

3D RECONSTRUCTION OF BREAST CANCER FROM MAMMOGRAMS USING VOLUME RENDERING TECHNIQUES

Article history

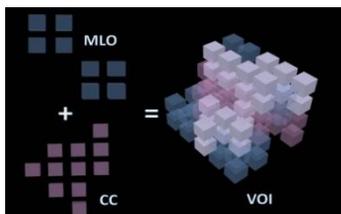
Received
3 December 2013
Received in revised form
2 July 2014
Accepted
25 November 2014

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Graphical abstract



Abstract

Over the past thirty years, a number of researchers have investigated on 3D organ reconstruction from medical images and there are a few 3D reconstruction software available on the market. However, not many researches have focused on 3D reconstruction of breast cancer's tumours. Due to the method complexity, most 3D breast cancer's tumours reconstruction were done based on MRI slices data even though mammogram is the current clinical practice for breast cancer screening. Therefore, this research will investigate the process of creating a method that will be able to reconstruct 3D breast cancer's tumours from mammograms effectively. Several steps were proposed for this research which includes data acquisition, volume reconstruction, and volume rendering. The expected output from this research is the 3D breast cancer's tumours model that is generated from correctly registered mammograms. The main purpose of this research is to come up with a 3D reconstruction method that can produce good breast cancer model from mammograms while using minimal computational cost.

Keywords: 3D reconstruction, direct volume rendering, breast cancer, scientific visualization

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1.0 INTRODUCTION

Over the past three decades, a number of researches have been visualizing the human anatomy. Currently, direct volume rendering techniques are the best techniques to visualize the human anatomy from medical images. There are several direct volume rendering techniques which are widely applied such as volume ray-casting, splatting and shear-warp factorization.

However, all of these techniques have their own drawback. There are no single "complete" techniques that can deliver both best image quality and best rendering time [1]. In this research, a simple volume rendering techniques is introduced. This is a simple technique that is believed will overcome the drawbacks of the previous techniques. In other words,

it is a complete technique that provide good image quality and render on best speed with minimum data input (using mammogram instead of MRI/CT Scan)

2.0 MOTIVATION

Breast cancer is considered one of the common diseases in the world. In 2012, 13.98% of recorded cancer related cases were breast cancers. Breast cancer caused 39920 deaths worldwide and 98.97% of those breast cancer deaths victims are women [2], [3]. In Malaysia, breast cancer can be classified as a common illness among all Malaysian women from all ethnicities. There are approximately one of every 20 women in Malaysia are carrying the risk of having breast cancer [4]. A study of breast cancer shows that

the peak age of having breast cancer is between 40-49 years old. Meanwhile, 50%-60% of diagnosed breast cancer patients are at stage 3 and 4, which is the final stage. There are several test for breast cancer screening such as mammography, breast ultrasound, tomosynthesis, MRI (Magnetic Resonance Images) and Ductogram [5], [6]. Mammograms are among the best early detection methods[7].

There are several treatment options for breast cancer patients including lumpectomy, mastectomy, radiation therapy, sentinel lymph node biopsy or axillary lymph node dissection; While the treatment options depend on several factors including the stage and grade of the tumour, the patient's menopausal status, the patient's age, general health and preferences [8]. Among the treatment options, the survival rate for lumpectomy and mastectomy are higher compared to others. Figure 1 shows the difference between lumpectomy and mastectomy. The grey area shows the removal part in each case. Lumpectomy is the removal of the tumour and a small clear margin of normal tissue around the tumour which is a breast-conserving surgery; On the other hand, a mastectomy is the surgical removal of the entire breast [9].

Although the survival rate for both approaches are the same, but the breast-conserving surgery is not optional for every breast cancer patient. In order to decide the most suitable surgery, the tumour- breast volume ratio is considered [10]. Unluckily, the mammograms are only two-dimensional projections of the breast. The two views of mammograms fail to provide an accurate volume data for the consideration of surgery. Thus, three-dimensional reconstruction from mammograms is needed to assist the decision making of surgeon.

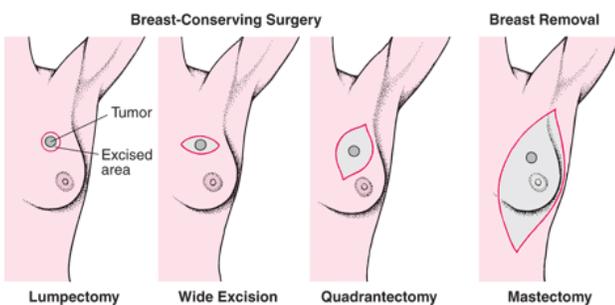


Figure 1 Surgery for breast cancer[11]

3.0 RELATED WORK

3.1 3D Reconstruction

3D reconstruction is the process of reverting the detail of a vanished structure. In medical field, this process has been widely applied in the medical visualization from medical imaging data such as CT, MRI, SPECT, 3D Ultrasound (US) and positron emission tomography (PET) that provide a wide range of 3D medical imaging modalities. There are several factors that

show the drawbacks of the current 3D reconstruction application:

- The manual creation of the 3D model is time consuming and therefore cost expensive[12]
- The manual creation of the 3D model is not accurate

Generally, there are four steps involve in the 3D reconstruction from medical[12], [14], which are shown in Figure 2.

