Application of Visualized Human Body as a 4D Anatomical Atlas

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1. Introduction

We developed an anatomical atlas of human structures in living condition and their function with 3D and 4D data using computer graphics and a MRI data set of volunteers. We used MRI to obtain a 3D set of morphological data of human's whole body and used ECG-triggered MRI to obtain a 4D set of functional information on cardiac function.

2. Materials and Method

We provide three functions in our 3D and 4D human atlas. We collected data and reconstructed two normal 3D human models from a young male and a young female. By using the 3D image as indicators, we designed a system to access 2D sectional images of the body in optional sectioning planes. We also tried to facilitate the observation of cardiac functions using 4D images obtained by ECG triggered 4D data sets in the thoracic region. And, we wanted to add textural information relevant to the surface anatomy. Information of organ surface obtained at autopsy was stored and mapped on the 3D organ model by identifying anatomical details on the organ surface. We constructed the atlas system on the assumption that the user would employ a high-speed graphic work station for the application of the system, because it requires real-time image manipulation of the 3D human body for rotation and magnification of images and precise delineation of anatomical information.

We used normal volunteers who gave written consent and whose ages ranged from 21 to 25 years. The volunteers were measured with superconductive MRI at 1.5T with a capsule which prevented deformation of the shape of the body surface morphology in the dorsal position in the gantry dome. The capsule was made of plastic foam, rubber and cloth. Capsules was prepared for each volunteer to maintain their own body surface contours. The second small part covered the thorax to prevent deformation. Particularly for the measurement of females, this second part is required to prevent surface contour deformation of the thoracic part. Serial images were made in the axial plane, 4-mm pitch in 4-mm slices, to obtain a 3D data set for the whole body structure of each subject.

3. Results

Fig.1 is a reconstructed image of the 3D data set of a female by the volume rendering method. The image was clipped on the right side in the sagittal sectioning plane at the central part of the body to show the inner structures of reconstructed 3D models. We extracted the contours of the body surface, principal organs and muscles and reconstructed them as surface rendering models in order to manipulate them in real time. Male and female 3D models are constructed with 225600 polygons (male) and 213400 polygons (female). It is possible to rotate or enlarge them at a speed of about 9 to 10 frames/sec. using a high speed workstation, Onyx Reality Engine2 (Silicon graphics Cray Inc.). It is possible to make the part of the body surface structure partially transparent, to observe interest organs underneath by the user's will and each body part such as organs can be individually moved or removed. Fig.1 shows the main menu of the atlas in case a female accessed. The left subwindow is a 3D reconstructed image of a whole body. User is able to rotate, enlarge, and move the image in the x,y and z axes with the bar switches at the lower central part of the menu. Model organs can be visualized with color and texture mapping of there surface anatomy obtained from autopsy data. If surface anatomy is not necessary, the user is able to change the surface texture mapping and color coding with a switch on the mouse. In Fig.2 (a) (b), the organ surfaces of reconstructed 3D images are shown with textures. With this system, it is possible to access the 2D sectioning image of the body by referring to the 3D image. Transparent indication planes that penetrate the body show the locations of the sectioning planes obtained by MRI. Selected MRI images appear in the upper right subwindow of the display. The lower right subwindow shows magnificated MRI images, and the region can be selected on the upper right subwindow with an ROI (region of interest). Every image manipulation is able to perform interactive operations. It is possible to superimpose anatomical names in English and Japanese on each sectioning images.

Fig.3 (a) (b) shows a male model. In Fig. 3 (b), the 3D image on the left subwindow was enlarged to observe the thoracic region, the body surface was made partially transparent, and the organs were also textured in these images.

Fig.4 shows the dynamics of the internal cavities of the heart with 4D imaging. In Fig.5a ,the thoracic region is enlarged to show the heart surface with its anatomical texture. Using the menu, the surface of the heart is able to make transparent. In Fig.5b the inner cavities are visible. Cardiac functions are displayed at a rate of 7 to 10 frames/sec. and the user is able to observe those motions of atriums and ventricles during rotation or enlargement of the 4D reconstructed image.

