Short Course 8
Statistical Methods for Image Reconstruction

Tuesday, October 19, 08:30 - 12:30 Room Cesarea

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Course description:
The recent commercial introduction of iterative algorithms for tomographic image reconstruction, and the increasing interest in scanners with nonstandard imaging geometries, has brought new relevance and timeliness to the topic of statistical methods for image reconstruction. This course will provide an orderly overview of the potpourri of statistical reconstruction methods that have been proposed recently. Rather than advocating any particular method, this course will emphasize the fundamental issues that one must consider when choosing between different reconstruction approaches. The intended audience is anyone who would like to reconstruct 'better' images from photon-limited measurements, and who wants to make informed choices between the various methods. Recent advances in convergent forms of 'ordered subsets' algorithms will be given particular attention, since these algorithms can be both practical for routine use, while also having desirable theoretical properties. Both emission tomography and transmission tomography algorithms will be discussed.

Background:
Attendees should be familiar with photon-counting imaging systems at the level presented in the Medical Imaging short course offered in previous years. Some past attendees have commented that at least a little experience with some type of iterative reconstruction (e.g., ART or OS-EM) would be helpful for getting the most value from this course.

Recommendation:
The potential attendees are recommended to register before September 25^{th} if they want to have/print the notes of the course in advance!

Course Outline (Tentative):

A. Introduction

- Overview
- The Poisson statistical model
- Mathematical statement of the reconstruction problem

B. The Statistical Framework

- Image parameterization
  - Bases
- System physical modeling
  - general
  - line, strip integrals
  - detector response etc.
  - projector/backprojector cautions
- Statistical modeling of measurements
  - Poisson
  - Gaussian (data-weighted least squares)
  - Reweighted least squares
  - Deviations, e.g. deadtime
  - Shifted Poisson (precorrected random coincidences)
  - Emission vs Transmission scans
- Objective functions
  - Constrast with älgebraicmethods
  - Bayesian estimation: Maximum a posteriori (MAP) methods
  - Data-fit terms
    - likelihood
    - quadratic
    - robust
- Regularization

- none
- separable
- quadratic
- convex
- nonconvex, entropy, ...

Object constraints

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C. Iterative algorithms for statistical image reconstruction

EM based

(EM, GEM, SAGE, OSEM)

Direct optimization

(Coordinate Descent, Conjugate Gradient, Surrogate Functions)

Considerations

- nonnegativity
- parallelizability
- simultaneous vs sequential
- convergence rate
- monotonicity
- global convergence

Optimization transfer / surrogate functions

BREAK

D. Additional topics

Ordered subsets / block iterative algorithms

- acceleration properties interpreted geometrically
- convergence issues

Properties

- Spatial resolution properties / modified penalty functions
- Noise properties
- Performance in detection tasks relative to FBP

Applications to real PET and SPECT data
(and associated practical issues)

- Model mismatch
- Precorrected data
- Comparisons to FBP
- Pseudo-3D PET reconstruction from Fourier rebinned data
- ...