14. Aulisa L, Tamburrelli F, Padua R, et al. Carpal tunnel syndrome: indication for surgical treatment based on electrophysiologic study. *J Hand Surg (Am)* 1998;23(4):687–691.

15. Jablecki CK, et al. Literature review of the usefulness of nerve conduction studies and electromyography for the evaluation of patients with carpal tunnel syndrome. *Muscle Nerve* 1993;16:1392–1414.

16. Grundberg AB. Carpal tunnel decompression in spite of normal electromyography. *J Hand Surg (Am)* 1983;8(3):348–349.

UTILIZAREA DE SOFTWARE GRATUIT ÎN RECONSTRUCȚIE ANATOMICĂ 3D

Octavian Ciobanu[1], Anatolie Taran[2], Eugeniu Gaponenco[3], Liliana Florea[4]

1. Universitatea de Medicină şi Farmacie "Gr. T. Popa", Iaşi, România (oct.ciobanu@gmail.com)
2. Catedra Ortopedie şi Traumatologie USMF "Nicolae Testemițanu" Chişinău, Moldova
3. Catedra Chirurgie 2 USMF "Nicolae Testemițanu", Chişinău, Moldova
4. Catedra Chirurgie 1 USMF "Nicolae Testemițanu", Chişinău, Moldova

Summary

The use of free software in 3D anatomic reconstruction

The paper deals with creation of three-dimensional (3D) models for anatomic tissues surfaces. Medical imaging technology (Computed tomography) and free (open source) software were used to obtain digitized 2D images of sections of bone, to segment the tissues of interest from the surrounding tissues and to create 3D reconstruction from the segmented structures. This study demonstrates the applicability and feasibility of open source software developed in our days for the 3D reconstruction of anatomic tissues. The use of open source software may improve the efficiency of investments in medical technologies for implants and prosthesis fabrication which need specialized software for reconstruction of bone materials

Rezumat

Această lucrare prezintă crearea modelelor trei-dimensionale (3D) a suprafețelor anatomice tisulare. Tehnologia imagisticii medicale (Tomografia Computerizată) şi software-ul liber (open source) au fost utilizate pentru a obține imagini 2D digitale din secțiuni de os, la segmentul de țesuturi de interes din țesuturile înconjurătoare şi pentru a crea o reconstrucție 3D din structurile segmentate. Acest studiu demonstrează aplicabilitatea şi fezabilitatea de software open source dezvoltat în zilele noastre pentru reconstrucția 3D a țesuturilor anatomice. Utilizarea de programe libere poate îmbunătăți eficiența investițiilor în tehnologii medicale pentru fabricare de implanturi şi proteze, care au nevoie de software specializat pentru reconstrucția materialelor osoase

Introduction

Anatomic tissue reconstruction is used in biomedical applications for preparation of surgical activities, for precise measurements of bone details, for implant and prosthesis preparation and customization and for implant and prosthesis conception and fabrication.

The use of free software in a country like Moldova reflects an alternative strategy for building, maintaining and changing the rules that govern information flows in the economy. A lot of specialists in informatics show that free software strategy will create value through the key ways of business opportunities, reduced investment cost and greater efficiency and effectiveness of government.

The main objective of *open source software* or *free software* is to let the programs to be more accessible, modifiable, understandable and still marketable. According to marketing specialists, free software does not exclude commercial use. "Free" word from free software is referring to freedom and not to price. The term free software was replaced by *open source* software which is considered more acceptable and less ambiguous for the software producers. The last definition was adapted and published for the first time in 1997 and shows that the user has the freedoms to:

- run the program, for any purpose ;
- redistribute copies so you can help your neighbor;
- study how the program works and adapt it to your needs ;
- improve the program, and release your improvements to the public, so that the whole community benefits .

The freedom to run the program means the freedom for any person or organization to use it on any kind of computer system, for any kind of job and purpose, without being required to communicate about it with the developer or any other specific entity. Free software can be translated "software libre" in Spanish, "software libero" in Italian "logiciels libre" in French and “programe libere” in Romanian.

Recently, the European Commission is promoting free software and intends to buy more of its computer software from open-source developers [1, 2]. This action is a potential setback for Microsoft, the world's largest software producer. The company is trying to prevent an increasing number of defections by governments from its proprietary software toward software from open-source developers. The action comes as the commission pursues two new antitrust cases against Microsoft.

