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Editorial

Algorithms for Compressive Sensing Signal Reconstruction with Applications

Srdjan Stanković,[1] Cornel Ioana,[2] Xiumei Li,[3] and Vladan Papic[4]

[1] *University of Montenegro, Podgorica, Montenegro*
[2] *Grenoble INP/ENSE3, Grenoble, France*
[3] *Hangzhou Normal University, Hangzhou, China*
[4] *Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, Electronics Department, Split, Croatia*

Correspondence should be addressed to Srdjan Stanković; srdjan@ac.me

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Compressive sensing appeared recently as a new sensing framework and very quickly became a rapidly growing area of great interest in many research communities and applications. As an alternative to the traditional sampling theory, this approach allows acquiring much smaller amount of data, still achieving the same quality (or almost the same) of the final representation. Compressive sensing opens the possibility of simplifying acquisition devices and apparatus for data and reducing the number of sensors, acquisition time, and storage capacities. Also, compressive sensing principles have been used for denoising by considering the randomly corrupted data as unavailable. The signal reconstruction from small set of measurements is possible if these are incoherent and the signal itself is sparse in a certain transform domain. The main challenges that arise here are related to the design of measurements process/matrix, exploring signal sparsity over certain transform basis and design of suitable reconstruction algorithms. Generally, the signal reconstruction problem in CS is formulated as an underdetermined system of linear equations that needs to be solved using sparse priors. Depending on the application of interest, the challenge in signal reconstruction is focused toward the development of fast reconstruction algorithm with high accuracy.

Nowadays, compressive sensing has found the potential applications in many real-world systems showing ability to provide substantial gain over traditional approach. Particularly, applications range between radar, sonar and remote sensing systems, biomedical imaging, multimedia systems, communications and sparse channel estimation.

The objective of this special issue is to bring together novel theoretical developments and modern applications dealing with compressive sensing strategy and thus to promote the state of the art in this attractive research area as well as to bring new advanced results. Therefore, it welcomes novel contributions, modifications, and extensions in theory, analysis, and algorithms, with the special emphasis on applications.

This special issue consists of sixteen papers.

A survey of the compressive sensing theory, assumptions, and commonly used signal reconstruction methods is provided in the form of review paper by I. Orović et al. Some of the widely used signal reconstruction approaches are summarized in the form of algorithms to provide an easier insight into the state of the art in this field. Also, the CS problem formulation and sparsity property are observed in several transformation domains: the Fourier transform domain, the polynomial Fourier transform domain, Hermite transform domain, and combined time-frequency domain.

In recent years, the advantages of dictionary learning have attracted significant attention in compressive sensing and many other signal processing applications, because it allows capturing significant features of training samples. In general, the dictionary is trained to adapt to a particular class of signals. However, as the size of the dictionary increases, the coherence between dictionary atoms becomes higher, which further worsen the implementation of sparse coding.

H. Bai et al. propose a novel approach for learning dictionary that minimizes the sparse representation error, whereas the coherence is constrained by making the Gram matrix of

the desired dictionary approximate to an identity matrix of proper dimension. The implementation is done using an iterative algorithm that updates alternately the sparse coefficients and the components of the dictionary.

An incoherent dictionary learning method for sparse representation is proposed by H. Tang et al. The algorithm is based on the fact that the coherence of a previous dictionary is reduced by finding a new dictionary, which is closest to the reference unit norm tight frame of the previous one. The optimization problem is solved through the iterations by restricting the tightness and coherence alternately. The efficiency of the proposed method is tested on audio data showing faster performance, robustness, and much lower coherence compared to other existing methods.

B. Hou et al. propose an algorithm to solve the optimal sparsifying transform design problem. The transform is updated using alternating minimization-based procedure with a derived closed-form solution. This appears to be more efficient than to use a gradient-based numerical procedure as it is time consuming and may suffer from local minimum issue. The superiority of the proposed approach is shown experimentally in terms of the averaged representation and denoising errors.

Based on the compressive sensing framework, Z. Wang et al. propose a novel algorithm for underdetermined speech separation in order to separate source signal from their mixture, in the situation where the number of mixtures is less than the number of sources, which is a form of compressive sensing problem. The problem is formulated in a sparse Bayesian framework and solved by Bayesian inference technique, providing better estimation performance than the other methods reported in the literature.

Liu et al. employed a temporally correlated Multiple Sparse Bayesian Learning technique in order to develop space-time adaptive processing that can suppress clutter for target detection in airborne MIMO radar with only one snapshot. The proposed solution provides high accuracy and robustness to noise.

