Medical Image Processing for Diagnostic Applications

3-D Data – Cone Beam Data

Online Course – Unit 46

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Pattern Recognition Lab (CS 5)

Topics

Cone Beam Geometry

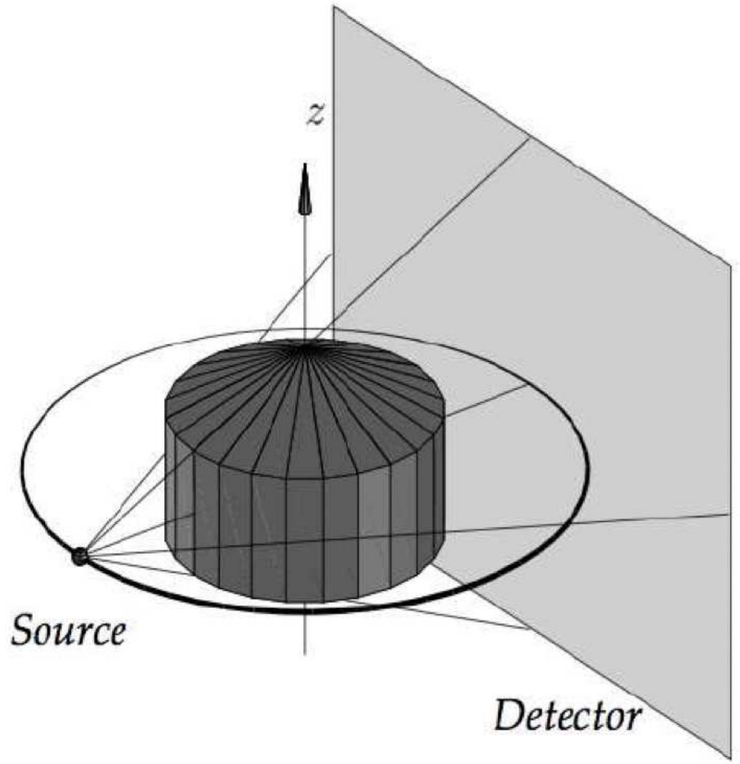

Figure 1: Schematic of a cone beam projection

Cone Beam Geometry

- Flat panel or multi-row detectors can detect considerably more data at a time.
- This geometry is very popular.
- Projection and backprojection can be described using projection matrices.
- Unlike in fan beam geometry, we do not have a central slice theorem.
- Data sufficiency conditions are different than in 3-D parallel beam geometry.

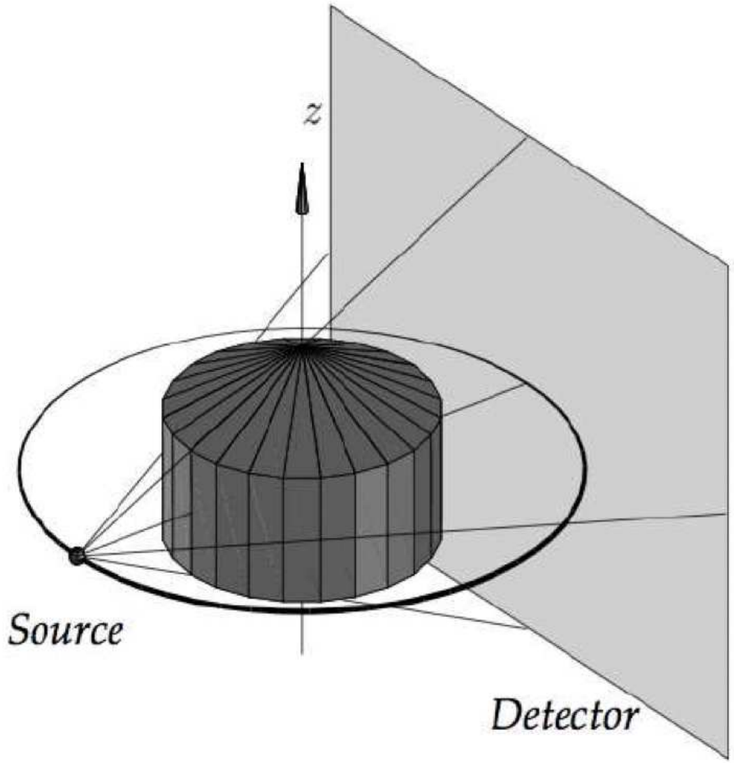

Figure 2: Schematic of a cone beam projection

Condition for Data Completeness

Tuy's condition: Every plane that intersects the object of interest must contain a cone beam focal point.