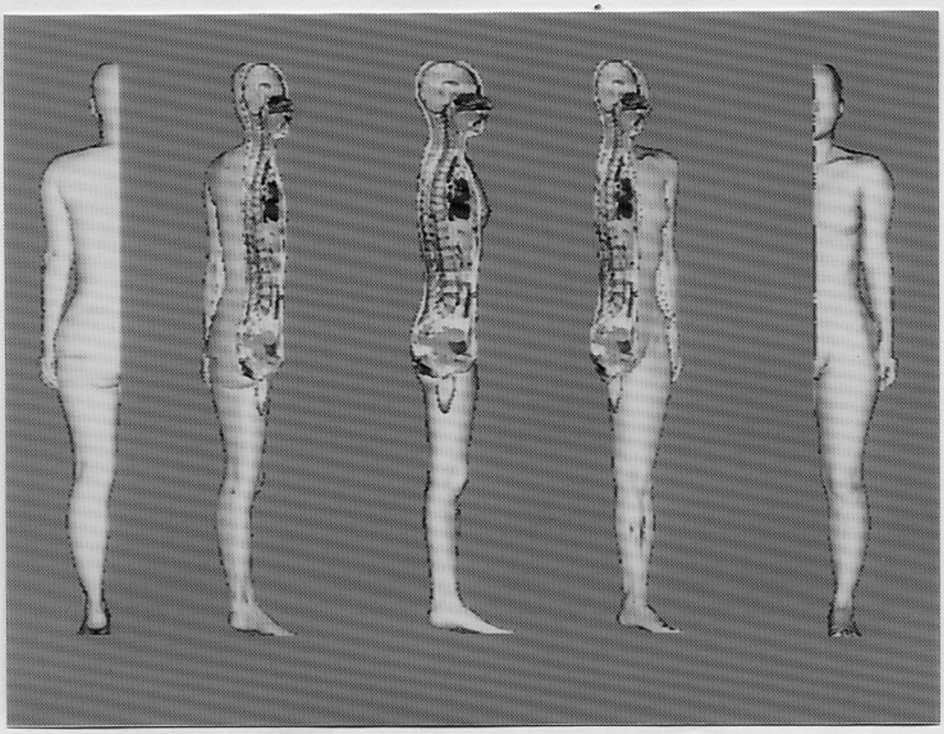
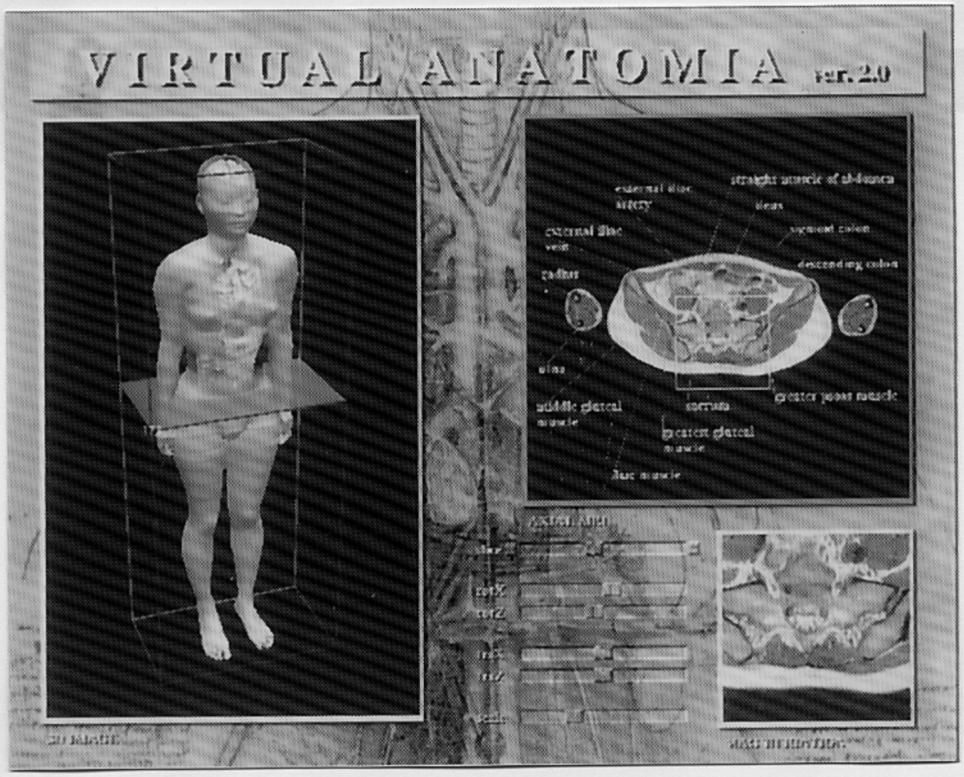