The nonlinear compressive sensing can be observed as an extension of the classical compressive sensing, where the measurements are nonlinear, requiring the adaptations and modifications of signal reconstruction algorithms. X. Zhu proposes an approximately normalized iterative hard thresholding (IHT) algorithm for nonlinear compressive sensing based on the combination of approximate optimal step-size and Armijo step-size rule. The author shows that, due to the nonconvex programming problem, the accumulation point of the algorithm is the stationary point (rather than the local minimizer).

An example of nonlinear measurements appears as a consequence of sensor physics: the phase information is lost in CXDI (Coherent X-ray Diffraction Imaging) measurement, since the measured intensity pattern is the modulus square of the scattered X-rays. In these circumstances, the scattering data with missing phase information can be considered as undersampled. A. Seel et al. propose to apply the $l1$-minimizing technique to nonlinear quadratic observations by inverting the observation model with Kalman filtering. Applying the Kalman filter to the $l1$ minimization procedure is used to suitably linearize the nonanalytic $l1$-norm. The authors show that the Kalman filter approach to quadratic compressive sensing can be used to reconstruct the scattering data from their spatial intensity distribution.

In parallel with the compressive sensing theory, Low-Rank Matrix theory can also solve signal reconstruction problems, since both theories are closely related to signal sparsity and sparse recovery. The convex constrained rank minimization problem has been considered by W. Yang et al. The convex objective function is reformulated as a difference of convex functions based on the closed-form solutions, which can be reformulated as a DC programming and solved via linear approximation method. The reformulated model is solved by applying a stepwise linear approximative algorithm.

An efficient signal/image reconstruction algorithm based on the gradient of sparsity measure is proposed by L. Stankovic and M. Dakovic. The missing samples are considered as the minimization variables, while their reconstruction is performed using a gradient-based algorithm with an adaptive step. The algorithm step size is adapted through the iterations based on the gradient directions.

The application of the gradient-based compressing sensing reconstruction in aerial photography using unmanned aerial vehicles is considered by J. Music et al. Due to the limited transmission capacities and significant battery consumption for recording high resolution images by using unmanned aerial vehicles, the use of smart acquisition strategy with reduced amount of pixels is assumed. The images are firstly reconstructed in the control center using the gradient-based iterative approach. Then the image processing for suspicious objects detection is performed. The efficiency of object detection using the proposed combined approach is tested on various high resolution aerial images.

M. Yin et al. propose a compressed sampling and collaborative reconstruction framework for wireless sensor array network. Instead of transmitting all sensor data to the fusion center, random sampling and deep quantization are performed to significantly reduce the amount of data that needs to be transmitted via wireless channel. A collaborative reconstruction method is proposed by exploiting similar sparsity structure of acoustic signal from nodes in the same array.

Further, the algorithm for reconstruction of time-varying sparse signals in a wireless sensor network with severe communication constraints has been proposed by Z. Zhao and J. Feng. A particle filter algorithm based on coarsely quantized innovation is presented. The algorithm applies the sparsity constraint on fused estimate by either iterative pseudo-measurement update method or sparse cubature point filter method, where the second one is preferable due to the comparable performance and lower complexity.

An interesting compressing sensing application to LEO mobile satellite systems is proposed by F. Li et al.

LEO mobile satellite network entails some major technical challenges such as the high sampling rate for wideband sensing, limited power, and computing resources. Hence, the authors define the novel wideband spectrum compressed sensing method based on discrete sine transform as an orthogonal sparse basis, to provide more accurate recovery and lower processing complexity compared to the solution based

on discrete Fourier transform. The minimization problem is solved using LASSO.

It has been known that the compressive sensing based channel estimation can provide an accurate signal reconstruction with less pilot symbols in OFDM systems. Z. Ma et al. propose a reduced complexity channel estimation approach based on the modified OMP algorithm with sliding windows for ISDB-T (Integrated Services Digital Broadcasting for Terrestrial) system. Also, a reconstruction method of channel matrix is introduced with the derivation of initial phases.

The moving object trajectory compression becomes an emerging issue in moving object data mining due to the intensified use of RFID and GPS devices and increased number of traced objects. Consequently, the development and analysis of typical moving object compression algorithms are reviewed by P. Sun et al., including a method of compressing trajectories by compressive sensing to reduce the data scale in the process of data acquisition.

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