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# MAPPING POINTS OF CLOUD OF SINGLE IMAGE ONTO MRI FOR 3D CARDIAC MODELING FOR AUGMENTED REALITY

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## ABSTRACT

This research is about obtaining the realism in virtual heart surgery. Normally, novice cardiac surgeons learn the surgery by observing the experts perform the operation on a patient. The physical involvement from these novice cardiac surgeons are very minimal. As such, virtual surgery might help in simulating the cardiac surgery and provide the feeling of doing a real surgery without putting any patients' life at risk. The main challenge in virtual surgery is to ensure the 3D model of the heart is as realistic as the real heart. Currently artificial 3D heart is used in virtual cardiac surgery. In order to provide realism in the virtual surgery, MRI are used to capture the internal part of the heart and camera-captured images are used to portray the external part. The MRI slices are combined to create a 3D heart. In order to increase the accuracy of the texture mapping, the captured image are transformed into 3D points of cloud based on the depth of the surface, before they can be mapped on the 3D heart. These two types of images (MRI slices and camera captured) are taken from real patients. Here, MRI and point clouds provides accuracy and the captured images provide realism.

**Keywords:** mapping points, modeling, augmented reality.

## INTRODUCTION

Augmented Reality (AR) is a technology that incorporates the virtual objects to the physical real world [1] [2], and it is seen as being closer to the real world rather than the virtual world [3]. As it is cost effective, safe and efficient [4] it is a great tools that can be used in medical domain where human life is the main concern. It can be a powerful distance learning and training tools [5].

In the past, medical training for surgery is done by having several novice surgeons observing a senior surgeon doing the surgery in the operation theater [6]. However, only one of them will get the opportunity to assist the senior surgeon directly. The other novice surgeons will only get to learn the process by watching. With the advance technology of AR and Google Glass, the teaching and training process can be done virtually and involves more participants around the world [7] [8]. Here, the surgeon wore the Google Glass, projected his view of the surgery in real time and communicated with the participants in relation of the cancer removal surgery. This enables the training to be done, with the novice surgeon getting a better and clearer view of the surgery. Although this method has improve the traditional apprenticeship method, most of the surgical educators begins to include simulations and models in the training [9][10]. The main challenges in medical training via AR is to have the realistic virtual objects to be assimilated in the operation theater environment [11] [12]. This is crucial in ensuring the sense of inter-relation between those two.

The aim of our research is to provide realistic 3D model of a heart that can be used in a virtual surgery. The flow of the system is as shown in Figure-1. Here, Magnetic Resonance Imaging (MRI) images are used to ensure accuracy and captured images and point clouds are used for texturing to ensure realism.

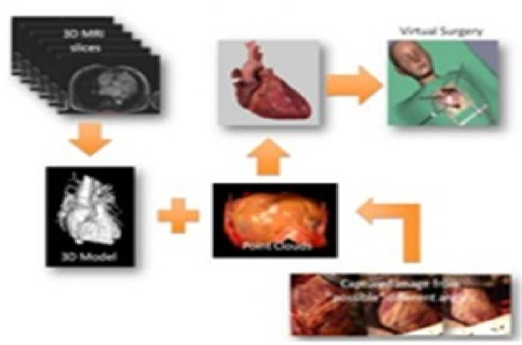


**Figure-1.** The aim of research.

Previous works in our lab towards the goal of Cardiac Intervention Environment, Cardiovascular Information System, Heart Diseases Diagnostic Systems, Computer Assisted Medical Research and 3D Medical Visualization has included the develop a new human heart vessel segmentation and 3D reconstruction mechanism under different illumination conditions [13] [14], an automatic coronary arterial tree extraction in angiograms [15], cardiac ultrasound fusion system development [16], reconstruction of Tricuspid valve using TEE echocardiography [17], Wavelet enhancement for x-ray angiography [18], image reconstruction of heart with specular reflection remover [19], 3D Multimodal Cardiac Data Reconstruction in CT Angiography [20], CT Angiography components categorization and coronary artery enhancement [21], and some surveys including review on segmentation approaches [22] [23] [24], review on registration of cardiac images [25] and the image registration on a medical related images [26].

In this paper, we proposed the solution for the problems discussed earlier, together with the literature review for all of the phases involved, which will be explained in the next section.

**Statement of problem**

Most of the accurate 3D model are scanned using the 3D scanner, however this is not possible for human heart. Therefore MRI is used in getting the accurate heart model. However, MRI does not produce the realistic texture for the surface. The external image is to be obtained from the camera that is taking the images during the open heart surgery. This will create a realistic 3D heart model that can be used in the virtual training.

