An Ultra-high Definition and Interactive Simulator for Human Dissection in Anatomic Learning

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Keywords: Human Anatomy Learning, Dissection, Simulation, Ultra-high Definition, Real Bodies Models.

Abstract: This paper presents an ultra-high definition simulator for the teaching of human anatomy in class. The simulator in question consists of hardware and software specially developed for this purpose. The hardware seeks to meet the requirements of real-scale representation of models, visual acuity, color, texture, depth perception e touch-based interactivity. The software, in turn, offers a set of dissecting tools typically used in anatomical studies, in addition to allowing connectivity to educational environments and the Internet. The characteristic that stands out most in this simulator is the fact that it is not an anatomical atlas, but a dissecting table that uses models from real bodies, which differentiates it from most of the simulators and anatomical atlases developed to this end.

1 INTRODUCTION

In almost all courses related to life sciences, especially those related to health such as medicine, nursing, physiotherapy, dentistry, and others, required the study of human anatomy. The consensus among anatomy teachers is that there is currently no replica, book, or 3D computational tool to replace the direct manipulation of a real human body. Some features, such as color, depth, texture, anatomical position, and detail, are essential for comprehensive learning. It is also unanimous among anatomy teachers that the corpse is as close as we can have to a living human being, even though in dead tissues we cannot observe some properties. As an example, it is possible to cite the cerebral activities, vascularisation, heartbeats, among others. According to the literature (Ghosh, 2015) (Shaikh, 2015) (Singh A.K. and D.M., 2011), the manipulation of corpses opens the discussion of three main aspects. The first one concerns ethical issues since many of unclaimed bodies come from donations and are made by forensic laboratories or simple purchase when the law of the country allows. The second one concerns health issues. Toxic chemical, such as formaldehyde, is the main component used in the preservation of bodies and parts. It makes the anatomy laboratories unhealthy environments and inappropriate for teaching and learning. The third one is the quality of learning. The permanent manipulations of the bodies makes them not suitable for teaching and learning in a short time.

Over the point of view of clinical and surgical procedures, we can observe the increased use of the non-invasive procedure, whose supporting instrument is the images made from cameras coupled to surgical instruments or from CT (Computerised Tomography) and MR (Magnetic Resonance) exams. Procedures such as laparoscopy, endoscopy, and surgeries guided by neuronavigation have become the most viable solutions for the reduction of the risks of postoperative infection and the rapid recovery of the patient.

Given the current scenario, researchers all over the world have been efforts in finding solutions to minimize the use of cadavers in the teaching of anatomy and surgical practices. Among another kind of simulation, the digital models have been showing promise. There are some excellent examples, such as the Anatomage table[1] a high-quality artistic atlas. However, Ackerman (Ackerman, 1998) and Azer (Azer and Azer, 2016) asserts there are some reasons

[1]Anatomage - https://www.anatomage.com/table6/

Brongel, A., Brobouski, W., Pierin, L., Gomes, C., Almeida, M. and Justino, E.
An Ultra-high Definition and Interactive Simulator for Human Dissection in Anatomic Learning.
DOI: 10.5220/0007707102840291
In *Proceedings of the 11th International Conference on Computer Supported Education (CSEDU 2019)*, pages 284-291
ISBN: 978-989-758-367-4

to restrict the use of this kind of atlas. Among other things, the diversity of structures found in nature that is a limiting factor, according to them, because it is difficult to replicate in computational models still in the present day. Moreover, it is almost complicated for a graphic artist to map all the nuances of the human body.

Based on the last discussion, this paper presents an ultra-high definition simulator for the teaching of human anatomy in class. The simulator consists of hardware and software specially developed for this purpose. The device seeks to meet the requirements of high-quality representation of models, visual acuity, color, texture, depth perception e touch-based interactivity. The application (App), in turn, offers a set of dissecting tools typically used in anatomical studies, in addition to allowing connectivity to educational environments and the Internet. The characteristic that stands out most in this simulator is the fact that it is not an anatomical atlas, but a dissecting table that may perform almost all operations that can be executed in a real necropsy table, which differentiates it from most of the digital anatomical atlases developed to this end. To simulate a necropsy table, we adopted the same format for the interactive table. However, the hardware supports two additional projectors with the same hardware features.

