3D IMAGE RECONSTRUCTION TECHNIQUES FOR CONE BEAM COMPUTED TOMOGRAPHY

By

Mohammed Abdulraheem Mohammed Almasani

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
Biomedical Engineering and Systems

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
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Under the Supervision of

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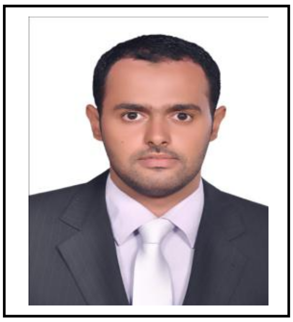

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Title of Thesis:

3D Image Reconstruction Techniques for Cone Beam Computed Tomography.

Keywords:
CBCT; Cone-beam; Projections; Analytical reconstruction methods; Iterative reconstruction methods.

Summary:

Computed Tomography (CT) is a widely used imaging technique in medical diagnosis. It relies on collecting data about an object from multiple views representing its projections and subsequently using these data to construct an image. Among the latest advances in CT is the utilization of cone-beam geometry of x-ray projections is used instead of the usual planar fan beam. This technique is called Cone Beam CT (CBCT) and promises even faster yet safer 3D imaging compared to previous CT technologies. These advantages come at the expense of a more challenging reconstruction problem that is still an active research area to optimize for speed and image quality. Present reconstruction methods are classified into two main categories, namely; analytical and iterative methods. In this thesis, we study the performance of the leading reconstruction methods from both categories and investigate modifications in their parameter selection. We also compared their quality, speed and dose quantity of x-ray radiation using analytical phantoms. The results indicate that the reconstructed volumes produced from the iterative methods provide better quality but at the cost of a higher computational complexity. We develop a parallel computing version of the algorithms and show that the computation time can be improved using multi-core processing. The results of this work provide a framework for optimizing the quality, computation time, projection data required and hence the patient dose.

Acknowledgement

In the name of ALLAH the most Merciful the most Gracious; all thanks to ALLAH the Lord of the Heavens and Earth. I wish to express my gratitude to my supervisor, **Prof. Dr. Yasser M. Kadah** who was helpful and offered invaluable assistance, support and guidance. I would also to thank him for his great efforts and constant care.

Finally, my sincere thanks go to my family and friends.

This thesis is dedicated to my Parents, Brothers, Wife, Son (Ahmed), Family and my Friends.

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μ	Attenuation coefficient of the object.
A	Coefficient matrix.
a_{ij}	Segment length of the path towards the detector bin *i* within the pixel *j*.
D	Half of the object diagonal.
d_{12}	Distance from point 1 (x-ray source) to point 2 (detector element).
d_x , d_y , d_z	The distance from one plane to the next one in each direction.
E	Correction of the calculated projection.
$f(x, y)$	2D object.
$f_{i,j}$	Reconstructed Volume pixels.
$g_{i,j}$	Original volume pixels.
i_{min} ,i_{max}	Range of voxel indices in *x*-axis.
j_{min} ,j_{max}	Range of voxel indices in *y*-axis.
k_{min} ,k_{max}	Range of voxel indices in *z*-axis.
λ	Relaxation factor which controls the convergence rate.
$L(\beta, u)$	The line across the object
$L_{detector}$	detector length.
M_{ART}	Number of projections images in ART method.
M_{FB}	Number of projections images in FDK method.

$\boldsymbol{P}$	Projection vector.
$\boldsymbol{P(i,\theta)}$	Projection at specific ray *i* at angle θ.
$\boldsymbol{P_{\alpha}\,(\gamma, \varphi)}$	Cone beam projections.
$\boldsymbol{P_{\alpha}(\gamma)}$	Fan beam projections.
$\boldsymbol{P_{\beta}(u)}$	Projection of pencil beam at a specific angle β and distance *u*.
$\boldsymbol{P^{F}{}_{\alpha}\,(\gamma, \varphi)}$	Filtered projection.
$\boldsymbol{P^{W}{}_{\alpha}\,(\gamma, \varphi)}$	Weighted projection.
$\boldsymbol{\theta}$	Angle of projection view.
SDD	Source to detector distance.
$\boldsymbol{T}$	Transformation matrix.
$\boldsymbol{t_x , t_y , t_z}$	Translation distances on the directions *x, y* and *z* respectively.
$\boldsymbol{u}$	Distance from ray to the centre of rotation.
$\boldsymbol{W}$	Intersection length of ray within voxel.
$\boldsymbol{X}$	Unknown voxels of the object.
$\boldsymbol{x_j}$	The *jth* pixel in 2D or *jth* voxel in 3D.
$\boldsymbol{A}$	Angular position of the x-ray source (rotation angle).
$\boldsymbol{\alpha_{max}}$	Parameter value of the exit point of the ray through the voxel grid.
$\boldsymbol{\alpha_{min}}$	Parameter value of the entrance point of the ray through the voxel grid.
$\boldsymbol{\alpha_x , \alpha_y , \alpha_z}$	Parameter values of the ray intersection with the *x, y* and *z* direction planes.
$\boldsymbol{\beta}$	Angle of pencil beam.
$\boldsymbol{\gamma}$	Angle of fan beam.