Alanker Kotwal

Contact Information

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Research Interests

I am passionate about Computer and Medical Vision (visual recognition, imaging modalities, inverse problems, computational photography), Compressed Sensing (theoretical guarantees, sensing matrix optimization), Machine Learning (graphical models, language processing), Optimization, Astrophysics (stellar structure and evolution) and Cosmology (the ΛCDM model and constituent resolution). I enjoy learning about and experimenting with Robotics (navigation systems, extraterrestrial robotics), Computer Networks and Security, Graphics and applications of 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 and Signal Processing*

- **Major CGPA:** 8.92/10 (Detailed List of Courses)
- **Minor Degree:** Department of Computer Science & Engineering

Ratanbai Walbai Junior Science College, Mumbai, India — *July 2010 – April 2012*

Intermediate Education: Physics, Chemistry and Maths
Specialization: *Electrical Maintenance*

- **Major CGPA:** 9.38/10

Saraswati Vidyalaya High School, Thane, India — *July 2000 – April 2010*

Matriculation

- **Major CGPA:** 9.53/10

Publications

- 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. 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. 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. This has many disadvantages, like small camera field of view (small maximum speeds), bad sonar readings at low range (during take-off), requirement of an inertial unit for angle measurement and height-dependent camera focus. We aimed to replace this with a small-baseline stereo camera. With the field of view parallel to the baseline, the height of the vehicle is obtained from a robust estimate of horizontal disparity. Alternatively, height, pitch and roll are jointly estimated using a robust gradient-descent homography fit between stereo pairs. Similar, 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 Source 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.

Srujana – Center for Innovation, L. V. Prasad Eye Institute
Guide: Ashutosh Richhariya *Winter 2014*

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 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. 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.

Coded Source Separation for Compressed Video Recovery *Dual Degree 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. Basis pursuit recovery with Gaussian–random sensing matrices gives excellent results with no ghosting for both similar and radically different images. Unfortunately, the more realizable non–negative sensing matrices don't work as well, because they do not have the nice incoherence properties of Gaussian–random matrices. We aim to design such sensing matrices with low mutual coherence, making them ideal for compressed video. We also aim to design matrices that when rotated circularly, still have low mutual coherence so that they can be tiled for patch-wise reconstruction. 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

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 surgical smoke–affected laparoscopic images, accelerated it in time and got good results. Code here.

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

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*
Guide: Prof. Suyash Awate & 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.

Astrophysics Projects

Detecting Short γ-Ray Bursts in Astrosat CZTI Data *PH426: Astrophysics*
Guide: Prof. Vikram Rentala, PH, IITB and Prof. A. R. Rao, TIFR, Mumbai *Spring 2015-16*

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*
Guide: Prof. Priya Hasan, MANUU, Hyderabad *December 2015*

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*

Guide: Prof. Manojendu Choudhury, Center for Basic Sciences — *December 2013*

We analyzed spectral data from the RXTE for the low-mass X-Ray Binary 4U 1630-47, for an outburst in the source. We extracted 3-30 keV spectra and fit them with a model accounting for disk blackbody radiation, non-thermal power-law radiation, and interstellar extinction. We obtained best fit values of system parameters like internal radius and temperature. Report here.

Estimation of Photometric Redshifts Using Machine Learning — *NIUS, Astronomy*

Guide: Prof. Ninan Sajeeth Philip, IUCAA, Pune — *December 2012*

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

Olympiads and Competitive Exams

- 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 (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

Key Talks and Seminars

Coded Source Separation for Compressed Video Recovery — *Dual Degree 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*

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. Presentation here.

The Cosmic Distance Ladder — *Invited Talk*

Krittika – The Astronomy Club, IIT Bombay — *September 2014, February 2016*

This open-to-all popular talk climbs the Cosmic Distance Ladder, 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 enormous distances where the only option is using indirect methods like photometric redshifts. Presentation here.

Mentoring Experience

Teaching Assistant for IITB Courses

CS663: Digital Image Processing	Prof. S. Awate & 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 Indian Astronomy Olympiad Camps, to mentor students for their selection to the International Astronomy Olympiads. Involved in mentoring students ranging from the 9th to the 12th grades in Astronomy, and in setting up challenging questions and evaluating them.

Technical Mentor *April 2013 – March 2014*

Mentored 1st year students for Robotics Competitions and contributed towards generation of ideas and debugging for Institute Technical Summer Projects. Member of the Electronics club.

Key Coursework

Computer Sciences and Engineering

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

Electrical Engineering

Estimation and Identification, Adaptive Signal Processing, Digital Signal Processing, Speech Processing, Matrix Computations, Information Theory, Advanced Probability and Random Processes, Communication Networks and Systems, Microprocessors, Signals and Systems, Digital and Analog Systems, Electronic Devices and Circuits, Network Theory

Physics and Mathematics

Astrophysics, The 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, 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, SDSS tools
Hardware	*Microprocessors:* 8051, 8085, AVR and PIC, CPLDs and FPGAs, *Embedded Platforms:* Arduino, Raspberry Pi, NVIDIA Jetson TK1 *standard digital logic families*

Languages

English, Hindi (working knowledge), Marathi (first language), Sanskrit (elementary knowledge)

Other Interests

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

References

Prof. Suyash Awate, CSE
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