Five sections make up this paper. The first section is this introduction. The second section presents the material used to make the simulator. The third section contains the method used for building the software of the simulator. The fourth section presents the results. Finally, the last section presents a conclusion and future works.

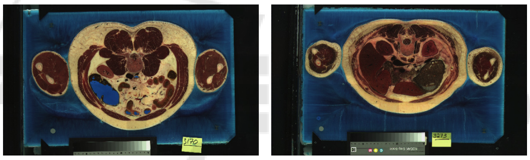
2 MATERIAL

We divided the materials used on the simulator into two groups. The first one belongs to the software and is made up of the database. The database is the most relevant material for the characterization of the simulator since it must have its origin in real human bodies and not coming from artistic models. The second group belongs to the hardware. The hardware must meet the usability requirements in anatomy classes, be dynamic and have a user-friendly interface.

2.1 Data Base

In the last four decades, several databases of real human bodies have emerged, whose objective was to create a digital database of human bodies, both masculine and feminine, for educational and research purposes. The first database started in the 1990s by Michael J. Ackerman of the US National Library of Medicine became known as The Visible Human Body Project (VHP)(Ackerman, 2002) (Spitzer and Whitlock, 1998). Other databases came later, like Korean (Park et al., 2005) and Chinese (Chen et al., 2018) , all using the same cryosection process. However, only the VHP database became public and available for the development of new applications under an agreement with the US National Library of Medicine. The other databases are private.

The VHP database consists of a 1mm thick sliced male body, photographed on 70mm colored films and then scanned in 2k (2048 x 1216 pixels) and 4k (4096 x 2700 pixels) resolution, totaling 1871 sections. In addition to the anatomical images, the X-ray, Computed Tomography and Magnetic Resonance complete the set. The female body has the same characteristics as the male corpse, with one exception. The intervals used in the anatomical images were 0.33 mm instead of 1.0 mm. The female set results in more than 5,000 anatomical images. In Figure 1, we can see a sample of the male and female database.



(a) (b)

Figure 1: Database samples: (a) Male criosection, (b) Female criosection.

2.2 Interactive Table

The use of interactive screen has been growing significantly in recent years with the advent of the multitouch screens. This kind of screen allows complex interactions with the user. Two crucial factors were taken into account to determine the sizing of the table and therefore the dimensioning of the screen. The first one was the screen size. The screen should contain the body of a human with approximately 1.70m. This feature would ensure the representation of the organs of the human body in the standard scale (1:1). The second is the screen resolution. The screen in question should also support resolutions up to 4k. The high resolution would guarantee the visual acuity necessary for anatomy studies. Another relevant factor is the application server, which should support the manipulation of a high volume of data from the image databases. The interactive table was designed and built following the usability parameters in the laboratory for a student group and the teacher. Figure 2 shows the large screen interactive table.

Figure 2: The large screen interactive table.

3 METHOD

The method used to create the simulator took into account two constructive aspects. The first one dealt with the adequacy of 2k images databases of the female and male corpses, to be used by the simulator. The choice of resolution in 2k was due to the maintenance of the body's near from the natural scale, one of the first prerequisites of the project. The second took care of the interactivity and the user interface, to make the interface user-friendly.

The choice of VHP occurred because it is a database of public domain and the existence of both sexes, the masculine and the feminine. Another important aspect is in the fact that they are images of real bodies in ultra-high definition 2k and 4k. Since its making in the 1990s, numerous works have been developed using the VHP database images (Ackerman, 2002) (Spitzer and Whitlock, 1998), many of them resulted and simulators for different purposes such as endoscopy (Pflesser et al., 2001). However, due to the byte size of the 2k and 4k databases, the generation of synthetic or rendered models was the most adopted solution. Even with current technology, it is necessary to use powerful game support computational resources to manipulate such bases in their original form, and this has become the great challenge of this project (the last generation of microprocessor, high memory capacity, solid state disk, and others). Another aspect to be highlighted is the resolution of the images. Rendered models adapt to the display capabilities, making it easy to create and manipulate 3D models. Only a few years ago the technology of GPUs or Video Graphics Cards started to support the resolution in 4k and have memory capabilities and speed to allow the processing of the VHP base in its original form. Based on that features we build the interactive table hardware. Therefore, for this project, the VHP database was chosen in 2k resolution. The chosen resolution allows for the maintenance of the original scale of the slices of cryosection images and the FULLHD (1920 x 1080 pixels) projection of the volumetric visualization model. Figure 3 shows an example.

