

## Michael (Miki) Lustig

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RESEARCH INTERESTS	My research interests lie in the broad area of signal and image processing. More specifically, my interest is in developing and improving the numerous theoretical and practical aspects of imaging systems and, in particular, the application of Compressed Sensing (CS) to imaging. My projects so far have focused on magnetic resonance imaging (MRI), where I was the first to develop and demonstrate the application of compressed sensing to rapid MRI. In addition I developed parallel imaging reconstruction techniques, image artifacts reduction methods, motion estimation and correction techniques, novel RF-excitation pulses, rapid MRI pulse sequence design and improved functional MRI techniques.	
EDUCATION	<b>Stanford University</b> , Stanford, California USA Ph.D., Electrical Engineering, August 2008 M.Sc., Electrical Engineering, June 2004  <b>Technion IIT</b> , Haifa, Israel BSc., <i>cum laude</i> , Electrical Engineering, June 2001	
HONORS AND AWARDS	<ul style="list-style-type: none"><li>• Thomas Schwartz award for distinguished projects, Technion IIT, 2001</li><li>• Winner of the Texas instruments <i>DSP and analog Challenge</i> world wide competition receiving a 100,000\$ prize for the project: <i>Real-time digital watermarking for audio signals</i>, Dallas Texas, USA, August 2001</li><li>• GE Healthcare's "Thought Leader Class 09" award for ground-breaking work in compressed-sensing MRI, 2009.</li></ul>	
ACADEMIC ACTIVITIES	<b>Invited Talks</b> <ul style="list-style-type: none"><li>• Compressed Sensing, plenary talk, annual meeting of the European Society of Magnetic Resonance in Medicine and Biology, Antalia, Turkey, September '09</li><li>• Frontiers in Rapid MRI, HSEMB Conference, Houston, TX, March 2009</li><li>• <i>Assumptions and Stability of Model-Based Reconstruction</i>, ISMRM Workshop on Data Sampling and Image Reconstruction, January 2009</li><li>• <i>A Compressed Tutorial on Rapid MRI: From Basic Principles to Parallel Imaging and Compressed Sensing</i>, International Conference on Image Processing (ICIP) San-Diego, October 2008</li><li>• <i>Sparse MRI</i>, GE Global Research, Niskayuna, NY, July 2008</li><li>• <i>Compressed Sensing</i>, International Society of Magnetic Resonance in Medicine annual meeting, Toronto, May 2008</li></ul>	
EXPERIENCE	<b>Stanford University</b> , Stanford, California USA <i>Engineering Research Associate</i> <b>2008 - present</b> Developing rapid magnetic resonance imaging techniques, advanced image reconstructions, massive coil array processing, and non-rigid body motion correction techniques with focus on robust pediatric MRI.  <i>Research Assistant</i> <b>2003 - 2008</b> Developed methods for rapid magnetic resonance imaging. I was the first to develop and demonstrate the application of compressed sensing to MRI. In addition, developed methods for image artifacts	

suppression, motion correction and several pulse design techniques. These resulted in six issued and pending US patents. Primary advisor: John M. Pauly and secondary advisor: David L. Donoho

*Teaching Assistant*

**2002 - 2003**

- EE263 Linear Dynamic Systems, Fall 2003/2004
- EE102 Signal Processing and Linear Systems, Spring 2002/2003
- EE101 Introduction to Circuits, Winter 2002/2003
- EE103 Introduction to Digital Signal Processing, Fall 2002/2003

**Technion IIT, Computer Science Department**, Haifa, Israel

*Research Assistant*

**2001-2002**

Developed advanced methods for optical flow estimation and feature tracking under the supervision of Prof. Ron Kimmel

**Jigami Ltd**, Haifa, Israel

*DSP engineer*

**2000 - 2001**

Developed advanced image compression techniques for internet content over wireless networks. In particular, studied image compression schemes at low bit-rate compression and implemented them on a DSP-based system.

**Israeli Defense Forces**, Israel

*Infantry Officer (rank: Captain)*

**1992 - 1997**

Infantry company commander - Was in charge of the training, operations and logistics of more than 80 infantry soldiers and officers.

