Implicit Volume Ray Cast Mesh Renderer for Breast Cancer Detection

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***Abstract*— a 3D reconstruction method using Implicit Volume Ray Cast Mesh Renderer is proposed to construct a 3D model from a series of real patient breast images. This method aims to visualize the diagnosed result from the 2D gray scale Digital Imaging and Communications in Medicine (DICOM) images. It provides an interactive 3D model for medical doctors to have a better explanation regarding the diagnosed results to the patients. A series of 2D breast DICOM images are generated by using magnetic resonance imaging (MRI). Then, the images are sorted by using the directory reconstruction system. After the breast images are sorted, implicit ray cast algorithm and Otsu's multi threshold are employed for 3D reconstruction of breast cancer images and overlay with segmented breast cancer lesion. By comparing the proposed method with existing commercial software, the proposed method has utilized the breasts lesion detection to classify breast lesions during the 3D reconstruction process. Moreover, the tabulated results show that proposed method outperforms other commercial software.**

***Index Terms*—breast cancer, medical imaging, image processing, volume rendering, and breast cancer visualization**

I. Introduction

According to latest statistics provided by United States Breast Cancer in year 2017, 252,710 new invasive breast cancer cases are estimated to be diagnosed in women [1]. In Malaysia, a woman has five percent chances to be diagnosed for breast cancer during her whole lifetime [2]. Furthermore, the Chinese women have the highest risk of diagnose of breast cancer among other races.

Early diagnosis might increase the survival rate of breast cancer patients [3]. Therefore, early diagnosis is mandatory for adequate and early treatment. A high performance computer aided diagnosis (CAD) for different types of cancers is crucial for medical doctors to provide assistance in classifying the most proper treatment method [4].

Usually, mammography and MRI are widely employed screen test for breast cancer disease. Medical images generated through MRI machine are provided in the standard of digital imaging and communication in medicine (DICOM). During the MRI screening procedure, an injection of contrast agent (Gadolinium-based contrast agent) is common standard for the visualisation of the detailed information regarding breast cancer lesion [3].

The generated DICOM images are generated in anatomical plane cross-sectioned images. The medical doctors are required to diagnose the patient condition through these 16-bit grayscale cross-sectional images. However, it is hard for them to visualize the reconstructed 3D model structure of the breast region within these 2D cross-sectional images [5].

Several presented reconstruction algorithms were applied for volume render visualization. Nevertheless, major visualization only focused on exterior information and quality for reconstructed volume. For example, the 3D volume of patient medical images can be rendered from various images from different angle, multi-planar rendering, and orthographic view of the original object and a series of cross-sectional area of the object [6-9].

In this paper, Implicit Volume Ray Cast Mesh Renderer for Breast Cancer Detection (IVRCMR) is presented to assist medical doctors in breast cancer diagnosis. Implicit ray cast algorithm and OTSU's multi threshold are employed for 3D reconstruction of breast cancer images and overlay with segmented breast cancer lesion.

II. Method and Materials

The presented IVRCMR rendered real patient raw DICOM images into 3D volume with adjustable opacity. The rendered volume with semi opacity reveals crucial information regarding patient's condition. The IVRCMR working principle is shown as Fig. 1.

A. Directory Reconstruction

For the collected datasets, breast cancer patients MRI were captured in six continuous measurements for every patient. During the screen test, hundreds of gray scale DICOM images are generated for those six measurements. The raw DICOM images are named in numerical format without details regarding images specification. Hence, the diagnosis process involves tedious procedures as medical experts need to access all hundreds of images in numerical format to search for relevant sorting order. Directory reconstruction designed by [10-12] is employed to sort the directories of patients images. Entire directory is searched and insignificant images are filtered by comparing the unique tag assigned to each image. The informative 864 pre-processing slices are placed into another directory and renamed according the format as shown in Table I.

Manuscript received June 9, 2018; revised July 7, 2019.

