亮点报道：兼顾低剂量与高质量——基于多高斯聚类方差缩减的可解释低剂量 CT 图像增强

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在低剂量 CT 成像中，图像常受高噪声、边界模糊及细节对比度下降的影响，干扰医生对病灶的判断。尽管现有的深度学习增强方法在视觉效果上表现出色，但其“黑箱”特性导致推理过程缺乏物理可解释性。因此，发展一种兼具物理意义与强去噪能力的可解释图像增强算法，对于推动低剂量 CT 的应用具有重要意义。

针对低剂量 CT 图像噪声强、结构信息易被掩盖的问题，中山大学理学院葛昕副教授及其研究团队提出了一种基于直方图域的可解释图像增强算法 mGCVR。研究团队以离体斑马鱼为样本，分别利用多项评价指标评估了 mGCVR 算法在真实生物样本上的表现。实验结果表明，在辐射剂量大幅降低 6 倍的情况下，mGCVR 能实现全局高保真的 CT 图像增强。该算法在极低光子数 (仅为真值的 1/80) 的仿真测试中，仍表现出有效的噪声抑制能力。

多样本实验表明，mGCVR 能够灵活适配多样化的噪声特性，在不同扫描设备及组织特性下均具有极强的鲁棒性。这一成果充分体现了 mGCVR 在低剂量 CT 成像及相关科学成像中的广阔应用潜力。

Highlights: Interpretable low-dose CT enhancement via multi-Gaussian cluster variance reduction

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Computed tomography (CT) has been widely applied in clinical diagnosis, biomedical research and related fields because of its ability to noninvasively acquire internal structural information from samples. However, CT imaging relies on X-ray irradiation and inevitably introduces radiation exposure while obtaining high-quality images, thereby increasing the radiation burden on patients. Consequently, how to reduce radiation dose while maintaining imaging quality has long been an important issue in the field of CT imaging.

To overcome the challenge that strong noise in low-dose CT images may obscure critical structural information, the research group of Prof. Xin Ge from Sun Yat-sen University proposed an interpretable image enhancement algorithm in the histogram domain, termed mGCVR. Using a fixed zebrafish specimen as the sample, the research group evaluate the performance of the mGCVR algorithm on a real biological specimen using multiple quantitative metrics. The experimental results demonstrate that, even under a sixfold reduction in radiation dose, mGCVR is capable of achieving globally high-fidelity CT image enhancement. The mGCVR still performs effective noise suppression capability in simulation tests under an extremely low intensity level, with the photon count reduced to only 1/80 of the ground truth.

Experiments across diverse samples further demonstrate that mGCVR can flexibly accommodate varying noise levels and exhibits strong robustness across different scanning devices and tissue characteristics. These findings fully highlight the broad application potential of mGCVR in low-dose CT imaging and related scientific imaging applications.

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