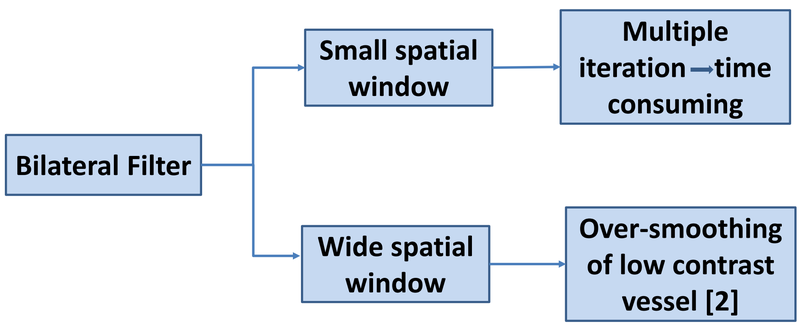
A Novel Trilateral Filter for Digital Subtraction Angiography

Purvi Tripathi[1], Richard Obler[2], Andreas Maier[1], Hendrik Janssen[3]

[1] *Pattern Recognition Lab, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Erlangen, Germany*
[2] *Department of Interventional Radiology, Advanced Therapies, Siemens Healthineers GmbH, Forchheim, Germany*
[3] *Institute of Neuroradiology, Center for Radiology and Neuroradiology, Hospital of Ingolstadt, Ingolstadt, Germany*

Introduction

- **Challenge of Low-dose Digital Subtraction Angiography (DSA):**
  - Reduced X-ray dose degrades the image.
  - Clear and accurate vessel representation is crucial.
  - Denoising filter must be time efficient for safe hand-eye-coordination.
- **Limitation of bilateral filter (BF) [1]:**



- **Aim**: To denoise the DSA as efficiently as BF in single iteration without any structural loss.

Material and Methods

- The proposed vessel preserving Trilateral Filter (TF) combines BF with Frangi vessel enhancement filter [3] in a wider neighborhood.

$$I_{filtered}(p) = \frac{1}{W_p} \sum_{q \in S} G_{\sigma s}(p-q) \cdot G_{\sigma r}(I_p - I_q) \cdot G_{\sigma v}(V_p - V_q)$$

- **Geometric similarity**:
  -Spatial difference between the pixels.
- **Photometric similarity**:
  -Difference between intensity values.
  (No sharp edge detection around the low-contrast regions)
- **Structural similarity**:
  -Considers vesselness difference in vessel enhanced Frangi image.

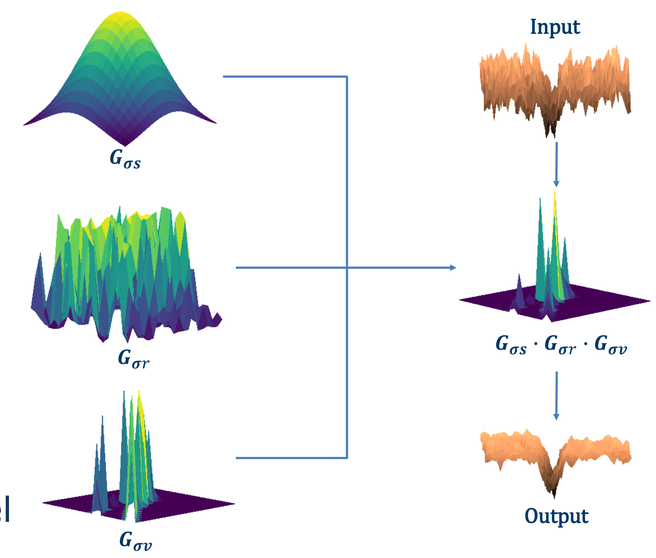


Fig 1: Trilateral filter kernel around low-contrast vessel

Results and Discussion

Qualitative Analysis:

- TF was preferred for 55 out of 60 DSA scenes presented to physicians.

