Diagnostic Medical Image Processing

Introduction

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Diagnostic Medical Image Processing

Computed Tomography

A few historical remarks on computed tomography (CT):

- **1917** Inverse Radon Transform: Radon was first to address tomographic reconstruction, but he did it with a purely mathematical viewpoint, he was far away from application, and for that reason no attention was put to his results for mostly 50 years.
- **1971** Godfrey Hounsfield and Allan Cormack built the first computer tomography system
- **1979** Godfrey Hounsfield and Allan Cormack received the Nobel Prize in Medicine on Dec. 10, 1979.
- **1990** Introduction of Spiral CT by W. A. Kalender, W. Seissler, E. Klotz, and P. Vock (Siemens Medical Solutions)
- **2002** 16-slice CT and 4D reconstruction of the beating heart
- **2003** 64-slice (2×32) scanning
- **2004** Cardiac CT
- **2005** Dual source CT

Computed Tomography

Development of CT-scanners in numbers:

1972 reconstruction of a 80×80–matrix, 4 min per rotation, 8 intensity levels, overnight reconstruction

2002 reconstruction of a 512×512–matrix, 0.4 sec per rotation, 16 slice scanning, on–the–fly reconstruction

2003 reconstruction of a 512×512–matrix, 0.33 sec per rotation, 64 slice scanning, whole body scan

2005 dual source CT system provides 83 ms temporal resolution and 0.4 mm spatial resolution in direction independent the heart rate for coronary CT angiography; 0.33 sec per rotation.

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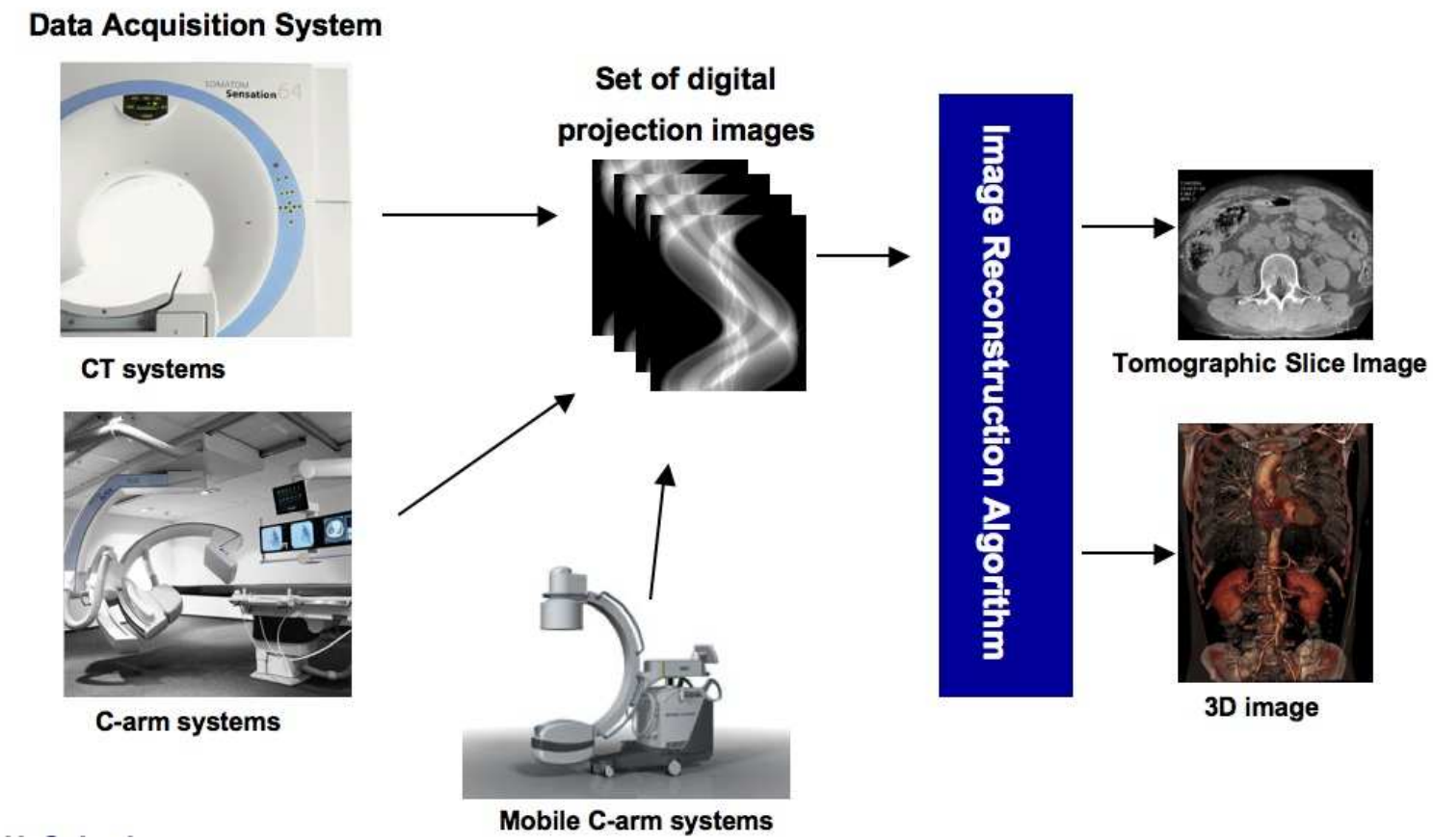