The Dutch government announced in September 2007 that it would favor free software when purchasing desktop software. State administration from Singapore stopped using Microsoft's Office software in 2004 and some organizations from Munich have decided to use the Linux-based operating system rather than Microsoft's Windows program. Adoption of *free software* is extensive all around the world. Following these trends, the paper presents some details in using the free software In Vesalius, for 3D reconstruction of anatomic tissues.

Method

The 3D reconstruction of bone materials starting from CTs can be performed in three characteristic ways:

- using dedicated licensed software for 3D reconstruction (like Mimics or 3D doctor etc);
- using CAD licensed software with 3D reconstruction facilities (Solid Works, AutoCAD etc);
- using open source software with free license (In Vesalius, ADOR 3D etc)

Steps in processing graphic reconstruction with open source software

In order to reconstruct a 3D anatomic surface starting from CT images there are 5 main steps:

- preparing 2D images of slices obtained from CT in order to obtain images in a suitable format
(DICOM format or bmp format)
- introducing the 2D images in the software;
- performing the segmentation or contouring all images with a special line;
- performing the transformation from 2D to 3D;
- saving the final 3D image in a specific format.

2. 1 Processing the 2D images of slices

Usually CT images produced by a CT are "stacks", a series of images in DICOM format. But DICOM is not suitable for all 3D reconstruction software and sometimes the format must be changed. There are some useful software in changing the image formats:

1. The DICOM Works software can change DICOM formats to BMP, TIFF, WMF, JPEG and others;
2. The ImageJ software can change DICOM formats to BMP, TIFF, JPEG GIF and others.It supports "stacks", a series of images that share a single window. It is multithreaded, so

time-consuming operations such as image file reading can be performed in parallel with other operations.

Changing of formats can be done by opening the DICOM files and saving them in the necessary format. Considering the use of the In Vesalius free software in the next processing steps, the format must be DICOM.

2.2 Introducing the 2D images in the software

In the In Vesalius software, the introduction of images of slices can be performed using File and New commands. The New command will start a new reconstruction. After entering the New command, a new window will start (Fig. 1), and user must select the directory and the files containing the DICOM images displayed in the upper left corner of window.

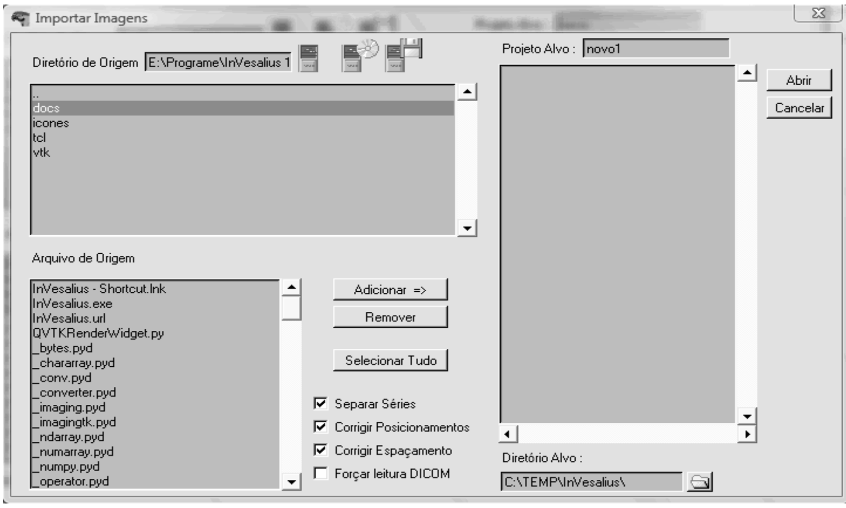

Fig. 1 The In Vesalius window of for importing the DICOM images

If selected images are in DICOM format, after a click on their file, images will fill the upper central part of window. Clicking the Import slices button will bring all images in the central part of window and some of them in the right side like in Fig. 2.

