COMPRESSED SENSING LASER-SCANNING MICROSCOPY

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Compressed sensing (CS) is a method that allows to reduce the number of required samples measured for retrieving an accurate representation of the object without employing any assumptions about the observed object [1]. Recent developments and applications in microscopy, such as three-dimensional imaging, dynamic measurements, or multi-photon interactions, involve the acquisition of a large amount of data, while also having to cope with lower amount of signal to speed up acquisition and reduce photo-bleaching. CS has recently been employed with several imaging modalities, such as wide-field fluorescence [2], to efficiently image specimens with less data measured. However, due to its functioning principle based on the selective excitation by specifically defined masks, applications of CS have been mostly limited to wide-field imaging, precluding its use for widely used techniques such as confocal and non-linear microscopy. Furthermore, specifically lab-designed systems are often required to generate the excitation patterns.

We recently developed an approach that enables the use of CS data reduction to standard laser-scanning microscopes, by including a model of the point-spread function into the CS reconstruction framework. We demonstrate how this method can lead to data reduction of 10-15 times, while being applicable to unmodified laser-scanning commercial systems. We also show the robustness of this approach in terms of spatial resolution, where comparable performance can be achieved even with 10% of the full data recorded. We also experimentally demonstrate these performances for confocal microscopy employed for biological targets and sub-cellular imaging.
We also show that it is possible to employ this approach under low-light conditions, by achieving similar performance in the case of Raman micro-spectroscopy. The regularization that is employed during CS reconstruction also significantly reduces the noise of Raman spectra recorded for spectral imaging, effectively increasing the signal-to-noise ratio of Raman images and spectra.
Recently, we extended our models to enable the reconstruction of three-dimensional data, which further increases the possible data reduction rate. We present preliminary results demonstrating the capability of reconstructing full 3D images of biological targets.

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