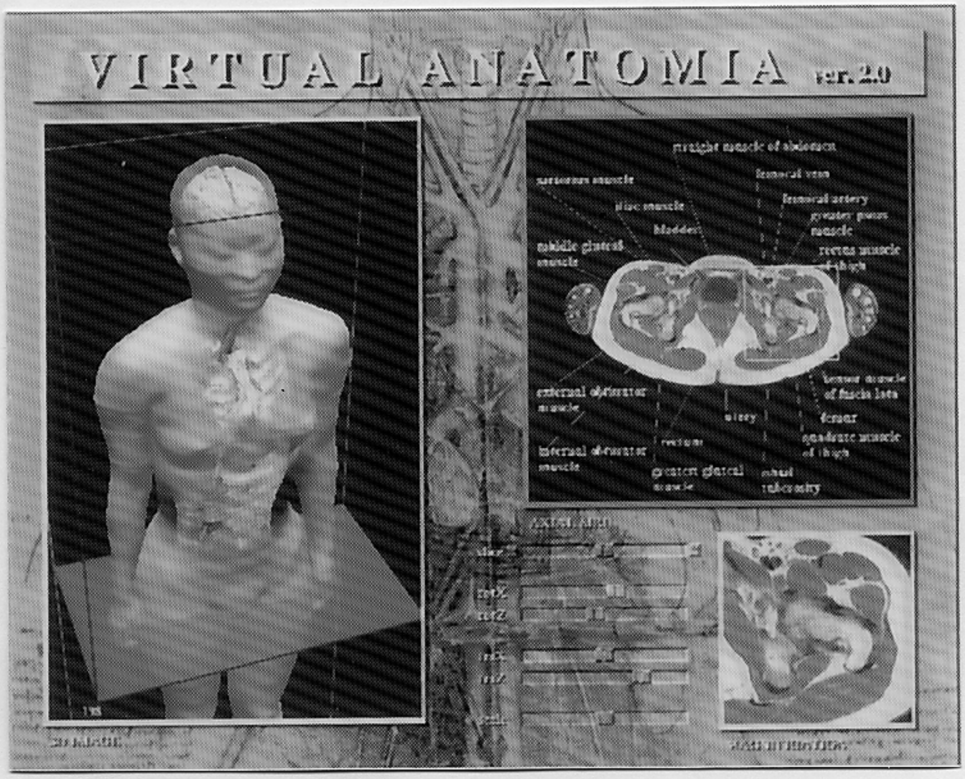


