Development of an e-learning environment for anatomical female pelvic region

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Abstract

Anatomy of female pelvic area is complex and gives a great challenge to medical students. In this study, we present an e-learning environment developed for anatomical female pelvic region based on Chinese Visible Human Datasets. A series of cryo-sectional photographs with corresponding computed tomography and magnetic resonance imaging slices was used to establish an image database aiming to provide two-dimensional anatomical information of pelvic region. Based on image segmentation and contouring, a three-dimensional virtual pelvic floor with associated organs and structures was reconstructed in Javascript, HyperText Markup Language and Virtual Reality Modeling Language, which can offer the feasibility for network-based on-line manipulation. Additionally, an e-learning program derived from instructional videos of interactive operations based on Dextrobeam system was developed for medical students and not only which share the training resources of a virtual reality platform. By designing and implementing such an e-learning environment, the local educational materials and tools can be adapted to meet remote learning objectives as a cost-effective means of facilitating the study of human anatomy and fostering more flexible approaches to improve e-learning performance.
Keywords: *e-learning, pelvic region, human anatomy, virtual reality*

1. Introduction

Network is an extremely powerful tool for the transmission of data and knowledge. With rapid spread of network techniques, e-learning has played a vital role in the field of medical teaching. Utilization of an e-learning methodology may offer significant advantages due to its multimedia character and the possibility of distributing knowledge for worldwide students(1).

Pelvis is an important part of the human skeleton, which is in conjunction with the sacrum and contributes to the stability of body and the protection of organs inside(2,3). The organs, muscles and associated structures involved in the pelvic floor comprise one of the most complex regions of human anatomy. Clear understanding of pelvic region anatomy is crucial for medical students and not only to validate their knowledge into applications, such as gynecologic surgery, radiotherapy and total hip arthroplasty.

Cadaver dissection has been an essential step in the study of human anatomy. However, increasing student enrolments and major availability of cadavers have made it difficult for medical students to access and manipulate cadaver within limited laboratory-training time(4). The digital human body datasets acquired in Chinese Visible Human Datasets (CVHD)(5) project make it possible to meet the specific needs of anatomical training and learning.

The aim of this study was to develop an e-learning environment for anatomical female pelvic region. More exactly, an image database of pelvic region was built upon two-dimensional (2D) transverse sectional photographs from the data resources of CVHD. Following the registration and segmentation of these 2D CVHD slices, a realistic three-dimensional (3D) model of pelvic floor with associated organs and structures was rebuild to facilitate the use of network-based interactive manipulation. Moreover, a video-based program about the interactive operations with Dextrobeam system (Volume Interactions Ltd., Singapore) was also recorded. Using this program, the medical students can also take advantage of the built-up 3D model to learn clinical instructions even when they have no access to the virtual reality (VR) platform. By integrating the above valuable approaches, an e-learning environment was realized, which would be useful for anatomical study and morphometric exploration.

2. Methods

2.1 Data acquisition and preprocessing

Approximately 386 cryo-sectional slices of female pelvic region were selected from CVHD. Each slice contains a 3072×2048 pixel-size, 3.6 MB memory consumption and 0.5 mm of a thickness. The corresponding computed tomography (CT) and magnetic resonance imaging (MRI) datasets were also collected by cadaver scanning and data transmission. All the slices were initially registered with an affine transformation based on the plastic markers.

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A series of organs and structures, including bone, ovary, fallopian tube, uterus, rectum, bladder, femoral head, vagina and urethra, were manually segmented.

2.2 Anatomical image database establishment

All the preprocessed images were collected together to establish an image database as an e-learning resource. In the next step, a detailed slice-level 2D virtual exploration within female pelvic region was implemented by selecting a specific high-resolution slice from the indexed image-list of the database. Further, a CT and MRI slices were also included in the database to provide the radiological knowledge.

2.3 3D Virtual model reconstructions

Considering the fact that 2D illustrations and photographic atlases sometimes may be insufficient for better understanding anatomy in 3D reality, a virtual model of female pelvic region and the interface program to allow remote education by using Virtual Reality Modeling Language (VRML), HyperText Markup Language (HTML) and JavaScript was constructed.

