A General Framework for Smoothing Arbitrary Signals in Computer Graphics and Biomedicine

Simone Cammarasana
CNR-IMATI, Via de Marini 6, Genova (Italy)
simone.cammarasana@ge.imati.cnr.it

Signal smoothing is a relevant topic in many applications, such as image processing in biomedicine [1], and geology [2]. Previous work has proposed denoising methods tailored to the input signal, such as external learning applied to 2D images [3], diffusive methods applied to volumetric images [4], wavelets applied to vector fields [5], and low-rank methods applied to 2D videos [6].

We propose a novel framework [7] for the smoothing of arbitrary signals, which combines regularisation with learning-based models and is general with respect to the input signal, the noise type (e.g., speckle, Gaussian noise), the selected regulariser/denoising (e.g., SVD - Singular Values Decomposition, block matching), and the learning architecture (e.g., network's weights optimisation). Given a data set of ground-truth signals, we apply an artificial noise and extract data groups with high similarity. For an arbitrary signal, we apply a regularisation and compute the parameters that allow us the best reconstruction of the ground-truth signal from the regularised signal. Then, the data groups (e.g., the 3D blocks of the block-matching algorithm) are aggregated to reconstruct the smoothed signal. We iterate this approach, where the input signal of each iteration is the smoothed signal at the previous step. The input and optimal parameters compose the training data set, which is used to train a learning model to predict the optimal coefficients of the regularisation.

As example, we apply the SVD to images, where the optimal coefficients to be predicted are the threshold values of the shrinkage of the singular values. After the optimisation of the weights of the learning-based network, the trained models are used to smooth images with a different noise, such as 2D/3D ultrasound images affected by speckle noise, or synthetic images and videos with Gaussian noise.

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References

[1] Zhang, Ju, and Yun Cheng: Despeckling Methods for Medical Ultrasound Images. In: Springer, 2020.

[2] Zhan, Yunjun and Dai, Tengda and Huang, Jiejun and Dong, Yusen and Ye, Fawang and Tang, Cong Double iterative optimal dictionary learning-based SAR image filtering method. In: Signal, Image and Video Processing.

[3] Dong, W., Zhang, L., Shi, G., Li, X.: Nonlocally centralized sparse representation for image restoration. In: Trans. on Image Processing 22(4),1620–1630 (2012), IEEE.

[4] Patanè G.: Diffusive Smoothing of 3D Segmented Medical Data. In: Journal of Advanced Research, Elsevier, Volume 6, Issue 3, May 2015, Pages 425-431

[5] M. A. Westenberg, and T. Ertl: Denoising 2-D vector fields by vector wavelet thresholding. In: J. WSCG, vol. 13, no. 1, pp. 33–40, 2005.

[6] H. Ji, C. Liu, Z. Shen, and Y. Xu: Robust video denoising using low rank matrix completion. Proc. IEEE Int. Conf. Computer Vision and Pattern Recognition, 2010.

[7] Simone Cammarasana, Paolo Nicolardi, Giuseppe Patanè: A Universal Deep Learning Framework for Real-Time Denoising of Ultrasound Images In: arXiv preprint arXiv:2101.09122 (2021)