Computational Out-Of-Focus Imaging Increases The Space-Bandwidth Product In Lens-Based Coherent Microscopy

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SUMMARY

UCLA researchers in the Department of Electrical Engineering have developed a wide-field and high-resolution coherent imaging method that uses a stack of out-of-focus images to provide much better utilization of the space-bandwidth product (SBP) of an objective-lens.

BACKGROUND

The space-bandwidth product (SBP) of an optical system, which is defined by the field-of-view (FOV) of the optical system divided by the area of a resolvable spot, describes the maximum amount of information that it can collect and transmit. For a coherent imaging system, both phase and amplitude channels independently contribute to the SBP. However, due to the signal readout mechanism and imaging speed requirements, most cameras that are used in optical microscopes are designed with limited number of pixels.

Therefore much of the information transmitted by the optical system cannot be adequately sampled or digitized, and it sets a practical limitation for the overall SBP of the microscopic imaging system. This gap between objective-lenses and opto-electronic image sensor chips, which is generally bridged by matching the optical resolution to the effective pixel size of the imaging configuration, significantly wastes the objective-lens FOV and result in sub-optimal use of the SBP of the microscopic imaging system.

INNOVATION

Researchers at UCLA have developed a novel wide-field and high-resolution computational imaging method that increases the SBP of coherent microscopy by bridging the gap between digital cameras and objective-lenses. They employed an iterative pixel super-resolution (PSR) algorithm that uses a few out-of-focus images of the sample to recover a high-resolution complex image of the specimen and significantly increase the overall SBP of the microscope. Unlike conventional PSR methods that require either a high precision motorized stage to laterally shift the sample or a specialized camera with a built-in pixel-shifting mechanism to shift the sensor chip inside the camera in order to create a stack of undersampled images, each with a sub-pixel lateral displacement, implementation of the described new PSR framework only requires the use of a stack of out-of-focus images of the sample without having to complicate the mechanical design of the microscope.

Researchers have shown that the resulting spatial undersampling caused by capturing a large FOV can be mitigated through an iterative PSR algorithm that uses ~3-5 slightly out-of-focus images, yielding ~6-fold increase in the SBP of the microscope. When compared to traditional off-axis and phase-shifting digital holographic microscope modalities, this method has demonstrated a ~3-fold reduction in the number of images required to achieve the same SBP. In addition, this same PSR algorithm also achieves phase retrieval, revealing the optical phase information of the specimen.

APPLICATIONS

- Lens-based coherent imaging and holographic systems
- Microscope design with improved throughput and SBPs

ADVANTAGES

- Increases the space-bandwidth product (SBP) of coherent microscopy
- The pixel super-resolution (PSR) technique does not require lateral displacements between the specimen and the objective-lens
- Allows phase retrieval of the sample

STATE OF DEVELOPMENT

The researchers have demonstrated the success of this wide-field imaging method using a conventional lens-based microscope and imaged resolution test-targets and biological samples.

RELATED MATERIALS


PATENT STATUS

Patent Pending
ADDITIONAL TECHNOLOGIES BY THESE INVENTORS

- Ultra-Large Field-of-View Fluorescent Imaging Using a Flatbed Scanner
- Detection and Spatial Mapping of Mercury Contamination in Water Samples Using a Smart-Phone
- Automated Semen Analysis Using Holographic Imaging
- Tunable Vapor-Condensed Nano-Lenses
- Single Molecule Imaging and Sizing of DNA on a Cell Phone
- Rapid, Portable And Cost-Effective Yeast Cell Viability And Concentration Analysis Using Lensfree On-Chip Microscopy And Machine Learning
- Wide-Field Imaging Of Birefringent Crystals In Synovial Fluid Using Lens-Free Polarized Microscopy For Crystal Arthropathy Diagnosis
- Quantitative Fluorescence Sensing Through Highly Autofluorescent And Scattering Media Using Cost-Effective Mobile Microscopy
- Demosaiced Pixel Super-Resolution For Multiplexed Holographic Color Imaging
- Microscopic Color Imaging And Calibration
- Pixel Super-Resolution Using Wavelength Scanning
- Fluorescent Imaging Of Single Nano-Particles And Viruses On A Smart-Phone
- Holographic Opto-Fluidic Microscopy
- Lensfree Wide-Field Fluorescent Imaging On A Chip Using Compressive Decoding
- Revolutionizing Micro-Array Technologies: A Microscopy Method and System Incorporating Nanofeatures
- Sparsity-Based Multi-Height Phase Recovery In Holographic Microscopy
- Computational Sensing Using Low-Cost and Mobile Plasmonic Readers Designed by Machine Learning
- Deep Learning Microscopy
- Mobile Phone Based Fluorescence Multi-Well Plate Reader
- Phase Recovery And Holographic Image Reconstruction Using Neural Networks
- Lensfree Tomographic Imaging
- Air Quality Monitoring Using Mobile Microscopy And Machine Learning