Figure: Different CT systems: from low end to high end scanners (image source: Siemens Medical Solutions)

Computed Tomography

Spiral CT was the major breakthrough for 3-D imaging in CT

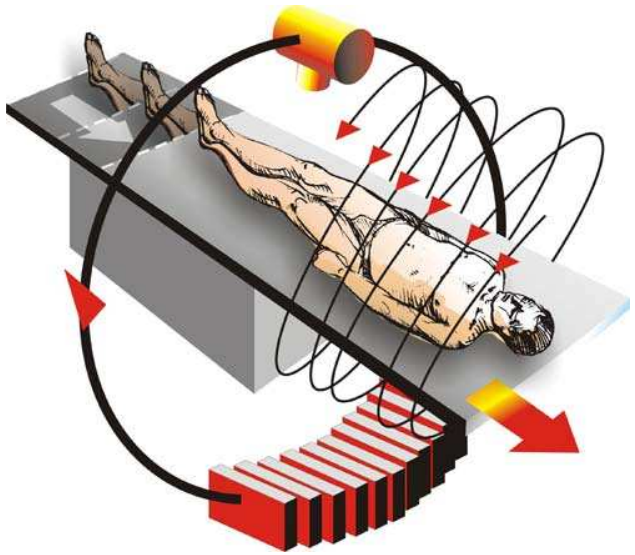
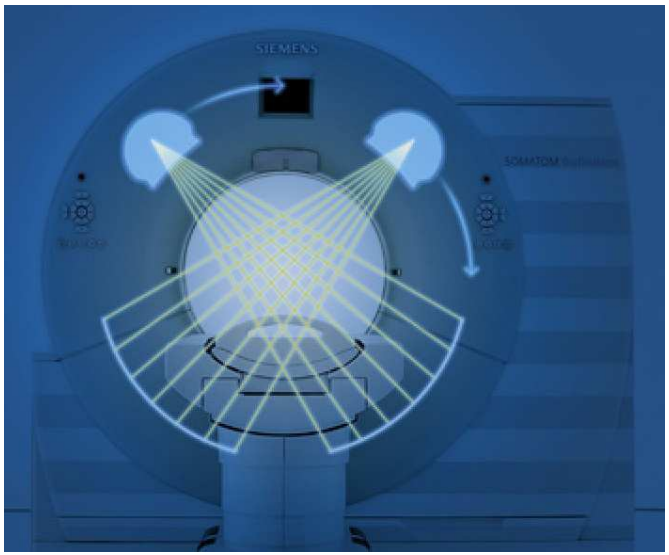


Figure: Principle of spiral CT: simultaneous rotation of the gantry and translation of the patient table. (image source: http://kabayim.com/images/spiralCT.jpg)

Computed Tomography

Dual source CT is of major importance for non-invasive cardiac imaging.



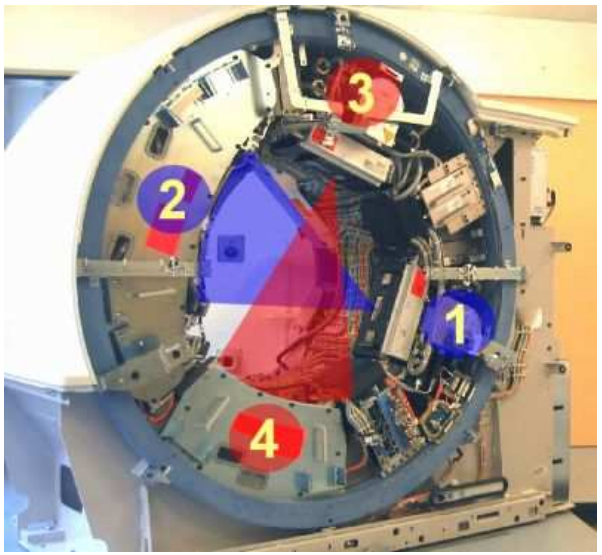


Figure: Dual Source CT Scanner (1: first x-ray tube, 2: first detector, 3: second x-ray tube, 4: second detector) (image source: Siemens Medical Solutions (left) and Universitätsspital Zürich http://www.radiologie.usz.ch/german/HealthProfessionals/Computertomographie)