Fig.1. A reconstructed image of the 3D data set of a female by the volume rendering method.

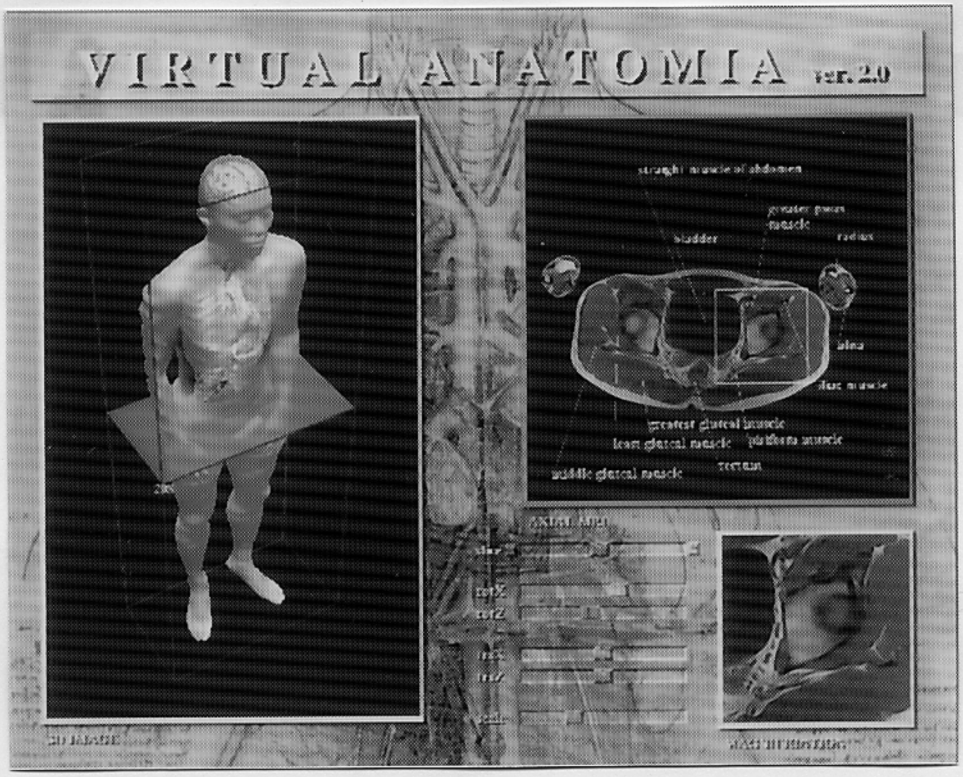


(a)

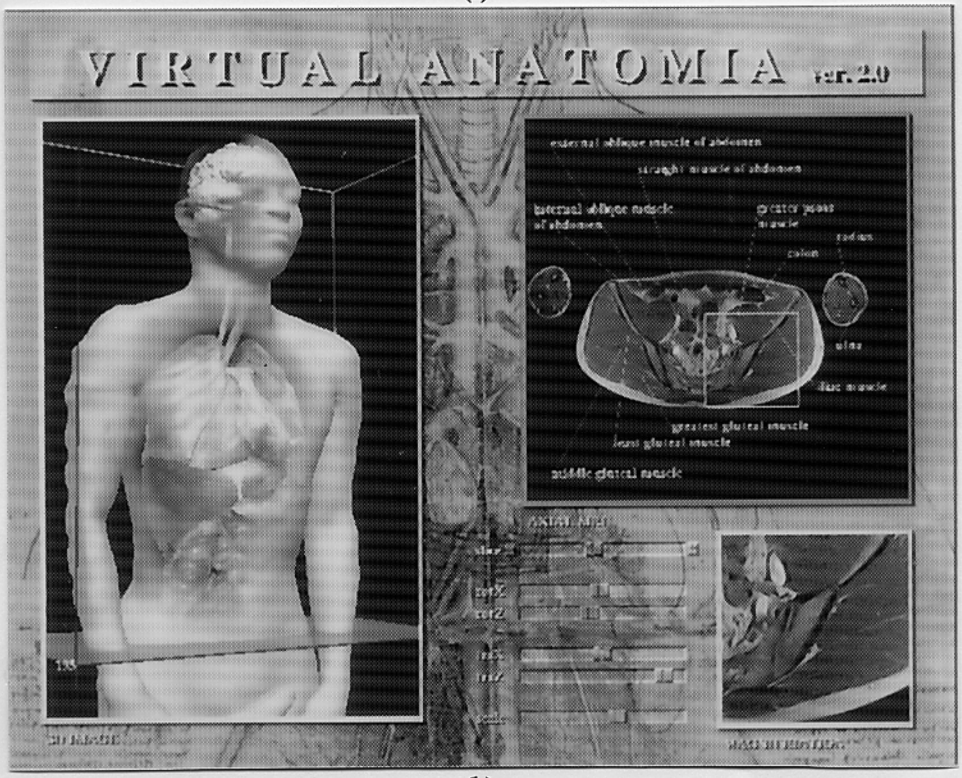


(b)

Fig. 2 (a) (b). Main menu of the atlas in case of a female. Organ surfaces of reconstructed 3D images are shown with textures .

