An Efficient Approach to 3D Image Reconstruction

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Summary
The images can be visualized in three dimensional (3D) using standard techniques, these 3D techniques are used to enhance the view of images. Converting two dimensional (2D) images into 3D images is an important part of image application. An efficient approach of 3D image reconstruction is implemented to perform a certain process that applied to X-ray medical image. In this paper we have demonstrated that the proposed approach is a useful technique for effective 3D visualization. This approach is implemented via four steps; preprocessing, image enhancement, image contour then image reconstruction and visualization. The obtained results show a good reconstruction of the tested image.

Key words:
3D imaging; 3D visualization; volume estimation; volume rendering and image reconstruction.

1. Introduction

Nowadays and even long time ago, there was a big demand to 3D volumetric medical images. Many medical imaging applications involve aligning 2D images, e.g. X-ray imaging. X-ray imaging has many pervasive applications in the surgery, both preoperatively or intraoperatively. 3D images are useful in understanding the state of the patients. The physician, surgeons and radiologists in dire need for the 3D image to extract information and diagnosis the case.

In X-ray radiography images are produced by casting an X-ray shadow onto a photographic film or digital detector. Like gamma rays, X-rays can travel through soft tissues in body with little attenuation and are only “stopped” by high density tissues such as bone [1]. The discovery of X-rays and the invention of CT represented major advances in medicine. X-ray imaging exams are recognized as a valuable medical tool for a wide variety of examinations and procedures. They are used to [2]:

•Noninvasively and painlessly help to diagnose disease and monitor therapy;

•Support medical and surgical treatment planning; and

•Guide medical personnel as they insert catheters, stents, or other devices inside the body, treat tumors, or remove blood clots or other blockages.

The goal of this work is to enhance the medical X-ray images after preprocessing and then converting it to 3D images. The rest of the paper is organized as follows. In section II, we present the related work. Section III discusses 3D medical images. Section IV describes an overview of the volume reconstruction while section V presented the proposed 3D reconstruction approach used in this work. Section VI focuses on experimental results on X-ray images. Finally, section VII concludes the paper.

2. Related Work

In the last decades, many researchers have attempted to enhance medical images and develop methods to reconstruct 3D image. Bandyopadhyaya, Biswasa and Bhattacharyab [3] proposed an integrated tool for the detection and evaluation of orthopedic fractures in long-bone digital X-ray image.

It is beneficial to obtain 3D images for assessment of patient case and diagnose the disease in many cases such as cerebrovascular diseases on vessel morphology and haemodynamics as described in [4].

Çimen et al. [5] presented a review of the state-of-the-art approaches on reconstruction of high-contrast coronary arteries from X-ray angiography. They also discussed the potential role of reconstructions in clinical decision making and interventional guidance, and highlight areas for future research.

Arakeri and Reddy [6] proposed an approach to 3D reconstruction of brain tumor and estimation of its volume from a set of two dimensional (2D) cross sectional magnetic resonance (MR) images of the brain. They do the work by developing methods for segmentation, inter-slice interpolation, mesh generation and simplification. Also [7,8,9] presented a work for 3D reconstruction of the brain.

A 2D/3D correspondence building method based on a non-rigid 2D point matching process is presented by Zheng et al. [10]. They developed a 2D/3D reconstruction scheme combining a statistical instantiation with a regularized shape deformation. Experimental results on clinical images are valid for both quantitative and qualitative evaluation.

Markelj et al. [11] presented a review of 3D/2D registration methods with respect to image modality, image dimensionality, registration basis, geometric transformation, user interaction, optimization procedure, subject, and object of registration.

Gunay et al. [12] proposed a method to generate 3D bone shape. The result of this work is to obtain an image similar to an input X-ray image when projected onto a two-dimensional plane. This method is more computationally

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efficient, cost-effective and portable compared to the conventional CT- or MRI-based methods.

Ehlke et al. [13] proposed a method to render virtual X-ray projections of deformable tetrahedral meshes. They applied the method to improve the geometric reconstruction of 3D anatomy from 2D X-ray images.