There are several problem statements that motivate us in doing this research. Firstly, AR demands realism. As such, all the components involved in a virtual training surgery need to be as realistic as it can be. In order to ensure a better model is obtained, MRI is used. MRI slices can be used to create an accurate 3D model. They are able to create a 3D model of the heart but as the MR images includes the whole chest, a proper segmentation method needs to be identified in ensuring only the heart is segmented. Another issue that arises during this phase is that after the rendering process has been implemented, the model is still far from real, as it does not has any color. MRI images are in grayscales [27], therefore it produces a 3D model in grayscale. This brings difficulties to the trainee surgeons to differentiate between the arteries and veins. This can be seen in Figure-2 and Figure-3. As such, it is important to apply color and texture on the 3D model to increase realism in virtual training.

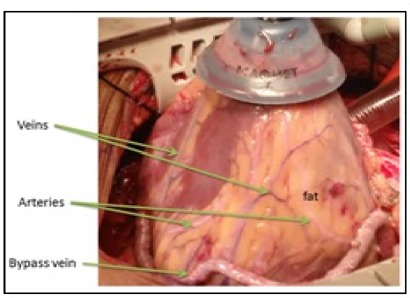


**Figure-2.** Veins, arteries and fat.

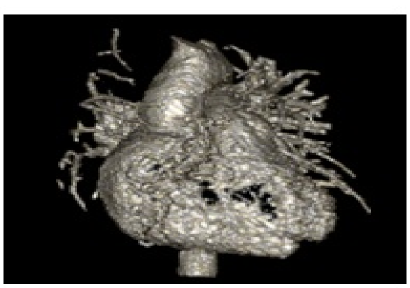

**Figure-3.** A 3D model of a heart.

In order to do this, images of the heart during the operation need to be captured and mapped onto the 3D heart. In spite of this, before the mapping process can be implemented, the images must first be stitched together. This brings us to our second problem statement in our research, which is the variation of the illumination value from different images. This problem occurs as the images are taken from variation of angle or view [28]. Thus the illumination correction needs to be applied before the image can be mapped onto the 3D model.

The paper is organized as follows; Section 3 explains the objectives of the study, Section 4 will explain on the literature review done for all the phases involved, Section 5 will explain on the proposed solution and Section 6 will conclude this paper.

**Purpose of study and contributions**

There are several objectives that we want to achieve in doing this research. The research is divided into 2 phase, which are the MRI segmentation and mapping the points of cloud of single image onto the 3D cardiac. In the first phase, 2 objectives that we are trying to achieve is to automatically segment the heart from the MRI slices and to construct a 3D model of the heart based on the segmented slices obtained. For the second phase, we are focusing on 3 objectives which are to automatically find several common points between the points of cloud and the 3D cardiac, to stretch the distance between each point cloud according to the 3D model and to transform the points of clouds based on the texture on the 3D cardiac model.

**Literature review**

This section explains the study that has been done on the main five phases of the research which are MRI, automatic MRI segmentation, illumination correction, image registration and texture mapping. It is organized based on the flow of the research, which will be explained in detail in Section 5.

**Magnetic resonance imaging (MRI)**

MRI is an imaging technique that is based on nuclear magnetic resonance [29], and, it produces moving images of the body, using high frequency sound waves [30]. MRI is used to view the detailed images of organs, soft tissues, bones, ligaments and cartilage [31]. MRI is safer and shows better result compared to the other medical imaging modalities [32]. Cardiac MRI is the medical imaging technology for evaluating the structure and the function of the cardiovascular system [33]. It is used to evaluate chest discomfort, jaw/ left shoulder/ left arm pain, shortness of breath, lightheadedness/dizziness and fatigue. It is also used to assess the heart after an attack or before the ablation procedures [34].

MRI will produce slices of images based on 3 planes; axial, coronal and sagittal [35]. These separate views give the reader more information compared to single vision available on other medical image such as the x-ray. The axial is the plane for capturing the slices from

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top to bottom of the body, the coronal plane will capture the slices from back to front of the body and the sagittal plane is for slices captured from left to right. This is shown in Figure 4. An example of a 3D model of a heart, generated from slices obtained from these 3 views, using OsiriX software, is as shown in Figure-4.

