Preface

High-throughput real-time imaging and vision systems for capture and identification of fast phenomena are among the most essential tools for scientific, industrial, military, and most importantly biomedical applications. The key challenge in these instruments is the fundamental trade-off between speed and sensitivity of the measurement system due to the limited signal energy collected in each measurement window. Based on two enabling technologies, namely, photonic time stretch and optical amplification, several novel high-throughput optical measurement tools are recently developed for applications such as volumetric scanning, vibrometry, and flow cytometry. Here, we introduce time stretch imaging, a high-content computer vision system developed for big data acquisition and analysis of images. Time stretch imaging is able to capture quantitative optical phase and intensity images simultaneously, enabling accurate surface inspection, volumetric scans, defect detection, cell analysis, and cancer diagnostics.

We further describe a complete artificial intelligence pipeline for time stretch microscopy that performs optical phase measurement, image processing, feature extraction, and classification. Multiple biophysical features such as morphological parameters, optical loss characteristics, and protein concentration are measured on individual biological cells. These biophysical measurements form a hyperdimensional feature space in which supervised learning is performed for cell classification. The technology is in clinical testing for blood screening and circulating tumor cell detection, as well as studying lipid-accumulating algal strains for biofuel production. By integrating machine learning with high-throughput quantitative imaging, this system achieves record-high accuracy in label-free cellular phenotypic screening and opens up a new path to data-driven diagnosis.

Furthermore, we explained a real-time image compression technique performed in the optical domain to solve the big data challenge created by ultrafast measurement systems. Many ultrafast and high-throughput data acquisition equipment, including time stretch imaging, produce a torrent of data in a short time, e.g., several gigabytes per second. Such a data volume and velocity place a burden on data acquisition, storage, and processing and call for technologies that compress images in optical domain and in real-time. As a solution, we have experimentally demonstrated warped time stretch, which offers variable spectral-domain sampling rate, as well as the ability to engineer the time-bandwidth product of the signal's envelope to match that of the data acquisition systems. We also show how to design the kernel of the transform and, specifically, the nonlinear group delay profile governed by the signal sparsity. Such a kernel leads to smart detection with nonuniform spectral resolution, having direct utility in improvement of data acquisition rate, real-time data compression, and enhancement of ultrafast data capture accuracy.

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