Varshney et al. [14] reconstructed the 3D shape of prostheses and even more so of bones from multiple X-ray images.

Hosseinian and Arefi [15] classified and evaluated different methods of 3D reconstruction of bony structures from radiographs. A comparison has been done with these methods with respect to several metrics such as accuracy, reconstruction time and their applications.

While Cardiac Magnetic Resonance (CMR) can identify the optimal site in three dimensions. Choi et al. [16] registered 3D CMR data to clinical standard x- ray fluoroscopy to achieve an optimal pacing of the left ventricle LV. They developed a 3D CMR to 2D X-ray image registration method for CRT procedures. Also, they have employed the LV pacing lead on X-ray images and coronary sinus on MR data as landmarks. The registration method makes use of a guidewire simulation algorithm, edge based image registration technique and X-ray C-arm tracking to register the coronary sinus and pacing lead landmarks.

3. 3D Medical Images

Medical images have a vital role in disease diagnosis. These images are needed to support more accurate clinical information to radiologists, physicians and surgeons for better diagnosis. 3D reconstruction is important to understand the medical images. There are many acquisition systems to capture medical images. There are techniques used to display medical images, such as X-ray, computed tomography (CT), magnetic resonance imaging (MRI), Positron Emission Tomography (PET) and Single-Photon Emission Computed Tomography (SPECT). Gkoumas et al. [17] mentioned that the synchronized evolution of X-ray medical imaging and detectors dates back to the beginning of the 19th century, when Wilhelm Conrad Röntgen discovered X-ray photons in 1895.

Bismuth et al. [18] proposed an algorithm of Digital Stent Enhancement (DSE). They begin with the analysis of the requirements for the validation of the proposed solution. The algorithm combines automatic detection, tracking, registration and contrast enhancement. Validation on a large number of synthetic and clinical images demonstrated that DSE improves significantly image quality (by more than 1 point out of 5), works automatically (in 91% of the cases) and performs fast enough (16.6 ± 3s) to be integrated into a typical angioplasty workflow with success.

Harmouche et al. [19] proposed 3D reconstructions of the spine using an articulated model which calculates intervertebral transformations. They used two types of images one obtained from X-ray images and the other one obtained from MR images in order to compensate for spine shape differences between standing and prone postures. Results presented in the paper show significant decrease in registration error when the proposed articulated model is compared with rigid registration. They also mentioned that the method can be used as a basis for full body MRI/X-ray registration incorporating soft tissues for surgical simulation.

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Waechter et al. [4] presented a method for estimating a blood flow waveform and the mean volumetric blood flow rate from rotational angiography. They extracted blood flow information, namely the mean flow rate and the waveform, from rotational angiography.

Researchers presented a real-time simulated work like in [20,21,22]. There are a number of techniques presented to improve image acquisition during real-time.

4. Volume Reconstruction

Volume reconstruction is an important topic in the field of image visualization, including medical images. Numerous studies have been performed on volume reconstruction. Many of 3D reconstruction approaches as described in [13] is to project a large amount of variations of a 3D shape onto the image plane. In recent years, the computer-aided reconstruction of a patient's 3D anatomy based on a single or few X-ray images has therefore received increasing interest [10,13,23,24,25].

Al-Shayea and Al-Ani [26] proposed 3D image visualization that extract information from the given slices. The purposed method deals with the 3D object visualization via 2D images that included many objects. The first step is to find the contour of the given object in each slice and then merging these contours to reconstruct the 3D objects. The method is easy to use as well as it can be implemented on various types of images.

The procedure of the proposed reconstruction is shown in Fig.1 as follows [26,27]:

1- Find the contour of the interested areas in each image.
2- Specify the desired zone in each image as a rectangle (S1, S2&S3).
3- Calculate the distance between two images (D).
4- Calculate the volume for the two images.

$$V_n = \frac{1}{3} D(S_1 + \sqrt{S_1 S_2} + S_2) \quad (1)$$

Where D is the distance between two images.

