Chapter 19
3-D Shape Reconstruction Based CT Image Enhancement

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19.1 Introduction

Computed Tomography has become the diagnostic tool of choice in a wide variety of situations. Computed Tomography images show organ of interest at selected levels of the body. They are the visual equivalent of bloodless slices of anatomy, with each scan being a single slice. CT examinations produce detailed organ studies by stacking individual images. To analyze CT scanned images in depth, three-dimensional (3-D) image surface reconstruction has been an important research area in computer vision. For minimizing the cost function of CT scanning and analyzing in depth, 3D image reconstruction method has a great potential to improve the image quality with noise reduction [1].

2-D image reconstruction is an effective tool for medical specialist to analysis the medical scientific organs [2], which can help to improve the medical diagnostic accuracy greatly. Three dimensional tomography improves the sensitivity of the scanner in terms of shape reconstruction in such a way that photons traverse several slices and 3D reconstructed shape are also recovered [3, 4]. Another way to deal is use projection-based techniques to improve image quality [5]. In this case problems are reduced by improving 2D projection images obtained directly from the scanning device. Projections are processed in a way to reduce the problems in the resulting 3D volume. For that, reconstruction algorithm is applied to provide corrected projections in a 3D volume with reduced problems [6]. Analytic reconstruction

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methods have traditional understanding that incomplete data reconstruction implies some type of approximation of the object to be reconstructed [7, 8].

This paper deals direct 3d surface reconstruction where shading technique is used to reconstruct the image with the help of fast marching method. These methods can be problem from image reconstruction by interpreting an image as the propagating interface to the final position [9, 10].

19.1.1 Radon Transform

CT image reconstruction is one important mathematical representation where CT images are generated via a mathematical model. This mathematical model is known as Radon transform which is only help to generate the CT images. The mathematical model of Radon transform is used to collect all the raw data from n number of angels. These raw data are collected from detectors which were absorbed via X-Ray transmission [11]. The radon transform is an integral transform whose inverse is used to reconstruct the CT images.

In Fig. 19.1, Radon transform is applied over the phantom image with 180° angels. The middle of Fig. 19.1 shows the results of radon transform which indicates the sine waves and it is impossible to understand these sine waves. Hence to understand the meaning of sine waves, inverse Radon transform is applied with same number of angels. Last of Fig. 19.1 shows the results of inverse radon transform. This is the process of CT image reconstruction.

With the help of the Dirac "function" δ, which is zero for every argument except to 0 and its integral is one, $g(0, \theta)$ is expressed as:

$$g\left(0, \theta\right) = \iint f\left(x, y\right) \cdot \delta\left(x \cos\theta + y \sin\theta\right)\ dxdy$$

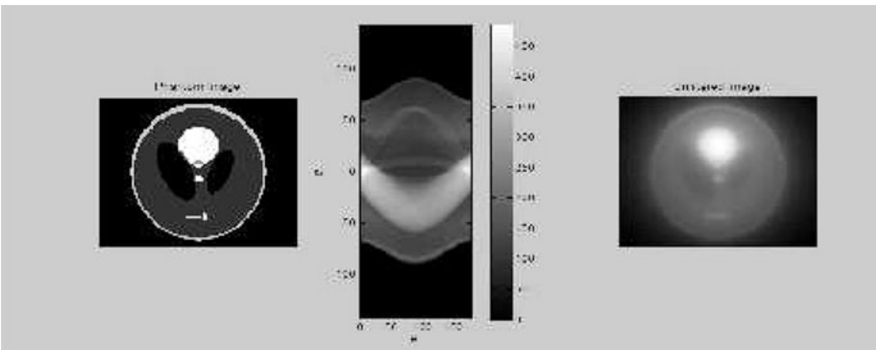

Fig. 19.1 The Radon transform computation over the phantom image: (**a**) Phantom Image, (**b**) Sinogram and, (**c**) Unfiltered reconstructed image

