3D Thermal Medical Image Visualization Tool: Integration between MRI and Thermographic Images

Mauren Abreu de Souza, André Augusto Chagas Paz, Ionildo José Sanches, Percy Nohama and Humberto Remigio Gamba, *IEEE Member*

Abstract— **Three-dimensional medical image reconstruction using different images modalities require registration techniques that are, in general, based on the stacking of 2D MRI/CT images slices. In this way, the integration of two different imaging modalities: anatomical (MRI/CT) and physiological information (infrared image), to generate a 3D thermal model, is a new methodology still under development. This paper presents a 3D THERMO interface that provides flexibility for the 3D visualization: it incorporates the DICOM parameters; different color scale palettes at the final 3D model; 3D visualization at different planes of sections; and a filtering option that provides better image visualization. To summarize, the 3D thermographc medical image visualization provides a realistic and precise medical tool. The merging of two different imaging modalities allows better quality and more fidelity, especially for medical applications in which the temperature changes are clinically significant.**

I. Introduction

A variety of biomedical applications demands a proper representation of the object being reconstructed for the 3D visualization. In the case of tomographic planes, such as those obtained from medical imaging systems, e.g. Magnetic Resonance Imaging (MRI) or X-ray Computer Tomography (CT), the 3D volume is obtained by stacking up the 2D images.

Infrared (IR) imaging is a 2D, noninvasive diagnostic technique that allows the examiner to evaluate and quantify changes on skin surface temperature.

The development of 3D image registration algorithms applied for the fusion of different imaging modalities are becoming important tools for helping medical diagnosis.

The proposed 3D THERMO methodology [1, 2, 3] unifies two different medical images: MRI/CT and thermographic images. The result is a hybrid three-dimensional model that provides a new concept for 3D visualization. This 3D THERMO model combines internally the slices of the MRI/CT images with the external functional information coming from the infrared images surrounding such model. The challenge is to generate a three-dimensional model from bidimensional images of both MRI/CT and infrared images.

Research supported by CAPES Foundation - Brazil.

M. A. de Souza, A. A. C. Paz, I. J. Sanches, H. R. Gamba and P. Nohama are with Graduate School on Electrical Engineering (CPGEI), Federal University of Technology (UTFPR), Av. Sete de Setembro 3165, CEP 80230-901, Curitiba, PR - Brazil (phone: +55-41-3310-4836; fax: +55-41-3310-4683; e-mail: mauren.abreu.souza@gmail.com).

To provide the image fusion, of the MRI/CT with the thermal images, four different 2D image projection planes (range images [4]) are used: frontal or 0º; left lateral or 90º; posterior or 180º and right lateral or 270º. Based on these 2D projection images, it is possible to register such images with the correspondent thermal images (obtained from the same view angle).

The affine registration of both imaging modalities generates a 3D model containing both: anatomical (MRI/CT) and functional information (infrared images).

This paper focuses on presenting several different improvements for displaying the final 3D models. For this purpose, some additional 3D visualization resources were included. Originally, it was applied a volumetric visualization based only on displaying 3D points or voxels. Although, now it is presented the image visualization based on a surface rendering for generating a 3D triangular mesh, which can be displayed at different planes of sections (axial, coronal and sagittal).

II. Methodology

The proposed 3D visualization tool comprises: the DICOM reading parameters, required for 3D reconstruction (*pixel spacing* and *spacing between slices*); different palettes at the final 3D model; creation of a polygonal (triangular) well known format file (called PLY); and 3D visualization at other planes of sections, with interpolated image slices. The key significance about these tools is to provide better image quality and more assurance for medical inspection and diagnosis.

The thermographic images were acquired using a FLIR ThermaCam A320 camera, resolution 320 x 240 pixels, thermal resolution 0.1° C. The MRI images were acquired with a Siemens Avanto System 1.5T.

A. DICOM Parameters

Most of the digital medical imaging systems (e.g. MRI or CT) are stored in the DICOM (Digital Imaging and Communication in Medicine) format [5].

In order to perform the 3D reconstruction with the tomographic planes, or cross sections, it is necessary to know the system acquisition parameters. This leads us to obtain the following physical parameters in the DICOM format file header: *"Pixel Spacing"* and *"Spacing between Slices"*:

- ***Pixel Spacing***: In the tomographic plane, it represents the physical distance between the centers of adjacent pixels. This attribute defines the real size of the pixel and make it possible to determine the real object dimensions.
- ***Spacing between Slices*****:** It gives the distance between two adjacent slices (perpendicular to the image plane). Depending on the image system protocol that is employed, the distance between slices may vary significantly. The gap between the slices is an image protocol parameter that is set before image acquisition.

Those parameters are provided in millimeters.