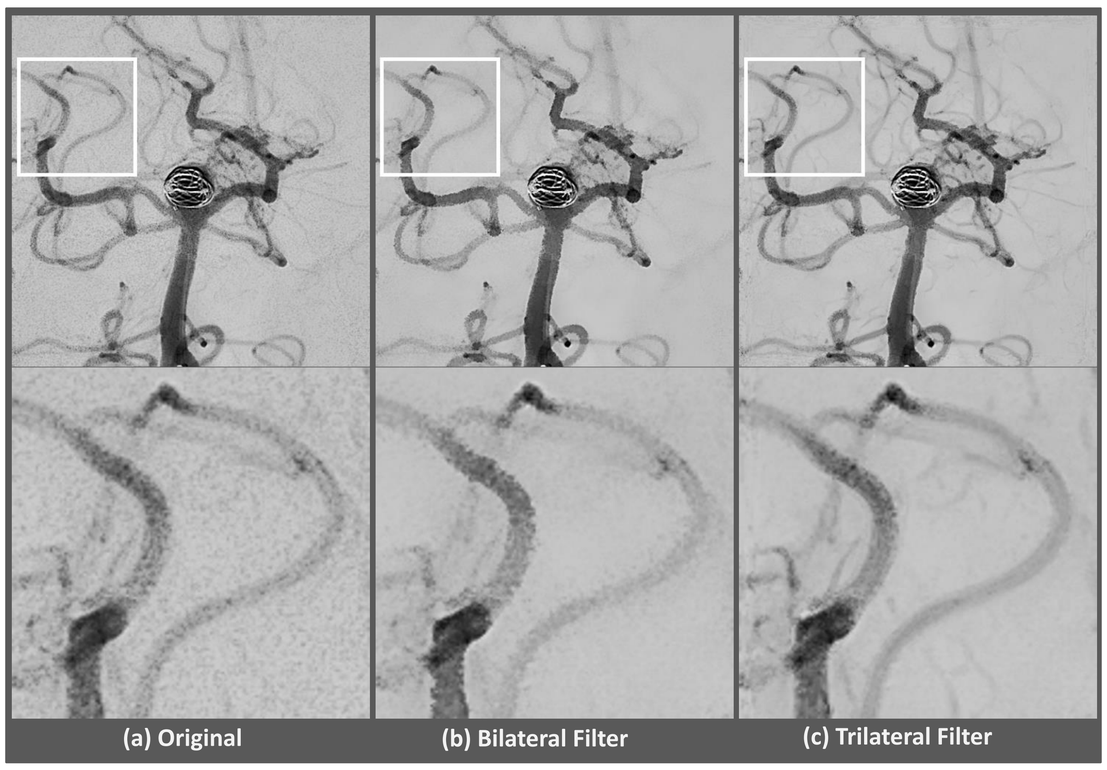


Fig 2: TF prevents over-smoothing and improves the visibility of low-contrast vessels

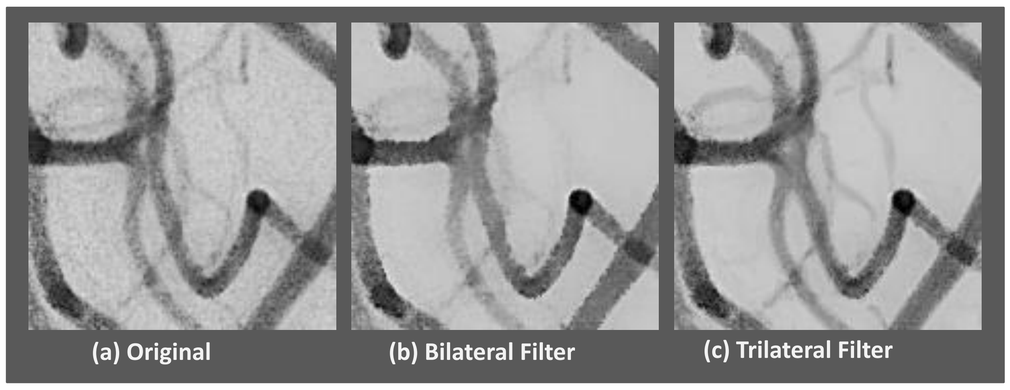


Fig 3: TF gives a natural looking edge to high-contrast vessels

Quantitative Analysis:

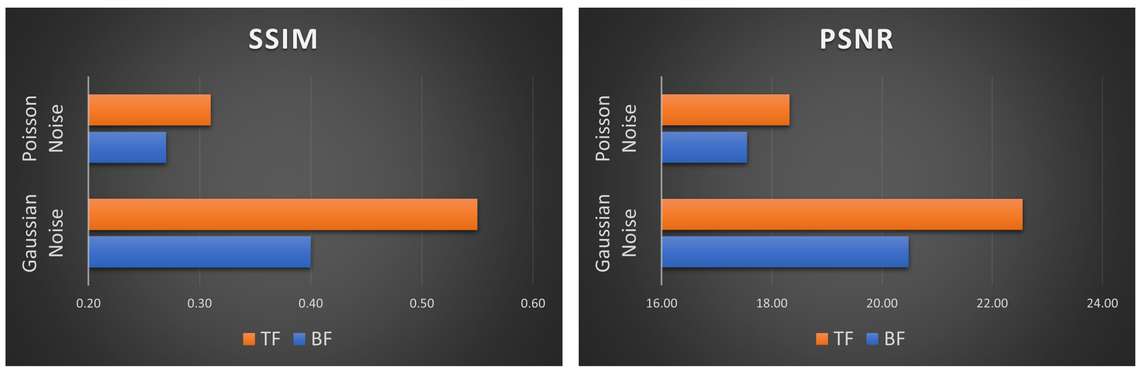


Fig 4: Structural Similarity Index Measure (SSIM) and Peak Signal-to-Noise Ratio (PSNR) for low-dose DSA

Conclusion

- TF outperforms BF in terms of noise reduction & vessel preservation.
- **Expandability:**
  - Can be further improved by automated parameterization.
  - Can benefit from other vessel enhancement filters.

References

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Purvi.tripathi@fau.de