

Alankar Kotwal

CONTACT INFORMATION

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RESEARCH INTERESTS

I am passionate about Computer and Medical Vision (image analysis, inverse problems, imaging modalities), Robotics (applications in automatic surgery, navigation systems), Compressed Sensing (sensing matrix optimization, applications in medical imaging), Computational Imaging and Optics, Machine Learning (Bayesian inference, graphical models), Astrophysics and Cosmology (the Λ CDM model and constituent resolution). I enjoy learning about and experimenting with Computer Networks and Security, Graphics and applications of all these fields in one another.

EDUCATION

Indian Institute of Technology Bombay, Mumbai, India July 2012 – Present

Final Year, Dual Degree (Bachelor & Master of Technology), Department of [Electrical Engineering](#)
Specialization: *Communication & Signal Processing*

- **Major CGPA:** 9.08/10 ([Detailed List of Courses](#))
- **Minor Degree:** Department of [Computer Science & Engineering](#)

PUBLICATIONS AND PREPRINTS

- Baid, A., Kotwal, A., Bhalodia, R., Awate, S., *Joint Desmoking, Despeckling, and Denoising of Laparoscopy Images via Graphical Models with Variational Bayesian Expectation Maximization*. Accepted for the [14th International Symposium on Biomedical Imaging \(2017\)](#). Paper [here](#).
- Kotwal, A., Rajwade, A. V., *Optimizing Codes for Source Separation in Compressed Video Recovery and Color Image Demosaicing*. To be submitted. Preprint: [arXiv:1609.02135 \[cs.CV\]](#).
- Kotwal, A., Bhalodia, R., Awate, S., *Joint Desmoking and Denoising of Laparoscopy Images* (oral), Proc. of the [13th International Symposium on Biomedical Imaging \(2016\)](#). Paper [here](#).
- Clarke, J. *et al.*, *Field Robotics, Astrobiology and Mars Analogue Research on the Arkaroola Mars Robot Challenge*, Proc. of the [14th Australian Space Research Conference 2014](#). Paper [here](#).

RESEARCH INTERNSHIPS

The AIR Lab, Carnegie Mellon University Robotics Institute

Guide: *Prof. Sebastian Scherer & Stephen Nuske*

Summer 2015

Stereo Odometry from a Downward-facing Stereo Camera on an Aerial Vehicle

For aerial vehicles, odometry is often done by using sensors like the Pixhawk PX4FLOW, which use a single camera doing correlation-based tracking with a sonar for odometry. Disadvantages here include small camera field and maximum speeds, bad sonar readings at low range (during take-off), height-dependent camera focus and need of an inertial unit. We aimed to mitigate these with a small-baseline stereo camera. First, height, pitch and roll are jointly estimated using a robust gradient-descent homography fit between stereo pairs. Rigid tracking across frames is then used to measure position. We obtained better height estimates, maximum speeds and comparable accuracy without an inertial unit as compared to the PX4FLOW. Code [here](#).

Laboratory for Cosmological Data Mining, University of Illinois, Urbana – Champaign

Guide: *Prof. Robert Brunner, under Google Summer of Code*

Summer 2014

A Pixel-Level Machine Learning Method for Calculating Photometric Redshifts

Spectrometry is a prominent distance measurement technique in Astrophysics. Here, features in the spectrum (like emission or absorption lines) can be fit with known lines to obtain redshift, which is a measure of distance at cosmologically significant distances. However, there exist sources which are either very far or very dim, so we do not get enough flux from them to measure their spectrum. Broad-band energies from these sources, as an approximation to the entire spectrum, are used as features for a machine learning algorithm to calculate redshifts, or alternatively classify them. Unlike previous work, we calculate features pixel-wise instead of integrating over entire source area, giving benefits like source de-blending and better background separation. Redshift calculation and source classification from the method are reasonably accurate. Code [here](#).

