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Inverse problems in signal processing: Old problems and new opportunities

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In many applied research fields—including Geophysics, Medicine, Engineering, Economics, and Finance—fundamental challenges involve extracting hidden information and meaningful features from complex signals, such as quasi-periodicities, time-varying frequency patterns, and underlying components like trends.

Classical signal processing techniques based on Fourier and Wavelet transforms, while powerful, often exhibit intrinsic limitations when dealing with nonlinear and strongly non-stationary phenomena. Over the past two decades, this has motivated the development of several adaptive, data-driven nonlinear methods, which have been successfully applied across a wide range of scientific disciplines.

In this talk, we first briefly review the Hilbert–Huang Transform (also known as Empirical Mode Decomposition) and discuss its main theoretical and practical limitations. We then introduce the Iterative Filtering framework and its extensions for the analysis of multidimensional, multivariate, and highly non-stationary signals, together with the recently proposed time–frequency representations known as the IMFogram and JADE algorithms. We will illustrate their theoretical properties and numerical performance through applications to real-world data. We will also present open challenges that await being tackled in this field of research.

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