VR Tool for Interaction with the Abdomen Anatomy

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Abstract. Due to ethical issues with the use of human and animal corpses in medical education, difficulty interacting with organs using sensory channels as sight and touch, and the possibility to have a tool compatible with low-cost equipment such as laptops and Novint Falcon haptic system, an interactive tool of the abdominal organs is being developed taking advantage of virtual reality tools that are increasingly available in the academic environment. The process of building this interactive system consists of the following steps: Source data are taken from images acquired by abdominal computed tomography (CT) or magnetic resonance imaging (MRI). Each selected abdominal organ (liver, kidney and spleen) is segmented by a semi-automatic process, from which a polygonal mesh is obtained to represent the 3D shape of the organ. Then the visual and mechanical properties of tissues, extracted from the recent literature, are associated to the polygonal representation with H3DAPI.

Keywords: H3DAPI, Haptic, Novint Falcon, Organ palpation, Simulation, Soft tissues.

1 Introduction

Every day is more complex to use human and animal corpses to learn anatomy. Ethical and legal aspects, besides the increase in the number of people that requires this kind of knowledge, has made that the use of appropriate academic methodologies for the teaching-learning process becomes more difficult. Thus, alternative methods are required to facilitate teaching and to approach the students to highly accurate, interactive computer models to have the same or similar results that are obtained with traditional methods.

Taking advantage of virtual reality tools that are increasingly available in the academic environment, an interactive tool of the abdominal organs is being developed. This library facilitates for medical students the learning process of anatomical structures, permitting to interact with the models in an affordable way, expanding the landscape that provides library resources and virtual applications currently available [1].

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2 Methodology

The process of building this interactive system consists of the following steps: Data acquisition of medical images, abdominal organs segmentation and 3D surface construction, and the integration to a visuo-haptic an interactive system.

2.1 Data Acquisition

Source data are taken from images acquired by abdominal computed tomography (CT) or magnetic resonance imaging (MRI).

2.2 Surface Delimitation

The liver, kidneys and spleen were segmented by a semi-automatic process, first the organ is selected as shown in Fig. 1(a), then, the organ is delimited in each image from the dataset shown in Fig. 1(b). Finally the segmentation organ is obtained as it can be seen in Fig1(c).

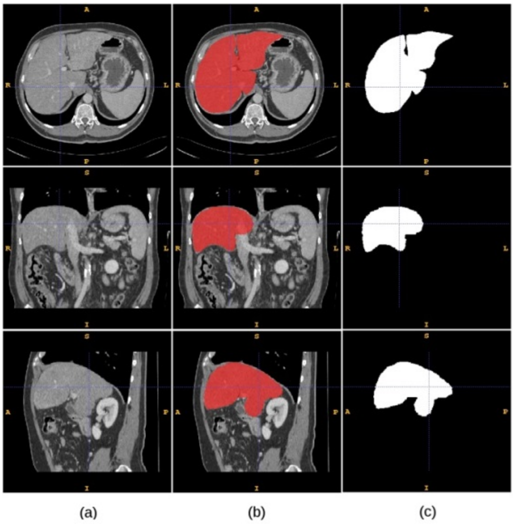

Fig. 1. Liver segmentation process using CT images

2.3 3D Surface Construction

After the segmentation is obtained, the next procedure is to construct a 3D closed surface using the algorithms based on Delaunay Triangulation [2]. This surface will behave as a solid because it does not have spaces or holes in it.

2.4 Haptic Interaction

After obtaining the 3D surface of the liver, spleen and right and left kidneys they are imported to H3DAPI[1] as shown in Fig. 2. There, the material properties of the surfaces as color, stiffness, damping, can be modified.