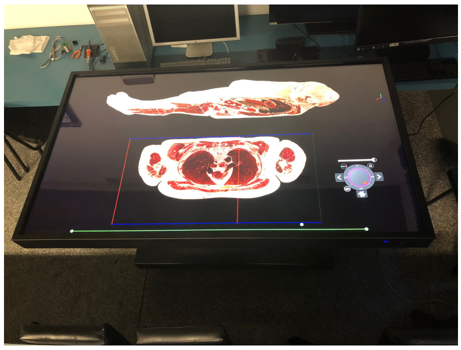


Figure 3: An Exemple of the 2k (slice) and FULLHD projection (volumetric projection).

3.1 Database Pre-processing

In the pre-processing of the database, we applied a classification algorithm based on the SVM (Support Vector Machine) (Wang et al., 2012) (Tsai et al., 2006) for the removal of the blue background (ice) that covered the external part of the bodies and some internal areas. In Figure 1 it is possible to see such areas. We apply four different classifiers for the complete removal the ice over the skin, one for each four different body regions. We do not use any post-processing.

3.2 Screen Interface

Figure 4 shows the different simulator manipulation capabilities. We divided the screen area into two subareas. The first contains the anatomical projection planes chosen for the visualization (coronal in blue, axial in green and sagittal in red), following the didactic perception in the anatomy study. Each plane allows navigation between the slices of the body in a thickness of 0.33 mm (for the female body) and 1 mm (for the male body) (Figure 5, Figure 6, and Figure 7). This navigation also allows adjusting the other two planes in a cut position, in order to enable the visualization of the three cuts in the volumetric model, in perspective (Figure 4). The second subarea is able the projection of the volumetric model in perspective (Figure 4). The model can undergo several geometric transformations, such as the rotation in the axis of the current anatomical plane of cut, inversion from the point of view of the body (volumetric model in perspective, Figure 8), adjustment of the transparency (Figure 9), stereoscopic visualization for depth perception (Figure 10), among other resources .

3.3 Stereoscopy

The ability to perceive and interact with the structure of space is one of the fundamental goals of the visual system. Two retinal images are different because the retinas are in slightly different places. Stereopsis is the ability to use binocular disparity as a cue to depth. The stereoscopy is the technic used to create the stereopsis by devices. There are two kinds of stereoscopy applicable to digital devices. The first and oldest technic is the anaglyphic. In this kind, two images create the stereo pair, one in red and the other in cyan. To view the effect anaglyphic glasses must be used. The second is the polarized stereoscopy. Its use is more recent, having a wide range of applications, such as 3D TV's, 3D cinema and 3D projectors. There are two kinds of technics of polarization, the linear and the circular. In both cases, we must use polarized glasses (Daly et al., 2011).

The use of stereoscopy in medical applications has been growing in recent years (Livatino et al., 2015) (van Beurden et al., 2009). In the simulator, we used anaglyphic stereoscopy initially, in order to evaluate its performance at the table. Although the results are promising, as seen in the projection of the body of Figure 10, its use will be more effective in the visualization of the inner organs, whose segmentation process is in progress.