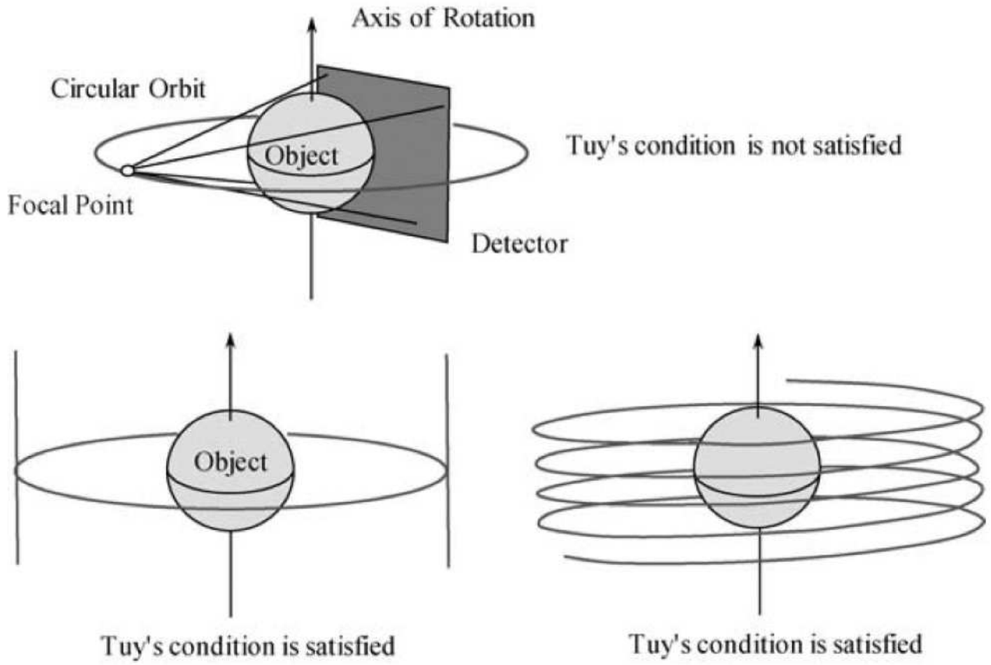

Figure 3: A circular trajectory not satisfying Tuy's condition (top) can be adjusted by moving up and down twice to satisfy it (bottom left). Following this idea, the helical trajectory (bottom right) is a much more practical version (Zeng, 2009).

Cone Beam Geometry: Data Sufficiency

- How to obtain a helical trajectory?

- How to make a circular scan complete?

Cone Beam Geometry: Data Sufficiency

- Consider plane-integrals along $\boldsymbol{\theta}$ for a reconstruction point in the plane of rotation.
- All angles are observed within the plane that is perpendicular to the viewing direction.

