Hey there,

Here is what's been going on in medical physics and related areas the last 24 hours. Here's what you folks might find interesting today.

Novel Architectures and Objectives for Imaging

- Differentiable Cardiac Electrophysiology Simulations for Dynamical State and Parameter Estimation -- This paper introduces a differentiable PDE solver for cardiac electrophysiology that enables gradient-based optimization of model parameters directly from spatio-temporal imaging data of action potential waves. The key novelty is backpropagating a loss through the differentiable PDE solver (implemented via both finite-difference and smoothed particle hydrodynamics), allowing recovery of full dynamics even from sparse, noisy, or partial observations. They also employ a perceptual loss based on the Video Joint-Embedding Predictive Architecture for fitting to noisy experimental imaging data, plus a generative diffusion model to estimate initial conditions. This is a strong example of **physics-informed loss functions** derived from forward-model structure rather than empirical tuning, and the approach to **likelihood-free parameter estimation** via differentiable simulation is directly relevant to digital twin construction.

- E3DGS: Unified Geometric-Photometric Equivariance for 3D Gaussian Splatting via Color-as-Geometry Embedding -- This work tackles a fundamental representation bottleneck in building SE(3)-equivariant architectures on 3D Gaussian Splatting primitives: the heterogeneous action of rotations on position, covariance, and spherical harmonic coefficients. The authors prove that for SH degrees up to 2, photometry is algebraically isomorphic to a rank-2 geometric tensor, and that the Wigner-D action on SH coefficients can be exactly reformulated as conjugation on 3x3 matrices. This yields a Unified Matrix Embedding lifting all Gaussian attributes into gl(3), enabling a rigid-body equivariant architecture without Clebsch-Gordan tensor products. While demonstrated on object vision and world modeling, the **equivariant architectural primitive** is transferable to medical imaging tasks involving geometric symmetries, particularly in reconstruction and registration where SE(3) equivariance is often desired but hard to achieve.

Imaging Physics and Reconstruction

- Joint-decoupled iterative CBCT reconstruction with hybrid scatter estimation and voxel-adaptive beam hardening correction -- This paper addresses the coupled scatter and beam-hardening artifact problem in CBCT through a **physics-driven iterative framework** rooted in the polychromatic Polyquant attenuation model. The novelty lies in decoupling these artifacts via an optimization loop between scatter estimation and relative electron density (RED) reconstruction, using a hybrid strategy where first-order scattering is analytically derived from a polychromatic physical model while multiple scattering is estimated via an object-adaptive convolution module. The voxel-adaptive beam-hardening correction solves linearized scatter-corrected polychromatic equations for optimal weights without manual parameter tuning. The reduction of mean relative error from ~12% to ~1.3% on an anthropomorphic head phantom is substantial, and the method is benchmarked against Monte Carlo simulations and physical experiments, making it **translational and clinically relevant** for CBCT imaging pipelines.

Radiotherapy and Hadron Therapy

- Fast ungated five-dimensional cardiac MRI on a 1.5 T MR-linac for MRI-guided radiotherapy -- This work tackles a practical bottleneck in stereotactic arrhythmia radio-ablation (STAR): the need for fast, personalized cardiorespiratory motion characterization on an MR-linac. The authors propose a fast ungated 5D-MRI reconstruction within the CMR-MOTUS framework, using a joint optimization to reconstruct a motion-corrected reference image alongside low-rank deformation vector fields that explicitly disentangle respiratory and cardiac motion. The low-rank structure is the key architectural choice

enabling retrospective adjustment of motion states. Achieving 1-minute acquisition and 6-minute reconstruction with sub-millimeter motion errors in volunteers is a meaningful step toward **clinical integration into MRI-guided radiotherapy workflows**, and the public release of k-space data and reconstructions adds translational value.

Back tomorrow with more!

P.S. In the most recent submission window: physics.med-ph: 3 papers cs.CV: 83 papers