3.4 Interface Objects

The simulator has a graphical interface managed by an Interface Object called Draggable DIAL (virtual mouse that concentrates the manipulation tools of the volumetric model of the bodies such as rotation Figure 11(f), perspective Figure 11(e), and transparency Figure 11(a). It also has rotating menu functionality for selecting anatomical pieces available in a library, and also an option for selecting a type of tissue to be viewed and manipulated from the selected anatomical piece, Figure 12. It has too a push button (on/off) for enabling stereoscopic visualization features (with anaglyph glasses), Figure 11(b). A push button (on/off) for visualization of the 2D cut in the bodies volumetric model, Figure 11(e). A push button (lock/unlock) the touchscreen to avoid unwanted touch, Figure 11(c). A push button (on/off) for enabling the slices viewer in the volumetric model, Figure 11(d). A button for activating active blackboard functions (pens, markers, rubber, save screen, and colors), Figure 13(c) and Figure 14. A button for activating the browser for Internet search, 13(b). Finally, a button for activating accessibility to the Online Education Platforms (OEP), 13(a). In addition to the DIAL, the simulator has a second control area for the manipulation of the cuts (1mm slices of the male body or 0.33mm of the female body). This area has sliding bars of the three anatomical planes (axial, coronal and sagittal), for each cut of the plane in highlighted. The displacement of those bars in the 2D visualization allows the same cut in the volumetric model. It should note that such planes orthogonal to the body can adjust to any angle by merely shifting the bar of the plane to the desired angular position.

3.5 Reproductive System

As already mentioned in previous sessions, the simulator has two bodies, one male, and one female. The sex selection is in an initial screen of the simulator, or later, through the rotating menu of the DIAL. The different sexes allow the anatomy teachers to explore, along with the students, the anatomical differences of both sexes, as well as to present in detail the reproductive apparatus. The use of real body models provides biological data that could not be observed in synthetic models, such as the influence of hormones, testosterone, and progesterone, on the formation, growth, and aging of organs. In Figures 15 and 16 we can see both male and female sex respectively.

3.6 Imaging Exams

As seen in the sessions where we described the VHP database, it has two kinds of set of the imaging exams. The first set is the computed tomography (CT) images and the second set is the magnetic resonance (MR) imaging . The male database consists of axial MR images of the head and neck taken at 4mm intervals and longitudinal sections of the rest of the body also at 4mm intervals. The resolution of the MR images is 256 pixels by 256 pixels, in grayscale. The MR imaging database consists of three acquisition modes, T1, T2, and Proton Density Image (PD). CT data are taken in the axial plane of computed tomography of the whole body taken at intervals of 1mm at a resolution of 512 pixels by 512 pixels in grayscale. The female corpse data set has the same characteristics as the male corpse, with one exception. Axial anatomical images were obtained at intervals of 0.33 mm instead of 1.0 mm intervals. As seen, CT and MR images can provide important educational resources for studying and practice in imaging exams analysis. The