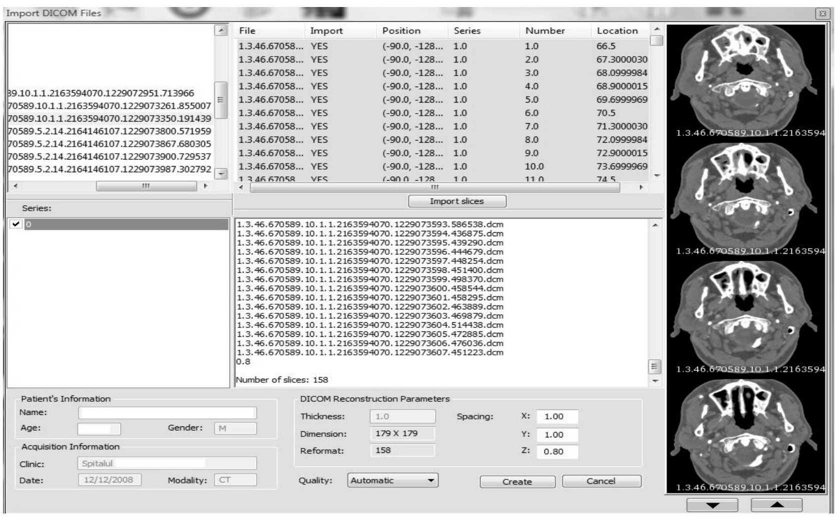

Fig.2 The In Vesalius window after importing DICOM images

2.3 Performing the transformation from 2D to 3D

Transformation process consists of assembling 2D images to form a 3D image. Before assembling, all images must be contoured (segmentation process).

User must click on Create button (Fig. 2) and to wait for the processing of images (creation of a coarse 3D model). After processing, a new window will appear (Fig. 3) and user may register the name of the project or of the 3D reconstruction using File and Save commands.

The new window contains different buttons for visualization, segmentation, modifications and for the 3D model exporting. The coarse 3D model is displayed in the main part of window and is interactive. User can apply different transformations on the 3D object by rotating and zooming, pointing and clicking the image with the mouse.

Software may perform segmentation in order to obtain a smoother 3D model. User has to choose Segmentation button and a new name in the Model box and finally to press Create model for the next step. A smooth 3D surface model will appear according to threshold settings.

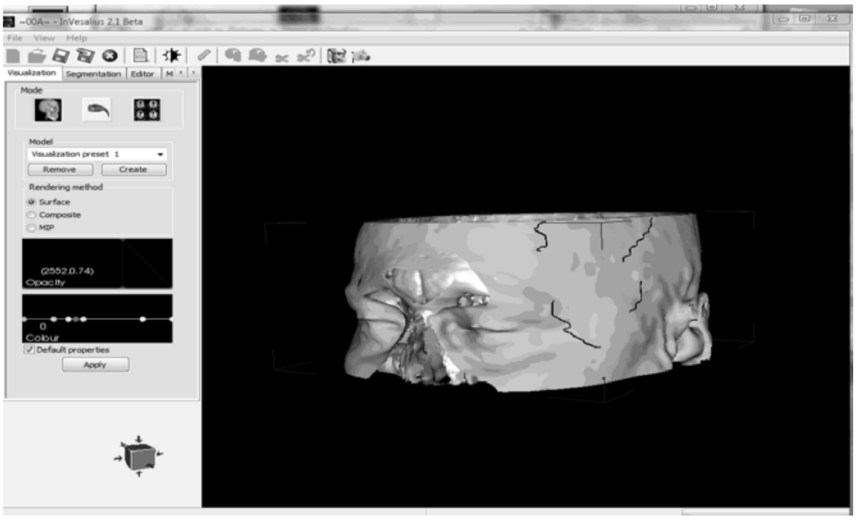

Fig.3 Transformation window

User may examine the 3D image (Surface button) and may choose new values for the threshold in order to visualize certain tissues and details or in order to measure distances. Different other commands permit rendering and modifications.

2.4 Saving and exporting the final 3D image

The new 3D model can be exported using Models button then Export 3D Surface button (Fig.4). After pressing Export 3D button, a new window will permit to save the 3D smooth model in WRML, OBJ and STL formats.