doi: 10.18178/ijmerr.8.5.803-806

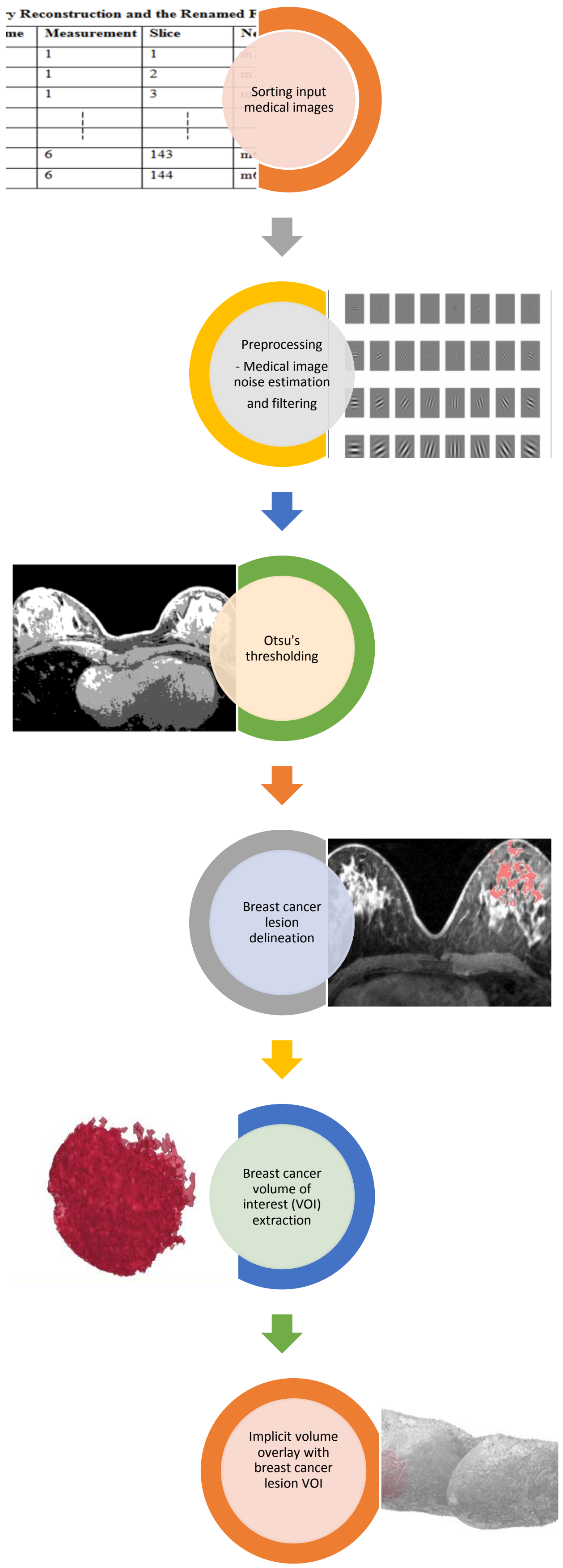


Figure 1. The flow of implicit volume ray cast mesh renderer for breast cancer detection.

TABLE I. DIRECTORY RECONSTRUCTION AND RENAME STRUCTURE.

Original filename	Measurement	Slice	New filename
103115073	1	1	m1s1
103115076	1	2	m1s2
103115081	1	3	m1s3
:	:	:	:
:	:	:	:
103160204	6	143	m6s143
103160211	6	144	m6s144

B. *Pre-processing*

Medical images may contain Rician noises which can affect the image quality. In order to enhance medical image quality for better interpretation of image detail, a rapid medical image noise variance estimation method is applied to estimate the Rician noise variance. The designed image filter is applied to denoise the image.

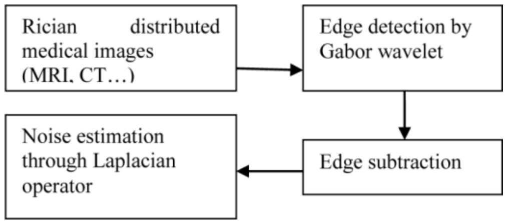


Figure 2. Pre-processing the medical images through [13].

C. *Otsu's Thresholding*

Multi thresholding is applied on breast cancer medical images to segment the image into multiple layer of gradient. Different voxel intensity are categorised according to the threshold level.

D. *Breast Cancer Lesion Delineation*

Region of breast medical images are segmented into various threshold value. The suspected region of interest is delineated through voxel intensity similarity. Voxel with similar intensity values are connected and coloured accordingly. Volume of interest (VOI) is delineated from the breast MRI slice by slice.

E. *Implicit Volume Overlay with Breast Cancer Lesion VOI*

Isosurface is a smooth surface of connected voxels that contains an interpolated value, which is equal to the value of threshold. Fig. 3 illustrates the Isosurface volume render technique.

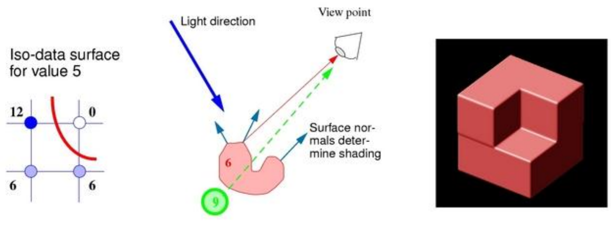


Figure 3. The Illustrations of Isosurface Render Technique [14].

The contour of a scalar field in 3D space is defined as an isosurface. Hence, $F(x, y, z)$ denotes a set of surfaces at value v of a volume where $F(x, y, z) = v$.

The level set of a function $f: R^n \rightarrow R$ is equal to the set of points **x** as shown in (1):

$$L_c(f) = \{x | f(x) = c\}, \qquad (1)$$

where $L_c(f)$ represents the level set *c* under function *f*.