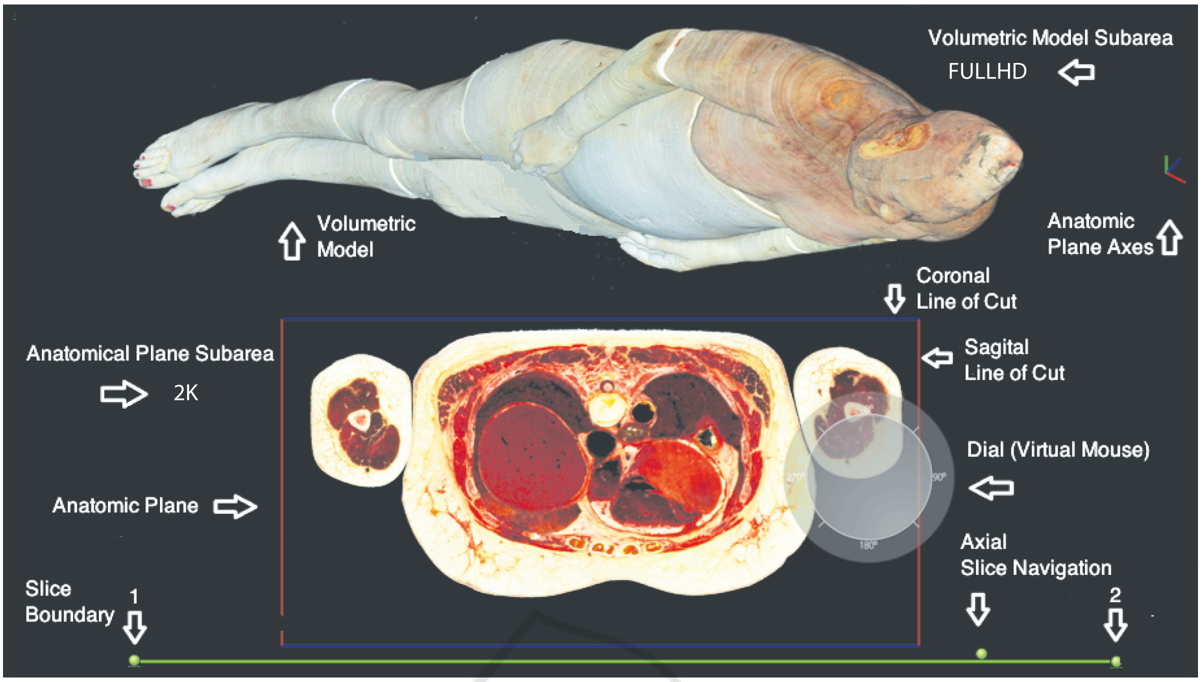


Figure 4: The Interactive Simulator Interface.

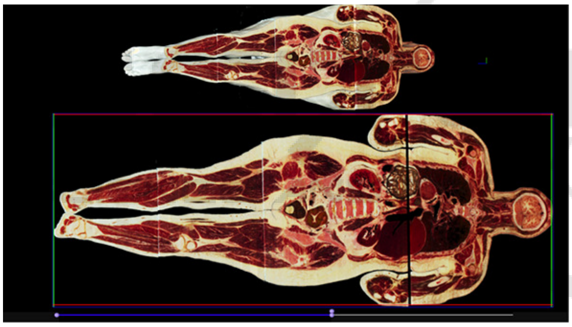


Figure 5: Adjustable coronal plane view mode.

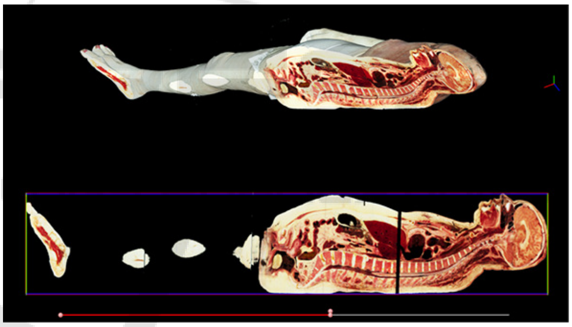


Figure 7: Adjustable sagittal plane view mode.

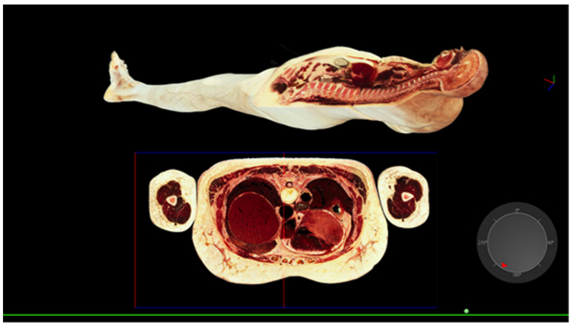


Figure 6: Adjustable axial plane view mode.

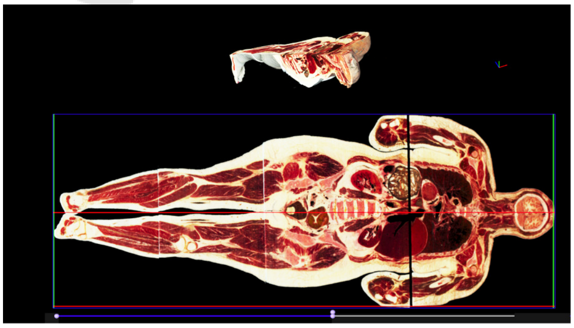


Figure 8: Adjustable perspective view mode.

simulator offers teachers and students the possibility of associating each CT and MR image with the correlated anatomical cut of the body and the volumetric model. In this way, the student can observe the exams, such as in real practice, and relating it to the body. Figures 17, 18 and 19 show an example of a slice, the CT and MR (T1, T2, and PD) images.

