A bootstrap approach for analyzing the statistical properties of SPECT and PET images

Irène Buvat and Cyril Riddell, U494 INSERM, CHU Pitié-Salpêtrière, Paris, France
Contact: buvat@imed.jussieu.fr

What is this poster about?
We describe and validate a non-parametric bootstrap approach to determine the statistical properties of SPECT and PET images (especially the variance of reconstructed values) whatever the statistical properties of the projections and the reconstruction algorithm.

What is the bootstrap?
A computer-based statistical approach for determining the statistical distribution (or related parameters) of a statistic 0 associated with an experimental sample [1]:

1. From the N=40 acquired sub-sinograms
2. Best gold standard GS available: the 40 acquired sub-sinograms
3. Gold standard GS: 1000 noisy realizations of sub-sinograms

Adapting the bootstrap concept to SPECT and PET

This is the key point!

A PET image with a regional value of X

Sub-image statistical properties (case 1)

Numerical simulations
- 2D phantom
- RECLBL simulation
- 128 SPECT parallel projections, 128 bins each
- Scatter, attenuation, detector response function
- Poisson or Gaussian noise with constant variance added to the simulated sinograms

PET acquisitions
- Data Spectrum cardiac phantom: 99.9 MBq/ml in the left ventricle (LV) wall, no lung nor LV cavity activity and 13.32 MBq/ml in soft tissues.
- GE-Advance PET 2D acquisition
- 128 SPECT parallel projections, 128 bins each
- RECLBL simulation
- Data Spectrum cardiac phantom: 99.9 ± 20% MBq/ml in the LV wall (9.2%), 13.32 MBq/ml in soft tissues

Results and discussion

Sub-image statistical properties (case 1)

Image statistical properties
- 128 SPECT parallel projections, 128 bins each
- Scatter, attenuation, detector response function
- Poisson or Gaussian noise with constant variance added to the simulated sinograms

Validation method

We considered different types of noise ...

Images introduced different types of noise ...

Sub-image statistical properties (case 1)

Using numerical simulations
- Gold standard GS: 1000 noisy realizations of sub-sinograms
- Bootstrap: from N=40 noisy sub-sinograms

Using real PET data
- Best gold standard GS available: the 40 acquired sub-sinograms
- Bootstrap: from the N=40 acquired sub-sinograms

Image statistical properties (case 2)

Using numerical simulations only
- Gold standard GS: 1000 noisy realizations of sinograms with C counts
- Bootstrap: from N=40 noisy sub-sinograms with C counts

The resulting bootstrap sub-sinograms were then summed N by N:

... and different reconstruction algorithms

Reconstructions were performed using:
- FBP: Ramp
- FBP-Hann
- OSEM-400: OSEM with 8 subsets and 50 iterations
- MLEM-24: Maximum-Likelihood Expectation-Maximization with 24 iterations

Image statistical properties (case 2)

Impact of the parameters involved in the bootstrap approach

N: number of empirical sub-sinograms for image distribution estimates
B: number of bootstrap realizations

Increase of $\text{bias}$ in estimate accuracy resulting from the bootstrap

Bias and bias variability are reduced by a half (case 1)

Conclusion

Using the bootstrap, accurate estimates of pixel variance in SPECT and PET image is possible, whatever the statistical properties of the projections and the reconstruction algorithm, and even from a single acquisition (case 2). Knowing the variance images should facilitate the optimization of the acquisition and processing parameters and should contribute to a reliable quantitative analysis of the reconstructed images.

References

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