The inverse of Radon transform is calculated by the following equation:

$$f(x, y) = \int_{-\pi/2}^{\pi/2} \rho \cdot R_\theta (s(x, y)) \, d\theta$$

19.2 Fast Marching Method

To generate the CT images, CT image reconstruction is a big tool to underhand the processing of reconstruction. Similarly Shape from Shading [12–16] is one other important tool to enhance the shape of images in terms of shape which can be applied via curve analysis. For shape from shading there are number of methods to provide the edges in terms of shape. One of major methods is Fast Marching Method which is introduced by Sethian [11]. There are various problems in CT image reconstructions such as blurring, noise, artifacts and so on, but many solutions are also provided to solve it [18–27]. The main concept of Fast Marching method is to identify the pixels and their neighborhood pixels and give a speed function to identify the curve or line [28–31].

This method is to move the curve from one pixel in a progressive manner according to the speed function while preserving the nature of the implicit function [12]. The Fast Marching method can be defined as follows:

Algorithm

- Definition:
  - Label the set of all grid points as Alive for values which has been reached and will not be changed;
  - Label the set of next grid points (6-connexity neighbors) as Trial for examined and estimate of surface grid;
  - Label the set of all other grid points as Far for which surface grid can't estimate;
- Loop:
  - Let A(i_{min}, j_{min}, k_{min}) be the Trial point with the smallest Value;
  - Move it from the Trial to the Alive set
  - For each neighbor (i, j, k) (6-connexity in 3D) of (i_{min}, j_{min}, k_{min})

    If (i, j, k) is Far, add it to the Trial set and compute T using Loop;

    If (i, j, k) is Trial, recomputed the value of T, and update it.

19.3 Results and Discussion

Synthetic phantom image has been created with the help of ellipse and geometric methods on the MATLAB as Fig. 19.2a. To get the synthetic image in the form of 2D-CT scanned data, some pre-processing methods are applied. After applying radon transform over the synthetic image, the image is filtered with the help of Ram-Lak Kernel. Ram-Lak kernel which acts as high pass filter is recommended for filtered back projection. To obtain the intensities at each pixel in the surfaces should be projected orthographically on $z = 0$ plane. The obtained shaded image of phantom image is in Fig. 19.2b. These shaded images are used as the input FMM algorithms for the possible 3D shape reconstruction. Since the images are synthetic and we have the true depth values corresponding to them, the true depth values are assigned on the minimum singular points. The minimum singular points are chosen by the visualization of image, which are basically the brightest points in the local

