[C7] Adaptive Compressed Sensing of Wideband Dynamic Signals

Theme: Distributed Signal Processing

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Project Objectives

The aim of this project is to develop adaptive compressed sampling (CS) techniques to achieve sub-Nyquist sampling rates for wideband signals. The objectives are to develop algorithms to *automatically adjust* CS measurements and to exploit the structure and *dynamics* of wideband signals so that one can sample the desired signals more efficiently. The developed techniques are intended to address the challenges behind many applications in defence, such as, sustainable unattended surveillance of the RF spectrum, and real-time monitoring of a battle-field.

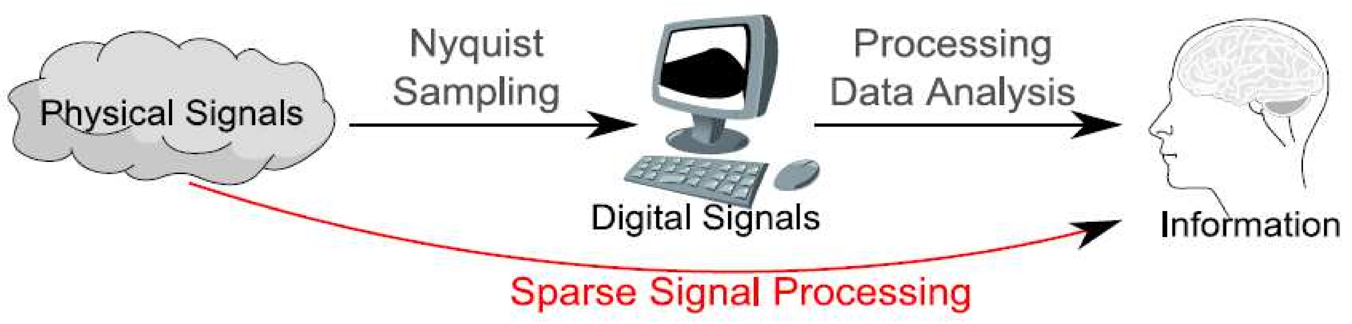

Fig. 1. CS concept.

Proposed Compressed Sensing Approach

CS is an emerging data acquisition and processing paradigm where certain signals can be acquired and precisely reconstructed from a small number of linear measurements (see Fig. 1). The latter is significantly less than that imposed by Nyquist rate [1], i.e., sub-Nyquist sampling rates. This is possible because in many applications, the processed signals are sparse (possibly in an appropriate basis or frame) or can be closely approximated by sparse signals, i.e., compressible signals.