5- Reconstruct the volume by adding all the volumes calculated between two images.

$$V = \sum_{n=0}^{n-1} v_n \quad (2)$$

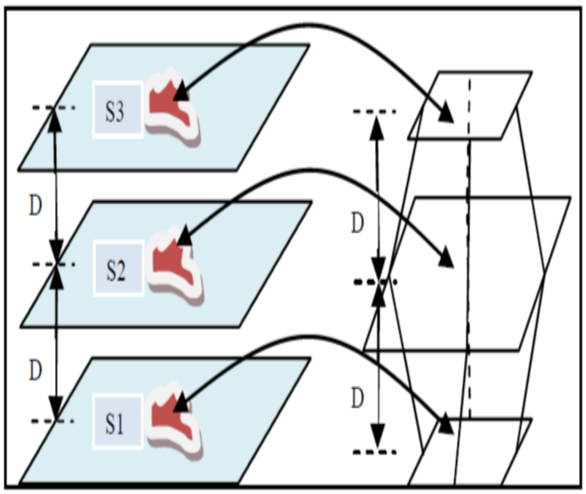

Fig. 1 [26] Volume reconstruction from slices.

5. 3D Imaging Approach

The basic steps of our proposed 3D reconstruction approach are shown in Fig. 2. These steps are:

a) Preprocessing Step: it is an important step. It introduces many crucial operations to prepare the image for the next step. Fig. 3 demonstrates the flowchart for image preprocessing proposed. This step includes:

b)

- Resizing operation to generate images with the same size to be ready for the next step.
- Color to Gray scale image converting that is required to generate gray values of images.
- Noise reduction operation to remove noise as possible that is implemented via median filter in order to remove noise from needing objects. As mentioned in [28] that medical images are often deteriorated by noise.

c) Enhancement Step: in this step, it is required to enhance image features that are obtained via applying the histogram equalization operation.

d) Contour Step: The contour is the first step in reconstruction in many works as in [26,29,30,31]. In this step the contours of the image are detected and located to view the contour levels in the test image.

e) Rendering Step: in this step elevate and fill the contours that reconstruct the 3D image.

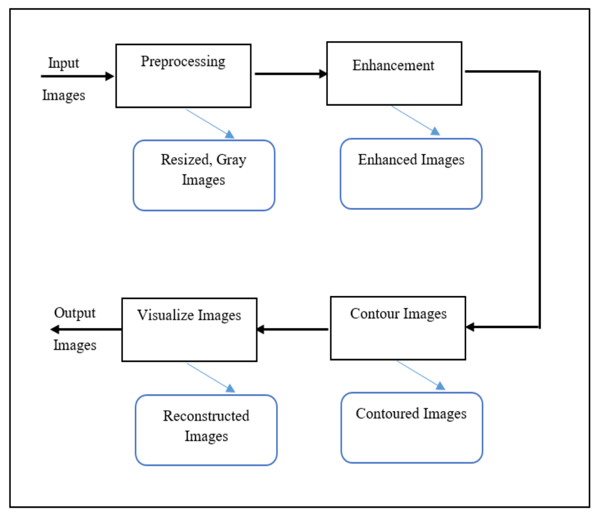

Fig. 2 Block diagram of the proposed method for 3D imaging approach

6. Results and Analysis

The implemented system applied to different types of X-ray medical images (hand, chest and head images). To examine and analysis the obtained results we demonstrate the tested images step by step with their histograms. The following figures show the demonstration steps of the reconstruction algorithm applied on hand geometry X-ray image. The original X-ray image is illustrated in Fig. 4. Fig. 5 shows the image after applying the preprocessing operations and its histogram in Fig. 6 that operation is resizing, converting into gray scale. This image shows the perfect image to be processed via the implemented system approach. Whenever Fig. 7 demonstrate the noise removal operation via applying median filter while Fig. 8 shows its histogram, in which cleared the image.