According to (1), a level set is defined as an isosurface in R^3 setting. In addition, *c* also denotes as the sublevel set,

$$L_c^-(f) = \{x | f(x) \leq c\}, \qquad (2)$$

where the super level set is shown in (3):

$$L_c^+(f) = \{x | f(x) \geq c\}, \qquad (3)$$

Both sublevel set in (2) and super level set in (3) are bounded manifolds in R^nenvironment. Fig. 4 illustrates the basic concept of isosurface of a stack of MRI.

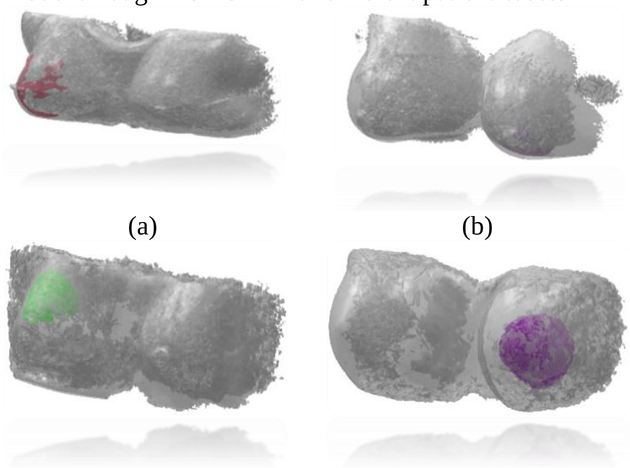
Figure 4. The 3D reconstructed breast model through proposed method with segmented breast cancer lesion.

III. Experimental Results and Discussion

A. Experiment Setup and Patient Protocol

In this section, the outcomes of our designed IVRCMR are discussed. For the experiment setup, total 84 real patient breasts MRI were assessed. Every set of patient medical images is consisted of 864 slices of images. The presented IVRCMR can visualize the segmented breast cancer lesion and render breast section medical images into a 3D model. The detected and segmented lesion is overlaid with the constructed 3D model of real patient breasts regions.

This visualization method is aimed to assist medical doctors in breast cancer diagnosis for better interpretation of medical images. Fig. 5 shows the constructed 3D model through TVRCMR for different patient cases.

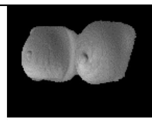
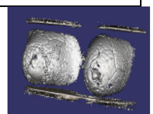
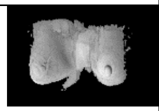
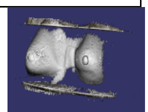
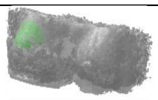
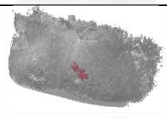
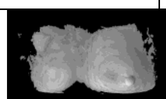


(a) (b) (c) (d)

Figure 5. The 3D reconstructed breast model with segmented breast cancer lesion for several real patients.

According to Fig. 4, the IVRCMR can render the 3D model of the patient breast section with the segmented breast cancer lesion. In order to justify the performance of the proposed IVRCMR, the rendered 3D models are compared with commercial medical 3D viewer. The output of IVRCMR is compared with the Sante Dicom Viewer 3D [15] and 3 DIM viewer [16] as shown in Table II.

TABLE II. Presented Method is Compared with Commercial Software on Real Patient Breast Cancer Images.

Method / Patient	IVRCMR	Sante DICOM Viewer 3D [15]	3Dim Viewer [16]
Patient 1			
Patient 2			
Patient 3			
Patient 4			
Patient 5			

From results as shown in Table II, the existing commercial methods have the solid and rough outermost surface material. In the compared methods, the rendered breast tissues are not shown. The existing technique is more prioritise on the exterior isosurface texture instead of interior information.

In comparison, the proposed IVRCMR has adjustable opacity feature to render the outermost surface. IVRCMR can visualize the exterior and interior information. It also provides better interpretation of the real patient medical images. Furthermore, IVRCMR is able to render the segmented breast cancer lesion with patient breast region in moderate opacity level and assists medical experts in breast cancer diagnosis.

IV. Conclusion

The IVRCMR is presented in this paper. 3D model is rendered through IVRCMR from a series of real patient breast images. IVRCMR is employed to visualize the diagnosed result from the 2D grayscale DICOM images.

It rendered an interactive 3D volume with overlay segmented breast cancer lesion for doctors to have a better explanation regarding the diagnosed result to the patients. The pre-processed medical images are rendered through implicit ray cast algorithm and Otsu's multi threshold is employed. By comparing the presented method with existing commercial software, the proposed method has utilized the breasts lesion detection to classify breast lesions during the 3D reconstruction process. Moreover, the tabulated results show that proposed method outperforms than other commercial software techniques. The IVRCMR can be implemented for supervised artificial neural network breast cancer classification [17-19].

Acknowledgment

Fundamental Research Grant Scheme (FRGS) funds this research. It is a research grant from the Ministry of Higher Education (MOHE), Malaysia.

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