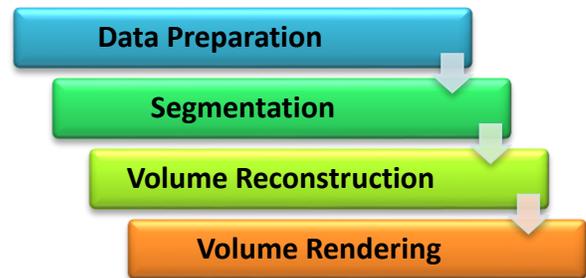


Figure 2 3D Reconstruction pipeline

Data acquisition is the process of sampling physical objects that is going to be reconstructed. For the 3D reconstruction from medical imaging, the volumetric information will be obtained from medical scanning devices such as CT and MRI scanner [14]. Sometimes, the medical images have to be enhanced so that the ROI can be identified easily. Then, the ROI will be extracted from the medical images during the image segmentation process [13]. After extracting the ROI, the slices of ROI needs to be registered at the correct position. The next step will be the smoothing operation which is performed by using interpolation method that returns smoothed data. Lastly, the tumour's model will be rendered using volume rendering techniques.

Several researches that are related to breast cancer and computation application were done in the past to assist the specialists in the diagnosis and surgical planning. Christian P. Behrenbrunch *et al.* presented a data fusion technique whereby medial-lateral oblique (MLO) and cranial-caudal (CC) mammograms are registered to enhance 3D volume produced from MRI data. The result obtained from this method is satisfying. In 2005, Wirth *et al.* has developed an algorithm for breast region segmentation using fuzzy reasoning. This technique produced results for the tumour segmentation however the result is not accurate [15]. In the same year, E. Coto *et al.* reconstructed breast volume from MRI data and it produced an interesting result [16]. J. Rodriguez *et al.* segmented the region of interest using interactive scissor techniques and visualized the mammograms in 3D. By using his method, the breast shape was reconstructed but the tumour was only represented by bounding box [10].

3.2 Direct Volume Rendering

Volume rendering techniques basically renders every voxel in the volume raster directly. Unlike surface rendering, there are no rendering from the converted domain or the conversion of geometric primitives during rendering. Commonly, an illumination model which supports semi-transparent voxels will be included in the rendering to ensure every voxel in the volume is (potentially) visible. Thus, each voxel contributes to the final 2D projection [17], [18], [19], [20]. Figure 3 shows the classification of direct volume rendering.

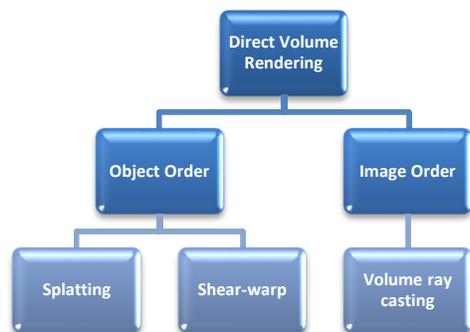


Figure 3 Direct volume rendering

One of the most effective ways to classify the volume rendering techniques is by classifying the techniques according to the order of the algorithm that traverse the volume [1]. In object-order rendering, or forward mapping, the data is projected in a forward direction, which is from the object to screen. All the projection of voxel is traversed as a 3D point. The 3D point is transformed by the viewing matrix and then projected onto a Z-buffer and plotted onto the screen. The advantage of object-order rendering is the fast rendering speed. However the image quality produced ranges from moderate to good. Splatting and shear-warp are the two major techniques that belong to this category.

Fundamentally, image-order rendering (also called backward mapping) are different from object-order rendering techniques. Each on screen pixels are evaluated one at a time. In image order rendering, the ray are cast backward, which is from the screen into the object. Then, the ray is sampled to calculate how much it contributes to that particular pixel. Generally, image order rendering produces best image quality but the rendering speed is slow [1]. Volume ray-casting and variations of it are the examples of the techniques that belong to this category.