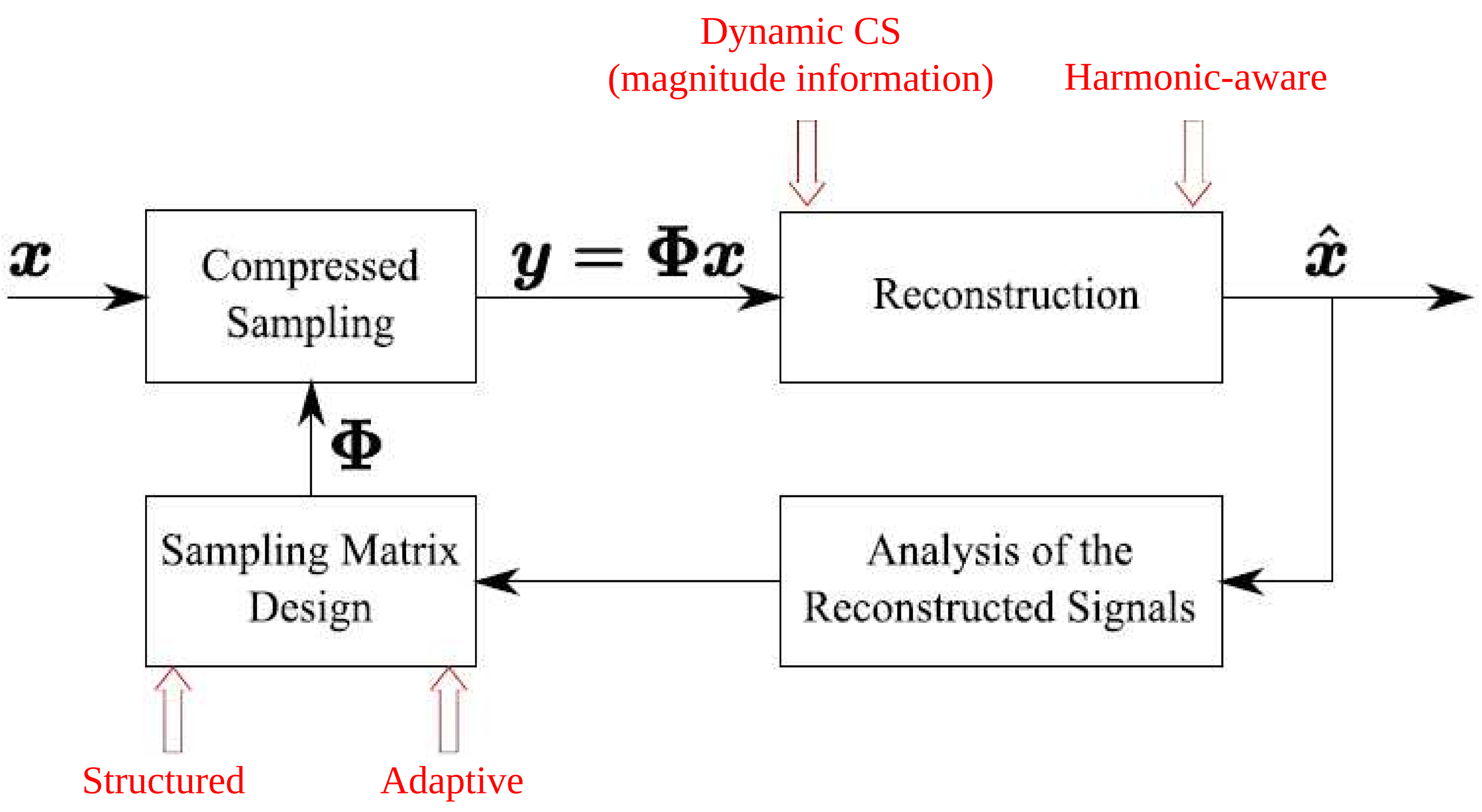

Fig. 2. Block diagram of the proposed CS approach.

Proposed Approach: To achieve the sought reductions in the data acquisition requirements efficiently, we propose a sampling and recovery stages described in Fig. 2. Given a sampling matrix Φ and an unknown signal $\mathbf{x}$, one is able to obtain measurements $\mathbf{y} = \Phi\mathbf{x}$. According to the measurements, an estimate of the original signal can be obtained; a recovery technique that incorporates the signal structure and dynamics is deployed. Based on the reconstructed signal one can understand which signal components are significant and then adjust the sampling matrix accordingly to put more emphasis on the significant components.

Sampling Technique: Most common CS sensing matrices are random with i.i.d. entries; they are difficult to implement for large-scale problems. Investigated low-complexity practical approaches include:

- ***Random filtering***: equivalent to deterministic Toeplitz sensing matrix [2].
- ***Random nonuniform sampling*** [3].
- ***Random demodulator*** and ***MWC***.

The sensing matrix can be adapted online according to the information obtained from previous signal samples.

Signal Recovery: Model-based greedy recovery algorithm [4] is used:

- Fast, low-complexity and is based on the subspaces pursuit [5].
- Leverages the harmonic structure of the processed signal.
- Outperform existing greedy approaches.

Signal dynamics can also be used to robustly reconstruct the signals [6].

Numerical Examples

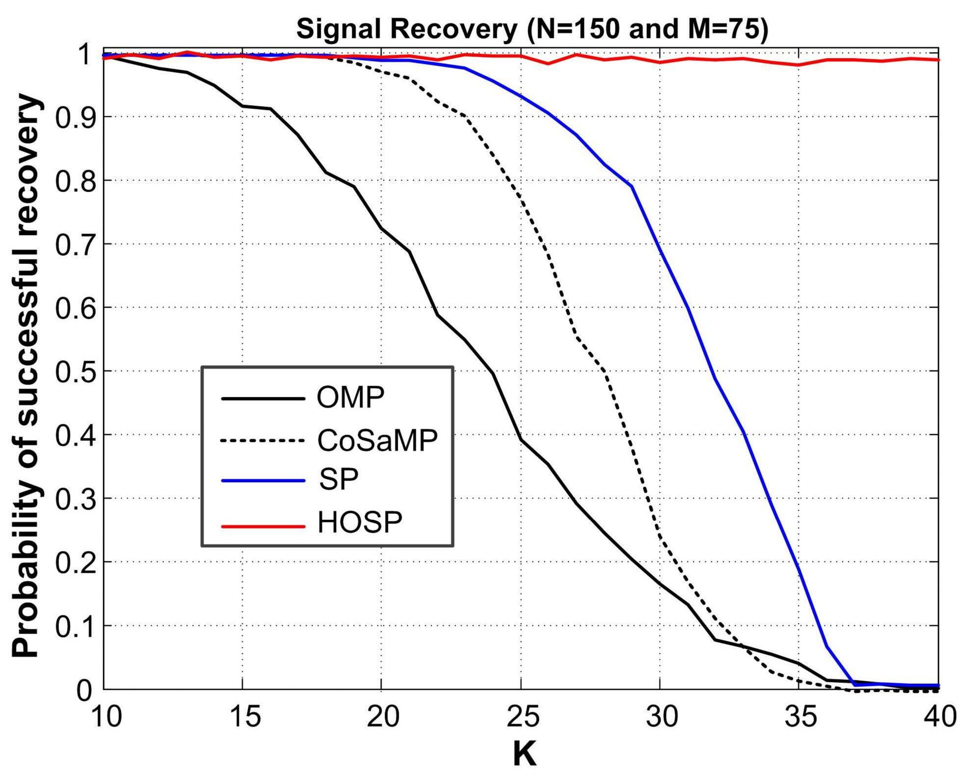

Fig. 3. Proposed HOSP

Experiment 1

Fig. 3 depicts the gains of the proposed harmonics-oriented recovery algorithm HOSP for a 50% reduction in samples.

