.wrl);* (c) *the 'obese' tissue depth data, represented by 40 × 40 co-ordinates (../nmhofc180.40.wrl); and* (d) *the 'obese' tissue depth data, represented by 151 × 151 co-ordinates (../nmhofc180.151.wrl).*



A B

FIG. 3—*A reconstruction of a male forensic skull produced using the mean tissue depth data, represented by:* (a) *a 40 × 40 co-ordinate VRML image loaded on the Internet (../plastic____3D.wrl) and a photograph of the original* (b).



A B

FIG. 4—*Image of the reconstruction of a female archaeological skull produced using the 'obese' data with:* (a) *a point light source added (../iaci97.wrl), and* (b) *with the point light source in a different position (../iaci97.2.wrl).*

shown at 40 × 40 and 151 × 151 resolutions. The maximum attainable resolution using our platform in its current configuration is 512 × 512 co-ordinates, but at six megabytes the 151 × 151 image is at present slow to download via the Internet and cannot be browsed smoothly. This may represent the upper limit in resolution for our planned facial reconstruction service via the Internet for the time being. The cost of computing power continues to decrease however and, contrary to our recent statement (3), we believe that collection of craniofacial volume and contour data and associated tissue depth measurements from computed tomography (CT) and magnetic resonance (MR) imaging has become cost effective for forensic purposes.

Existing computer systems for forensic facial reconstruction (1,2) continue to use the *circa* 21 traditional land mark sites as co-ordinates, and the appearance of a high resolution image is achieved by superimposing a composite photographic image derived from photographs of a number of real individuals. In some circumstances, the finished reconstruction can continue to resemble composite image irrespective of the influence of the underlying bone structure.

Using the approach we have presented here, adequate resolution can be achieved while avoiding the use of composite photographic images. The simple monochrome image we produce leaves out potentially misleading details, such as the hair line and style or ear shape, and allows the viewer to impose their own interpretation on the facial reconstruction. The image can be aged or fattened using ‘morphing’ programs. The point-lit images illustrate the influence of different lighting conditions on facial appearance and illustrate how 3-D editors such as *Cosmo Worlds* may be used to enhance the lighting, texture, and presentation of computerized facial reconstructions. The finalized image can be presented via the Internet, downloaded to videotape directly from the O_2 workstation or submitted for stereolithographic reproduction (7).

The Internet offers an additional medium for presenting images to the public which will complement the traditional methods. International round-the-clock accessibility to images is gained, combined with the facility to interact freely with the reconstruction in three dimensions. Use of the Internet will also facilitate an efficient internationally available service for computerized forensic facial reconstruction.

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