## PATENTS

- 1 William Grissom and **Michael Lustig** *Robust Referenceless PRF-Shift MR Thermometry*, In evaluation
- 2 **Michael Lustig**, Charles H Cunningham, Albert Chen, Daniel Vigniron, and John M Pauly *Optimized Spectral Spatial Pulse Design*, US Patent Pending
- 3 **Michael Lustig**, Simon Hu, Daniel Vigniron and John M Pauly *Blip design for random sampling compressed sensing of flyback 3D-MRSI with application to Hyperpolarized  $^{13}C$* , US patent Pending
- 4 **Michael Lustig**, and John M Pauly, *An Auto-calibrating Parallel Imaging Reconstruction Method from Arbitrary  $k$ -Space*, US patent Pending
- 5 **Michael Lustig**, Seung-Jean Kim and John M Pauly, *A Fast Method for Designing Time-Optimal Gradient Waveforms for Arbitrary  $k$ -Space Trajectories*, US patent Pending
- 6 **Michael Lustig** and Charlse H Cunningham, *Butterfly: A Self Navigating Cartesian Trajectory*, US Patent pending
- 7 **Michael Lustig**, Juan M Santos, David L Donoho and John M Pauly,  *$k$ -t SPARSE: High Frame Rate Dynamic MRI Exploiting Spatio-Temporal Sparsity*, US Patent Pending
- 8 **Michael Lustig** and John M Pauly, *Artifact Reduction in SSFP MRI Using Super Field of View Reconstruction*, US Patent 7,132,828

## PUBLICATIONS

- 9 **Michael Lustig** and John M. Pauly *SPIR-iT: autocalibrating iTerative Self-consistent Parallel Imaging Reconstruction from Arbitrary  $k$ -Space*, Magnetic Resonance in Medicine, 2008, Submitted
- 10 Daeho Lee, **Michael Lustig**, William Grissom and John M. Pauly *Time-Optimal Design for Multidimensional and Parallel Transmit Variable Rate Selective Excitation*, Magnetic Resonance