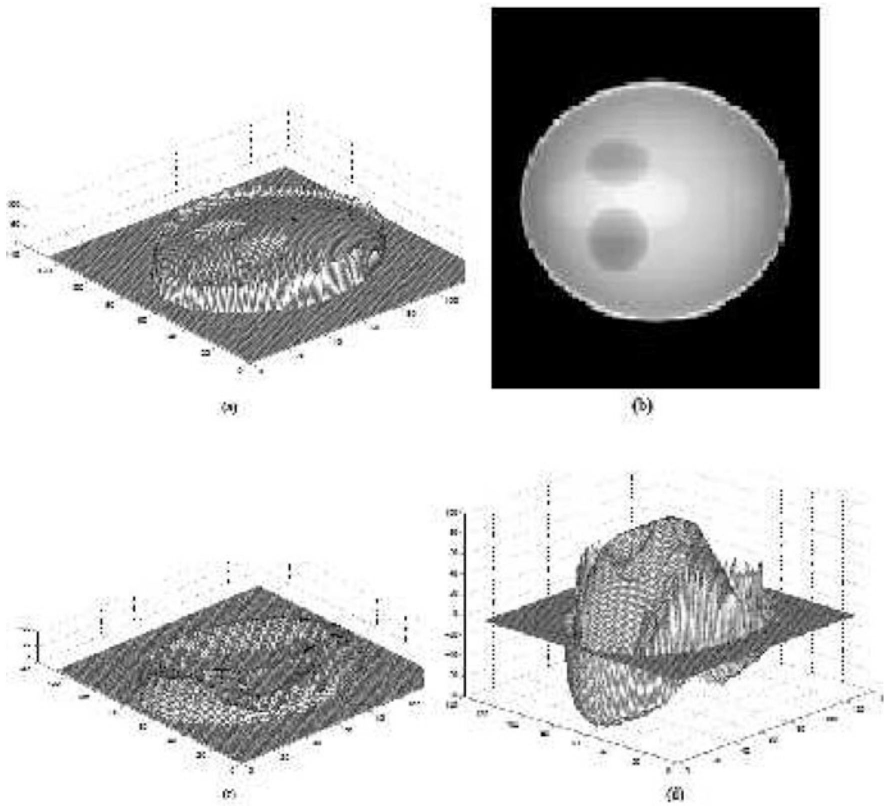

Fig. 19.2 (**a**) True 3D map from simulated image; (**b**) Simulated image; (**c**) Reconstructed 3D map; (**d**) Error map

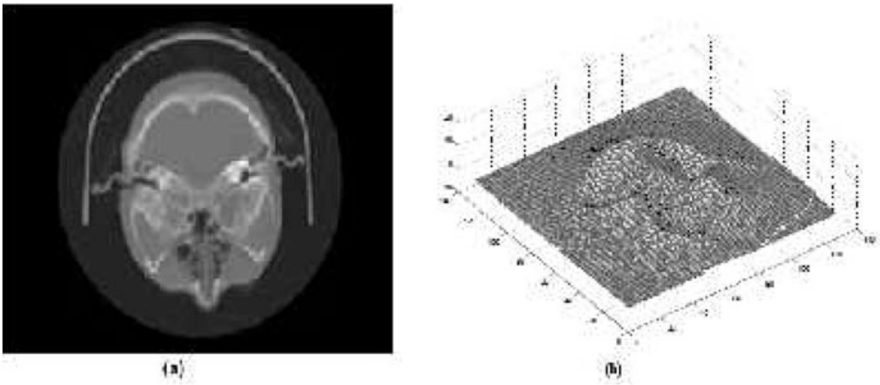

Fig. 19.3 (**a**) Real CT image; (**b**) 3D map from real image

regions of the images. The reconstructed surface is shown in Fig. 19.2c. The error maps corresponding to the synthetic image are shown in the Fig. 19.2d where, we get the value of mean error is 6.88.

We have tested the scheme on real CT scanned images. The original CT image has obtained in the format of DICOM. The size of the image is 128 × 128. We set two minimum singular points in CT scanned image. The reconstructed depth map of CT scanned image is shown in the Fig. 19.3a. The shaded image from the reconstructed depth maps is shown in Fig. 19.3b.

The algorithm for 3d shape reconstruction is coded in C++ and MATLAB is used as a tool to draw the images. The computational time for all synthetic and real images is recorded in milliseconds.

19.4 Conclusion

We have tested CT image reconstruction based on 3D fast marching method for produces significant improvements over direct analytical methods in terms of noise, and resolution. The fast marching is used to extract rough boundaries. The level set is used to fine tune the rough contour. This is because though the level set can smooth the contour, some details can also be lost. Using the level set with no fast marching presumably yields similar results, but takes much longer computation time. As the reconstruction technique remains independent from the exact form of the forward model, Fast Marching Method is applicable to any geometry and is particularly well suited to the reconstruction problem [17]. The orthographic projection and most widely used Lambertian reflectance map are used in SfS problem formulations. For the simplicity of the problem, the light source direction is considered as vertical to the image plane. In this case, Fast Marching Method is applied and shown that it solves the problem in less memory space and less computation time. Computational time varies according to images and their sizes.

Experiments are conducted on synthetic image and real CT scanned image. The qualitative results are found to be excellent. In case of synthetic data, there constructed shapes are closely matched with the true data, computed errors are also small and in case of real data, the shaded images obtained from the reconstructed depth values are quite similar to the original images. This work can supports for clinical application by providing further control over image quality and analysis.

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