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Vision Statement My research focus is to develop new classes of diffraction-based optical sensors. This past decade has seen the advent of microfabrication technology able to pattern features on length scales smaller than the wavelength of visible light. This unprecedented design freedom allows the creation of entirely new types of optical elements with the same economies of scale applicable to microchip manufacture. With my background in physics and sensory neuroscience, I invent fundamentally-new types of biomimetic, diffraction-exploiting imaging technology including the Planar Fourier Capture Array [2,5,6] and newer alternative lensless microfabricated optical sensors.

Highlights

- 2012–present: Senior research scientist at Rambus Labs developing lensless optical sensors.
- 2011–2012: Exploring the relationship between acetylcholine and compressed sensing in rats and aging humans.
- 2009–2012: Invented the PFCA [2,5], the first camera requiring no lens, mirror or moving parts; 10^5 times smaller by volume than the smallest focusing camera. Forecast applications include hyperspectral sensors, low-power optic flow accelerometers and imagers with minimal cost, space and weight.
- 2011: Created the in-crowd algorithm, the fastest solver of basis pursuit denoising (an optimization problem required by compressed sensing) for large, sparse problems [4], inspired by sensory cortex.
- 2011–2012: Post-Doctoral Researcher, De Rosa Lab, Department of Psychology, University of Toronto.
- 2008–2011: Post-Doctoral Researcher, Molnar Lab, School of Electrical and Computer Engineering; Smith Lab (2010–2011), Department of Psychology, Cornell University.
- 2007: Ph.D. in Biophysics, University of California, Berkeley; Alan J. Bearden Award for outstanding dissertation on a biophysical topic. Thesis: “Computational and Ethological Theories of Zebra Finch Audition”. Advisor: Frederic Theunissen.
- 2001: National Champion, Canadian Association of Physics University Prize Examination.
- 2001: Hon. B.Sc. with High Distinction in Physics with Mathematics minor, University of Toronto.
- 1993: National Champion, Canadian National Mathematics League Competition.

Research Interests Sensory system design; lensless imaging; angle-sensitive pixel techniques; sensory neuroscience; signal processing algorithms; neuromimetic learning.

Publications

- [1] P. Gill and A. C. Molnar, "Scaling properties of well-tiled pfcas," in *Imaging Systems and Applications*. Optical Society of America, 2012, p. JW3A.3. [Online]. Available: <http://www.opticsinfobase.org/abstract.cfm?URI=ISA-2012-JW3A.3>
- [2] P. R. Gill, C. Lee, S. Sivaramakrishnan, and A. Molnar, "Robustness of planar fourier capture arrays to colour changes and lost pixels," *Journal of Instrumentation*, vol. 7, no. 1, 2012. [Online]. Available: <http://stacks.iop.org/1748-0221/7/i=01/a=C01061>
- [3] P. Gill, S. Mizumori, and D. Smith, "Hippocampal episode fields develop with learning," *Hippocampus*, vol. 21, no. 11, pp. 1240–1249, Nov. 2011.
- [4] P. R. Gill, A. Wang, and A. Molnar, "The in-crowd algorithm for fast basis pursuit denoising," *IEEE Transactions on Signal Processing*, vol. 59, no. 10, pp. 4595–4605, Oct. 2011.
- [5] P. R. Gill, C. Lee, D.-G. Lee, A. Wang, and A. Molnar, "A microscale camera using direct fourier-domain scene capture," *Optics Letters*, vol. 36, no. 15, pp. 2949–2951, Aug. 2011.
- [6] A. Wang, P. Gill, and A. Molnar, "An angle-sensitive cmos imager for single-sensor 3d photography," in *Solid-State Circuits Conference Digest of Technical Papers (ISSCC), 2011 IEEE International*, Feb. 2011, pp. 412–414.
- [7] N. Amin, P. Gill, and F. Theunissen, "Role of the Zebra Finch Auditory Thalamus in Generating Complex Representations for Natural Sounds," *Journal of Neurophysiology*, vol. 104, no. 2, pp. 784–798, 2010.
- [8] M. Gastpar, P. Gill, A. Huth, and F. Theunissen, "Anthropic correction of information estimates and its application to neural coding," *IEEE Transactions on Information Theory*, vol. 56, no. 2, pp. 890–900, 2010.
- [9] A. Wang, P. Gill, and A. Molnar, "Angle sensitive pixels in cmos for lensless 3d imaging," in *IEEE Custom Integrated Circuits Conference*, Sept. 2009, pp. 371–374.
- [10] S. Woolley, P. Gill, T. Fremouw, and F. Theunissen, "Functional groups in the avian auditory system," *Journal of Neuroscience*, vol. 29, no. 9, pp. 2780–2793, 2009.
- [11] A. Wang, P. Gill, and A. Molnar, "Light field image sensors based on the talbot effect," *Applied Optics*, vol. 48, no. 31, pp. 5897–5905, 2009.
- [12] P. Gill, S. Woolley, T. Fremouw, and F. Theunissen, "What's that sound? Auditory area CLM encodes stimulus surprise, not intensity or intensity changes," *Journal of Neurophysiology*, vol. 99, no. 6, pp. 2809–2820, 2008.
- [13] Y. Cohen, F. Theunissen, B. Russ, and P. Gill, "Acoustic features of rhesus vocalizations and their representation in the ventrolateral prefrontal cortex," *Journal of Neurophysiology*, vol. 97, no. 2, pp. 1470–1484, 2007.
- [14] P. Gill, J. Zhang, S. Woolley, T. Fremouw, and F. Theunissen, "Sound representation methods for spectro-temporal receptive field estimation," *Journal of Computational Neuroscience*, vol. 21, no. 1, pp. 5–20, 2006.
- [15] S. Woolley, P. Gill, and F. Theunissen, "Stimulus-dependent auditory tuning results in synchronous population coding of vocalizations in the songbird mid-brain," *Journal of Neuroscience*, vol. 26, no. 9, pp. 2499–2512, 2006.
- [16] R. Edwards and P. Gill, "On synchronization and cross-talk in parallel networks," *Dynamics of Continuous, Discrete and Impulsive Systems Series B*, vol. 10, pp. 287–300, 2003.