VRML is an international standard for describing 3D shapes and scenery on the World Wide Web, which has very wide applicability for distributed-visualization and interactive simulation(7). The prepared CVHD slices were inserted into Amira system (Visage Imaging Inc.), where 3D polygon surface mesh based on triangles was generated for the corresponding organ or structure of pelvic region. At this stage, the generated 3D digital models were exported as the individual VRML files after refinement and smooth processing.

Only geometrical nodes were preserved in the output VRML files and other nodes were deleted. Each node was defined with several control parameters, such as route, viewpoint and sensor. Parameter transmission and control were achieved by JavaScript programming. The VRML files of each structure were combined together and compressed as a reduced file in zip software applications, used for file compression and decompression. A dynamic modification of the processed VRML files were implemented by means of JavaScript functions into HTML files. As a result, the attributes of VRML models become adjustable and the real-time interactive operations can be further performed.

2.4 Video-based training program generation

It is known that VR platform is an effective tool for medical teaching and simulation. However, it may not be available sometimes or to some students. In order to apply VR technology to student e-learning, a video-based training program was achieved to display the medical manipulations in 3D environment.

Dextrobeam is an interactive console intended for group collaborative discussions with 3D images using a stereoscopic projection system. It includes six-dimensional (6D) controller, 6D styluses, RadioDexter software, high-performance workstation and many more. In this view, we developed a series of instructional videos for clinical skills training based on Dextrobeam system and uploaded them to a common space. The input images of Dextrobeam were collected from the segmented CVHD and they were imported with RadioDexter software. All the images were transformed into the 8-bit format and loaded in Dextrobeam environment and further used it to construct a 3D virtual pelvic floor with the associated organs.

Several operations were performed immersive in the Dextrobeam system with 6D controller and 6D styluses, such as image clipping, bone drilling, volume measurement, 3D object fusion, tissue extraction and contour editing. The procedure of the above operations on the 3D pelvic model was recorded and converted into web-videos in National Television System Committee or Phase Alternative Line format. These video demonstrations were designed to meet the specific objectives, such as surgical direction or brachytherapy pathway.

3. Results

Approximately 386 cross-section slices were obtained from CVHD with high resolution. A rigid registration based on tags was realized and each organ or structure was manually segmented (Figure 1).

A 2D pelvic image database was created, which consisted of cryo-sectional photographs and corresponding MRI and CT slices. Each slice has an individual index number and can be queried from the image list. The database has provided a quick way to examine the entire region of female pelvis slice by slice using 2D axial images (Figure 2).

A 3D virtual pelvic floor with the associated organs was built into VRML, HTML, and Javascript, which affords a stereo representation of morphometric construction. For a better understanding of the spatial relationship of female pelvic region, we offered several manipulation capabilities with mouse and keyboard, such as hide or display organs, zoom in or zoom out and transparency adjustment (Figure 3).

The pelvis model can be turned around in all directions during the virtual operation. Organs and structures can be presented in a more idealized or schematic style by changing viewpoint. Small structures were also included in the 3D model as anatomical landmarks, such as blood vessels.

The segmented cross-section slices of female pelvic region were imported into Dextrobeam system. They were trans-

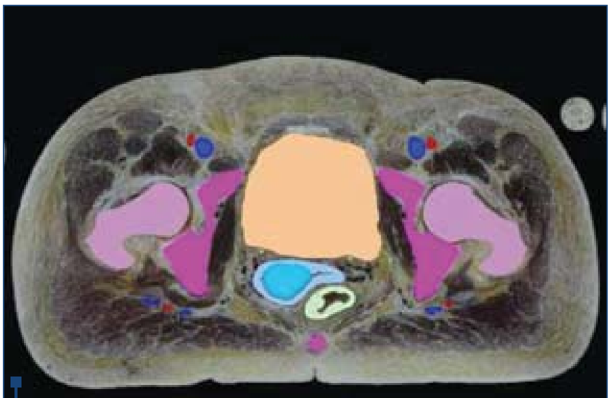

Figure 1

formed into stereoscopic 3D objects and projected onto a computer screen with interaction console. Several operation steps, including clip, drill, 3D fusion, measurement, surface extraction and rendering can be integrated as a procedure and recorded as movies to aid in diagnosis and treatment planning (Figure 4). All the movie reports can be saved and uploaded as web-based videos for e-learning instruction.

