# Three Dimensional Target Volume Reconstruction from Multiple Projection Images

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## ABSTRACT

The aim of this study is to reconstruct the 3D target volume from multiple projection images. It was assumed that we were already aware of the target position exactly, and all processes were performed in Target Coordinates whose origin was the center of the target. We used six projections : two projections were used to make a Reconstruction Box and four projections were for image acquisition. Reconstruction Box was made up of voxels of 3D matrix. Projection images were transformed into 3D volume in this virtual box using geometrical based back-projection method. Algorithm was applied to an ellipsoid model and horse-shoe shaped model. Projection images were created using C program language by geometrical method and reconstruction was also accomplished using C program language and Matlab(The Mathwork Inc., USA) . For ellipsoid model, reconstructed volume was slightly overestimated but target shape and position was proved to be correct. For horse-shoe shaped model, reconstructed volume was somewhat different from original target model but there was a considerable improvement in target volume determination.

Keywords: multiple projection images, 3D reconstruction, back-projection methods

## 1. INTRODUCTION

Nowadays, CT and MRI images are most commonly used to diagnose the cancer and find the lesion, but still angiograms are used as a "golden standard" in diagnoses of arteriovenous malformation, and X-ray images are preferred in many cases. For treatment planning or especially in stereotactic radiosurgery, it is very important to know the accurate position, size and volume of the target. We can determine the size and volume of the target using bi-projection images, but this conventional method has many problems such as an exaggeration or reduction of the size of lesion. This can lead the failure of tumor control. There were many attempts to reconstruct a three dimensional tumor volume from projection images, but it is known that it is impossible to reconstruct a three dimensional target volume using only bi-projection images [1]-[6]. We propose the reconstruction algorithm using multiple projection images and back-projection method.

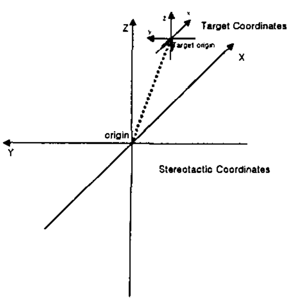
## 2. MATERIALS AND METHODS

### 2.1 Setting of Target Coordinates

The stereotactic target position can be acquired using stereotactic localizer and algorithm proposed by Siddon and Barth [7]. Next, Target Coordinates are settled. The center of target becomes the origin of Target Coordinates. (Fig. 1) Once the target position is determined, we can get six projection.. S means the source position and P means the projected images which are made in image devices. P1 and P2 are the bi-projection images, and P3 to P6 are projection images which are made by non-coplanar sources. Each source positions are already known. We set S3 and S4 were located 45 degree clockwise direction from S1, and S5 and S6 were located 45 degree counterclockwise direction from S1. S3 and S5 are on the same distance from the x axis as S4 and S6 are under the same distance from the x axis.

### 2.2 Setting of Reconstruction Box and four oblique projections

P1 and P2 were used to get a named virtual Reconstruction Box. The center of this box is the origin of the Target Coordinates. The length and width, heights of this box is the maximum length of the projected image. The length at the center is adjusted by magnification factor. Reconstruction Box is consisted of plenty of voxels. Then four projections are performed. (Fig. 2)



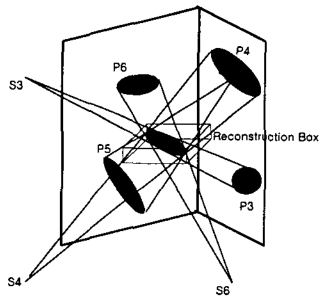




Fig. 1. Setting of Stereotactic Coordinates an Target Coordinates (Left)
Fig. 2. Four projection of arbitrarily locate ellipsoid target (Right)

### 2.3 Back-projection and reconstruction of target from multiple back-projections

As a preprocessing, contour the target and delete unnecessary regions. The only part that represented on the images is the projected target shape. The center of pixels can be converted to the coordinates. To convert the pixels on the images to the 3D coordinates, it is necessary to rotate the plane. Each plane is rotated in 45degree clockwise or counterclockwise direction from the x axis. If we know the exact absolute coordinates of the points on this plane, we can get 3D coordinates of this point. And we know the positions of sources by equipment setting and the coordinates of points on the images, we can get the 3D lines which pass these points and the Reconstruction Box. Because there are four sources and four projection images, total four back-projections are performed. Each voxel in the Reconstruction Box has its own value which is counted by the relationships of the voxels and lines. After normalization and applying the threshold value, the target is reconstructed as a goal.

