Biomedical imaging

Computed Tomography

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The purpose of this lab is to get familiar with the Radon transform and tomographic imaging with the help of matlab and the image processing toolbox. A short lab report should be submitted in electronic form as a PDF file. Illustrate your results with images and brief explanatory comments.

A short lab report should be submitted in electronic form as a PDF file. Hand in your work as a zip file containing your report, your code in one running .m file (script) and any supporting functions, along with the images you have used (reference your images with relative paths in your code). Submit your .zip files to mlanger@esrf.fr. Deadlines are:

27/01/2015 for the Tuesday group

29/01/2015 for the Thursday group.

Assignments

Properties of the Radon transform
The purpose of this section is to investigate the effect on the sinogram of geometrical transformations (translation, rotation, change of scale) on the input image.

1) Calculate the Radon Transform (with the function radon.m) of a real image (eg max_head_ct.tif, but you can use other suitable images) and a synthetic image (the Shepp-Logan phantom).

2) Generate new sinograms where you have applied geometric transformations to the image: translation, rotation, change of scale. Calculate the Radon transform of each new image. What is the effect of each geometrical transformation on the sinogram?

3) By a theoretical analysis, how can these properties be justified?

Filtered backprojection (FBP)
Here we will study some properties of the FBP algorithm.

1) Take the Radon transform of a real and a synthetic image using different number of projections. Take the inverse Radon transform of the images using FBP. How is the result influenced by the number of projections?

2) Sub-sample the projections by different ratios. What is the effect on the reconstructed image?

3) Add different amounts of Gaussian noise to the projections and reconstruct. How does noise level in the projections and number of projections affect the signal to noise ratio in the reconstructed image? What can be done to improve the reconstruction in the presence of noise? What are the advantages and drawbacks of your selected method?

Fanbeam geometry

In this part we will study the effect of a non-parallel imaging geometry.

1) Generate fanbeam projections in different geometries (different fanbeam vertex to center of rotation distances. You might have to play with the sensor element spacing to get the same image size). Compare the fanbeam and parallel geometry sinograms.

2) Look at reconstructing fanbeam data directly with the FBP algorithm. What errors do you get in the reconstructed image?

3) Compare reconstructions of fanbeam data with the fanbeam algorithm to the parallel geometry case with FBP.

Iterative reconstruction algorithms

1) Implement an iterative algorithm, for example Algebraic Reconstruction Technique (ART), Simultaneous Iterative Reconstruction Technique (SIRT) or Simultaneous Algebraic Reconstruction Technique (SART), for example by using the projection and backprojection operators from the image processing toolbox (you can find the algorithm in the lecture notes or for example in Kak & Slaney (1988), Section 7.2). Test your algorithm on a simple image (for example a white square on black background), a synthetic (but more complex) image and a real image.

2) Compare your results to the FBP algorithm (eg., behaviour for different number of projections, noise, missing angles, ...). What are the relative strengths and weaknesses of the two algorithms?

Matlab functions

`phantom()`	generates the Shepp-Logan phantom
`radon()`	takes the Radon transform of an image.
`iradon()`	takes the inverse radon transform of an image using the FBP algorithm (with or without filtering)
`fanbeam()`	takes the fanbeam transform of an image
`ifanbeam()`	converts a projection set to parallel beam, then performs FBP
`para2fan()`	converts parallel projections to fan beam projections
`fan2para()`	converts fan beam projections to parallel projections
`imread()`	read an image to a matrix
`imagesc()`	display a matrix as an image
`imrotate()`	rotate images

`circshift()` shifts arrays circularly
`randn()` generate a Gaussian random signal

References

A. C. Kak and Malcolm Slaney, *Principles of Computerized Tomographic Imaging*, IEEE Press, 1988, http://www.slaney.org/pct/ (retrieved 14/01/2013).