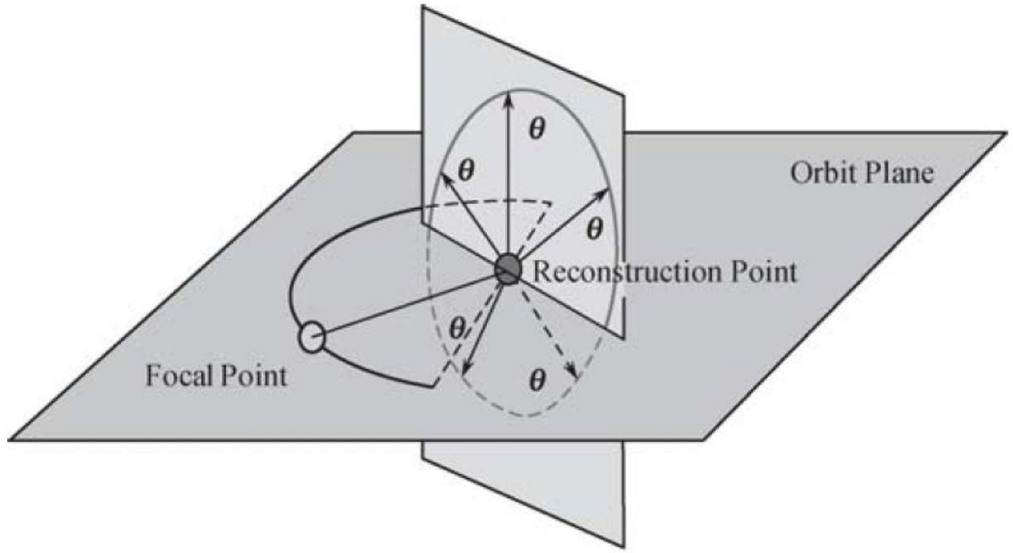

Figure 4: Reconstruction point lies in the plane of rotation (Zeng, 2009).

Cone Beam Geometry: Data Sufficiency

- If this is repeated for every point on the orbit, a full sphere will be sampled.
- Hence, data for this point is complete.
- We refer to this as a π-segment.

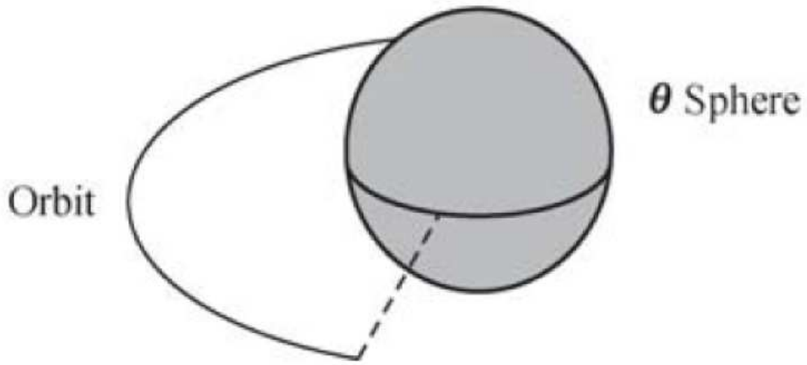

Figure 5: A π-segment (Zeng, 2009)

Cone Beam Geometry: Data Sufficiency

- On points above and below the orbit plane, there is missing data.
- The reconstruction will contain artifacts.
- The higher the angle to the reconstruction point, the stronger the cone beam artifact will appear.

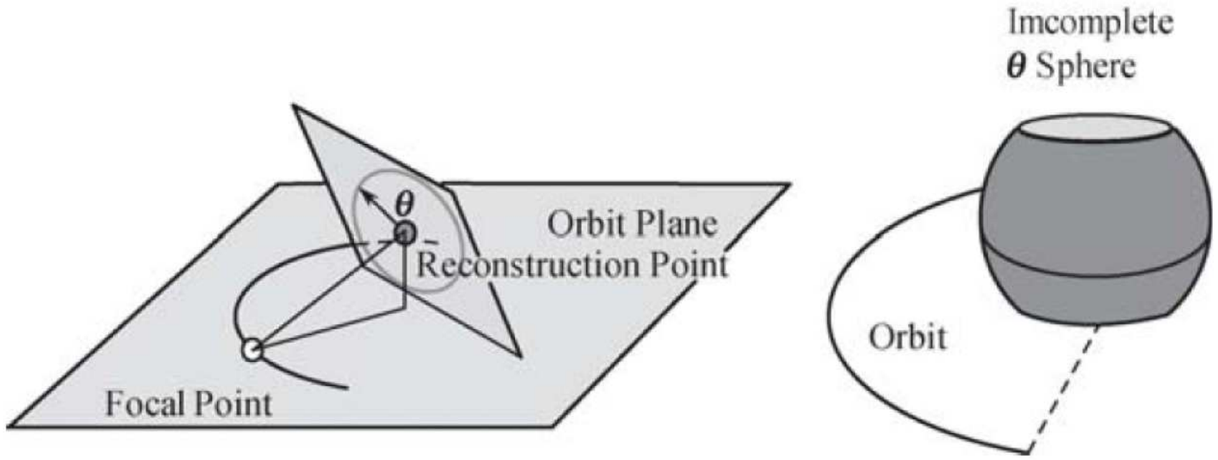

Figure 6: Reconstruction point lies outside the plane of rotation (Zeng, 2009).