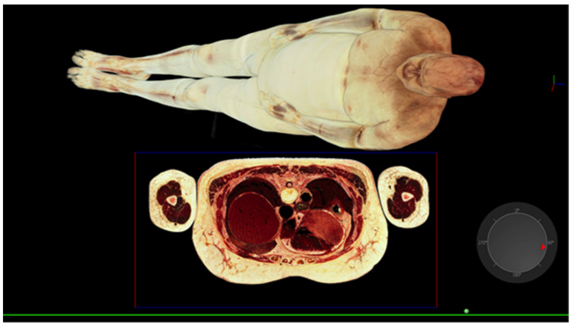


Figure 9: Adjustable transparency view mode.

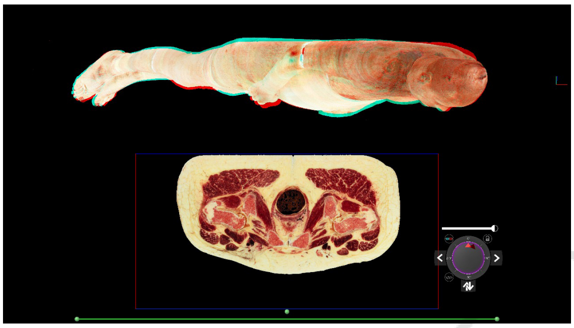


Figure 10: The full body in stereoscopic view (Anaglyph Stereoscopy).

Figure 11: The draggable dial in volumetric model tools.

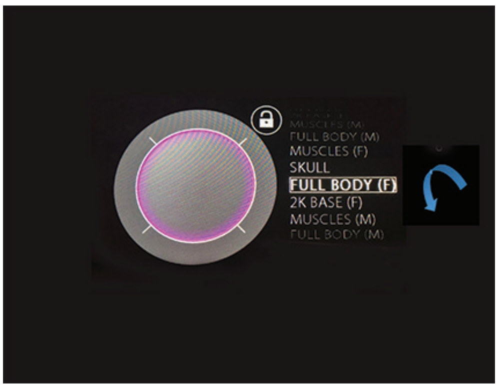


Figure 12: The draggable dial in circular menu library.

Figure 13: The draggable dial in eduction tools.

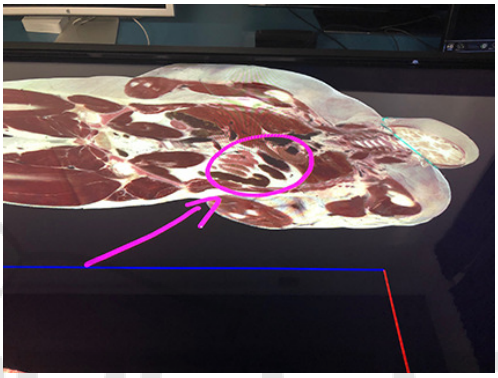


Figure 14: An exemple of the Active Blackboard.

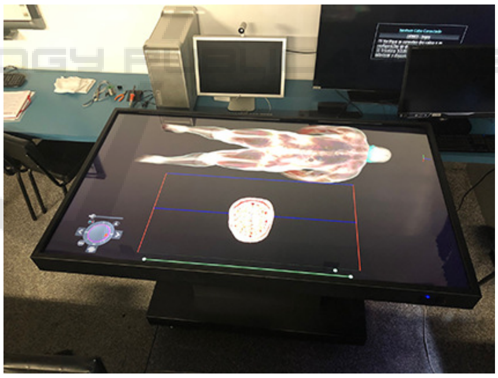


Figure 15: Male.

4 CONCLUSIONS

This paper presented an ultra-high definition simulator, now called The Visible Human Table (VHT)[2], for the dissection and teaching of the human anatomy in the classroom. The differential to other anatomical atlases and simulators are in the use of real body images in ultra-high resolution and non-synthetic body

[2]The VHT Project: https://www.youtube.com/watch?v=yZ-rDkC4UXY

Figure 16: Female.

