Alankar Kotwal

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Research Summary

I work in computational imaging, where we combine illumination, cameras and computation in innovative ways to sense the environment in a way that traditional cameras can't. I currently build optical imaging systems that use the wave nature of light to achieve exciting capabilities like seeing through scattering media and micron-scale shape acquisition, with applications in biomedical imaging and fabrication. Some of these are possible only in the lab now: We're bringing them out in the open!

Research Interests

Going forward, I would like to explore biomedical optics in the context of both optical imaging and optogenetics. I am especially interested in developing high-resolution optical imaging systems for *in vivo* diagnostics and functional imaging; and establishing computational methods to interpret the data acquired by these systems. Additionally, I am interested in applications of such systems in neuroscience research and their potential to study, monitor and control neurological conditions such as epilepsy.

Education

School of Computer Science, Carnegie Mellon University *Aug 2017 – present*

PhD in Robotics (ongoing)

Electrical Engineering, Indian Institute of Technology Bombay *Jul 2012 – Jun 2017*

Dual Degree (Bachelor & Master of Technology)

Research Experience

Computational light transport with interferometry [PhD thesis]

Prof. Ioannis Gkioulekas, Robotics, Carnegie Mellon University *Aug 2017 – present*

- Explored interferometry with light sources having specially designed wave-optics properties for micron-scale computational light transport, with applications to optical biomedical imaging
- Built a prototype full-field interferometer on an optical table demonstrating spatially-gated and pathlength-resolved imaging; and specialized it to descattering and ballistic light path imaging
- Specialized the above to implement fast, full-field, micron-resolution depth estimation for applications in precision fabrication and high-resolution inspection of critical parts in industry
- Demonstrated interferometry with naturally-available illumination, such as sunlight, to achieve the above capabilities passively, in the face of outdoor conditions such as vibrations and ambient light

Optimizing acquisition for a static X-ray computed tomography system [paper]

Dr. Rajiv Gupta, Neuroradiology, Massachusetts General Hospital *May 2019 – Jul 2019*

- Explored reconstruction and acquisition optimization methods for a novel portable static X-ray CT system with a circular arrangement of low-power X-ray sources around the patient
- Shadowed radiologists in the hospital to understand the process of diagnosing disorders in patients

A Bayesian framework for laparoscopic image enhancement [paper, code], [paper, code]

Prof. Suyash Awate, Computer Science, IIT Bombay *Jan 2015 – Jun 2017*

- Solved a Bayesian optimization problem to undo the detrimental effects of surgical smoke, specularities and noise on laparoscopy images for better visualization and instrument tracking
- Incorporated a novel, learned, histogram-based prior on color channels to restore color contrast in the presence of smoke, and a dictionary-based model for reconstruction in the presence of specularities

Optimizing sensing for compressed sampling recovery [Master's thesis, code]

Prof. Ajit Rajwade, Computer Science, IIT Bombay *Dec 2015 – Jun 2017*

- Designed physically-realizable compressive acquisition and patch-wise reconstruction for existing compressive cameras using a novel circularly-symmetric coherence criterion
- Empirically analyzed the looseness of various reconstruction error bounds and proposed a sampled average-case error design criterion with a proof-of-concept implementation

Estimating cosmological photometric redshifts with machine learning [code]

Prof. Robert Brunner, Astrophysics, Univ. of Illinois at Urbana-Champaign *May 2014 – Aug 2014*

- Developed a novel learning-based method for estimating pixel-wise redshifts in the spectra and distances of dim, faraway astrophysical sources imaged by the Sloan Digital Sky Survey
- Implemented overlapping source separation and classification into galaxies, stars and quasars

Publications Under Review

Passive micron-scale time-of-flight with sunlight interferometry [pre-print]
A. Kotwal, A. Levin and I. Gkioulekas

Swept-angle synthetic wavelength interferometry [pre-print]
A. Kotwal, A. Levin and I. Gkioulekas

Journal Publications

Interferometric transmission probing with coded mutual intensity
ACM Transactions on Graphics, 2020 [link, video]
A. Kotwal, A. Levin and I. Gkioulekas

Conference Publications

Joint desmoking, specularity removal, and denoising of laparoscopy images via Bayesian inference
International Symposium on Biomedical Imaging, 2017 [link]
A. Baid, **A. Kotwal**, R. Bhalodia, and S. Awate

Joint desmoking and denoising of laparoscopy images
International Symposium on Biomedical Imaging, 2016 [link]
A. Kotwal, R. Bhalodia and S. Awate

Designing constrained projections for compressed sensing: mean errors and anomalies with coherence
IEEE Global Conference on Signal and Information Processing, 2018 [link]
D. Shah, **A. Kotwal** and A. V. Rajwade

Technical Skills

Prototyping imaging setups on an optical table

Programming: Python & Matlab (fluent) | Java, SQL, Verilog & C/C++ (intermediate)

Software packages: Zemax OpticStudio, Lumerical, PyTorch, NumPy, SciPy, pandas, scikit-learn

Embedded platforms: FPGAs, Raspberry Pi, Arduino

Selected Coursework

Introductory Biology, Human Physiology, Nano-Bio-Photonics, Computational Imaging, Physics-based Methods in Vision, Computer Vision, Statistics, Convex Optimization, Machine Learning

Other Project Experience

Optimizing nanoparticles for efficient photothermal therapy *March 2020 – May 2020*

- Studied nanoplasmonics for photothermal therapy to drive tumor apoptosis in cancer treatment
- Performed FDTD simulations in the Lumerical wave equation solver to obtain the optical properties of gold nanoparticles of various parameterized shapes in response to laser irradiation
- Optimized energy absorption sequentially over wavelength and nanoparticle shape parameters

IIT Bombay Mars Rover project *Dec 2012 – Jun 2017*

- Designed, manufactured and assembled the electronics for rover and robotic arm mobility
- Developed the communication and control software for rover operation and piloted it in tests
- Participated in a simulated Mars mission consisting of various activities, such as sample collection, geology studies and rigorous rover testing on a challenging dry river bed in the Australian outback

Super-resolution with Fourier ptychographic microscopy *Nov 2014 – Jan 2015*

- Prototyped a Fourier ptychography system to examine histology sections in an eye hospital

Star variability analysis to detect exoplanets in NGC2419 [report, code] *Dec 2015*

- Obtained, corrected and analyzed CCD images of the globular cluster NGC2419 to estimate star brightness variability and locate microlensing events indicative of the presence of exoplanets

An X-ray study of black hole candidate X Norma X-1 [report] *Dec 2013*

- Estimated the temperature and luminosity of an X-ray binary star system suspected to contain a black hole by fitting X-ray spectra, considering emission processes and line-of-sight absorption

16-bit pipelined RISC processors on an FPGA [code, code] *Jul 2014 – Nov 2014*

- Designed in Verilog and implemented on FPGAs RISC processors based on two architectures