

## Ashok Veeraraghavan

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RESEARCH INTERESTS

- Computational Photography
- Computer Vision
- Multidimensional Signal Processing
- Pattern Recognition in Video (and other Light-field data)
- Shape and Dynamical models for activity perception and recognition

EDUCATION

**University of Maryland**, College Park, Maryland USA  
Ph.D. Candidate, Department of Electrical and Computer Engineering

- Advisor: Prof. Rama Chellappa
- Research Area: *Multidimensional Signal Processing: Computer Vision and Pattern Recognition*

**University of Maryland**, College Park, Maryland USA  
M.S, Electrical and Computer Engineering, May 2004

- Advisor: Prof. Rama Chellappa

**Indian Institute of Technology, Madras**, Chennai, Tamil Nadu India  
Bachelor of Technology, Electrical Engineering, May 2002

- Major: *Communications and Signal Processing.*      Minor: *Biomedical Engineering.*

RESEARCH EXPERIENCE

**Mitsubishi Electric Research Labs**, Boston, USA  
Research Intern      Aug, 2006 - Jan, 2007  
*Computational and Fourier Photography*  
Supervisor: Prof. Ramesh Raskar (Currently at MIT)

**Australian National University**, Canberra, Australia  
Visiting Researcher      May, 2005 - Aug, 2005  
*Automated Tracking and Analysis of Insect Behaviors*  
Supervisor: Prof. Mandyam Srinivasan (Currently at University of Queensland)

**University of Maryland**, College Park, Maryland USA  
Graduate Research Assistant      August, 2002 - present  
*Shape and Dynamical Models for Activity Recognition*  
Advisor: Prof. Rama Chellappa

**Center For Artificial Intelligence and Robotics**, Bangalore, Karnataka India  
Summer Intern      May, 2001 - August, 2001  
*Speech Communication over analog channels*  
Supervisor: Dr. Kesheorey

**Indian Institute of Technology Madras**, Chennai, TamilNadu India  
Undergraduate Research Assistant      August, 2001 - May, 2002

*Signal Processing: Fractional Fourier Transform*  
Advisor: Prof. K.M.M. Prabhu

TEACHING  
EXPERIENCE

*Graduate Teaching Assistant - University of Maryland*

August, 2002 - Present

- Was a tutor for undergraduate courses including Digital Signal Processing and Probability theory.
- Assisted Prof. Chellappa with several Graduate level courses including Digital Image Processing, Pattern Recognition and Image Understanding. Taught quite a few classes in these courses and was in charge of projects and assignments for these courses.
- Assisted Prof. Chellappa to design and conduct the Graduate level advanced seminar course on Pattern Recognition in Video.

*Graduate Mentor - GEMSTONE TEAM - University of Maryland*

August, 2006 - Present

- Assisting Prof. Chellappa in mentoring Team Vision, a three year undergraduate effort in developing vision based navigational aids for the blind and making University of Maryland blind friendly.

*Undergraduate Mentor - MERIT - University of Maryland*

Summer, 2006 and Summer, 2007

- Mentored two undergraduate students as a part of the Maryland Engineering Research Intership Teams (MERIT) program. As a part of this effort the students worked over a period of 3 months on a research project and submitted a final project report and presented their work at a MERIT fair at the University of Maryland.

HONORS AND  
AWARDS

**Distinguished Dissertation Fellowship** awarded by the Department of Electrical and Computer Engineering at the University of Maryland.

**First** in National Physics Talent Search Examination in 1998.

Rank **131 in IIT-JEE** 1998 conducted by the IITs.

99.6 percentile in GATE 2002 examination conducted by the IITs and IISc.

