Spatially Local Statistics for Adaptive Image Filtering

Alexandros-Stavros Iliopoulos* Dimitris Floros† Yawei Zhang‡ Nikos Pitsianis†* Xiaobai Sun* Fang-Fang Yin‡ Lei Ren‡

*Department of Computer Science, Duke University
†Department of Electrical and Computer Engineering, Aristotle University of Thessaloniki
‡Department of Radiation Oncology, Duke University Medical School

Purpose

- To capture and characterize spatially-varying noise which is inherent in medical images.
- To guide and aid adaptive filter design for much-desired improvements in noise suppression and signal extraction.

Guiding principles

a. Signal and noise in medical images are highly interrelated and spatially variant; noise suppression and signal extraction must be done in tandem.

b. Noise stems from multiple sources related to physical and digital processes, and corrupts images in various ways (e.g., scatter, impulse, quantum noise). Inadequate filtering may inadvertently introduce noise while degrading signal.

c. In-frame noise can be characterized statistically by random phase drifts in the spatial frequency domain. Alternatively, the study can be efficiently realized in the spatial domain.

Conclusions & discussion

1. The proposed methodology is capable of indicating, revealing, and suppressing spatially-varying noise, while retaining signal structure details.
2. The presented use of a scale map for adaptive bilateral filtering can be extended to other filter types.
3. The scale map may also be useful in iterative processing, for evaluating residual noise after each filtering stage.

Acknowledgments

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References

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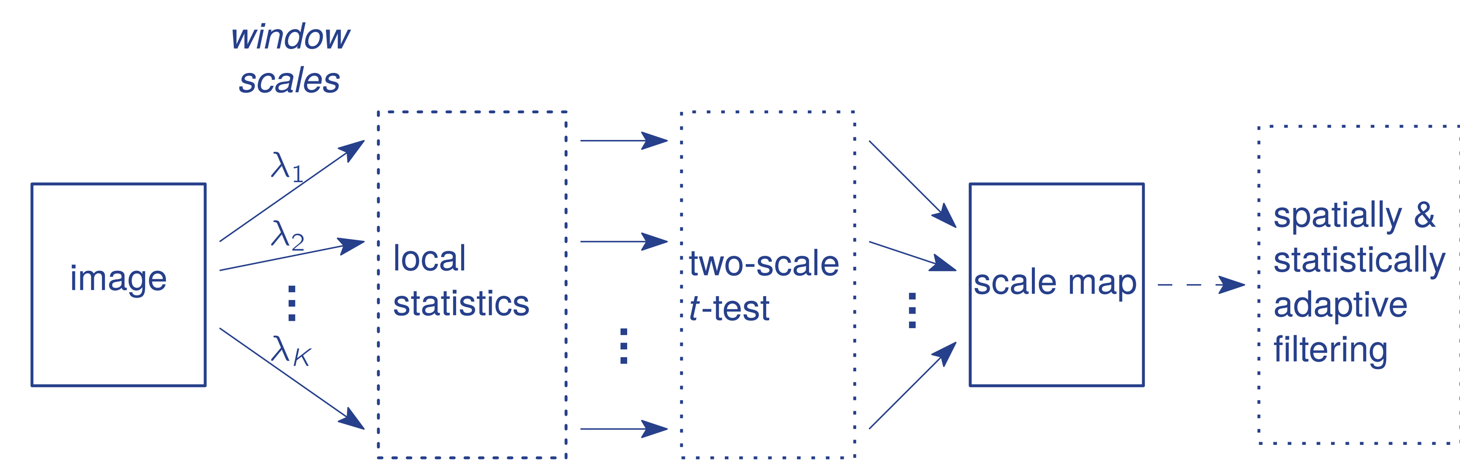
Contact

