亮点报道：突破硬件物理极限：AI 赋能超高速结构光三维成像

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频分复用技术引入的复杂频谱结构带来了挑战：傅里叶域中的滤波与反演问题变得高度病态，算法恢复严重受到频谱混叠、频谱泄漏、通道串扰等因素影响，使得重建精度、分辨率与可靠性等方面都远达不到实际应用的要求。

在深度学习与计算成像技术迅猛发展的背景下，南京理工大学陈钱、左超教授团队，联合波兰华沙理工大学 Malgorzata Kujawinska 和 Maciej Trusiak 教授，共同提出了一种融合频分多路复用与深度神经网络的新型三维成像方法——基于双频角度复用的条纹投影轮廓术 (DFAMFPP)，可突破硬件物理极限，实现超越相机帧率一个数量级以上的时间超分辨三维成像。该方法利用数字微镜器件 (DMD) 高时间分辨能力与频分多路复用技术优势，在相机单次曝光周期内高速投射多组双频条纹图案，将多个时序的三维信息编码至单帧复用图像中。随后，结合数论与集成深度神经网络，从单帧复用图像中精确解耦出多帧绝对三维信息。利用该技术，研究人员实现了超越传感器帧率 16 倍的高速、高精度时间超分辨三维成像。

该技术突破了探测器帧率对三维成像速度的固有限制，为基于低时间分辨成像器件探索高时空分辨率的动态过程提供了新的可能性。

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Highlights: Breaking physical hardware limits with AI-enabled ultra-high-speed structured-light 3D imaging

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Frequency division multiplexing (FDM) offers a promising solution and introduces challenges. The frequency domain becomes highly complex, with ill-conditioned filtering and inversion. Signal recovery suffers from spectral overlap, leakage, and crosstalk, leading to significant degradation in reconstruction accuracy, resolution, and robustness—far from meeting the demands of practical applications.

In response to these challenges, researchers from Nanjing University of Science and Technology (NJUST) led by Professors Qian Chen and Chao Zuo collaborated with Professors Malgorzata Kujawinska and Maciej Trusiak from Warsaw University of Technology. Together, they have developed a novel deep learning-enabled 3D imaging method: Dual-Frequency Angular-Multiplexed Fringe Projection Profilometry (DFAMFPP). Leveraging the high temporal resolution of digital micromirror devices (DMD), DFAMFPP projects multiple sets of dual-frequency fringe patterns within a single camera exposure period, encoding multiple moments of 3D information into a single multiplexed image.

By combining deep learning and computational imaging, DFAMFPP utilizes frequency-domain multiplexing to reconstruct multiple 3D frames from a single exposure—without sacrificing spatial resolution. This breakthrough overcomes the longstanding frame-rate limitation of imaging sensors, opening new possibilities for studying high-speed dynamic processes using low-frame-rate devices.

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