in Medicine, 2008, Accepted

- 11 Tolga Cukur, **Michael Lustig** and Dwight G. Nishimura *Improving Non-contrast-enhanced Steady-state Free Precession Angiography with Compressed Sensing*, Magnetic Resonance in Medicine, 2008, In Press.
- 12 Peder E. Z. Larson, **Michael Lustig** and Dwight G. Nishimura *Anisotropic Field-of-View Shapes for Improved PROPELLER Imaging*, Magnetic Resonance Imaging, 2008, doi:10.1016/j.mri.2008.07.023
- 13 **Michael Lustig** *Sparse MRI*, PhD Thesis, Department of Electrical Engineering Stanford University, 2008
- 14 Jongho Lee, **Michael Lustig**, Dong-hyun Kim and John M. Pauly *Improved Shim Method Based on the Minimization of the Maximum Off-resonance Frequency for Balanced SSFP*, Magnetic Resonance in Medicine, 2008, In Press
- 15 Tolga Cukur, **Michael Lustig** and Dwight G. Nishimura *Multiple-profile Homogeneous Image Combination: Application to Phase-cycled SSFP and Multi-coil Imaging*, Magnetic Resonance in Medicine, 2008;60(3): 732-8
- 16 Peder E. Z. Larson, Adam Kerr, Albert P. Chen, **Michael Lustig**, Matthew L. Zierhut, Simon Hu, Charles .H. Cunningham, John M. Pauly, John Kurhanewicz, and Daniel B. Vigneron *Multiband Excitation Pulses for Hyperpolarized  $^{13}\text{C}$  Dynamic Chemical Shift Imaging* Journal of Magnetic Resonance, 2008;194(1): 121-127
- 17 **Michael Lustig**, Seung-Jean Kim and John M Pauly, *A Fast Method for Designing Time-Optimal Gradient Waveforms for Arbitrary  $k$ -Space Trajectories*, Transactions on Medical Imaging, 2008; 27(6): 866-873
- 18 Charles H. Cunningham, Albert P. Chen, **Michael Lustig**, Janine Lupo, Duan Xu , John Kurhanewicz, Ralph E. Hurd, John M. Pauly, Sarah J. Nelson and Daniel B. Vigneron *Pulse Sequence for Dynamic Volumetric Imaging of Hyperpolarized Metabolic Products* , Journal of Magnetic Resonance, 2008;193(1): 139-146
- 19 Simon Hu, **Michael Lustig**, Albert P. Chen, Jason Crane, Adam Kerr, Douglas A.C. Kelley, Ralph Hurd, John Kurhanewicz, Sarah J. Nelson, John M. Pauly, Daniel B. Vigneron *Compressed Sensing for Resolution Enhancement of Hyperpolarized  $^{13}\text{C}$  Flyback 3D-MRSI*, Journal of Magnetic Resonance, 2008;192(2): 258-264
- 20 Seung-Jean Kim, K. Koh, **Michael Lustig**, Stephen Boyd and D. Gorinevsky *A Method for  $\ell^1$ -regularized Least-Squares*, IEEE Journal of Selected Topics in Signal Processing, 2007 Dec.;1(4): 606-617
- 21 **Michael Lustig**, David L. Donoho, Juan M. Santos and John M. Pauly *Compressed Sensing MRI*, IEEE Signal Processing Magazine, 2008; 25(2): 72-82
- 22 **Michael Lustig**, David L. Donoho and John M. Pauly, *Sparse MRI: The Application of Compressed Sensing for Rapid MR Imaging*, Magnetic Resonance in Medicine, 2007 Dec.; 58(6):1182-1195
- 23 Juan M. Santos, Charlse H. Cunningham, **Michael Lustig**, Brian A. Hargreaves, Bob S Hu, Dwight G. Nishimura and John M. Pauly, *Single Breath-Hold Whole-Heart MRA Using Variable-Density Spirals at 3T*, Magnetic Resonance in Medicine, 2006; 55:371-379
- 24 **M Lustig**, S-J Kim, and JM Pauly, *A Fast Method for Designing Time-Optimal Gradient Waveforms for Arbitrary  $k$ -Space*, in proceedings of the ISMRM 2008
- 25 CH Cunningham, AP Chen, **M Lustig**, J Lupo, D Xu, J Kurhanewicz, RE Hurd, JM Pauly,