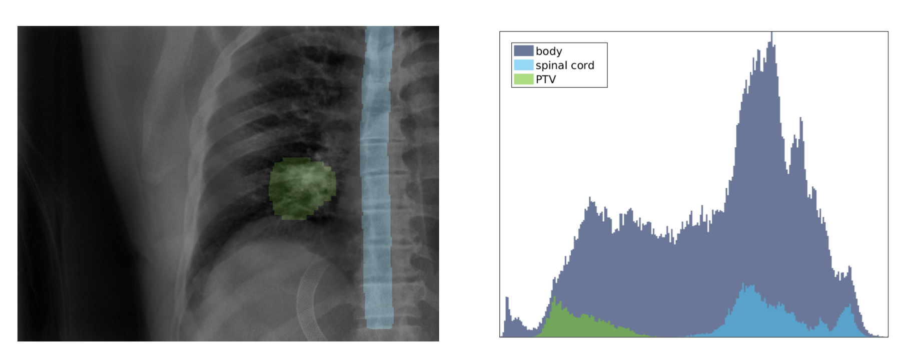
ailiop@cs.duke.edu

Method

Each pixel is assigned a particular spatial scale in terms of window size (related to spatial frequencies), according to the statistics within local windows at multiple scales. For example, pixel-specific scale is set as the maximum scale at which local statistics are not significantly different from those at finer scales.
Such maps render intrinsic noise information for designing or choosing filtering operations that adapt to spatial variation in signal and noise.