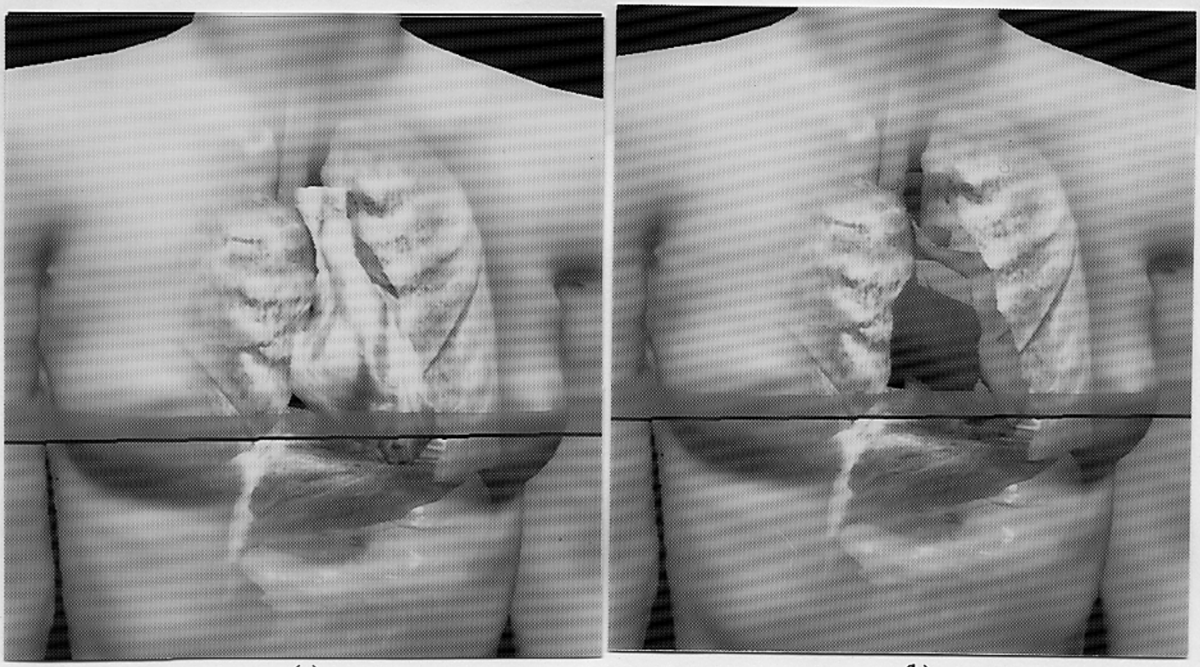


(a)



(b)

Fig.3 (a) (b). Main menu of the atlas in case of a male. In Fig.3(b), the 3D image on the left subwindow was enlarged to observe the thoracic region, the body surface was made partially transparent, and the organs were textured in this image.



(a) (b)

Fig.4. 4D display of the heart. In Fig.4a show the heart with its anatomical texture. In Fig.4b, the surface of the heart is made transparent and the inner cavities are visible in the image.

4. Conclusion

It is possible to point out few advantages of these kind of system during our development of our interactive human atlas. The first is a deeper understanding of the 3D anatomy and the relational locations of individual organs in terms of the structure of the body as a whole. Real-time 3D and 4D image generation allows this information to be obtained quickly, and facilitates and anatomical identification of the location of desired parts in the body. The second is free and rapid selection of 2D sectioning planes by identifying their location on the 3D image. It is possible to select the plane required by freely using 3D model as a reference. The location, 3D shape and volume of organs or muscles should be available in this database of living human. In addition, the 4D images of the four chambers of the heart can be visualized. We are now preparing to distribute this atlas via the internet from the GITI (Global Information and Telecommunication Institute) center which is supported by Waseda University and TAO(Telecommunications Advancement Organization of Japan) in Japan.

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