Super-Resolution with Fourier Ptychographic Microscopy

The maximum number of independent samples that an imaging setup can extract from the imaged scene is dictated by the limits set by Fourier optics: if the imaged scene is wide-field, there are limits on how much one can zoom in. However, wide-field, high-resolution images are generally desirable in microscopy, pathology and eye imaging. Traditional methods to achieve this, ptychography, for instance, involve mechanical adjustment and require precise control and actuation. Fourier Ptychographic Microscopy was introduced in 2013 as a computational tool to work around this. The idea is to shift, in the Fourier domain, high-frequency information to low frequencies (where the system's optics do not filter it), sense it, and shift it back while reconstructing. We worked on understanding and implementing this method for microscopy slides, and analyzed possible extensions to imaging reflective surfaces like the eye. Code [here](#).

RESEARCH
PROJECTS**A Bayesian Framework for Laparoscopic Image Dehazing and Denoising**Guide: [Prof. Suyash Awate](#), *CSE, IITB*

January 2015 – Present

Laparoscopic images in minimally invasive surgery get corrupted by surgical smoke and noise. This degrades the quality of the surgery and the results of further processing for, say, segmentation and tracking. Algorithms for desmoking and denoising laparoscopic images seem to be missing in the medical vision literature. We formulated the problem of joint desmoking and denoising of laparoscopic images as a Bayesian inference problem. This formulation relies on a novel probabilistic graphical model of images, which includes a Markov Random Field (MRF) formulation for color-contrast and another MRF for smoothness on the uncorrupted color image as well as the transmission-map image that indicates color attenuation due to smoke. We resort to a mode approximation (using gradient descent) to the Bayesian posterior to estimate the underlying scene. The results on simulated and real-world laparoscopic images, with clinical expert evaluation, shows the advantages of our method over the state of the art. We now extend this framework to include speckle removal, with better optimization techniques like Variational Bayes-based Expectation Maximization. Code [here](#).

Optimizing Sensing Matrices for Compressed Sampling Recovery

Master's Thesis

Guide: [Prof. Ajit Rajwade](#), *CSE & Prof. V. Rajbabu*, *EE, IITB*

December 2015 – Present

Recent efforts to apply the principles of compressed sensing to video data involve combining frames into coded snapshots while sensing and separating them with an over-complete dictionary. This works well, but needs a dictionary at the same frame-rate and time-smoothness as the video. We try relaxing this constraint using a source-separation approach to this problem where precise error bounds on recovery have been derived. We designed practically-realizable positive patch-wise sensing matrices that have low mutual coherence in all circular permutations, which facilitates accurate overlapping patchwise recovery. We currently aim to design general sensing matrices with quantities that yield tighter error bounds than the coherence. We thus explore bounds (like the l_1 -CMSV and l_∞ -based bounds) which 'soften' the sparsity criterion for l_1 recovery, resulting in quantities verifiable in polynomial time, as opposed to the RIC bound which is combinatorial and therefore difficult to optimize. Code [here](#).

The IITB Mars Rover Project

May 2013 – Present

The IITB Mars Rover project is a student initiative at IIT Bombay to build a prototype Mars rover capable of extra-terrestrial robotics and to participate in the [University Rover Challenge](#) at the Mars Society's [Mars Desert Research Station](#), Utah. The mechanical subsystem designed and developed a rover with a rocker-bogie suspension and novel air-filled beach tires. The electrical and software team designed power, logic and communication circuits for on-board control. Currently, localization and autonomous navigation are being developed. The role of machine vision for automating rover operations is being explored. One of the design goals for the future is to develop the capability to help astronauts on space missions. We participated in a simulated Martian expedition and tested Rover capabilities in the harsh conditions of the Australian outback, at the [Arkaroola Mars Robot Challenge](#). We participated in a series of exercises in Mars Operations Research, involving test extra-vehicular activities in space-suits (a sample collection task and a rover guidance task) conducted by [Saber Astronautics](#). Details and pictures [here](#).

COURSE
PROJECTS

Deep Learning and Information Theory

*CS709: Convex Optimization
Autumn 2016-17*

Guide: [Prof. Nikhil Karamchandani](#), EE, IITB

We investigated a paradigm for training and analyzing errors in deep neural networks in terms of the information bottleneck principle, viewing layers as successive refinements of features.