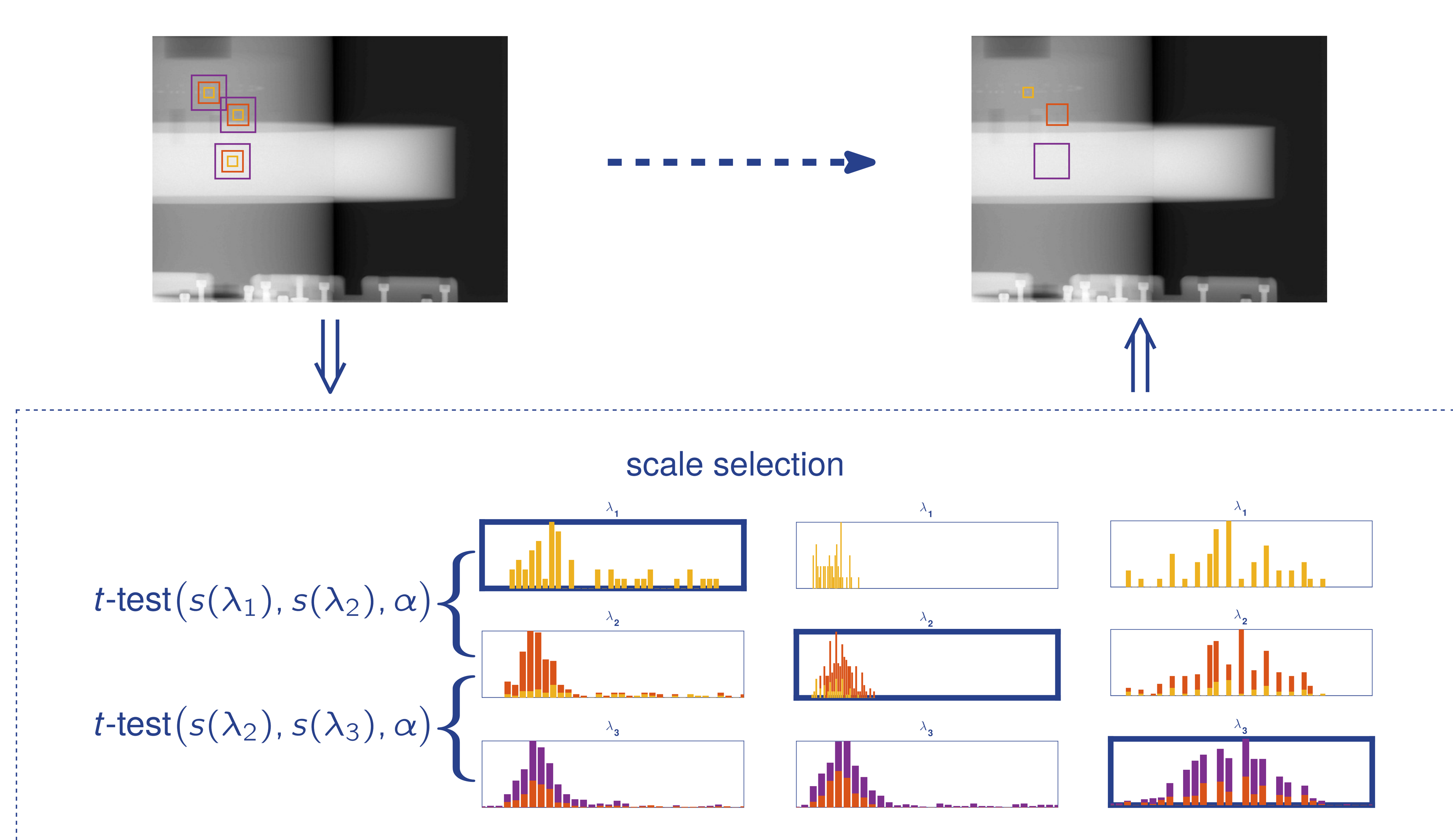


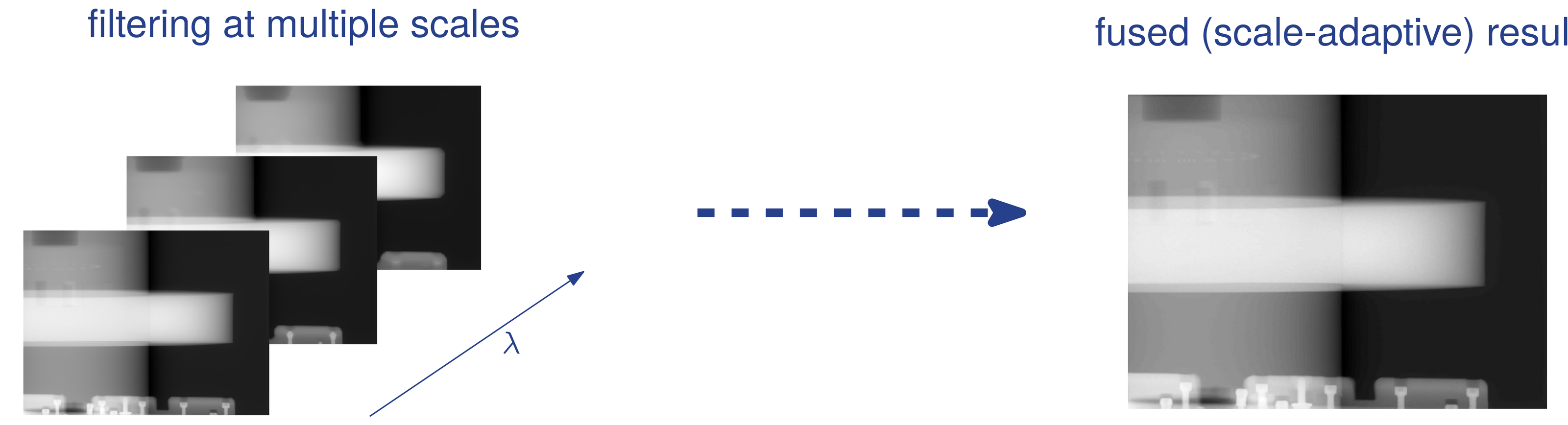
Noise can be correlated with image structure; e.g., in kV-source CBCT projections, high-density structures exacerbate X-ray scatter. It is important that low-contrast features of interest be preserved.



Left: CBCT projection of lung cancer patient, with overlaid PTV and spinal cord structures from planning-CT images. (Contrast was enhanced via histogram equalization.)
Right: Body and ROI-specific histograms show statistical differences.

We check for statistically significant changes across consecutive scales for each pixel using two-sample *t*-test.