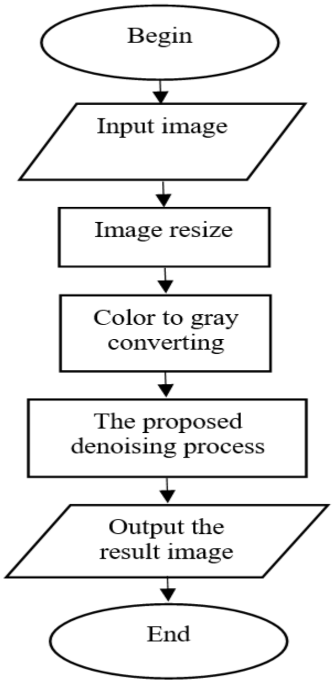

Fig. 3 Flowchart of the proposed image preprocessing

Fig. 4 Original image

Fig. 5 Preprocessed image

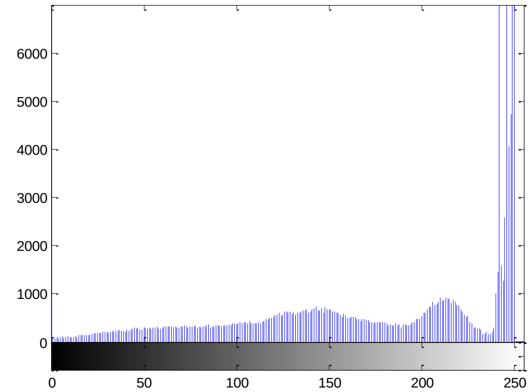

Fig. 6 Histogram of the preprocessed image

Fig. 7 Filtered image

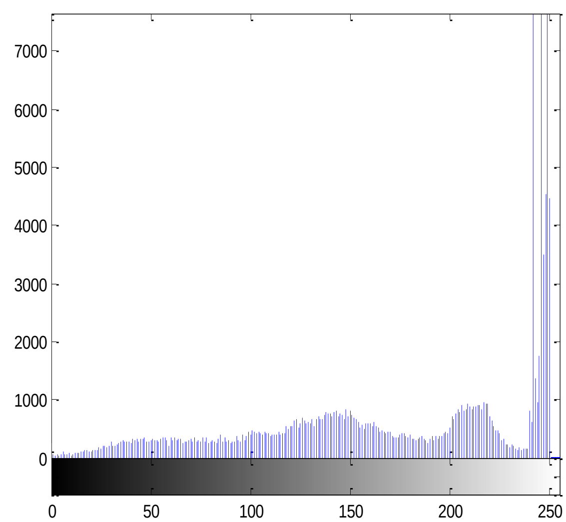

Fig. 8 Histogram of filtered Image

Fig. 9 illustrates the enhanced image and its histogram is illustrated in Fig. 10. This image is implemented via histogram equalization operation in which it is clear that equalized the distribution of pixels overall the image.

Fig. 9 Enhanced image

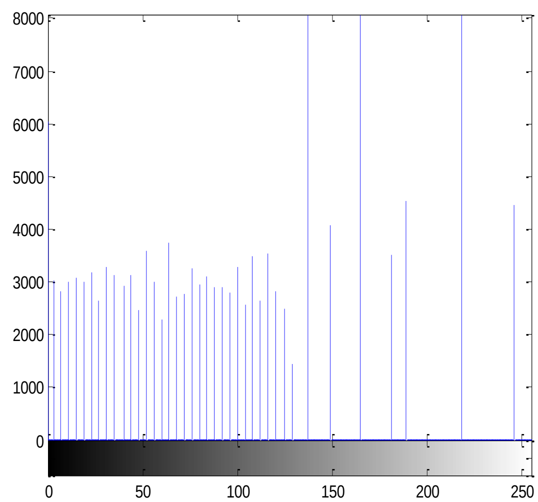

Fig. 10 Histogram of enhanced Image

Contour operation is applied to enhance the required counters of the image that is clear in Fig. 11. The histogram for the image is shown in Fig. 12. In this figure you can differentiate the bones from the overall contours of the image. In addition, Fig. 13 demonstrate the filled image. This image comes from level isolation that indicate the main objects of the image. Then the image is visualized from the obtained contours and you can see the 3D view reconstruction of the image as shown in Fig. 14.