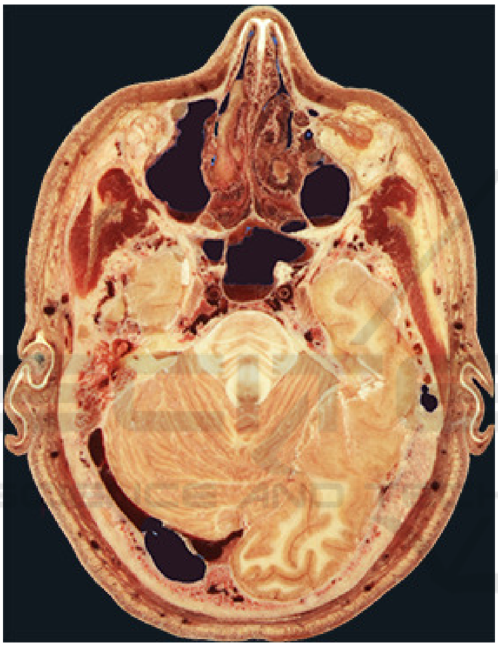
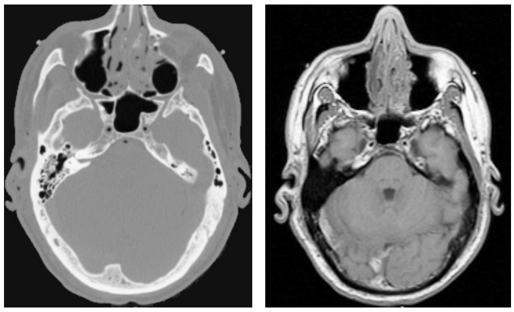


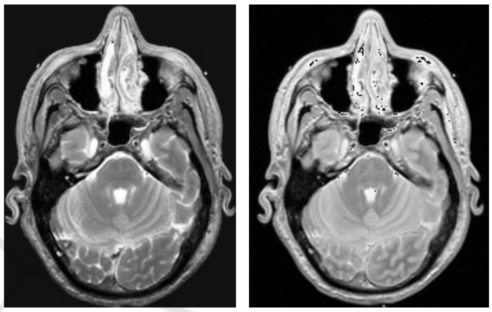
Figure 17: Male: anatomic image.

models which gives it visual acuity, scale compliance with real human organs, texture, color, and depth perception. Another positive aspect is the diversity of sex. From teaching and learning, the simulator complies with the precepts used in the study of anatomy, that is, respecting the anatomical planes of cutting, volumetric visualization, and dynamics in the dissection process. Another essential element that characterizes it as a learning tool is the availability of the imaging exams associated with the anatomical images in cuts, the connectivity with resources of the Online education platform and the active blackboard. As future work, we are planing the inclusion of new ultra-high-definition segmentations of tissues of specific organs, such as the skeleton, muscles, circulatory system, among others. We intend to include the X-ray exams set, from de VHP databases, in to the simulation and support for reading DICOM[3] standard.



(a) (b)

Figure 18: Database samples: (a) TC image, (b) MR image T1.



(a) (b)

Figure 19: Database samples: (a) MR image T2, (b) MR image PD.

ACKNOWLEDGEMENTS

We want to thank the US National Library of Medicine for providing us the databases of The Visible Human Body Project (www.nlm.nih.gov/reseach/visible/), without which this project would not become possible. The Voxel-Man for providing the database of segmented inner organs (Voxel-Man, www.voxel-man.com), which is assisting us in the process of ultra-high definition segmentation of the two bodies. To the Financiadora de Estudos e Projetos - FINEP for the financial support for the development of this project. Also, to the Center of Innovation in Medical Imaging of the PUCPR (CIIM) for the technical and laboratory support.

[3]The Digital Imaging and Communications in Medicine (DICOM) is a standard for handling, storing, printing, and transmitting information in medical imaging.

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