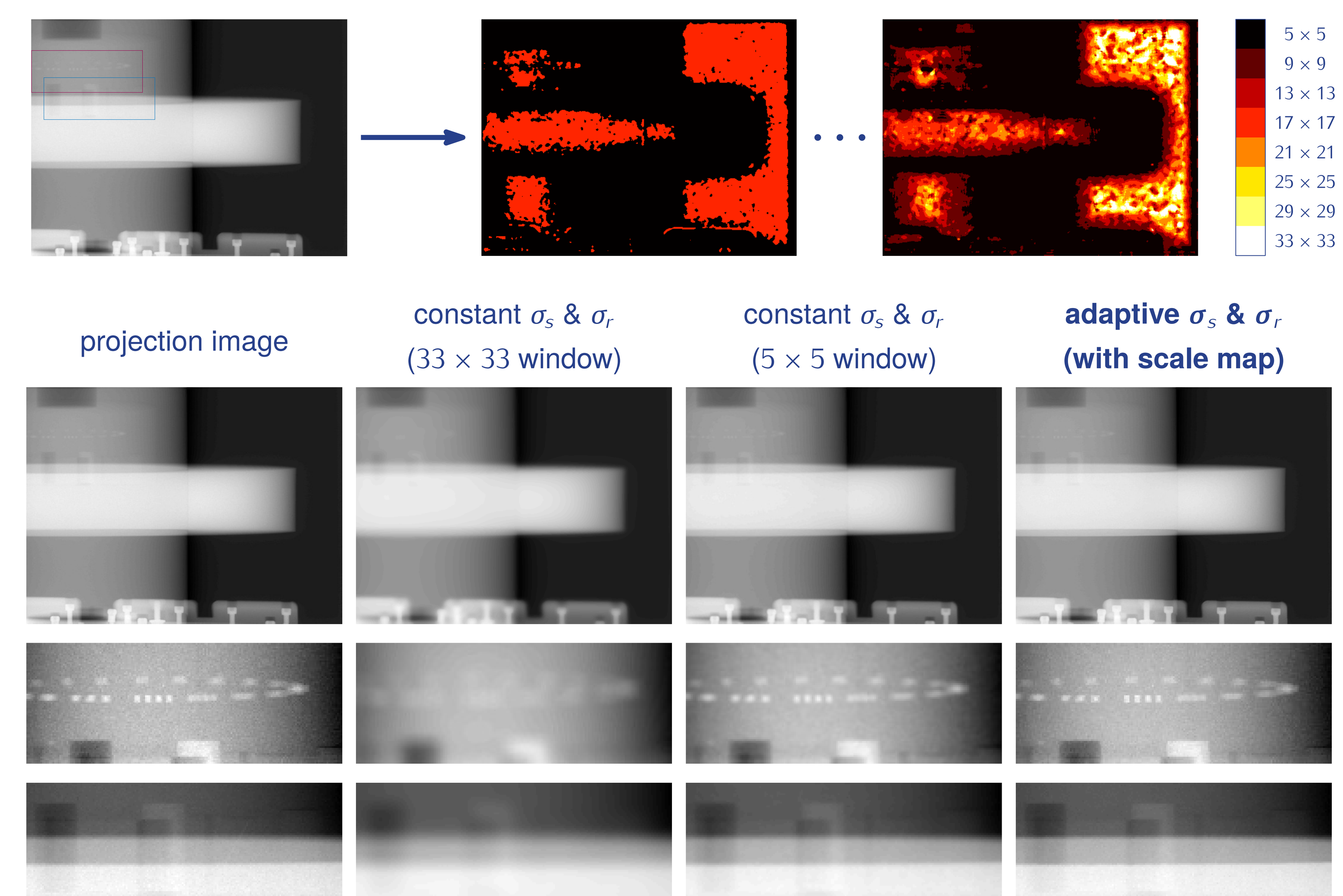




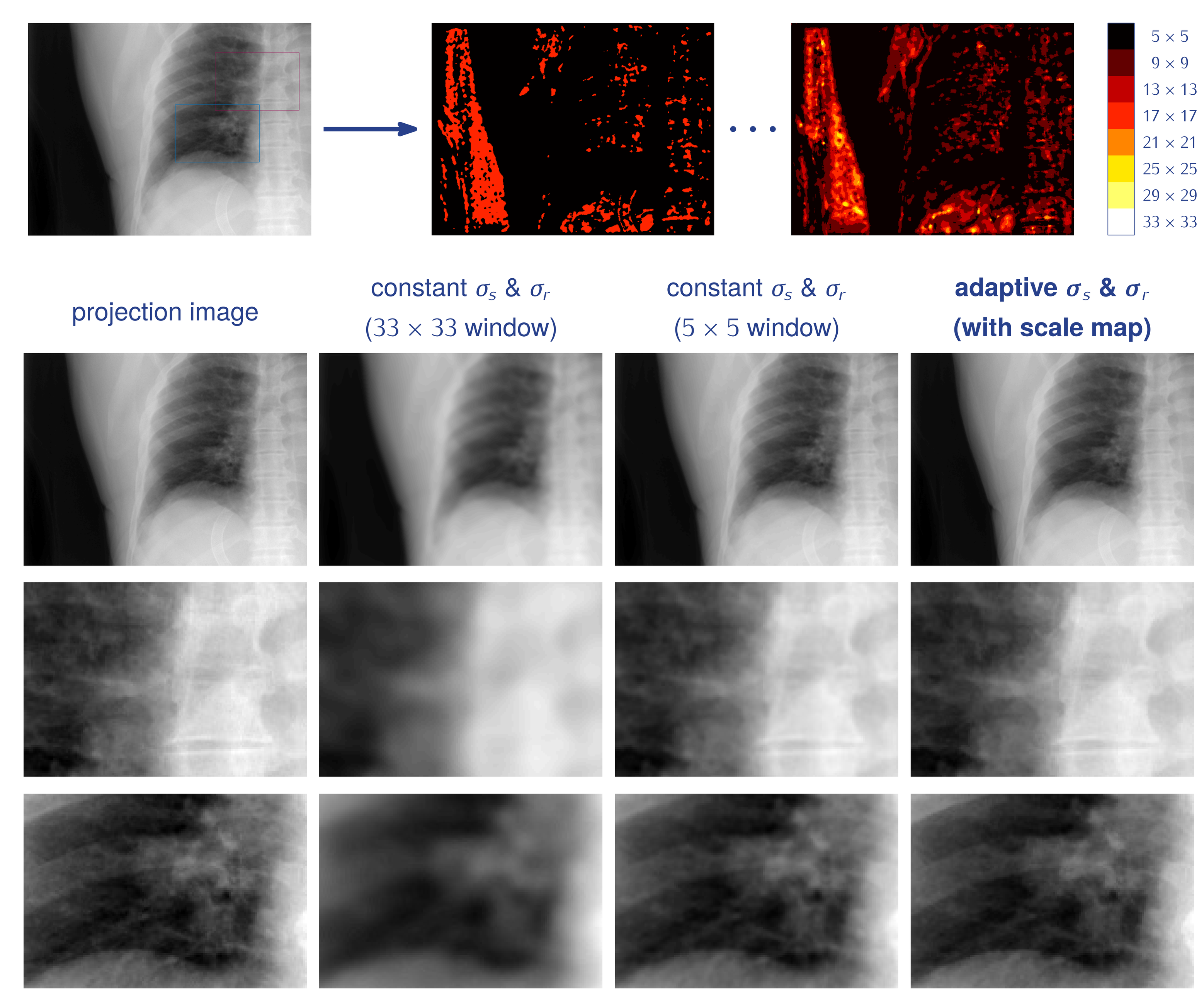
Materials & methods: experimental set-up

- Scale exploration via non-parametric, robust estimates of centrality (median) and dispersion (inter-quartile range).
- Filter type: Gaussian-based bilateral filtering; extended with adaptive spatial and intensity parameters, σ_s and σ_r.
- Data: CBCT projections (125 kV source) on $(0.388\ \mathrm{mm})^2$-resolution detector

Results: Catphan 700



Results: lung patient



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