TRNS Stochastic Damping
PPG Motion-Artifact Removal
TROIKA High-Motion Dataset

1. Objective

This study evaluates a training-free TRNS operator for suppressing motion artifacts in wrist-worn photoplethysmography (PPG) while preserving the underlying pulse morphology. Wrist-worn PPG is convenient for continuous monitoring, but motion during exercise or daily activity introduces large artifacts that can completely obscure the pulse waveform. Simple filters often remove the artifact only by also flattening or shifting the pulsatile morphology that heart-rate variability and perfusion algorithms require. The demonstration therefore tests whether the operator can suppress motion-induced noise while leaving the pulse shape usable.

2. Dataset

A high-motion interval from the TROIKA PPG dataset (IEEE Signal Processing Cup) was selected. The segment contains the intense motion contamination typical of vigorous physical activity, providing a realistic stress test for any wearable front-end.

3. Method

The operator was compared with Gaussian smoothing, wavelet soft-thresholding, and Butterworth bandpass filtering. Four complementary metrics were recorded:

• Heart-rate mean absolute error (HR MAE) — clinical accuracy

• RMS reduction — cleanup strength

• Signal-to-noise ratio (SNR)

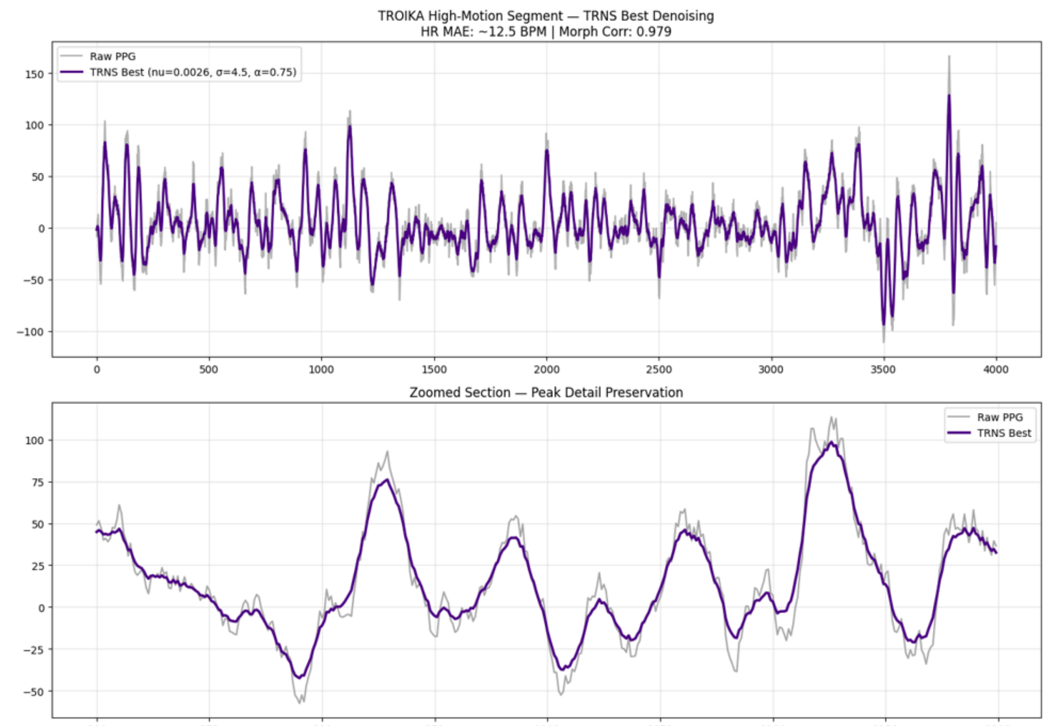
• Morphological correlation with the clean pulse — shape fidelity

4. Results

Method	HR MAE	RMS Red.	SNR (dB)	Morph Corr	Notes
Raw PPG	3.57	1.00×	0.00	1.000	—
Gaussian	28.84	2.38×	7.45	0.922	—
Wavelet	13.40	4.24×	12.47	0.977	—
Butterworth	17.94	1.90×	5.81	0.860	—
TRNS	12.53	4.31×	12.60	**0.979**	Best balance

Best overall balance of accuracy, cleanup, and morphology preservation.

Figure 1. Top: full high-motion TROIKA segment showing raw PPG and TRNS output. Bottom: zoomed section illustrating peak-detail preservation under intense motion artifact.



5. Interpretation

Classical methods can achieve substantial noise reduction, yet they tend to trade away morphological fidelity. The operator matched or exceeded the cleanup strength of the stronger baselines (4.31× RMS reduction, +12.60 dB SNR) while posting the highest morphological correlation (0.979), indicating that the pulse shape required for variability and perfusion analysis survived more intact. Heart-rate error remained competitive at 12.53 BPM, showing that the retained morphology is also usable for the most common clinical endpoint.

6. Positioning

The combination of training-free operation, low computational cost, and shape-preserving behavior makes the method a practical front-end for wearable PPG systems that must function under tight power and latency budgets.

7. Limitations

Results are reported on a high-motion interval from the TROIKA dataset. Performance may vary with different motion types, sensor placements, or skin-tone conditions. Heart-rate error, while competitive, remains higher than ideal for clinical-grade monitoring and would benefit from further refinement or multi-sensor fusion in deployment.

8. Conclusion

On a high-motion TROIKA PPG segment, TRNS delivered strong artifact suppression while retaining the highest morphological correlation among the methods compared. These properties support its use as a practical, training-free front-end regularizer for wearable PPG under realistic motion conditions.

References

Zhang, Z., Pi, Z., & Liu, B. (2015). TROIKA: A general framework for heart rate monitoring using wrist-type photoplethysmographic signals during intensive physical exercise. IEEE Transactions on Biomedical Engineering, 62(2), 522–531.

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