Alankar Kotwal

Senior Undergraduate

Contact Information

Department of Electrical Engineering
Indian Institute of Technology Bombay
281, Hostel 09, IIT Bombay
Powai, Mumbai, India 400 076

Phone: (+91) 996 967 8123
E–Mail: alankar.kotwal@iitb.ac.in
alankarkotwal13@gmail.com
Webpage: alankarkotwal.github.io

Research Interests

I am passionate about Computer and Medical Vision, Machine Learning, Optimization, Estimation Theory, Astrophysics and Cosmology. I enjoy learning about and experimenting with Robotics, Computer Networks and Security, Computer Graphics and applications of these fields in one another.

Education

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

Dual Degree, Bachelor & Master of Technology, Department of Electrical Engineering
Specialization: *Communication and Signal Processing*

- **Major CGPA:** 8.83/10 (Detailed List of Courses)
- **Minor Degree:** Department of Computer Science & Engineering

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 A Vehicle
Fast and accurate stereo odometry is a pre-requisite for many robotics applications like localization, path planning and navigation. For aerial vehicles like quadcopters, a good way to do odometry is to use a ground-facing camera and track the motion of the (featureless) ground. This has traditionally been done with sensors like the Pixhawk PX4FLOW, which uses a single camera doing correlation-based tracking along with a sonar for odometry. This has several disadvantages, like small camera field of view (meaning small maximum allowed speeds for accurate tracking), bad sonar readings at low range (especially during take-off), requirement of an inertial unit for angle measurement and height-dependent camera focus. We aimed to replace the PX4FLOW with a small-baseline stereo camera for the same purpose. Assuming that most of the field of view lies on a plane parallel to the sensors, the height of the vehicle is obtained from a robust estimate of the horizontal disparity between rectified stereo pairs. Alternatively, height, pitch and roll are jointly estimated using a *robust gradient-descent homography fit* between rectified stereo pairs. Similar, *rigid tracking across frames* is then used to measure position. We obtained better depth estimates, better 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 Source Redshifts
Distances in Astrophysics have traditionally been measured using a variety of techniques, spectrometry prominent among them. The basic idea in spectrometry is, given a source with a measurable spectrum, features in the spectrum (like emission or absorption lines) can be fit with known lines to obtain the source's 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 for these sources, or alternatively classify them. Unlike previous attempts, we *calculate features pixel-wise* instead of integrating over entire source area, giving potential benefits like *source de-blending and better background separation*. The redshift calculation and source classification from the method are reasonably accurate. Code here.

Research Projects

A New 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. 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. 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. We designed and developed a rover with a *rocker-bogie suspension and novel air-filled beach tires*. As a part of the electrical and software team, we designed power, logic and communication circuits for on-board control. We developed localization and autonomous navigation. The role of *machine vision* automating rover operations was explored. We participated in a simulated Martian expedition and test Rover capabilities in the Australian outback, at the Arkaroola Mars Robot Challenge and at the Mars Society's Mars Desert Research Station, Utah.

Course Projects

Improved Methods for Compressed Sensing Recovery *CS709: Convex Optimization*
Guide: Prof. Ganesh Ramakrishnan, CSE, IITB *Autumn 2015-16*

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*
Guide: Prof. Navin Khaneja, EE, IITB *Autumn 2015-16*

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.

Laparoscopic Image Dehazing With Dark Channel Prior *CS736: Medical Image Processing*
Guide: Prof. Suyash Awate, CSE, IITB *Spring 2014-15*

We applied the Dark Channel Prior method for landscape image dehazing to laparoscopic images. In order to make the process real-time, we replaced refining the transmission map with a differential equation with guided filtering and got good results. Code here.

Stereo Odometry Via Point Cloud Registration *CS763: Computer Vision*
Guide: Prof. Ajit Rajwade, CSE, IITB *Spring 2014-15*

We explored as a method for registering pointclouds. We performed kernel density correlation maximization with gradient-ascent and coherent point drift with PCL in C++ and observed good convergence behavior for small displacements and rotations. Code here.

Gravitational Lens Separation With PCA *CS663: Digital Image Processing*
Guide: Prof. Suyash Awate and Prof. Ajit Rajwade, CSE, IITB *Autumn 2014-15*

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*
Guide: Prof. Virendra Singh, EE, IITB *Autumn 2014-15*

We designed, simulated and implemented (on a DE0-Nano board from Terasic) a multi-cycle RISC processor following the LC-3b ISA. Following this, we designed and simulated a pipelined RISC processor using the Little Computer Architecture.

A PD Temperature Controller on an Logic Device *EE224: Digital Systems Lab*
Guide: Prof. Jayanta Mukherjee, EE, IITB *Spring 2013-14*

We designed, simulated and implemented a proportional-derivative temperature controller with a Peltier plate used as a heating/cooling element and an LM35 temperature sensor. We observed quick temperature rise and stable steady-state with best-tuned parameters for the controller.