Circular Trajectory

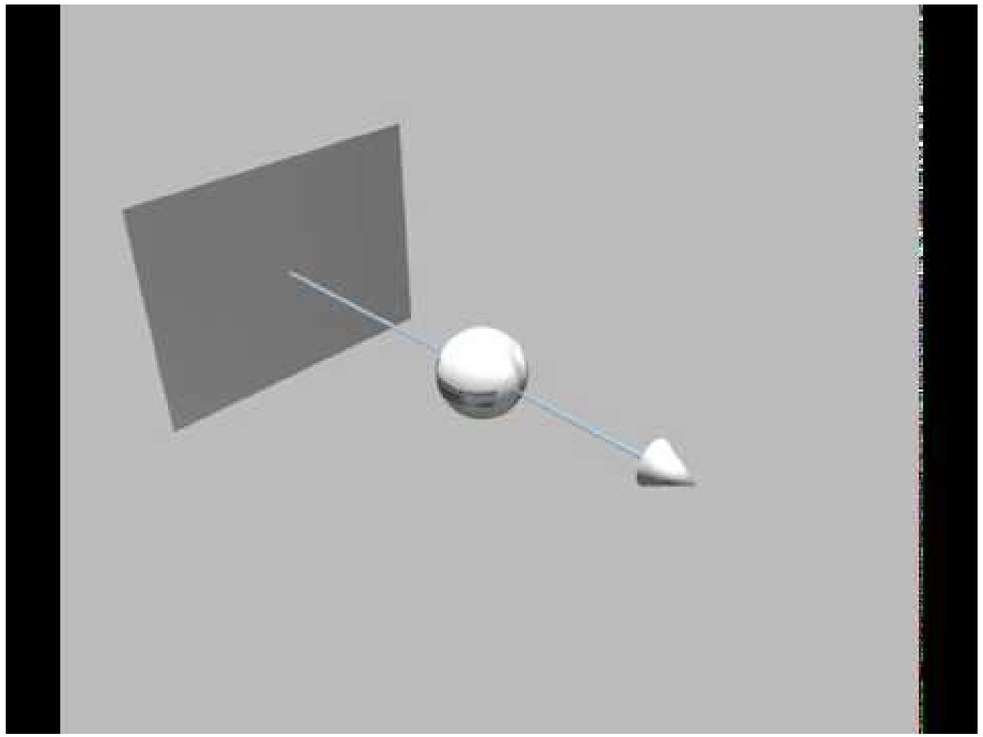

Figure 7: CT sampling circular trajectory in rotation plane, link: https://www.youtube.com/v/hFD9EZp2vok