4. Discussion

In the present study, an e-learning environment for anatomical female pelvic region was developed. The environment itself bypasses the labor of in-classroom education and furthermore, the underlying methodology and technology are potentially useful for other medical applications.

Female pelvic floor with involved organs is one of the most complicated parts of human body[8,9]. The anatomical knowledge of this area is critical for understanding pelvic floor dysfunction and performs orthopedic and gynecologic surgery.

It is not surprising that network is a significant communication technology for telemedicine and tele-care, respectively[10]. Fast growing penetration of the Internet and wireless technology has a strong impact on all fields

Figure 2

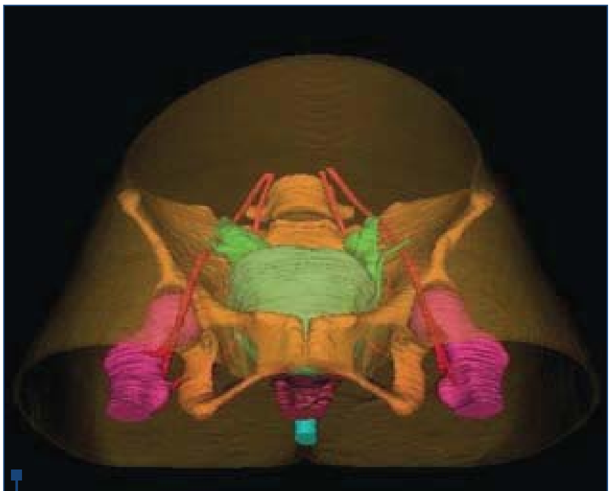

Figure 4

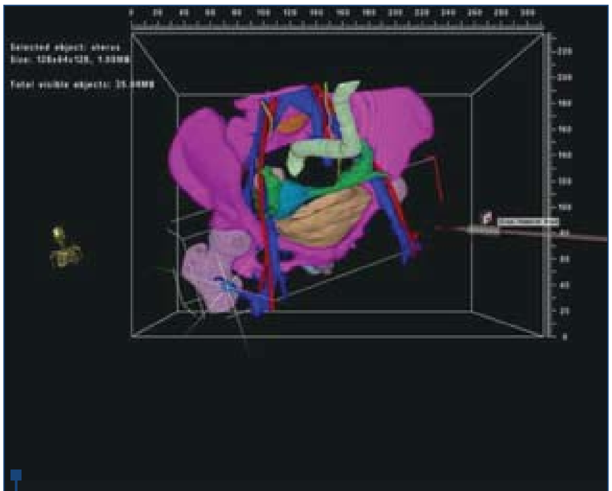

Figure 5

of the medicine, including medical education[11]. Many virtual systems only give only separate 2D slices or 3D models only. In the present study, accurate 2D images and realistic 3D objects were integrated in a framework based on CVH datasets for further processing and manipulation. Particular resolution of cross section image from CVH datasets and careful segmentation may offer high-quality outcomes for substantial objectives, especially for those small structures that are difficult to distinguish in pelvic region[12].

Future work includes the integration of more communication techniques and VR manipulations. Less experienced students would benefit more from the remote consultation and demonstrative operation. More extensively, the informative display incorporated with VR simulation would be very helpful for medical students and residents, specialists and researchers (i.e. in the fields of biomechanics, radiotherapy and sports medicine).

5. Conclusion

An e-learning environment of female pelvic region has been established for long distance education, which has great potentials to improve the learning and teaching performance. The successful 3D display and detailed slice-level exploration would be helpful for medical students and not only.

By designing and implementing such an e-learning environment, the local educational materials and tools can be adapted to meet remote learning objectives as a cost-effective means of facilitating the study of human anatomy and fostering more flexible approaches to improve e-learning performance. ■

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