Video Denoising

Video denoising refers to the process of **removing noise from sequences of image frames (videos)** to enhance visual clarity and data quality. In medical imaging, especially in fields like **light scattering imaging (LSI)** or **intraoperative video monitoring**, denoising is critical for **accurate interpretation and analysis**.

1. Purpose

- **Improve image quality**: Reduce random noise while preserving structural details and motion consistency.
- **Enhance signal detection**: Boost signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR) for better visualization of tissues, tumors, or instruments.
- **Facilitate automated analysis**: Clean data improves the performance of AI and machine learning algorithms.

2. Techniques

- **Traditional Filtering**:
  - Gaussian blur, median filters, and temporal averaging
  - Fast but often results in **loss of detail** and **motion blur**
- **Model-Based Methods**:
  - Total variation minimization, block-matching (e.g., BM3D)
  - Require manual tuning and are **computationally intensive**
- **Deep Learning-Based Methods**:
  - **FastDVDNet**, **DNNs**, **autoencoders**, or **GANs**
  - Exploit **temporal information** and **spatial correlations**
  - Can be trained in a **self-supervised (unsupervised)** manner, avoiding the need for clean ground-truth videos
  - More robust to complex, dynamic noise

3. Applications in Neurosurgery

- **Intraoperative Light Scattering Imaging (LSI)**:
  - Enhances visibility of brain structures, tumor margins, or blood flow dynamics
  - Reduces visual interference caused by tissue movement, blood, or lighting fluctuations
- **Neuroendoscopy and Microscope Recordings**:
  - Improves clarity in endoscopic video streams
  - Enables high-quality recordings for surgical planning, teaching, or AI training
- **Post-processing of Surgical Videos**:
  - Denoised videos can be used for case documentation, outcome analysis, or dataset generation

4. Key Challenges

- **Preserving fine details**: Especially important for small vessels or tumor boundaries
- **Real-time processing**: Denoising must be fast enough for intraoperative use
- **Generalizability**: Algorithms must adapt to different lighting conditions, tissue types, and imaging setups

5. Recent Advances

- Lin et al. (2025)

[1] proposed an **unsupervised adaptive denoising framework** using FastDVDNet and noise distribution maps to enhance LSI videos in applications such as nanoparticle analysis and single-cell imaging:

- Significant improvements in **SNR** and **CNR**
- Enhanced reliability in particle sizing and cell classification

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Video denoising is a vital step in modern neurosurgical imaging workflows. By improving visual and analytical quality, it supports safer surgeries, better diagnostics, and the integration of advanced AI tools.

[1]
Lin M, Zheng Y, Yang L, Yan J, Ma X, Guo Y. Unsupervised Adaptive Deep Learning Framework for Video Denoising in Light Scattering Imaging. Anal Chem. 2025 May 22. doi: 10.1021/acs.analchem.4c06905. Epub ahead of print. PMID: 40405330.