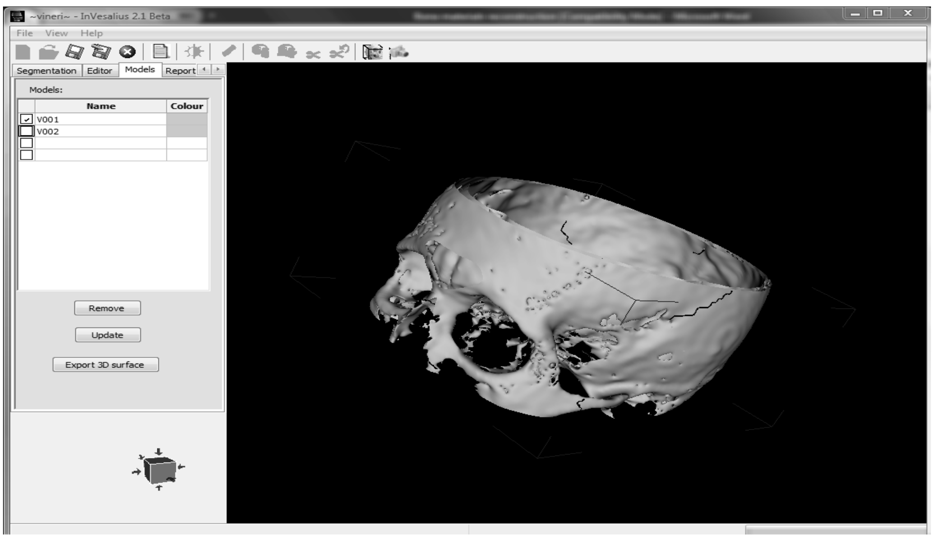

Fig. 4 Window for 3D image exporting

Discussion

Free software like In Vesalius, ADOR 3D, Freeform etc have a lot of necessary functions in the reconstruction of bone materials and tissues starting from CT slices. Presented steps show a smooth and accurate 3D reconstruction. The quality of reconstruction is equal to commercial software. The main advantage of these software is the price and frequently they are free. Equivalent commercial software with same functions are often offered for high prices between 5000 and 15000 Euro. In order take advantage of this situation, The European Commission is promoting open-source software and invites the European institutions to buy software from open-source developers. A lot of recent scientific papers are signaling the advantages of this type of software [1,2,3,4,5,6]. Today, lower budgets will force organizations to reassess their investments, and to try to optimize their development projects. This should have the result of favoring low cost solutions and in particular, the development of open source applications. Developing countries as Brazil, China, India etc. are implementing a strong industrial and public policy around open source applications so as to reduce the digital divide that separates them from rich countries. According to some analysts [7], free software could represent from 26 to 32% of software and IT services investment by 2012.

Conclusions

The free software assures the following advantages:

- very consistent reduction of software investment expenses;
- open source software licenses grant rights to users which would otherwise be prohibited by copyright; the license shall not require a royalty or other fee for such sale;
- the license shall not restrict any party from selling or giving away the software as a component of an aggregate software distribution containing programs from several different sources;
- can be used to develop custom medical imaging applications and biomechanical simulations which require little or no programming skills.

In medical domains such as surgery, orthopedics, prosthetics, free software facilitates technology transfer and will enable the development of virtual reality applications. In domains which are highly critical for public sector, companies and citizens, such as safety, security and privacy, the development of open source resources should be considered as strategic.

Public schools, universities and institutions should encourage academic research and to collaborate and develop these critical technologies.

References

1. Ciobanu O., *The use of a Computer Aided Design (CAD) environment in 3D reconstruction of anatomic surfaces*, Stud Health Technol Inform., 119, pp.:102-4, 2006
2. Ciobanu O., Staat M., Rahimi A., *The use of open source software in biomechanical finite elements analysis*, Bul. I.P.I. tom LIV (LVIII), fasc. X, pp. 213-220, 2008
3. Ciobanu O., *Reconstructia grafica a suprafetelor anatomice.* Revista medico-chirurgicala, vol. 108, Nr.4, ISSN 0048-7848, pp.920-923, 2004
4. Bercovici M., Lele S.K., Santiago J.G., *Open source simulation tool for electrophoretic stacking, focusing, and separation.* Journal of Chromatografy. A. Dec 14, 2008.
5. Caban J.J., Joshi A., Nagy P., *Rapid Development of Medical Imaging Tools with Open-Source Libraries*, Journal of Digital Imaging, Vol 20, Suppl 1, pp 83-93, 2007
6. Massaut J., Reper P., *Open source electronic health record and patient data management system for intensive care*. Stud Health Technol Inform., 141, pp.:139-45, 2008.
7. http://www.openworldobservatory.org/download/owf_roadmap_20020.pdf.