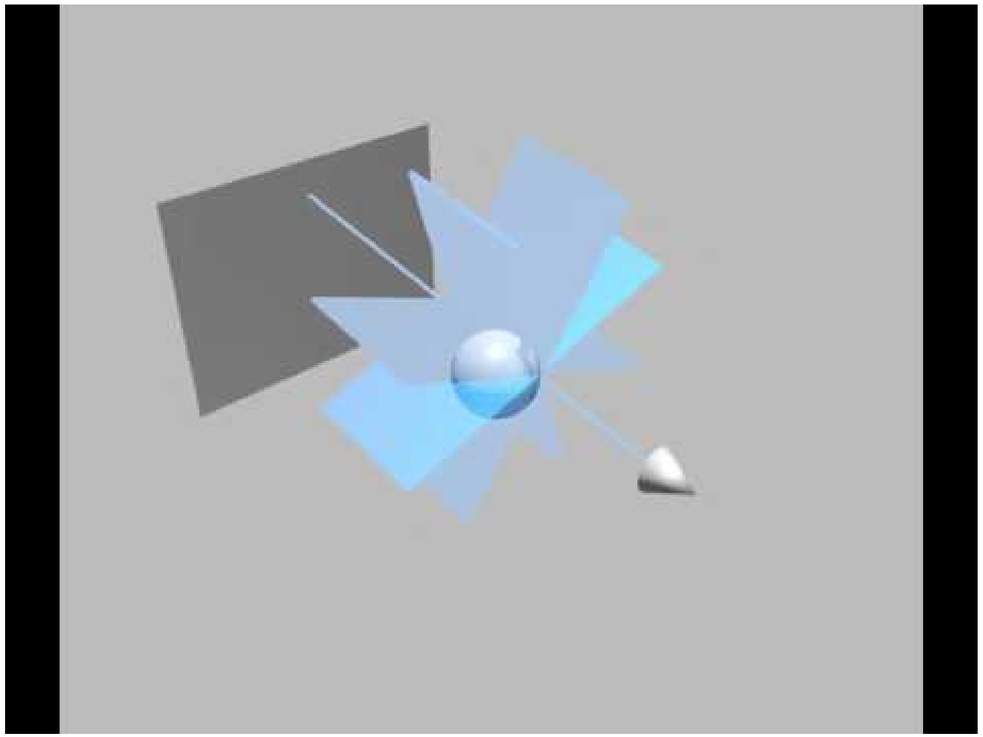

Figure 8: CT sampling circular trajectory out of rotation plane, link: https://www.youtube.com/v/iWIeScosduk

Cone Beam Geometry: Data Redundancy

A helical orbit will contain redundant observations:

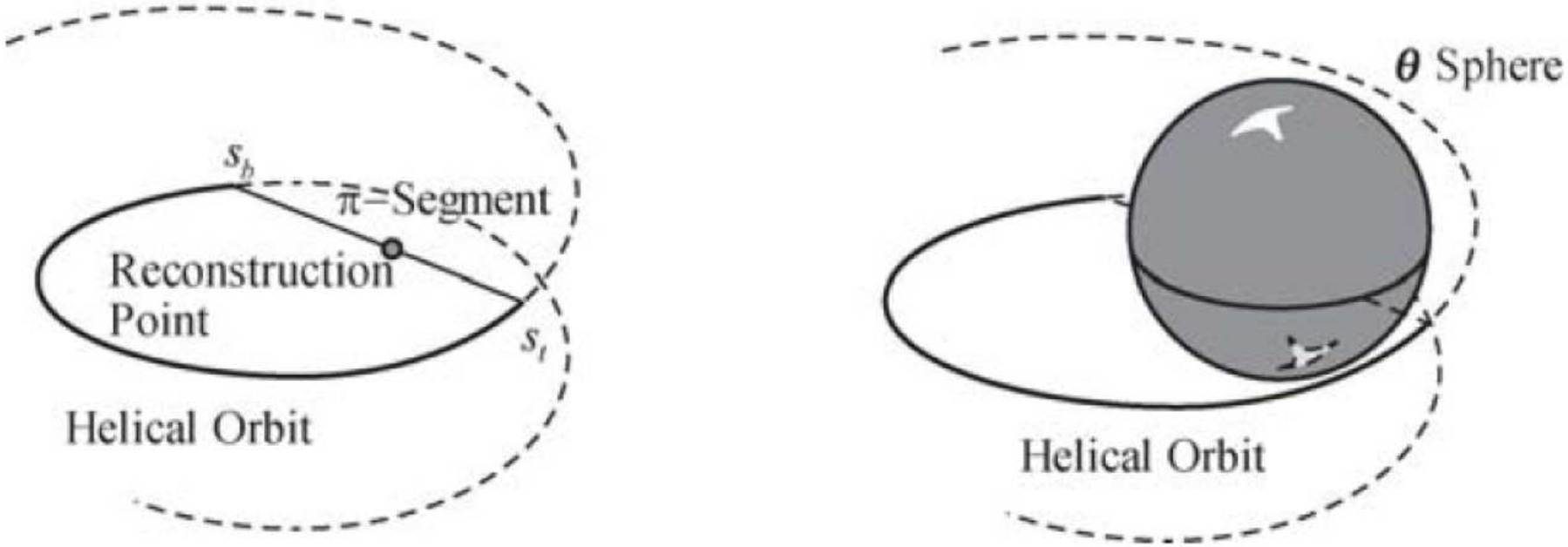

Figure 9: Some rays through the object hit the helical trajectory more than once (Zeng, 2009).

