AWARD TITLE: 2012 IEEE SPS Technical Achievement Award

NOMINEE: **Yoram Bresler**

SUGGESTED CITATION: For pioneering and fundamental contributions to optimal signal acquisition and reconstruction for the inverse problems in imaging and sensor array processing.

NOMINATING PERSON, COMMITTEE OR BOARD: Image, Video, and Multidimensional Signal Processing (IVMSP) Technical Committee

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For the past 25 years, Prof. Bresler's research has addressed fundamental problems in optimal signal acquisition and reconstruction for the solution of inverse problems. His work determined the fundamental limitations or bounds to signal and image recovery from partial information, and then used the resulting insight to develop optimum signal acquisition and reconstruction techniques that achieve these bounds. Another focus of his work has been to develop computationally efficient algorithms for the solution of inverse problems in imaging. Bresler's work has been directed to applications in sensor array processing and imaging, and has provided solutions to several long-standing open problems. In some cases, it also revealed unexpected possibilities with far reaching consequences to the entire field of signal processing. Following are some highlights of his numerous pioneering contributions to signal processing.

Invention of Compressed Sensing (CS). Compressed Sensing is now widely acknowledged as a theoretical and practical breakthrough, and remains one of the hottest research topics in signal processing. Bresler's work, in which he invented CS, preceded the papers that popularized it by almost a decade. Spectrum-blind sampling (SBS), proposed in a series of publications by Bresler with his student Feng in the mid-90's, and further developed into "image compression on the fly," with his students Venkataramani and Gastpar, is the first known compressed sensing technique. This seminal work from the 1990's already included the conceptual breakthrough of sampling at the sparsity level, and other key ingredients of compressed sensing that have been evolving over recent years: theoretical guarantees and computationally efficient algorithms, treatment of both finite-length vectors and of analog sampling, of the single-vector case and of jointly-sparse recovery (the so-called multiple measurement vector problem), random sampling, performance analysis using an information-theoretic framework, and applications to imaging.

Recent work on compressed sensing and low-rank approximation. In work with his student K. Lee, Bresler invented a new algorithm, dubbed SA-MUSIC, for compressed sensing with multiple measurement vectors. SA-MUSIC has theoretical performance guarantees and offers the best empirical performance of any algorithm to date, with several orders of magnitude reduced computational cost. From the sensor array processing perspective, it is the first extension of the MUSIC algorithm that overcomes in a complete way and for any valid array geometry the problem of coherent sources, which has been open for the past 30 years.

Signal Sampling Theory and Algorithms. Bresler developed fundamental performance bounds and algorithms for optimum (minimum rate) non-uniform sampling and recovery of signals that are bandlimited in non-standard sense. His contributions include the first such results for multiband signals, for multiple-input multiple output (MIMO) systems, and bounds on the aliasing error energy for non-bandlimited signals. In different work, addressing the fundamental problem of acquiring dynamic scenery, he developed a novel and complete unifying theory for time-sequential sampling of multi-dimensional spatio-temporal signals, providing fundamental bounds and simple design algorithms for sampling patterns. Solving a long standing problem, these new theoretical tools can lead to vast reduction in acquisition requirements, as demonstrated by Bresler's techniques for computed tomography and MRI.

Estimation, Detection, & Classification. Bresler developed new fundamental performance bounds for a wide range of different estimation and detection problems, including nonlinear parameter estimation, sensor array processing for high resolution multi-source location, object shape estimation in imaging, and detection using higher order statistics. This work was recognized by the 1988 IEEE Signal Processing Society Senior (Best Paper) Award.

Ultra-Fast CT Reconstruction. Bresler's algorithms (the subject of 8 issued US patents and 20 issued and pending foreign patents, and multiple publications, including a T-IP paper with his student Basu receiving a 2002 Best Young Author Paper award of the Signal Processing Society) are the first to reduce the $O(N^3)$ and $O(N^4)$ scaling of tomographic reconstruction in 2D and 3D, to favorable $O(N^2 \log N)$ and $O(N^3 \log N)$, respectively, while providing controllable accuracy and more than an order of magnitude acceleration in practice for all practical tomographic imaging geometries. This scientific and technological breakthrough, analogous to the FFT for signal processing, is poised to enable dramatic improvements in the performance of CT scanners of all kinds, and make computation-based x-ray dose reduction widely available and affordable. The first commercial product using this technology accelerates microCT reconstruction by more than fifty fold (50x) with no additional hardware, providing the fastest microCT reconstruction in the world.

Imaging. Bresler has addressed four problem areas in imaging: (1) new image reconstruction algorithms; (2) image reconstruction from limited data; (3) imaging of dynamic objects; and (4) fast algorithms for tomographic reconstruction. In particular, his work has focused on these problems in biomedical applications: computed tomography (CT); and magnetic resonance imaging (MRI). This work draws on the fundamental results and algorithms developed by Bresler to reveal new and hitherto unexpected possibilities, and to obtain computationally efficient solutions.

Prof. Bresler's technical contributions have been recognized by several paper awards (two Senior best paper awards, and one Young Author best paper award with his student), the Xerox Senior Faculty Award for Research, a University of Illinois Scholar award, an NCSA Fellowship, a Technion Fellowship, an IEEE Fellow grade with citation "for contributions to computer-based imaging and sensor array processing" and an AIMBE Fellow grade with citation "For pioneering contributions to fast tomographic reconstruction algorithms and fundamental contributions to sampling theory for fast dynamic imaging". With all of these contributions, Bresler is well deserved for a SPS Technical Achievement Award.