UNIVERSITY OF TORONTO

Research Opportunities

Intelligent Sensory Microsystems Lab & Computer Vision Group

Computational Cameras for Computer Vision and Robotics

Candidates at various education/experience levels are encouraged to apply for interdisciplinary research opportunities with our research group, including:
undergraduate, masters (MEng-project & MASc), and PhD students as well as post-doctoral and research fellows.

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And CC: Professor Roman Genov - **roman@eecg.utoronto.ca** and Professor Kyros Kutulakos - **kyros@cs.toronto.edu**

Project Description

Fig 1. InVisage drone navigation at night

*Fig 2. 3D Imaging using LIDAR**

Fig 3. Apple face ID

*https://tinyurl.com/y8bymdem

In a long-standing scientific collaboration between researchers in the department of Electrical and Computer Engineering (Prof. Roman Genov) and the Department of Computer Science (Prof. Kyros Kutulakos) at the University of Toronto and jointly with several world's leading research centers in Computer Vision and Robotics (including Carnegie Mellon and Stanford), our team is leading the development of a new family of coded-pixel cameras with never before seen capabilities, like the ability to sort incoming photons based on their properties. These cameras target the explosively growing space of new computer vision applications such as **3D imaging for robotic navigation of drones (Fig. 1) and self-driving cars (Fig. 2) in harsh environments; and next-generation information-rich user interfaces through face / gesture analysis (Fig. 3). Such applications often require programmability, or coding, of the camera exposure at the individual-pixel level. Unlike conventional cameras, which record all light incident onto a pixel, our coded-exposure-pixel (CEP) cameras can be programmed to selectively sort the light based on its path or time of travel. In conjunction with a concurrently coded illumination, this enables a wide range of previously unattainable video capabilities** such as seeing against the sun, seeing through the skin, or seeing behind an object/around the corner. This interdisciplinary project spans across many fields such as **the design of analog and digital integrated circuits for custom-fabricated CMOS image sensors, embedded systems with high-performance FPGA/DRAM/ASIC co-design, design of semiconductor devices such as novel 3D photodetectors, design and experimental deployment of computational-imaging algorithms, as well as various aspects of optics and photonics**. The interdisciplinary nature of our team enables all members to focus on their field of interest, and to have exposure to other disciplines.

Related videos can be found here:

1. https://youtu.be/8__WJb06h5E
2. https://www.dropbox.com/s/4q60jhp9vfmi4qy/1717-supp.mp4?dl=0

Positions Description

Undergraduate and Masters Students will actively participate in the development of various hardware prototypes and software applications for computational imaging systems / cameras. The most important tasks include FPGA firmware development and software programming. Masters students will also engage in team-based efforts for CMOS image sensor integrated circuit (IC) design.

PhD Students will lead research and development activities focusing on the design and experimental validation of computational image sensors in cutting-edge IC (and photonic) technologies. This research offer opportunities for the design of analog and digital integrated circuits for custom-fabricated CMOS image sensors, embedded systems with high-performance FPGA/DRAM/ASIC co-design, design of semiconductor devices such as novel 3D photodetectors, design and experimental deployment of computational-imaging algorithms, as well as various aspects of optics and photonics.

Post-Doctoral and Research Fellows: As a post-doctoral fellow you will supervise the development of the overall embedded computational imaging system and lead the overall hardware/software co-design of the next generation prototypes. Your main responsibility will be to contribute by adding new research ideas and directions and by handling research and development challenges related to the implementation of computational imaging algorithms on the dedicated hardware platform.

Preferred Qualifications of Applicants

All candidates (the level of expected experience varies based on the position):

- Proficiency in Verilog, C/C++, Python
- Prototyping experience with PCB and embedded sys. design & testing
- Knowledge of digital signal processing and image processing is plus

Additional Requirements:

Masters students:

- All of the above plus the following
- Good knowledge of analog and/or digital IC design.
- Experience in implementing/testing soft-core processors on FPGA.

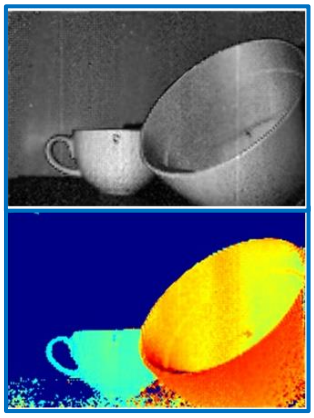
PhD students:

- All of the above plus the following
- Excellent knowledge analog and/or digital IC design.
- Thorough experience with Cadence CAD design tools.

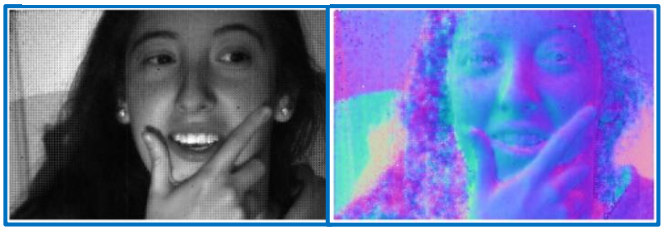
Post-doctoral fellow:

- All of the above plus the following
- Experience in design/verification of large-scale complex embedded systems.
- Analog and Digital IC design experience.
- Experience with Pixel design and device simulation experience is plus

Assembled Camera [1]



One-Shot Structured Light [2]



One-Shot Photometric-Stereo [2]

Additional Information and References:

[1] N.Sarhangnejad, "Dual-Tap Pipelined-Code-Memory Coded-Exposure-Pixel CMOS Image Sensor for Multi-Exposure Single-Frame Computational Imaging", *ISSCC'19*

[2] M.Wei, "Coded Two-Bucket Cameras for Computer Vision", *ECCV'18*

[3] M. O'Toole, "Transport-Aware Imaging," *SPIE'15*.

[4] http://www.eecg.toronto.edu/~roman