Volume Ray-casting

By the late 80's, a lot of surface extraction techniques was developed such as marching cubes [21]. Surface rendering produce a fairly good image on arbitrary data, however it has a big limitation which is the

aliasing effect. This is caused by the misclassification of the actual surface from the volume data. Generally, polygons are not very suitable to display a complex and fine details volume especially to visualize some volumes that need a near infinite number. The classification errors in surface rendering produces aliasing objects and cause some of the data to be missing in the final rendered image. In certain field, aliasing and artefact are not acceptable [1].

In 1998, the first direct volume rendering technique was introduced by Marc Levoy [22], [23]. This method is called volume ray-casting. Basically, the algorithm is simple, rays are cast into an object and samples are taken along each ray by interpolation of the surrounding voxels. This solves the classification problem of surface rendering and the object can be rendered in semi-transparent. As a result, it is possible to render a very detail object [1]. Although volume ray-casting can produce a very good image, it also have some drawback, such as the computational cost is relatively high [24], [25]. In 1993, William M. Hsu implemented parallel programming into volume ray-casting to improve the rendering speed [26]. However, the rendering speed was only slightly improved. Next, the researchers started to investigate parallel programming into volume ray-casting [27], [28]. Christoph Lurig *et al.* introduced implicit adaptive volume ray-casting that accelerated the rendering speed but the drawback of this technique is to find the ray-entrance point of the volume [29]. In 1999, Ming Wan *et al.* proposed a boundary cell-based acceleration technique for volume ray-casting. In this method, the empty space was skipped over. By doing this, a significant increase in speed was obtained without affecting image quality [30]. In the same year, the first hardware accelerating volume ray-casting was introduced [31]. This enables volume ray-casting to render in real-time. In 2013, plane-based sampling for volume ray-casting was introduced by Lili Lin *et al.* [32]. The method speeds up the sampling process of conventional volume ray-casting to more than three times the original speed and the image quality is still good.

4.0 OVERVIEW OF PROPOSED METHOD

Basically, a modified volume rendering method is proposed for 3D reconstruction from mammograms. A system will be developed to test the efficiency of the proposed techniques. The format for the input mammograms data will be lossless JPEG and the expected output will be a 3D breast tumour structure. There are several steps that are involved in the 3D reconstruction. Figure 4 shows the research pipeline of this project. There are three main sections in this research namely data acquisition, volume reconstruction and volume rendering.

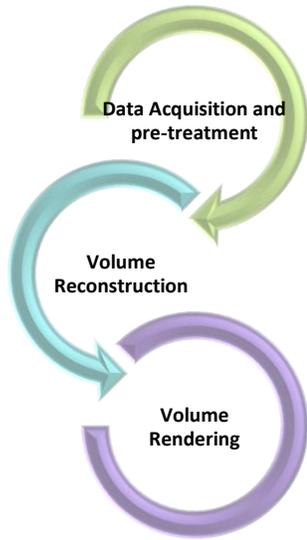


Figure 4 Pipeline for proposed system

4.1 Data Acquisition

Normally, mammograms images are taken from two different views for diagnostic purposes which are cranio-caudal view (CC) and medio-Lateral oblique view (MLO). Figure 5 shows the angle of each view. From the figure, the direction of x-ray is from head to the feet for CC view; whereas for the MLO view, the direction of x-ray is from medial to lateral and the orientation of breast is at an angle. In this stage, the two views of mammograms will be imported into the system and stored into memory. Then, a number of image pre-treatment processes will take place. The main purposes of image pre-treatment are noise reduction, contrast enhancement, and edge sharpening. However, if the quality of mammograms is good enough, the image pre-treatment step can be skipped.

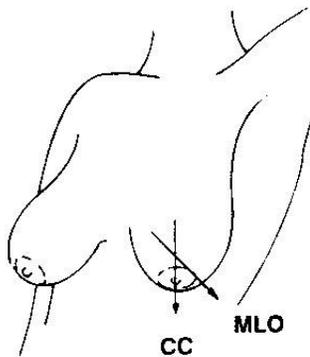


Figure 5 Different views of mammograms [33]

4.2 Volume Reconstruction

During this stage, the breast and tumour will be reconstructed from the two views of mammograms. There are two parts in this stage which are the breast boundary extraction and the volume of interest reconstruction. Figure 6 shows the flow of this stage.

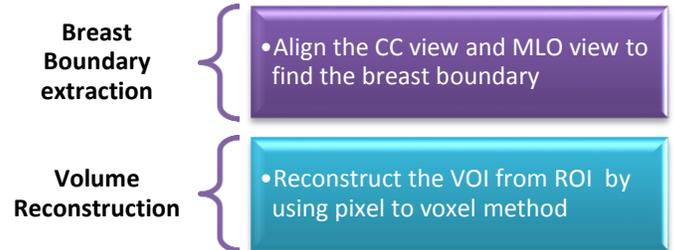


Figure 6 The flow of volume reconstruction stage

In breast boundary extraction part, CC view and MLO view of the mammograms will be aligned by matching the cross-sectional area. Figure 7 shows the alignment of CC view and MLO view. Once the aligning process is completed, the breast boundary will be determined and reconstructed based on the extracted part as shown in Figure 8.