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Figure: Siemens Siretom (1974) and today's dual source CT scanner (images: Siemens Medical Solutions)

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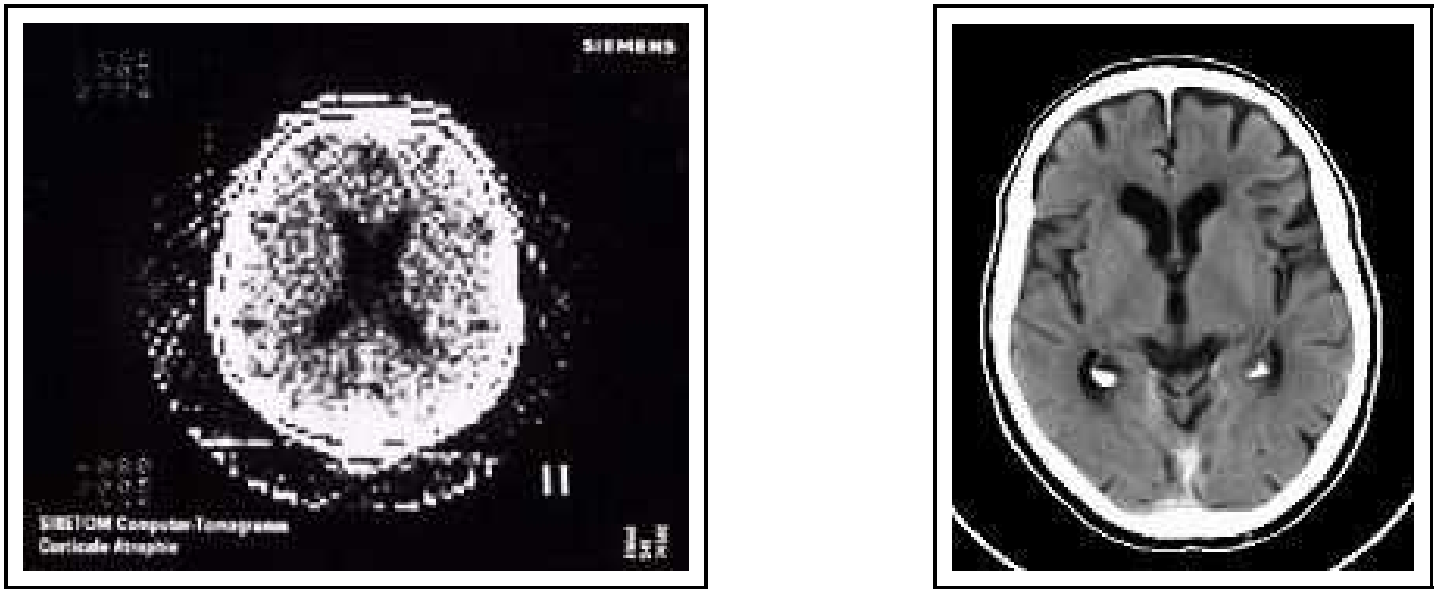

Figure: Axial CT slice captured around 1975 using the Siretom scanner (left), current CT image quality (right) (images: Siemens Medical Solutions)

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Figure: Examples of axial CT slices