RESEARCH PROJECTS **Computational and Fourier Photography**

- **Light-Field Heterodyning**  
Studied the effect of non-refractive modulators in an imaging system and introduced the fundamental principles of optical modulation via a mask. This is a very powerful concept and has already led to several innovative designs for cameras, optical range finders and omnifocus imaging applications. Used the principle of optical modulation and heterodyning to develop the first design of a light-field camera that uses no extra optical elements such as microlens arrays. This design was amongst the first devices to modulate a 4D signal so as to enable its capture on a 2D sensor.
- **Principles of Ray-Filters**  
Studied the space of ray filters and the space of modulations that may be achieved by using simple ray-filters. This study led to a design for optimal Nyquist sampling of light-fields which have arbitrarily shaped band-limits in the frequency domain allowing capture of higher resolution optical information.
- **Shield Fields: Shadows in Light Transport**  
Proposed a new representation for occluders in light-transport using shield-fields, the 4D attenuation function of the incident light-field due to the occluder. This allows us to decouple the effect of the incident illumination and the occluder which are both intricately intertwined in previous representations. This representation allows efficient algorithms for several applications such as generation of soft-shadows, visual hull analysis etc.

**Modeling, Tracking and Pattern Recognition in Videos**

- **Modeling, Tracking and Understanding Insect Behavior**

Modeling, tracking and understanding behavior of insects from videos. I have proposed and implemented a method to simultaneously model and track the location, orientation and behavior of bees. The temporal variations were modeled using a hierarchical Markov model while Monte Carlo methods were used to perform the filtering and state estimation.

- **Tracking 3-D flight paths of multiple bees using multiple cameras**

Proposed, developed and implemented a system to track and reconstruct the 3-D flight paths of multiple bees using two cameras placed arbitrarily. The system was used to obtain the flight paths from several hundred hours of videos of bees in an uncontrolled outdoor environment.

- **Optimal representations for multiple video streams in camera networks**

Currently working on developing an optimal (both with regards to compression and application specific query processing time) representation for multiple video streams in distributed camera networks. Recent results on coding distributed information streams (Slepian-Wolf coding and Wyner-Ziv coding) form the backbone of the representation.

- **3-D Facial Pose Tracking in Videos**

Developed an algorithm for 3-D model based facial pose tracking in complex video sequences. The efficacy of the algorithm was exploited by using it as a front-end for applications like video based face recognition.

- **Detection, Tracking and Recognition in Large scale Visual Sensor Networks**

I have also worked on developing a unifying theory for detection, tracking and recognition problems in large scale distributed visual sensor networks. I am working towards extending this principle to include both activity inference and person identification in large scale visual sensor networks by integrating some of the rich theory developed in distributed function estimation with the geometric constraints obtained while using multiple cameras.

## **Shape and Dynamical Models for Activity Perception**

- **Role of Shape and Kinematics in Gait Recognition**

Studied the importance of Shape and Kinematic cues in gait and activity recognition. Our work showed that shape is more important than kinematics in gait recognition while kinematic cues definitely improve performance. Similar conclusions can be drawn for the problem of Activity recognition also.

- **Matching Shape Sequences in Video**

Developed algorithms for comparing two sequence of deforming shapes using both parametric models and non-parametric methods. The non-parametric model is a modification of the Dynamic Time Warping algorithm in order to account for the spherical manifold on which the shapes lie. AR and ARMA models on the tangent space of the shape-space (Kendall's Statistical Shape space) were proposed as parametric models for shape sequences.

- **Characterizing the space of time-warping for sequence modeling**

Propose a non-parametric model to characterize the space of time-warps and derive algorithms to learn the model and solve problems like clustering and recognition using the model. Experiments were designed for both activity and gait recognition to show the efficacy of the time-warping model for sequences.

- **Event based unsupervised Clustering of Video Sequences**

Developed an event based model for view and rate invariant clustering of video sequences. A confluence of ideas from manifold learning, markov modeling, event analysis and invariances on dynamical models leads to a natural algorithm for clustering video sequences.