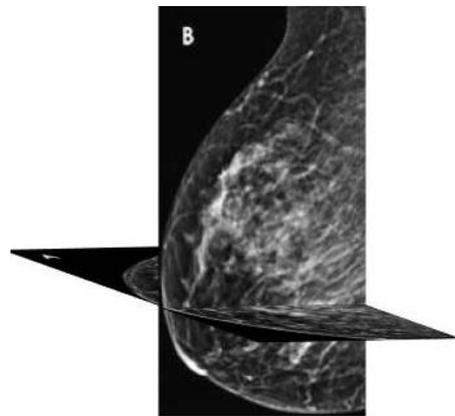


Figure 7 The alignment of CC view and MLO view

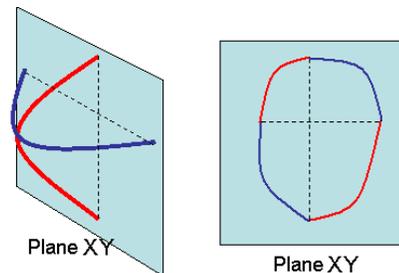


Figure 8 Construction of the breast boundary based on the mammograms [10]

In the volume reconstruction part, both of the mammograms view will be thresholded to detect the ROI. After the ROI is detected, each pixels in the ROI will be assigned with long blocks. Then, the blocks with intersection will be stored as voxel. The process is show in Figure 9. From the figure, the ROI that was extracted from the MLO view is represented by blue squares; while the red squares represent the ROI that was extracted from CC view. Each square represents one pixel in the mammograms. After the volume reconstruction, the VOI was obtained. The white cube represent the VOI and each white cubes represent one voxel in the VOI as shown in Figure 10.

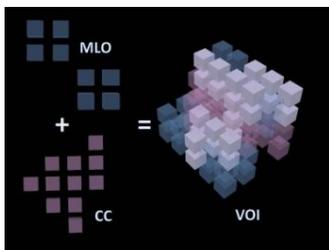


Figure 9 VOI that reconstruct from CC view and MLO view

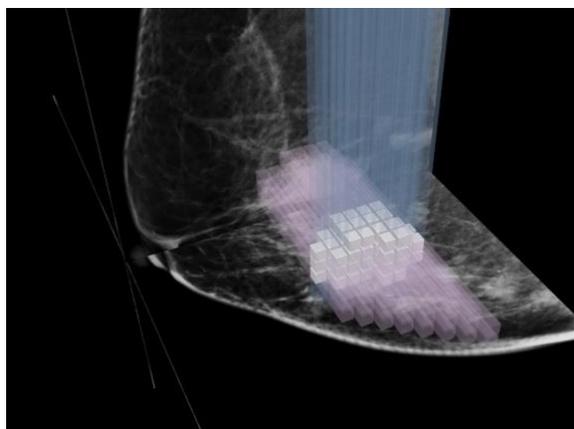


Figure 10 VOI that generates from proposed technique

4.3 Volume Rendering

In the volume rendering section, a modified volume ray-casting method is proposed. Generally, it is done by implementing conventional ray-casting technique. However, the projection of ray and the sampling method will be modified. In this technique, parallel viewing rays are projected instead of emitting the ray from a point. Besides that, the voxel data will be pre-processed and stored in the memory. The colour and opacity of each voxels are also stored in the memory along with the boundary of the breast and tumours so that the rays can be projected onto the VOI only. These data are very helpful in order to reduce the computational cost by eliminating the empty space calculation step.

5.0 CONCLUSION

In this paper, a software application that can be used as a decision support tool for the study of tumour-proportional from standard mammograms (cranio-caudal view and medio-Lateral oblique view) has been proposed. The system is still under development; thus, there are no initial results to be discussed. The expected output for this research is the 3D model of breast with tumours that are registered correctly. Besides that, the proposed method for volume reconstruction can directly convert the ROI from pixel to voxel. This will reduce the computational cost for the 3D reconstruction. The modified volume rendering technique is believed will be able to overcome the drawback of the traditional volume ray-casting.

Acknowledgement

This research is supported by FRGS grant (project code: FRGS0295-SG-1/2011) from the Ministry of Higher Education (MOHE), Malaysia. The author also wishes to thank the Real Time Graphics and Visualization Research Group (GRAVS) for their advice and support.

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