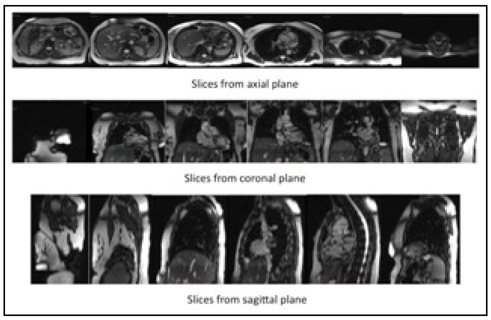


**Figure-4.** Views of MRI slices.

**Automatic MRI segmentation**

MRI heart segmentation is the process of segmenting the heart from the MRI of the chest. The MRI slices as shown in Figure-4 shows the whole chest area captured. According to Zhuang [36] and Peters et al [37], challenges in whole heart segmentation includes the geometrical complexity of the heart, the indistinct view of the anatomical structures, the appearance of heavy motion artifacts and noise, low tissue contrast and the lack of gray level calibration. The key techniques in whole heart segmentation can be divided into 2; prior model and fitting or registration model [36].

Prior model is the method that manipulated the shape and the intensity feature of the image and can be divided into atlas and deformable model. In their papers, Zuluaga *et al*. [38] and Kirisli et al [39] implemented the multi-atlas method manipulates the normal registration method and decrease the processing time. On the other hand, Peters [37] used shaped constrained deformable model with the application of the Generalized Hough Transform (GHT) in detecting the heart from the MRI slices.

Fitting process is the method that requires a global localisation to perform a deformable fitting [36]. It is a process of registering the model to the unseen image. Unseen image is the image that requires segmentation [40].

**Illumination correction**

Illumination correction is the process of correcting the uneven illumination that is usually caused by uneven lightings, sensor defaults or the orientation of the object [14][41] [42]. It can be divided into prospective and retrospective correction. Prospective correction depends on additional images for the correcting process, which can either be the images of the scene background with no lights or the images of the scene background with lights but without the objects. Retrospective correction, on the other hand, is the estimation of an ideal illumination model. Some of the method for implementing illumination correction are histogram equalization and filtering [43], illumination map [44] [45]and comparison of the tone mapping model with the luminance value of the image [46].

**Image registration**

Image registration is a method that extract information from multisensory or/and multi-temporal or/and multi-view images or objects [47] [48]. It is a process of establishing corresponding points between images before applying geometric transformation on those images. A more simple definition of image registration is defined as the process of combining two or more images or objects [49] [50] [51].

Image registration can be divided into five areas, which are transformation, dimensionality, feature, user interaction and nature of registration [52] [53]. In order to align the two or more images for the registration process, the images must be transformed first. The nature of transformation includes rigid, affine, projective and non-linear transformation [51] [52] [53]. Batchelor [29] included similarity transformation and anisotropic scaling as one of its rigid transformation.

**Texture map reconstruction method**

Texture map reconstruction method (also known as image based modeling) is a method where the patches to be mapped is developed based on combination of appropriately extracted parts of the source image [54]. Some of the algorithm used for texture reconstruction includes Structure Form Motion (SFM) [55], photogrammetric [56], silhouette information [57], View Dependent Texture Mapping (VDTM) [58] and video mosaic [59].

In their paper, Nguyen et al [60] used SFM combined with bundle adjustment in estimating extrinsic and intrinsic parameters for parameterization. In mapping the texture, back projecting the best fitting images is done to the model. The advantage of their system is that it uses high resolution texture map, the texture can be captured using unconstrained and uncalibrated camera and the texture is scalable. However, this method is having some issues where the images mapped might not be seamless as there is a discontinuity in color. Tzur and Tal [61] introduced FlexiStickers that uses the concept of photogrammetric in mapping casual images onto a 3D model. This method can be implemented on conventional hardware, fast in texturing the models and requires less user involvement.

**METHODOLOGY**

This section will explains the techniques and methods that will be used in the research and data needed for this research. The flow of this research is as shown in Figure-5. The processes can be divided into five parts: volume rendering, specularity removal and illumination correction, image registration and texture mapping.

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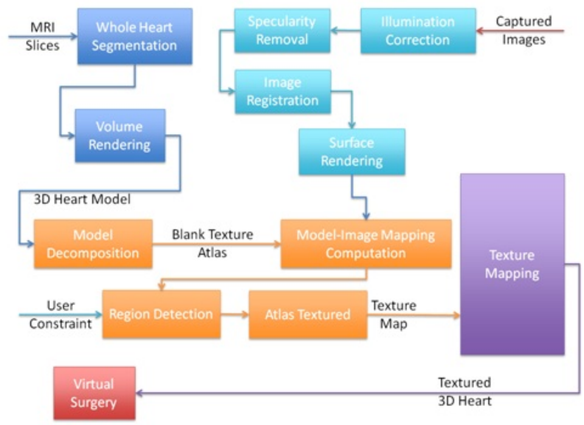


**Figure-5.** Research methodology.

## PRELIMINARY RESULT

The preliminary experiment of development of the MRI model is done on two data obtained from two difference sources. A series of MRI slices from a patient has been obtained from the radiologist at Hospital Universiti Teknologi MARA (UITM), Sungai Buluh, Selangor, Malaysia. The other series of MRI slices is obtained from public dataset readily available at the OsiriX website. Figure-6 and Figure-7 showed the slices from both sources in three different angles.