Improved Methods for Compressed Sensing Recovery

*CS709: Convex Optimization
Autumn 2015-16*

Guide: [Prof. Ganesh Ramakrishnan](#), CSE, IITB

Using convex approximations to the compressed sensing recovery problem, we reconstructed near-exact versions of images at extremely low compressions, with proofs of correctness. Code [here](#).

Hidden Markov Model Part-of-Speech Tagging

*EE638: Estimation and Identification
Autumn 2015-16*

Guide: [Prof. Navin Khaneja](#), EE, IITB

We implemented part-of-speech tagging with support for unknown words. An error rate of around 5% and capabilities of the system to discern context were observed. Code [here](#).

Stereo Odometry via Point Cloud Registration

*CS763: Computer Vision
Spring 2014-15*

Guide: [Prof. Ajit Rajwade](#), CSE, IITB

Maximizing kernel density correlation with gradient-ascent and coherent point drift, we registered pointclouds and observed good convergence behavior for small transformations. Code [here](#).

Gravitational Lens Separation with PCA

*CS663: Digital Image Processing
Autumn 2014-15*

Guide: [Prof. Suyash Awate](#) & [Prof. Ajit Rajwade](#), CSE, IITB

Gravitationally lensed images of galaxies have rare arc-like artifacts that can be used to calculate the mass of the lens. We used Anscombe denoising followed by PCA to build a basis for galaxy images and used the top few eigengalaxies to subtract sources and detect arcs. Code [here](#).

Processor Design

*EE309: Microprocessors
Autumn 2014-15*

Guide: [Prof. Virendra Singh](#), EE, IITB

We designed, simulated and implemented a [multi-cycle RISC processor](#) following the LC-3b ISA. Also, we designed and simulated a [pipelined RISC processor](#) using the Little Computer ISA.

ASTROPHYSICS
PROJECTS

Detecting Short γ -ray Bursts in Astrosat CZTI Data

*PH426: Astrophysics
Spring 2015-16*

Guide: [Prof. Vikram Rentala](#), PH, IITB and [Prof. A. R. Rao](#), TIFR, Mumbai

We did a literature survey on γ -ray bursts, including open problems in the field. We tackle detecting short γ -ray bursts from data acquired by the CZTI X-Ray Imager on-board Astrosat.

Variability Analysis for Globular Cluster NGC2419

*NIUS, Astronomy
December 2015*

Guide: [Prof. Priya Hasan](#), MANUU, Hyderabad

We analyzed raw data for the globular cluster NGC2419 taken at the [HCT](#), post-processed it to correct for detector bias and flat-fielding, inverted the effect of atmospheric mass and extracted the variation of magnitudes of stars in the cluster on the scale of a day. Code [here](#).

An X-ray Study of Black Hole Candidate X Norma X-1

*NIUS, Astronomy
December 2013*

Guide: [Prof. Manojendu Choudhury](#), Center for Basic Sciences

We analyzed data from the RXTE for a low-mass X-Ray Binary. Fitting 3-30 keV spectra with a model accounting for blackbody and non-thermal radiation, and interstellar extinction, we obtained values of system parameters like internal radius and temperature. Report [here](#).

Estimation of Photometric Redshifts with Machine Learning

*NIUS, Astronomy
December 2012*

Guide: [Prof. Ninan Sajeeth Philip](#), IUCAA, Pune

Here, we trained a neural network for photometric redshifts, given data for sources whose spectra and redshifts have been measured. We predicted spectra for these objects viewed at various other values of redshifts. Using this expanded dataset, we achieved good predictions for test data.

ACHIEVEMENTS
AND AWARDS

- Represented India at the [6th International Olympiad on Astronomy and Astrophysics](#), Brazil, 2012. Won a Gold Medal with International Rank 4 and a special prize for Best Data Analysis
- Represented India at the [5th International Earth Sciences Olympiad](#), Italy, 2011. Won a Bronze Medal and prizes for best performance in the Hydrosphere section and the team presentation
- Secured all-India rank 105 in the [IIT-JEE 2012](#) amongst half a million candidates
- Awarded [KVPY Scholarship](#) 2011 by Dept. of Science and Technology, Govt. of India
- Awarded [NTSE Scholarship](#) 2008 by NCERT, Govt. of India

KEY TALKS AND SEMINARS

Coded Source Separation for Compressed Video Recovery *Master's Thesis Talk*
Department of Electrical Engineering, Indian Institute of Technology Bombay *May 2016*
 Here, I presented results from the first stage of my dual degree thesis. Presentation [here](#).