HOSP notably outperforms existing greedy approaches; this is due to leveraging the harmonic structure of the processed signal.

Experiment 2

A joint Gaussian model for dynamic CS is used in Fig. 4 which quantitatively compares the proposed SP-MAP method with the standard Kalman filter.

The proposed framework have significant performance gains over the standard Kalman filter approach.

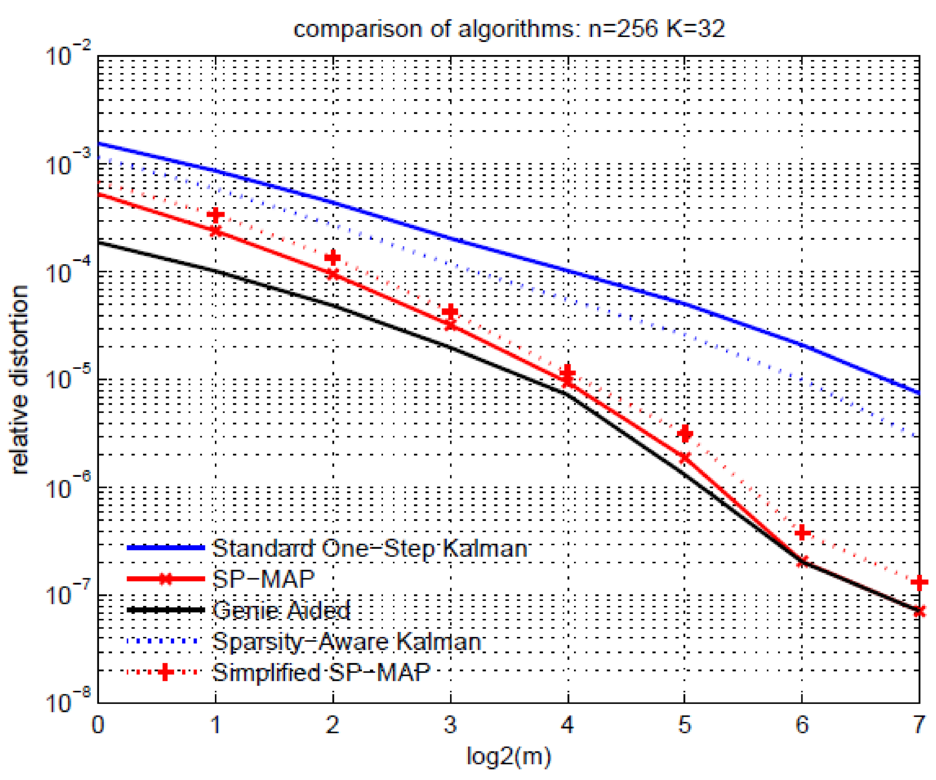

Fig. 4. SP-MAP

References:

[1] E. Candès, J. Romberg, and T. Tao, "Robust uncertainty principles: Exact signal reconstruction from highly incomplete frequency information," *IEEE Trans. Inform. Theory, vol. 52, pp. 489*–509, Feb. 2006.

[2] Kezhi Li, Cong Ling and Lu Gan, "Deterministic compressed-sensing matrices: Where Toeptlitz meets Golay," *IEEE ICASSP 2011*.

[3] B. Ahmad, W. Dai and C. Ling, " Reliable Sub-Nyquist Wideband Spectrum Sensing Based on Randomised Sampling", *Int. Workshop on Compressed Sensing Applied to Radar*, 2012.

[4] B. Ahmad, W. Dai and C. Ling, "Efficient Matching Pursuit Reconstruction Algorithm for Harmonic Signals in Compressive Sensing", *IMA Int. Conference on Mathematics in Signal Processing*, 2012.

[5] Wei Dai and Olgica Milenkovic, "Subspace pursuit for compressive sensing reconstruction," *IEEE Trans. Inform. Theory*, vol. 55, no. 5, pp. 2230-2249, 2009.

[6] W. Dai, D. Sejdinovic, and O. Milenkovic, "Gaussian dynamic compressive sensing," SampTA, 2011.

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EPSRC Engineering and Physical Sciences Research Council

This work was supported by the Engineering and Physical Sciences Research Council (EPSRC) and the MOD University Defence Research Centre on Signal Processing (UDRC).