- **Manifold based Style-Content Separation in Videos**

I am currently working on factorization of an activity sequence into its inherent covariates, those that are characteristics of the actor and those that are characteristics of the activity. This is made possible because of a careful manifold characterization of the observation space so as to account for the actor and activity based covariates jointly. We project the observations into an appropriate Stiefel manifold and distances measures computed on this manifold allow for efficient style-content separation.

## Other Projects

- **Fast algorithms for constrained Structure from Motion**

On-board vision systems in micro-air vehicles require fast and efficient algorithms to tackle fundamental tasks like structure from motion and ego-motion estimation. We have developed a fast-bilinear algorithm that exploits the constraints obtained from on-board inertial navigation units.

- **Characterizing the motion-camouflage manifold**

Motion camouflage is a stealthy pursuit strategy which has been observed in several insects and birds. We take a control-theoretic approach to the motion-camouflage pursuit strategy and characterize the manifold on which the manoeuvres of the pursuer can lie. We also develop an a feedback system that can mimic motion-camouflage in artificial systems (which can be used in games and in stealthy tracking).

- **Undergraduate Projects**

Developed a model for secure speech transmission over analog wireless channels.

Studied the theory and applications of Fractional Fourier Transforms and implemented several applications of Fractional Fourier Transform on a DSP.

## PUBLICATIONS

### Book Chapters

1. Rama Chellappa, S. Srinivasan, Gaurav Aggarwal and Ashok Veeraraghavan. Image Sequence Stabilization, Mosaicking and Super-Resolution. Handbook of Image and Video Processing, 2nd Edition, A. Bovik (Ed.), Academic Press, 2005

### Journal Articles

1. Ashok Veeraraghavan, Anuj Srivastava and Rama Chellappa. "Rate-invariant recognition of humans and their activities", Under Review for the IEEE Transactions on Image Processing.
2. Pavan Turaga, Ashok Veeraraghavan and Rama Chellappa. "Videos to Verbs: View and Rate Invariant Clustering of Video Sequences", Under Revision for the Elsevier Journal for Computer Vision and Image Understanding (CVIU).
3. Rama Chellappa, Aswin C. Sankaranarayanan and Ashok Veeraraghavan. "Distributed Detection, Tracking and Classification using a network of Video Cameras", Invited Paper under revision to the Proceedings of the IEEE - Special Issue on Distributed Smart Cameras.
4. Ramesh Raskar, Amit Agrawal, Cyrus Wilson and Ashok Veeraraghavan. "Glare Aware Photography: 4D Ray Sampling for Reducing Glare Effects of Camera Lenses" Conditionally Accepted for ACM Transactions on Graphics (Proceedings of SIGGRAPH) 2008.
5. Ashok Veeraraghavan, Ramesh Raskar, Amit Agrawal, Ankit Mohan, Jack Tumblin. "Dappled Photography: Mask Enhanced Cameras For Heterodyned Light Fields and Coded Aperture Refocussing" in ACM Transactions on Graphics (Proceedings of SIGGRAPH) 2007.
6. Ashok Veeraraghavan, Rama Chellappa and Mandyam Srinivasan. Shape and Behavior Encoded Tracking of Bee Dances. Accepted for Publication at IEEE Transactions on Pattern Analysis and Machine intelligence 2007(PAMI).
7. Ashok Veeraraghavan, Amit Roy Chowdhury and Rama Chellappa. Matching Shape Sequences in Video with an application to Human Movement Analysis. IEEE Transactions on Pattern Analysis and Machine Intelligence (PAMI), Dec 2005. (22 citations<sup>1</sup>)
8. Ashok Narayanan and K.M.M.Prabhu. 2003. The fractional Fourier transform: Theory, implementation and error analysis, Elsevier Journal on Microprocessors and Microsystems, Volume 27, Issue 10, 3 Nov 2003, Pages 511-521. (3 citations)

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<sup>1</sup>All citation information according to Google Scholar as on Dec 13, 2007: Query Index: Ashok Veeraraghavan