Template-Based Stereo Odometry *Invited Talk*
The AIR Lab, Carnegie Mellon University *July 2015*

I presented results of summer internship at CMU. The talk included a detailed description of the method used, comparisons with ground-truth and stress-tests on the method. Presentation [here](#).

The Cosmic Distance Ladder *Invited Talk*
Krittika – The Astronomy Club, IIT Bombay *September 2014, February 2016, August 2016*

This talk climbs the Cosmic Distance Ladder, a sequence of steps, each building on previous steps' results, for calculating distances in the universe. We begin with solar system distances, and end at enormous distances where the only option is using indirect methods. Presentation [here](#).

MENTORING EXPERIENCE

Teaching Assistant for IITB Courses

CS663: Digital Image Processing	Prof. S. Awate & Prof. A. Rajwade	<i>Autumn 2015-16</i>
CS736: Medical Image Processing	Prof. S. Awate	<i>Spring 2015-16</i>
EE638: Estimation and Identification	Prof. N. Khaneja	<i>Autumn 2016-17</i>
EE708: Information Theory and Coding	Prof. S. B. Pillai	<i>Spring 2016-17</i>

Resource Person, Indian Astronomy Olympiad Programme *May 2013, May 2014*

Selected twice as a resource person for Indian Astronomy Olympiad Camps, to mentor students for their selection to the International Astronomy Olympiads. Involved in mentoring 100-odd high school students in astronomy, and in setting up challenging questions and evaluating them.

KEY COURSEWORK

Computer Sciences and Engineering

Computer Vision, Digital & Medical Image Processing, Machine Learning, Convex Optimization, Graphics, Networks, Data Structures, Design & Analysis of Algorithms, Discrete Mathematics

Electrical Engineering

Estimation & Identification, Adaptive & Digital Signal Processing, Speech Processing, Matrix Computations, Information Theory, Advanced Probability, Communication Networks

Physics and Mathematics

Astrophysics, General Theory of Relativity, Electromagnetic Waves, Electricity & Magnetism, Classical Mechanics, Differential Equations, Linear Algebra, Complex Analysis, Calculus

TECHNICAL SKILLS

Programming	C/C++, Python, Bash, Matlab, Verilog, SQL, HTML/CSS, PHP, L ^A T _E X
Software Packages	ROS/Gazebo, OpenCV, The Point Cloud Library
Science Software	Python packages: NumPy, SciPy and Matplotlib, GNUPlot, Scikit-learn
Hardware	<i>Microprocessors:</i> 8051, 8085, AVR and PIC, CPLDs and FPGAs, <i>Embedded Platforms:</i> Arduino, Raspberry Pi, NVIDIA Jetson TK1

OTHER INTERESTS

OTHER than my academic interests, I like biking, long walks, trekking, climbing whatever can be climbed, swimming, table tennis, socializing, cooking good food and eating it. I especially enjoy classic rock music and people who enjoy my interests. I love Origami, the art of paper folding, and building complex, realistic models with Lego blocks.

REFERENCES

Prof. Suyash Awate , CSE IITB E-Mail Webpage	Prof. Ajit Rajwade , CSE IITB E-Mail Webpage
Dr. Sebastian Scherer , Robotics Institute CMU E-Mail Webpage	Ashutosh Richhariya , Ophthalmic Biophysics LVPEI E-Mail Webpage
Prof. Mayank Vahia , Astrophysics TIFR E-Mail Webpage	Dr. Aniket Sule , Astronomy HBCSE-TIFR E-Mail Webpage
Prof. Rajbabu Velmurugan , EE IITB E-Mail Webpage	Dr. Manojendu Choudhury , Astrophysics UM-DAE CBS E-Mail Webpage