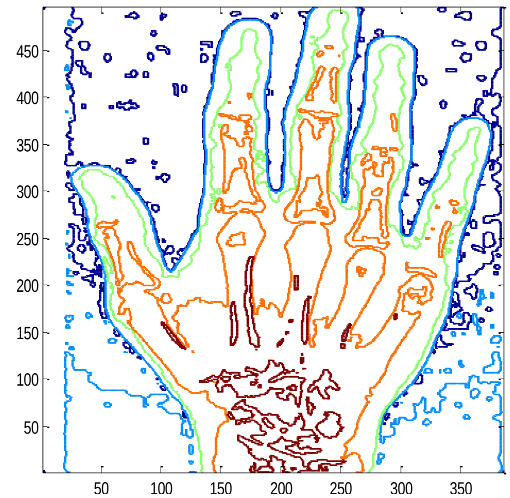

Fig. 11 Contoured image

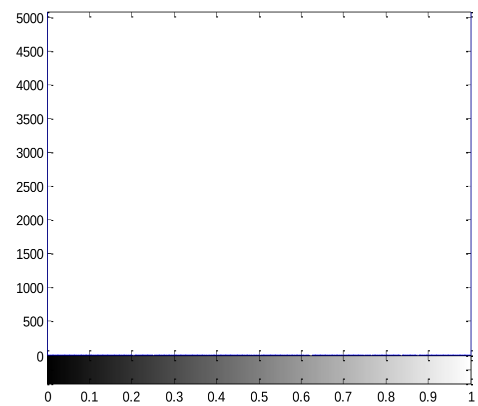

Fig. 12 Histogram of contoured image

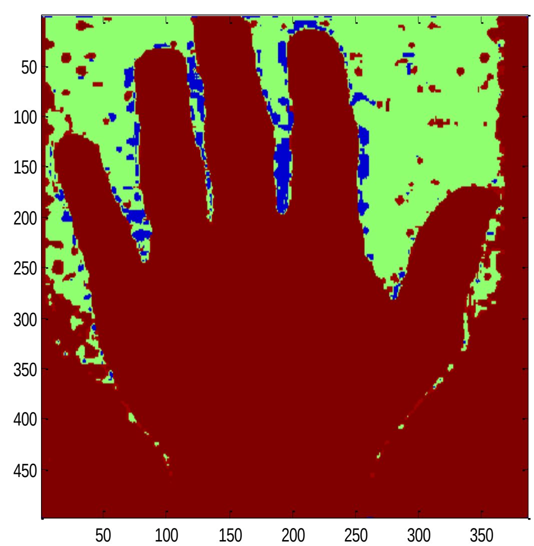

Fig. 13 Filled image

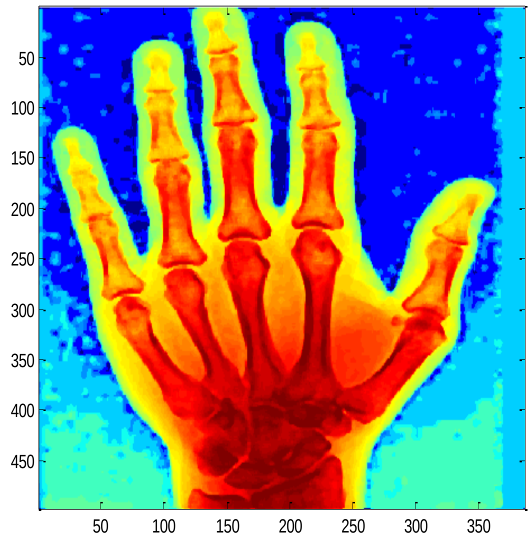

Fig. 14 Reconstructed visualized image

7. Conclusions

3D reconstruction image is an important part of image processing applications in various parts in our life including medical images. The implemented 3D reconstruction approach is tested via different type of X-ray medical image. The obtained results show the 3D reconstruction of 3D hand geometry X-ray image. This result shows a good 3D reconstruction via the steps applied to the tested image. All the results and tested of images have clearly shown that 3D visualization of this approach is much more appealing compared to 2D visualization. This efficient 3D approach can be expanded for more application such as entertainment, educational, and training systems, real-time visualization, games and more viewing requests in complex environments.

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