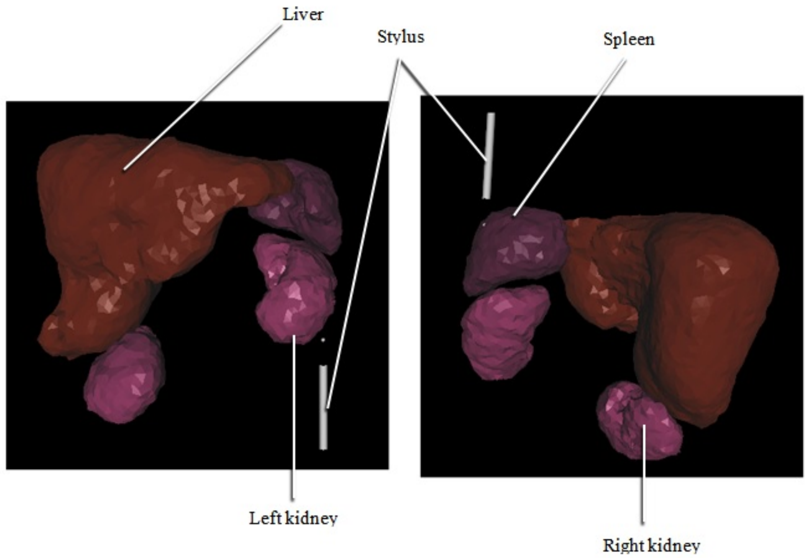

Fig. 2. Organs in H3DAPI

Then, the user is capable of feeling each one of the organs with the Novint Falcon Haptic Device. This permits the user to experience the shape, texture, stiffness, damping among others characteristics, in the simulated organ.

A basic spring-mass-damper model (Fig 3) were used to describe the behavior of a soft tissue and the interaction with the Novint Falcon. The model parameters were defined considering the experimental information of *in vivo* and *ex vivo* organs developed by Kerdok [3] and Rosen [4].

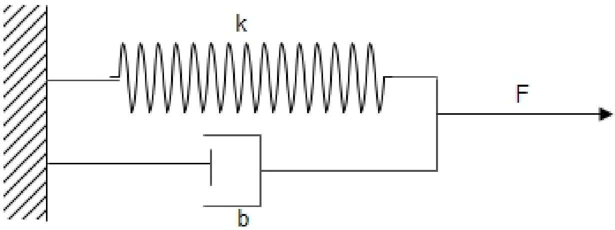

Fig. 3. Spring-mass-damper visco-elastic model

[1] http://www.h3dapi.org/

The model is represented by the equation (1)

$$F = F_s + F_d = kx + bv \tag{1}$$

Where F is the total force, F_s is the spring force, F_d is the damper force, k is the stiffness constant, x is the displacement, b is the damping constant and v is the velocity.

From (1) the parameters can be obtained to modify the material in H3DAPI, through the stress, strain and velocity extracted from the Kerdok and Rosen, the approximate constants of stiffness and damping are found.

$$\frac{F}{A} = \frac{F_s}{A} + \frac{F_d}{A} = Ee + \frac{bv}{A} \tag{2}$$

$$\sigma = \sigma_s + \sigma_d = Ee + \frac{bv}{A} \tag{3}$$

Where E is the Young's Modulus, e is the strain, σ_s and σ_d are the spring and damper stresses. The stiffness constant and the damping constant were found trough the stress-strain relations obtained from literature.

3 Results

An application was developed where the liver, spleen and kidneys were included using CT scans with resolution of 512x512x388 voxels and size of 0.58 x 0.58 x 1 mm. Each constructed mesh has different characteristics as shown in Table 1.

Table 1. Mesh description

Organ	Vertices	Polygons
Liver	2556	5108
Spleen	760	1516
Right kidney	596	1188
Left kidney	560	1114

It was necessary to make a scale to perceive the different textures according to the Novint Falcon characteristics, for this scale were used compact bone and oil parameters as the maximum value.

In this scenario the user can feel the stiffness and shape from these organs, besides seeing them and their spatial location between them, complementing this way the apprentice experience as shown in Fig.4.

Fig. 4. Interaction system

4 Discussion

The Novint Falcon performance is suitable for shape, size and spatial location recognition by the user but is not a proper device for small displacements and forces because of its small dynamic range, which is why in some occasions the user cannot feel the proper feedback when touching the surface from any meshed organ. Also the Novint Falcon can be replaced by other haptic devices as the Sensable Phantom Omni[2] or Entact Robotics W5D[3] with more degrees of freedom and dynamic range that permits small displacements, force feedback and realism but increasing the cost of the overall system.

As a future work, another organs as stomach, small intestine, large intestine and bladder will be included in the same way to complete the abdomen anatomy.

References

1. Primal Pictures Anatomy TV, `http://www.primalpictures.com`
2. Tibamoso, G., Perez-Gutierrez, B., Uribe-Quevedo, A.: 3D Liver Volume Reconstructed for Palpation Training. Studies Health Technology and Informatics 184, 450–452 (2013)
3. Kerdok, A.: Characterizing the Nonlinear Mechanical Response of Liver to Surgical Manipulation. Harvard University (2006)
4. Rosen, J., Brown, J.D., De, S., Sinanan, M., Hannaford, B.: Biomechanical Properties of Abdominal Organs In Vivo and Postmortem Under Compression Loads. Journal of Biomechanical Engineering 130 (2008)

[2] http://www.sensable.com/haptic-phantom-omni.htm

[3] http://www.entactrobotics.com/index.php/w5d-specifications