Cone Beam Geometry: Data Redundancy

Redundant observations will occur on cutting planes that hit the helix more than once:

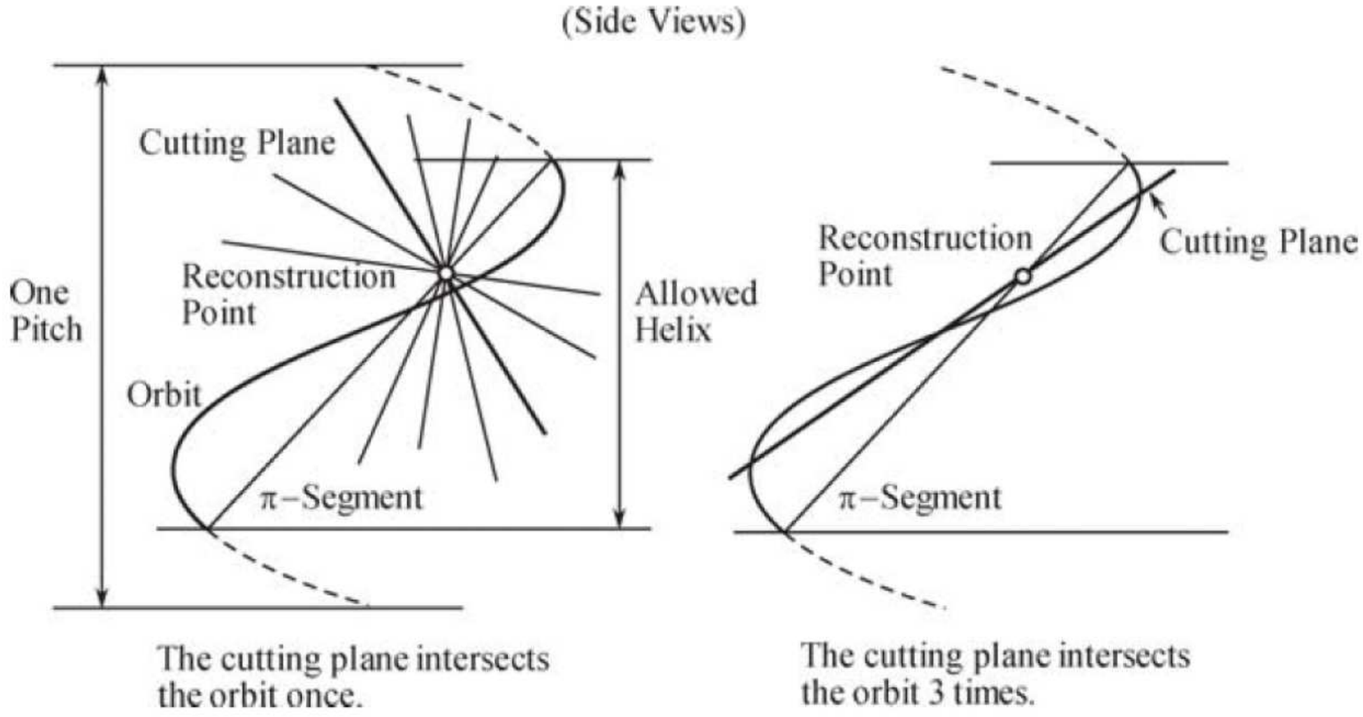

Figure 10: Some cutting planes intersect the orbit multiple times (Zeng, 2009).

Topics

Take Home Messages

- There is no central slice theorem for cone beam data.
- If we want to check for data completeness, Tuy's condition is a helpful tool.
- In cone beam geometry, reconstruction areas out of plane are not completely sampled, such that artifacts appear.
- In a helical scan there is data redundancy.

Further Readings

The best way to augment your knowledge of the shown concepts is to read the companion book of the current chapter:

Gengsheng Lawrence Zeng. *Medical Image Reconstruction – A Conceptual Tutorial*. Springer-Verlag Berlin Heidelberg, 2010. DOI: 10.1007/978-3-642-05368-9