B. PLY File Format

In this work, the PLY file format, also known as Polygon File Format or Stanford Triangle Format, was selected to store the graphics data, i.e., the reconstructed three-dimensional data.

The PLY is text file format that describes 3D graphics objects that are a collection of polygons. In our case, these polygons are triangles. Those triangles generate a triangular mesh that includes, apart from the 3D geometry, the colors, texture and transparency of the model. These characteristics are essential for the inclusion of thermal imaging information that is superimposed around the 3D anatomical model (obtained from the MRI/CT image slices).

PLY file is visualized with different graphical applications, for instance MeshLab: http://meshlab.sourceforge.net. However, with MeshLab it is possible to visualize only the external surface, i.e. the thermal shell surrounding the 3D model. While employing the 3D THERMO interface, there is the differential of visualizing both the internal anatomical information (MRI/CT image slices) and the external surface temperature.

C. 3D VISUALIZATION

Some medical image protocols, especially those sequences used for body members, such as hands, arms, knees and feet, the *"spacing between slices"* has several millimeters separation. Therefore, for the 3D image reconstruction there is a gap of information between consecutive slices. In order to fill this gap and have a 3D model with the correct height, the adjacent slices were replicated and a smoothing mean filter was applied.

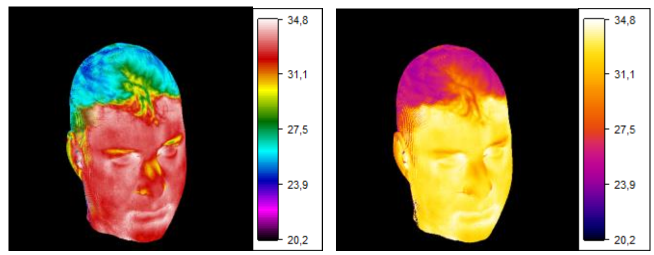
The visualization of the 3D thermal models was implemented using the OpenGL Library [6]. Once we build up a 3D model, additional details can be visualized in the other planes of sections, i.e. coronal and sagittal (apart from the original axial cross section).

III. RESULTS

The results are based on the visualization of real volunteers' image data. The items below represent the improvements and changes that were implemented in order to provide a more realistic 3D visualization of the final model.

- **Palettes**

The surface temperature of the 3D thermal model can be visualized using different pseudo-colors palettes. In addition, it is possible to change the color scale of the palettes to fit the best visualization, depending on each medical application. To illustrate, Figure 1 shows the 3D THERMO model of a volunteer, displayed using two different palettes.

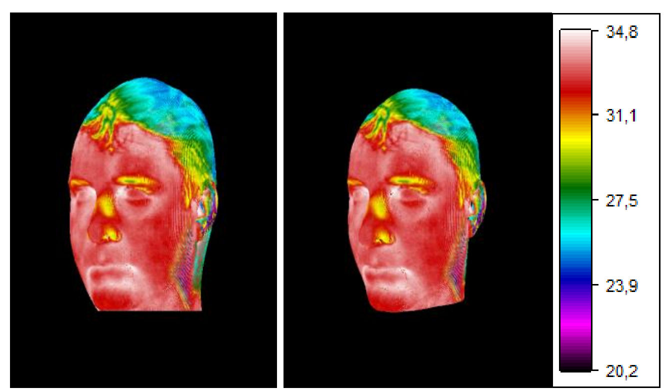


(a) (b)

Figure 1. Three-dimensional visualization of the same 3D model, shown at two different palettes: (a) Rain Palette; (b) Iron Palette.

- **Perspective versus Orthogonal:**

The 3D THERMO model can be displayed either in the perspective or in orthogonal imaging projection visualization. Figure 2(a) is visualized using the orthogonal projection and Figure 2(b) using the perspective projection. The end user can select which option is preferable, according to the medical application and region of the final 3D model being generated.

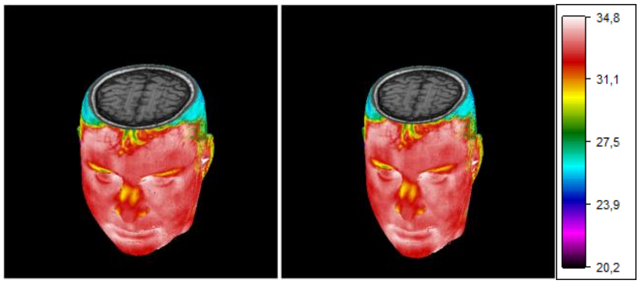


(a) (b)

Figure 2. Three-dimensional visualization of the same 3D model, under different imaging projections: (a) orthogonal; (b) perspective.

- **DICOM Parameters**

The parameters *pixel spacing* and *spacing between slices* are obtained from the DICOM file header. These parameters are automatically incorporated at the 3D reconstruction process, being able to generate 3D models proportional to its real size (especially regarding to the height), Figure 3.