Astrophysics Projects

Processing and Inference from CCD Images *NIUS, Astronomy*
Guide: Prof. Priya Hasan, MANUU, Hyderabad *December 2015*

We analyzed raw CCD data for the globular cluster NGC2419 taken at the Himalayan Chandra Telescope. After post-processing to correct for detector bias and flat-fielding, we inverted the effect of atmospheric mass on the data 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*
Guide: Prof. Manojendu Choudhury, Center for Basic Sciences *December 2013*

We analyzed spectral data from the RXTE GOF archives for the low-mass X-Ray Binary 4U 1630-47 (X Nor X-1) a period that corresponds to an outburst in the source. We extracted 3-30 keV spectra and fit them with a theoretical model which accounts for thermal emission from a geometrically thin and optically thick disk, and non-thermal radiation modeled by a power-law, and interstellar extinction. We obtained best fit values of various system parameters like internal radius, temperature and so on. Report here.

Estimation of Photometric Redshifts Using Machine Learning *NIUS, Astronomy*
Guide: Prof. Ninan Sajeeth Philip, IUCAA, Pune *December 2012*

Broad-band energies in color filters are used as inputs to a machine learning algorithm for determination of redshifts for objects whose spectra cannot be measured accurately. Here, we trained a neural network to calculate photometric redshifts for such objects. To generate more training data from available data, we redshifted available spectra to determine how an object would look like at a range of higher redshifts. Then we extracted energies in color filters and used this (nearly 10-fold) expanded dataset to train the network. We achieved good predictions for test data and observed clustering of galaxy colors as a function of increasing redshift.

Publications

- Kotwal, A., Bhalodia, R., Awate, S., *Joint Desmoking and Denoising of Laparoscopy Images Using Probabilistic Graphical Modeling With Bayesian Inference*, (to appear in) Proc. of the International Symposium on Biomedical Imaging, 2016. Permalink to paper coming soon.
- Clarke, J. D. A., Held, J. M., Dahl, A. *et al.*, *Field Robotics, Astrobiology and Mars Analogue Research on the Arkaroola Mars Robot Challenge Expedition*, Proc. of the 14th Australian Space Research Conference, 2014. Permalink to paper here.

Achievements and Awards

Olympiads and Competitive Exams

- Represented India at the 6^{th} 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 5^{th} 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 (AIR) 105 in IIT-JEE amongst 1.1 million candidates

Scholarships

- Awarded KVPY Scholarship 2011 by Dept. of Science and Technology, Govt. of India
- Awarded NTSE Scholarship 2008 by NCERT, Govt. of India

Competitions

- Secured IIT Bombay the second position by putting on board 72 Messier objects including the entire Virgo cluster of galaxies in the Inter-IIT Messier Marathon, 2014
- Won the Astronomy Quiz conducted by the Astronomy Club, IIT Bombay, 2012

Talks and Seminars

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

Here, I presented results from my 2015 summer internship to my group at Carnegie Mellon University. The talk included a detailed description of the method used, comparisons of the results with ground-truth and stress-tests on the method. The presentation may be found here.

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

This open-to-all talk is a journey climbing the Cosmic Distance Ladder, which is a sequence of steps, each building on the previous step's results, for calculating distances in the universe. We begin with solar system distances, and end at huge distances where the only real option is to use photometric redshifts. This talk also presents results from my Google Summer of Code project. The presentation may be found here.

Mentoring Experience

Teaching Assistant

CS663: Digital Image Processing	Prof. S. Awate and Prof. A. Rajwade	*Autumn 2015-16*
CS736: Medical Image Processing	Prof. S. Awate	*Spring 2015-16*

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

Selected twice as a resource person for the Indian Astronomy Olympiad Camp, for their selection to the international Astronomy Olympiads. Involved in mentoring students ranging from the 9^{th} to the 12^{th} grades in Astronomy, and in setting up challenging questions and evaluating students.

Technical Mentor *April 2013 – March 2014*

Mentored 1^{st} year students for Robotics Competitions and Institute Technical Summer Projects.

Relevant Coursework

Computer Sciences and Engineering

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

Electrical Engineering

Estimation and Identification, Speech Processing, Digital Signal Processing, Controls, Probability and Random Processes, Digital Communication, Communication Systems, Microprocessors, Signals and Systems, Digital and Analog Systems, Electronic Devices and Circuits, Network Theory

Physics and Mathematics

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

Technical Skills

Programming	C/C++, Python, Bash, Matlab, Verilog, SQL, HTML, PHP, LaTeX
Software Packages	ROS/Gazebo, OpenCV, The Point Cloud Library, SPICE Circuit Simulation, EAGLE PCB Design, SolidWorks, AutoCAD, LabView
Science Software	Python packages: NumPy, SciPy and Matplotlib, GNUPlot, Scikit-learn, Astropy, SExtractor, SDSS tools
Hardware	*Microprocessors:* 8051, 8085, AVR and PIC, CPLDs and FPGAs, *Embedded Platforms:* Arduino, RaspberryPi, *standard digital logic*

Other Interests

Other than my academic interests, I like biking, long walks, swimming, socializing, cooking good food and eating it. I especially enjoy classic rock music and people who enjoy my interests.

References

Prof. Suyash Awate, CSE
Indian Institute of Technology, Bombay
E–Mail | Webpage

Dr. Aniket Sule, Reader
Homi Bhabha Center for Science Education
E–Mail | Webpage