Locally adaptive image filtering for noise reduction in PET

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Motivation

- **PET** images can have a **low signal-to-noise ratio** (SNR).
- True for **whole-body** of heavy patients, **respiratory gated** and **dynamic studies** with short frames.
- **Linear smoothing filters** (LF) (e.g. Gaussian) are **usually applied** to improve images.
- However, **image resolution** is **reduced** by LFs.
- **Affects detectability** and **quantification** of small structures.

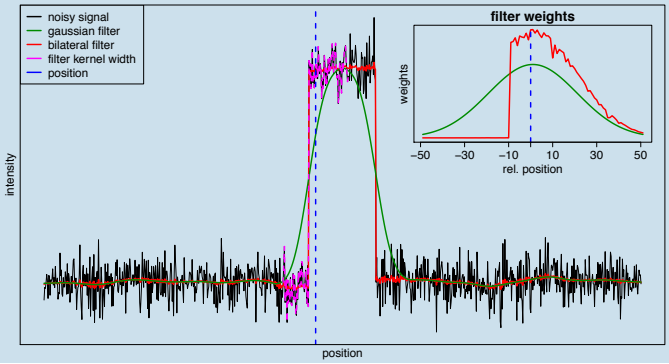
➡ **Non-linear, locally adaptive filters** (NLFs) are an interesting **alternative** to LFs.

➡ **Study on** performance of special NLF (**bilateral filter**, BF) when **applied to PET images** with low SNR.

Methods

- **BF** uses a **product** of a **spatial dependent part** and an **intensity dependent part**. [1]
- **penalizes distance** either in **spatial** (*n*) or **intensity** (*I*) domain and is local adaptive for each target voxel n_0:

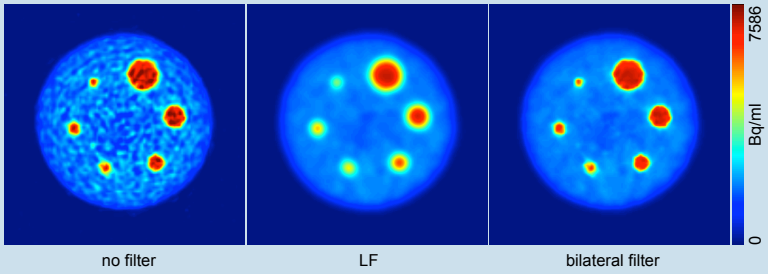
$$W(n-n_0) = S \cdot \exp\left(\frac{-(n-n_0)^2}{2\cdot\sigma_n^2}\right) \cdot \exp\left(\frac{-(I(n)-I(n_0))^2}{2\cdot\sigma_I^2}\right)$$

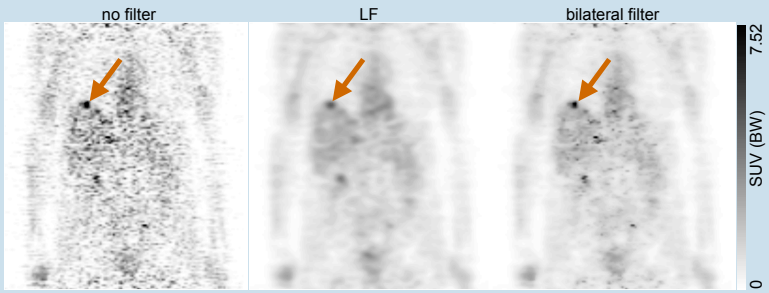


Results

- *3 phantom measurements with different sphere vs. background contrast:*
  cylinder phantom (⌀=20 cm, h=18 cm; 6 spheres 2.7 - 27 ml, F-18 FDG)

sphere / BG contrast	filter	noise level	resolution (FWHM) [mm]	rel. signal recovery
3:1	no filter	0.132	n/a	1.0
	LF	0.044	9.52 ± 0.30	0.75 ± 0.10
	bilateral	**0.046**	**4.68 ± 0.54**	**0.95 ± 0.03**
7:1	no filter	0.199	n/a	1.0
	LF	0.047	9.52 ± 0.35	0.77 ± 0.10
	bilateral	**0.057**	**4.71 ± 0.19**	**0.98 ± 0.01**
20:1	no filter	0.263	n/a	1.0
	LF	0.134	6.86 ± 0.40	0.84 ± 0.10
	bilateral	**0.078**	**5.26 ± 0.17**	**0.99 ± 0.02**





- *Respiratory gated study:*

single gate, 48 sec,
336 MBq F-18 FDG,
71 years old male, 70 kg,
amplitude-based gating

filter	SUV	volume [ml]
no filter	6.6 ± 1.7	3.1
LF	3.5 ± 0.6	7.8
bilateral	**5.6 ± 1.1**	**2.3**

Conclusions

- **NLF** using a bilateral filter is a **powerful alternative** to LF (Gaussian, Hann, etc.) when **applied** to low SNR **PET images**.
- Its **performance** is, however, **critically** dependent on a **sensible choice** of the **intensity deviation** (σ_I).
- **Further studies** will show whether this filter proofs **suitable** for **clinical use** (cf. clinical poster P63; B. Beuthien-Baumann)

[1] S. Paris, P. Kornprobst, and J. Tumblin. *Bilateral Filtering*. Now Publishers Inc, 2009. ISBN 160198250X.

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