- SJ Nelson, and DB Vigneron *Pulse Sequence for Dynamic Volumetric Imaging of Hyperpolarized Metabolic Products* , in proceedings of the ISMRM 2008
- 26 JH Lee, **M Lustig**, and JM Pauly *Improved Shim Method for Balanced SSFP*, in proceedings of the ISMRM 2008
- 27 AB Kerr, PE Larson, **M Lustig**, CH Cunningham, AP Chen, DB Vigneron, and JM Pauly *Multi-band Spectral-Spatial Design for High-Field and Hyperpolarized  $^{13}\text{C}$  Applications*, in proceedings of the ISMRM 2008
- 28 S Hu, **M Lustig**, AP Chen, J Crane, A Kerr, DAC Kelley, R Hurd, J Kurhanewicz, SJ Nelson, JM Pauly, DB Vigneron *Compressed Sensing for Resolution Enhancement of Hyperpolarized  $^{13}\text{C}$  Flyback 3D-MRSI*, in proceedings of the ISMRM 2008
- 29 T Cukur, **M Lustig**, and D Nishimura, *Improving Non-contrast Enhanced SSFP Angiography with Compressed Sensing*, in proceedings of the ISMRM 2008
- 30 T Cukur, **M Lustig**, and D Nishimura, *Banding Reduction in SSFP Imaging through Accurate, Image-based Estimation of the SSFP Profile*, in proceedings of the ISMRM 2008
- 31 D Lee, **M Lustig**, and JM Pauly, *Equiripple Design of Multidimensional RF Pulses via Convex Optimization*, in proceedings of the ISMRM 2008
- 32 S-J Kim, K Koh, **M Lustig** , and S Boyd, *An efficient method for compressed sensing*, the 14<sup>th</sup> International Conference on Image Processing (ICIP) 2007.
- 33 **M Lustig** and JM Pauly, *Further Advances in Parallel Imaging Reconstruction from Arbitrary  $k$ Space Trajectories* in Proceedings of the ISMRM Workshop on Non Cartesian MRI 2007
- 34 **M Lustig**, DL Donoho and JM Pauly *Multi-Slice Compressed Sensing Imaging*, in proceedings of the ISMRM 2007
- 35 **M Lustig** and JM Pauly, *Iterative GRAPPA: a General Solution for the GRAPPA Reconstruction from Arbitrary  $k$ -Space Sampling*, in proceedings of the ISMRM 2007
- 36 **M Lustig**, CH Cunningham, BS Hu and JM Pauly, *Multiple Narrow-Band Excitations Spiral Imaging*, in proceedings of ISMRM 2007
- 37 **M Lustig**, E Daniyaldaze, CH Cunningham and JM Pauly, *Butterfly MRI: A Self Navigating Cartesian Trajectory*, in proceedings of the ISMRM 2007
- 38 CH Cunningham, **M Lustig**, BS Hu, JM Santos, T Shin, KS Nayak, and JM Pauly, *Novel Design for Notched RF Saturation Pulses Using the SLR Transform*, in proceedings of the ISMRM 2007
- 39 PEZ Larson, **M Lustig**, J Liu, B Wandell and JM Pauly, *High Resolution Retinotopy with Transition-band SSFP (BOSS) fMRI*, in Proceedings of Human Brain Mapping 2006
- 40 **M Lustig**, JM Santos, DL Donoho and JM Pauly,  *$k$ - $t$  SPARSE: High Frame Rate Dynamic MRI Exploiting Spatio-Temporal Sparsity*, in proceedings of the ISMRM, 2006
- 41 **M Lustig**, DL Donoho and JM Pauly, *Rapid MR Imaging with Compressed Sensing and Randomly Under-Sampled 3DFT Trajectory*, in proceedings of the ISMRM, 2006
- 42 CH Cunningham, DB Vigneron, AP Chen, D Xu, **M Lustig**, DA Kelly and JM Pauly, *Spectral-spatial Excitation and Refocusing for Reduced Volume Mis-Registration at 7 Tesla*, in proceedings of the ISMRM, 2006
- 43 N Stikov, CH Cunningham, **M Lustig** and JM Pauly, *Single-Sided Quadratic Phase Outer Volume Suppression Pulses*, in Proceedings of the ISMRM, 2006
- 44 **M Lustig**, CH Cunningham and JM Pauly, *A Monte-Carlo Algorithm for Designing Ultra-*

- High Time-Bandwidth, Minimum Peak  $|B_1|$ , Selective Saturation and Inversion RF-Pulses*, in proceedings of the ENC, 2006
- 45 **M Lustig**, DL Donoho and JM Pauly, *Rapid MR Angiography with Randomly Under-Sampled 3DFT Trajectories and Non-Linear Reconstruction*, in proceedings of the SCMR, 2006
  - 46 **M Lustig**, JM Santos, JH Lee, DL Donoho and JM Pauly, *Compressed Sensing for Rapid MR Imaging*, in proceedings of SPARS'05, 2005
  - 47 **M Lustig**, JM Santos and JM Pauly, *A Super-FOV Method for Rapid SSFP Banding Artifact Reduction*, in Proceedings of the ISMRM, 2005.
  - 48 **M Lustig**, JH Lee, DL Donoho and JM Pauly, *Faster Imaging with Randomly Perturbed, Undersampled Spirals and  $\ell^1$  Reconstruction*, in proceedings of the ISMRM, 2005
  - 49 **M Lustig**, J Tsaig, JH Lee, DL Donoho, *Fast Spiral Fourier Transform for Iterative MR Image Reconstruction*, in proceedings of the IEEE International Symposium on Biomedical Imaging, 2004
  - 50 **M. Lustig**, Y Cassuto and S. Mizrahi, *Real-time digital watermarking of audio signals*, in proceedings of the 3<sup>rd</sup> European DSP Research and Education Conference, 1999