### 2.4 Ellipsoid target and Horseshoe-shaped target reconstruction

To verify this algorithm we used an ellipsoid target and Horseshoe-shaped target to consider the extreme cases of determining the target volume. In this study, acquirement of projection images and back-projection were performed using C program language. Ellipsoid target was assumed that the major axis was positioned in 45 degree rotated in clockwise direction, and the center of this target is the origin of Target Coordinates. In the case of Horseshoe-shaped target, center of the target was determined from the bi-projection images P1 and P2. 3D reconstruction was performed using MatLab 6 (The MathWorks, Inc, USA).

## 3. RESULTS

### *3.1 Reconstructed target volume of target model*

From the projection images P1 and P2, Reconstruction Box was set to 30×30×20 for ellipsoid target and 30×60×40 for Horseshoe-shaped target. Each voxel size was set to 1×1×1㎣ to increase the calculation speed. Fig. 3 shows the reconstructed volume of each target.

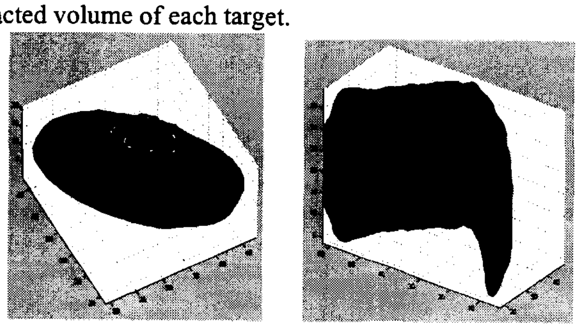
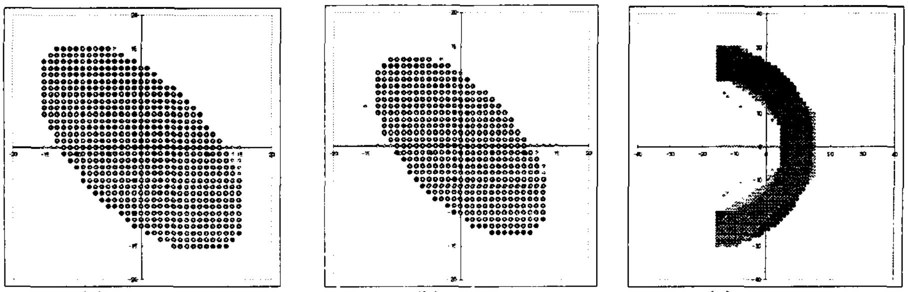


Fig. 3. Reconstructed image of ellipsoid target an Horseshoe-shaped target

### 3.2 Comparison of reconstructed volume with theoretical volume and bi-projection methods

Reconstruction volume was acquired by counting all reconstructed voxels. For ellipsoid model, theoretical volume was 6,283㎣ and reconstructed volume was 7,100㎣. This volume was 13% larger than theoretical volume. Fig. 4 shows the comparison of the theoretical and reconstructed area of slice at z=0mm and z=5mm. Two areas were agreed well. For Horseshoe-shaped target, theoretical volume of this target model was 31,415㎣ and reconstructed volume was 31,846 ㎣. Reconstructed volume was 1.3% larger than theoretical volume, but in slice area comparison study, it showed more significant errors.



(a) (b) (c)

Fig. 4. Comparison of the area of the reconstructed target volume with theoretical area . Blue dots represent the theoretical target area and red-rounded yellow dots represent the reconstructed area. For ellipsoid target (a) at z=0mm, (b) at z=5mm and for Horseshoe-shaped target (c) at z=0mm

## 4. DISCUSSION AND CONCLUSION

We could get a 3D reconstructed target volume. Theoretical area and reconstructed area were agreed well within a voxel size in ellipsoid model, but showed more significant error in horseshoe-shaped model. Original target shape of Horseshoe-shaped target is looks like U shape, but reconstructed target is looks like L shape. It seems that this is the limitation of reconstruction from four projections. So it needs serious considerations to apply this algorithm to concave targets. Threshold value to apply in the last step is very important, because the reconstruction volume is strongly dependent to this value. If this value is low, Total volume will be increased and vice versa. From bi-projection images and four oblique projection images, we have reconstructed the target volume. Reconstructed volume was 13% greater than theoretical volume in ellipsoid target model and the shape was almost same as original target. In Horseshoe-shaped target study, there was 1.3% size exaggeration, but reconstructed shape was not agreed well. Reconstruction completed just a few seconds, but execution time is dependent on the image sizes and the voxel sizes. Though reconstruction was not accomplished perfectly, but proposed algorithm may be helpful to determine the GTV of the tumor target. And more study on various models and apply on clinical situation will be necessary to improve the accuracy and the performances.

## ACKNOWLEDGEMENTS

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