Optically Compressed Sensing by under sampling the polar Fourier plane

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Abstract. In a previous work we presented a compressed imaging approach that uses a row of rotating sensors to capture indirectly polar strips of the Fourier transform of the image. Here we present further developments of this technique and present new results. The advantages of our technique, compared to other optically compressed imaging techniques, is that its optical implementation is relatively easy, it does not require complicate calibrations and that it can be implemented in near-real time.

Compressed sensing (CS) [1] – or compressive sensing as it is also known – is a new field that has been rapidly emerging over the past few years. CS suggests a new framework for simultaneous sampling and compression of signals. As opposed to the presently used framework in which as much data as possible is first collected and then the redundant data is discarded by digital compression techniques, CS seeks to minimize the collection of redundant data in the acquisition step. Despite the young age of the CS theory, several implementation of CS concept in imaging have already appeared [3]. In this work we further elaborate a compressive imaging (CI) approach introduced in [2] which captures image projections containing information of radial strips of the Fourier domain of the image. This CI approach can be implemented with coherent and incoherent imaging with a vector (row) sensor that scans the field-of-view by rotational motion. As illustrated in Fig.1 the approach in [2] takes benefit of very good trade between implementation complexity and acquisition time. By complexity we generally refer to system implementation complexity, system calibration, reconstruction complexity and other computational and storage requirements [4].

One way to capture radial strips in the Fourier domain, applicable for incoherent imaging, is by utilizing a cylindrical lens as described schematically in [2]. The system performs an integral projection and such that the sensor measures the Radon transform of the image [2].

Figure 2 presents image reconstruction from data captured with an optical experiment based on the scheme on the scheme described in Fig. 4 in [2]. The system uses a cylindrical lens to capture the Radon transform of the image with a linear sensor. Therefore, according to the central slice theorem [2] the captured field is related to the 2D Fourier transform of the image on a radial strip. The object is an image of a goat imaged with the incoherent CI system working in the visible spectrum range. In this experiment, the vector sensor had 200 effective pixels and the number of rotated projections was 36. The rotational scan covered 180 degrees. Note that
the reconstruction presented in Fig. 2 is obtained from only 7200 measurements, compared to 40,000 measurements required for a conventional imaging system to obtain an image of 200x200 pixels. That is, a compression ratio of 5.55:1 is obtained optically with negligible lost of visual information. For illustration of the ability of the method to preserve the visual information, Fig.2(b) presents the image that would be obtained using a conventional imaging system that scans horizontally the same field of view, using the same sensor, and capturing the same number (6400) of samples.

The CI technique considered here exhibits many attractive features compared to other CI techniques (see Fig.1). Let us consider the acquisition time of an $n \times n$ pixels image for the various imaging techniques. A single sensor conventional camera takes $n \times n$ exposures to capture the image. A single sensor CI camera needs $c$ times less exposures for capturing the same image, were $c$ is typically between 5-10. Single shot CI cameras require only one exposure; however, this comes on account of complexity and computational burden, while the proposed sensor requires no calibration or storage of "system matrix" [4]. Thus, we might conclude that the CI technique described in this work technique exhibits a very good trade between acquisition time and system complexity.

**References**