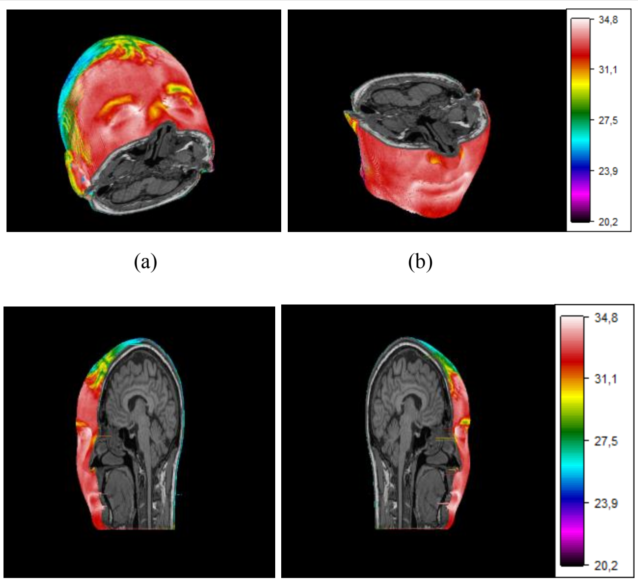


(a) (b)

Figure 3. Comparison between the final 3D model of a volunteer, reconstructed by two different approaches: (a) Without considering the *Pixel Spacing* and *Spacing between Slices* parametes; (b) Including such parameters.

- **Visualization in other Planes of Sections:**

The implemented visualization tool allows the 3D THERMO model to be turn in any direction. Therefore, it is possible to inspect the model around all its faces (sides), as shown in Figure 4. Such option leads to additional flexibility in terms of visualization. Also, geometric transformations (such as rotation, translation and scaling) can be done.



(a) (b)

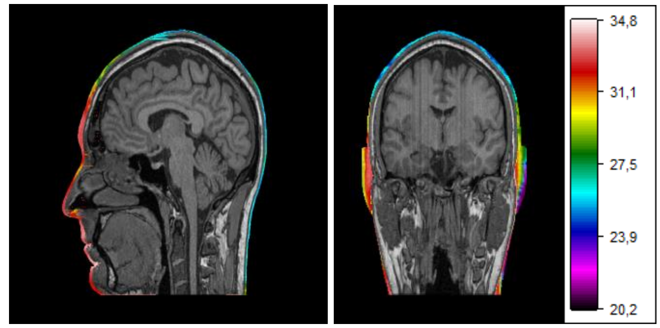
(c) (d)

Figure 4. Visualization example of differente planes of sections of the same image slice (MRI), viewed from both sides. (a) and (b) – Axial plane of section; (c) and (d) - Sagital plane of section.

In addition to the axial planes (MRI/CT image slices) employed for the 3D THERMO image reconstruction, other visualization display options were implemented.

In the final 3D model visualization tool it is possible to modify the display of the model by slicing it in coronal and sagittal planes orientation.

This means an important addition since it provides a better inspection through the final 3D model, becoming possible to interact with it, allowing important clinical findings. Figure 5 illustrates the 3D model of a head/skull, which is additionally visualized through coronal and sagittal planes of sections.



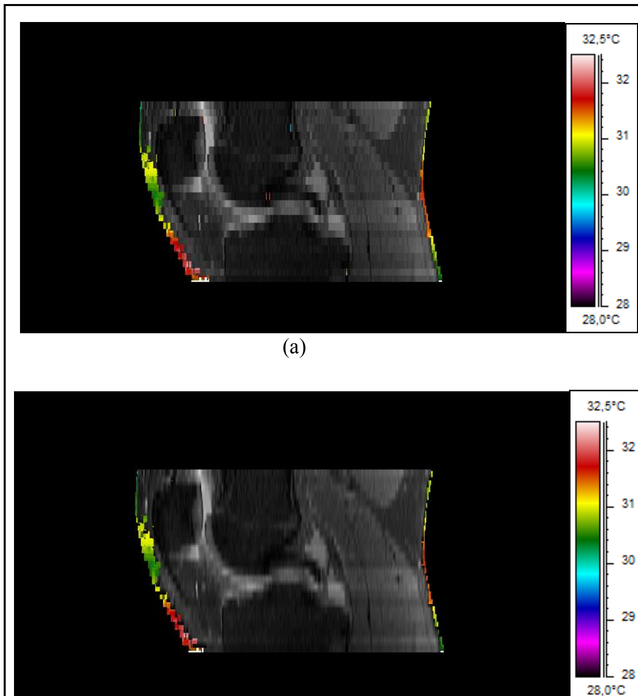
(a) (b)

Figure 5. 3D visualization of the same 3D model, displayed from different planes of sections: (a) Sagittal and (b) Coronal.