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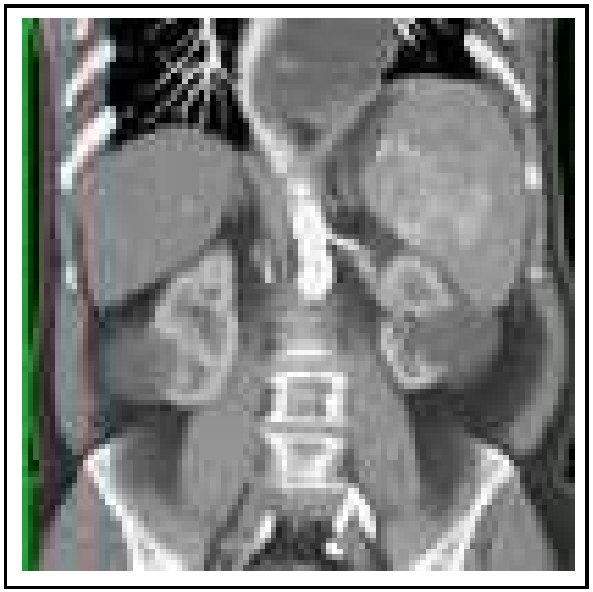
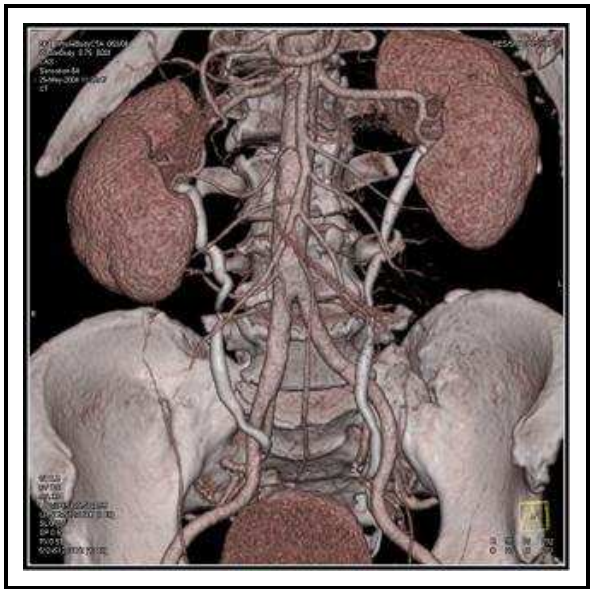
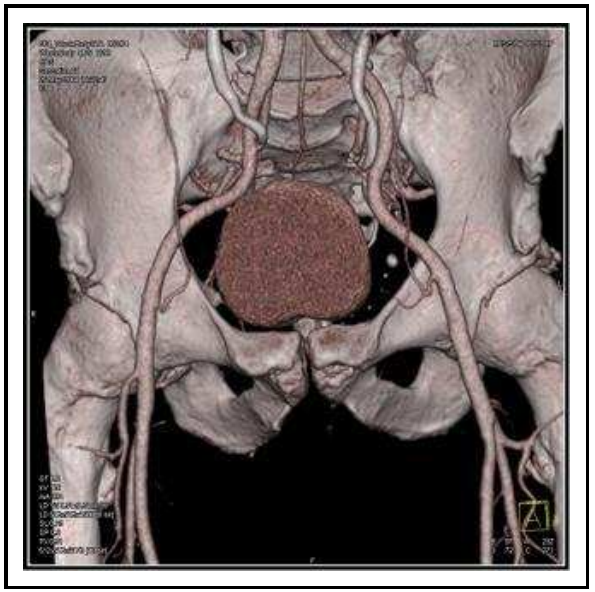

Figure: Examples of volume rendered CT volumes using different rendering parameters (images: Prof. Fishman, Johns Hopkins University)

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Figure: Examples of one CT volume rendered using different settings (images: Prof. Fishman, JHU)

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Figure: Examples of cardiac CT images (images: Prof. Fishman, JHU)

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Figure: Examples of cardiac CT images (image: Siemens Medical Solutions)

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Major CT Research at LME

- subtraction imaging in CT
- image registration using CT data
- hardware accelerated CT reconstruction optimized for various architectures
- dose reduction and image enhancement
- spectral CT reconstruction
- CT image segmentation

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Take Home Messages

- CT wouldn’t exist without reconstruction algorithms and computers
- in CT we still have an incredible innovation speed
- dynamic imaging is the hot topic in CT

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Further Readings

Original and historic texts on Computed Tomography:

- Alan M. Cormack: Representation of a function by its line integrals with some radiological applications, Journal of Applied Physics, Vol. 34, No. 9, 1963, p. 2722-2727
- J. Ambrose and G. N. Hounsfield: Computerized transverse axial scanning (tomography). 1. Description of system British Journal of Radiology, Vol. 46, No. 542, February 1973, p. 148-149.
- J. Ambrose: Computerized transverse axial scanning (tomography). 2. Clinical application British Journal of Radiology, Vol. 46, No. 552, December 1973, p. 1023-1047.
- B. J. Perry and C. Bridges Computerized transverse axial scanning (tomography). 3. Radiation dose considerations British Journal of Radiology, Vol. 46, No. 552, December 1973, p. 1048-1051.

Further Readings

- A nice article on the history of CT:
  E. C. Beckmann: CT scanning the early days, The British Journal of Radiology, Vol. 79, No. 937, January 2006, p. 5-8.
  an alternative overview is given by the German article of two FAU authors:
  W. Bautz, W. Kalender: Godfrey N. Hounsfield und die Folgen, Der Radiologe, Vol. 45, No. 4, April 2005, S. 350-355.
- The physics and mathematics of CT can be found in
  Thorsten M. Buzug: Einführung in die Computertomographie. Mathematisch-physikalische Grundlagen der Bildrekonstruktion, 2nd edition, Springer, Heidelberg, 2007. (amazon here).
- Another nice book on CT is:
  Willi A. Kalender: Computed Tomography: Fundamentals, System Technology, Image Quality, Applications, 2nd edition, Wiley, 2006 (amazon here)