Recent Awards and Honors

- 2012: Lewis Winner Outstanding Paper Award for [6], ISSCC 2012.
- 2011: Cover story [3], November 1st issue of *Hippocampus*.
- 2011: Cover story and top download [5], August 1st issue of *Optics Letters*.

Patents

- S. M. H. Amroabadi, P. R. Gill, and N. S. Paul. "Method and system for compressed sensing image reconstruction," Attorney Ref. 05014971-52USPR. Method for improving the dose/computation time tradeoff for compressed sensing CT scans.
- P. R. Gill, A. Wang, and A. Molnar, "Imaging device, methods and applications," USPTO Appl No. PCT/US11/57,970. Methods by which a diverse collection of angle-sensitive pixels may jointly represent a complicated stimulus. Enables PFCAs to be made from angle-sensitive pixels.
- P. R. Gill, A. Wang, and A. Molnar, "Angle sensitive pixels employing the Talbot effect and phase gratings," USPTO Appl. No. 61/407,202. Improvements allowing angle-sensitive pixels to operate in low-light regimes.

Co-Authored Grants

- National Institute of Biomedical Imaging and Bioengineering: "Three dimensional fluorescent imaging on a chip" (R21 NIBIB, GCO OSP 57698, 1 R21 EB 009841-01 01/06/09–01/06/11; annual direct costs for fabrication of new CMOS chips: \$185,099; ranked in the top 0.5% of applicants).
- National Institute of Mental Health: "Quantitative tools for investigating sensory systems" (R01 MH26990 01/05/02–30/04/11; annual direct costs for STRF-PAK: \$225,000).
- National Institute on Deafness and Other Communication Disorders (NIDCD) Collaborative Research in Computational Neurosciences: "Ethological theories of optimal auditory processing" (R01 NIDCD 007292 01/07/04–30/06/07; annual direct costs for Theunissen laboratory auditory research: \$203,000).

Selected Presentations

- "Sclaing properties of well-tiled PFCAs." Invited talk, Computational Optical Sensing and Imaging, Monterey CA, USA, June 2012.
- "Learning to Cope with Incomplete Sensory Data by Studying Neurons: The Brain as a Compressive Sensor." Mathematical biology seminar, University of Victoria, Victoria BC, Canada, March 2012.
- "Enhanced Angle Sensitive Pixels for Light Field Imaging." Conference presentation, Electron Devices Meeting (IEDM), 2011 IEEE International, Washington DC, December 2011.
- "Planar Fourier Capture Arrays: Tiny Optical Sensors Built Entirely in Unmodified CMOS." Keynote talk, 9th International Conference on Position Sensitive Detectors, University of Aberystwyth, Wales, September 2011.
- "Songbird Hearing, Algorithms and Lensless Imaging: Discovering and Applying Neural Sensory Tricks." Invited talk, Università Vita-Salute San Raffaele, Milan, Italy, May 2011.
- "Neural and ASP-Based Sensory Systems: Learning Seemingly Impossible Tricks by Observing Brain Function." Invited talk, University of Toronto at Mississauga, Mississauga ON, Canada, March 2011.
- "An Alternative Type of Reductionism: Neural Algorithms and Perception." Invited talk, Massachusetts Institute of Technology, Cambridge MA, January 2011.

- “Fluorescent Imaging and Localization with Angle Sensitive Pixel Arrays in Standard CMOS.” IEEE Sensors 2010 Conference, Waikoloa, Big Island HI, November 2010.
- “Finch Song and Angle Sensitive Pixels: Principles of Robust Sensory Systems.” Invited talk, Dalhousie University, Halifax NS, Canada, June 2010.
- “Hippocampal Neurons Exhibit ‘Episode Fields’ During the Intertrial Delay of a Blocked Spatial Alternation Task.” Poster, Society for Neuroscience Conference, Chicago IL, October 2009.
- “Surprise: a Functional Consequence of STDP?” Seminar, Behavioral, Computational, and Systems Neuroscience Journal Club, Cornell University, Ithaca NY, October 2008.

Selected Presentations, Continued

- “Synapses and Surprise: Efficient Sensory Codes and Plasticity.” Seminar, Salk Institute, San Diego CA, April 2008.
- “Spikes in the Auditory Forebrain: Surprise, Not Intensity.” Talk, CoSyNe, Salt Lake City UT, February 2007.
- “Tuning Diversity Among Auditory Midbrain and Forebrain Neurons in Adult Male Zebra Finches.” Poster, Society for Neuroscience Conference, Washington DC, November 2005.
- “Physiologically Inspired Time-Frequency Representations of Sound for the Optimal Estimation of Spectro-Temporal Receptive Fields.” Poster, Gordon Conference for Sensory Coding and the Natural Environment, Oxford, England, September 2004.

Additional Professional Experience

- 2009–2011: Developer of “Wee Waves” PDE package for designing angle sensitive pixels, available at <http://tinyurl.com/WeeWave>.
- 2009–2011: MATLAB implementation of in-crowd algorithm for basis pursuit denoising [4], available at <http://tinyurl.com/InCrowdBeta1>.
- 2006–2008: Lead Developer of STRFPAK, a spectro-temporal receptive field software package, available at <http://strfpak.berkeley.edu>.

References

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