- **Smoothing Algorithm - Filter**

The image-smoothing filter applied to fill the gap between adjacent slices was implemented using a mean filter [7]. This filter provides a smoothing effect in the image visualization. This effect is stronger when the MRI images are widely spaced acquired, which typically occurs for the acquisition of body members (e.g. hands, knees, foot, shoulders, among others).

Figure 6 illustrates a knee´s sagittal section, obtained from the axial cross sections. Figure 6(a) shows the image without the smoothing and Figure 6(b) shows the same image after applying the smoothing filter. Those images were acquired using a RM Oni MSK Extreme 1,5T.



(a)

(b)

Figure 6. 3D reconstruction of a knee, showing a sagittal plane of section: (a) Without interpolação; (b) Applying a filter interpolation.

IV. DISCUSSION

The implemented visualization tool makes the clinical inspection easier. This is mainly due to the combination into a unique model of both MRI/CT images (anatomical information) and infrared thermal images (functional information).

The main application is related to medical purposes, since the 3D THERMO tool (with all the recent inclusions) will allow the physicians to inspect, interact and monitor over the time the progression of different lesions and pathologies. Especially the ones that request physiological measurements (termographic images) associated with the physical spatial location (MRI/CT anatomical images) in the human body.

So far, based on the literature review, none methodology for incorporating both imaging modalities (MRI/CT and thermal images) was found. Either the available methods are interested in showing only the internal/anatomical information or only the external/thermal images [8, 9]. A more recent possibility consists in generating a model based on a technique called "Thermal Tomography", which is still under development [10], however such methodology does not incorporates the visualization of anatomical images together with the thermal images, resulting into a single 3D model.

The visualization tool (3D THERMO) automatically reads the DICOM Parameters (*pixel spacing* and *spacing between slices*) providing the correct scale of the virtual model being reconstructed (regarding height, length and thickness). Also, the possibility of changing the final 3D model to different color scale palettes. Visualization at three different planes of sections (such as axial, coronal and sagittal); smoothing algorithm to visualize the image slices (mean filtering); and visualization in other planes of sections.

V. CONCLUSION

This paper presented a visualization tool for the 3D THERMO model that combines two different imaging modalities: MRI/CT and thermographic images. The significance of such methodology consists in providing a more precise and realistic 3D THERMO data for medical diagnosis and inspection.

ACKNOWLEDGMENT

The authors acknowledge the support of DAPI Medical Clinic and the volunteers´ participation.

REFERENCES

[1] G. L. Bichinho, M. A. Gariba, I. J. Sanches, F. P. F. Cruz, H. R. Gamba, and P. Nohama, "A computer tool for the fusion and visualization of thermal and magnetic resonance images", *Journal of Digital Imaging*, vol. 22, n. 5, pp. 527-534, Oct., 2009.

[2] M. A. Souza, I. J. Sanches, and H. R. Gamba, "A new method for generating 3D thermography models", in *Proceedings of 9th IASTED International Conference on Biomedical Engineering (BioMed 2012)*, Innsbruck, Austria, Feb. 2012.

[3] M. A. Souza, I. J. Sanches, H. R. Gamba, and P. Nohama "Image fusion improvements applied at the generation of 3D thermal models", *in 35th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*, vol. 1. pp. 3371-3374, Osaka, Japan, July, 2013.

[4] R. Jain, R. Kasturi, and B. G. Schunck, *Machine Vision*, McGraw-Hill, 1995.

[5] O. S. Pianykh, *Digital imaging and communications in medicine (DICOM): a practical introduction and survival guide*, 2nd ed., Springer-Verlag, 2012.

[6] M. Woo, J. Neider, T. Davis, and D. Shreiner, *OpenGL Programming Guide: The Official Guide to Learning OpenGL*, Version 1.2, 3rd ed., Addison Wesley, 1999.

[7] R. C. Gonzalez, and R. E. Woods, *Digital Image Processing*, 3rd ed., New Jersey: Pearson Prentice Hall, 2008.

[8] S. Colantonio, G. Pieri, O. Salvetti, M. Benvenuti, S. Barone, and L. Carassale. "A method to integrate thermographic data and 3D shapes for Diabetic Foot Disease", in Proceedings ITC-CNR (International Conference on Quantitative InfraRed Thermography), Padova, Italy, June, 2006.

[9] I. Grubiši, L. Gjenero, T. Lipic, I. Sovic, and T. Skala. "Medical 3D thermography system". *Periodicum Biologorum,* vol. 113, no. 4, pp. 401–406, 2011.

[10] C. Jin, Z. Z. He, Y. Yang, and J. Liu, "MRI-based three-dimensional thermal physiological characterization of thyroid gland of human body", *Medical Engineering & Physics*, vol. 36, n. 1, pp. 16-25, Jan., 2014.