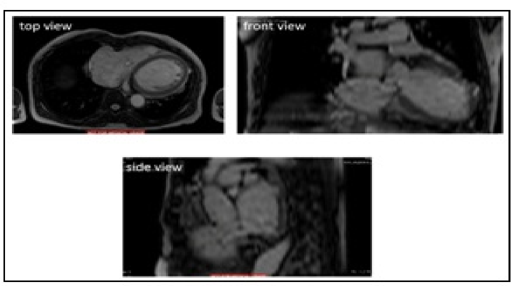


**Figure-6.** MRI slices from Hospital UITM.

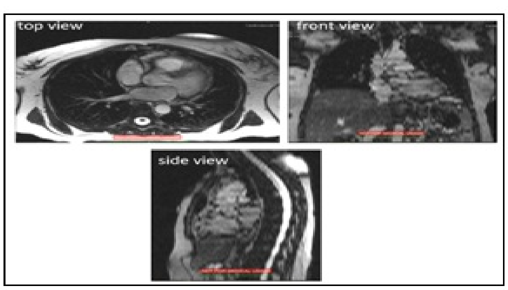


**Figure-7.** MRI slices from OsiriX.

The maximum number of slices for the cardiac MRI data obtained from the Hospital UITM is 30 and the OsiriX public dataset provided a maximum of 45 slices for a series of data. The process of converting the slices into a three-dimensional model is done in the OsiriX software through volume rendering. Figure 8 shows the three-dimensional model of the patient's body for both Hospital UITM and OsiriX slices.

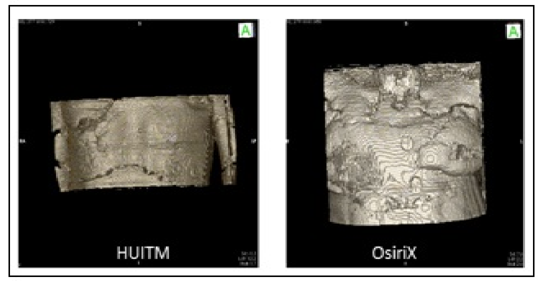


**Figure-8.** Three-dimensional model developed from hospital UITM and OsiriX MRI slices

The bodies are then being cropped to eliminate the other organs. The flow of the process is as shown in Figure-9. From left to right, the model is being cropped until only the heart is left.

However, when being compared, the model developed from the OsiriX MRI data is better than the model generated using the Hospital UITM MRI data, as can be seen in Figure-10. This happens because the number of MRI slices available for OsiriX data is more that the number of slices available from the Hospital UITM data.

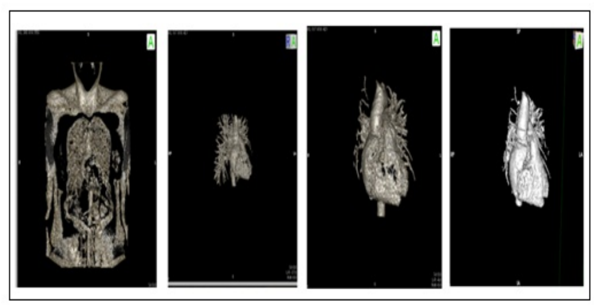

**Figure-9.** The flow of the process of cropping the three-dimensional model.

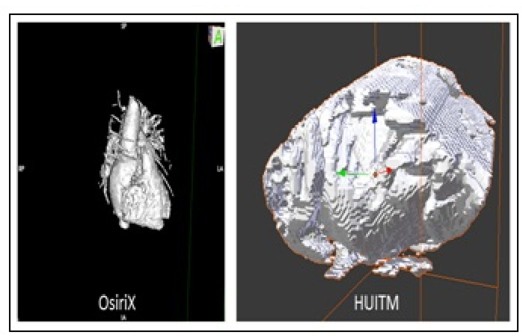


**Figure-10.** 35 Three-dimensional heart model for both series of data.

**CONCLUSIONS**

In this report, a proposal has been presented. A virtual surgery system that promote realism is proposed. The main aim of this research is to have a robust and effective technique in creating a realistic 3D cardiac that can be visualized in Augmented Reality environment.

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