### **Highly Selective Conference Proceedings**(Acceptance rates similar to major journals)

1. Ashok Veeraraghavan, Ramesh Raskar, Amit Agrawal, Rama Chellappa, Ankit Mohan and Jack Tumblin. "Non-refractive modulators for encoding and capturing scene appearance and depth", Accepted for presentation at IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR), 2008.
2. Pavan Turaga, Ashok Veeraraghavan and Rama Chellappa. "Statistical Analysis on Stiefel and Grassmann manifolds with applications in computer vision", Accepted for presentation at IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR), 2008.
3. Mahesh Ramachandran, Ashok Veeraraghavan and Rama Chellappa. "Fast Bilinear SFM with side information", in the Proceedings of IEEE International Conference on Computer Vision (ICCV), Oct 2007.
4. Pavan Turaga, Ashok Veeraraghavan and Rama Chellappa. Mining Videos for Events using a cascade of dynamical systems: From videos to verbs, in the Proceedings of IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR), June 2007.
5. Ashok Veeraraghavan, Rama Chellappa and Amit K. Roy-Chowdhury. "The Function Space of an Activity", in the Proceedings of IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR), June 2006. (13 citations)
6. Ashok Veeraraghavan, Amit Roy Chowdhury and Rama Chellappa. "Role of Shape and Kinematics in Human Movement Analysis", in the Proceedings of IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR), June 2004. (36 citations)

### **Other Refereed Conference Papers and Tech Reports**

1. Ashok Veeraraghavan, Mahesh Ramachandran and Manohar Mareboyana. "Homography based multi-video coding for a network of cameras", Accepted for presentation at IEEE International Conference on Image Processing (ICIP) 2008.
2. Pavan Turaga, Ashok Veeraraghavan and Rama Chellappa. "Recognizing Humans and their Activities using Statistical Analysis on Stiefel and Grassmann manifold", Snowbird Learning Workshop, Apr 2008.
3. Ashok Veeraraghavan, Ramesh Raskar, Amit Agrawal, Ankit Mohan and Jack Tumblin. "Non-Refractive Modulators for Coding and Capturing Scene Appearance", University of Maryland, UMIACS Tech Report UMIACS-TR-2007-21.
4. Ashok Veeraraghavan, Mandyam Srinivasan, Rama Chellappa, Emily Baird and Richard Lamont. "Motion Based Correspondence for 3D Tracking of Multiple Dim Objects", In Proceedings of IEEE International Conference on Acoustics, Speech and Signal Processing, May 2006 (ICASSP).
5. Ashok Veeraraghavan, Rama Chellappa and Amit K.Roy-Chowdhury. "Learning the function space of an Activity", Snowbird Learning Workshop Apr 2006.
6. Sankalita Saha, Chung-Ching Shen, Chia-Jui Hsu, Gaurav Aggarwal, Ashok Veeraraghavan, Alan Sussman, Shuvra S. Bhattacharyya, "Model-Based OpenMP Implementation of a 3D Facial Pose Tracking System". ICPP Workshops 2006: 66-73. (1 citation)
7. Rama Chellappa, Ashok Veeraraghavan and Gaurav Aggarwal. "Pattern Recognition in Video". Invited paper in International Conference on Pattern Recognition and Machine Intelligence(PReMI), 2005. Published in Lecture Notes in Computer Science, Volume 3776, Dec 2005, Pages 11-20.
8. Gaurav Aggarwal, Ashok Veeraraghavan and Rama Chellappa. "3D Facial Pose Tracking in Uncalibrated Videos". International Conference on Pattern Recognition and Machine Intelligence(PReMI), 2005. Published in Lecture Notes in Computer Science, Volume 3776, Dec 2005, Pages 515-520. (3 citations)

9. Ashok Veeraraghavan and Rama Chellappa. Tracking Bees in a hive. Snowbird Learning Workshop 2005. (Invited Paper)

PROFESSIONAL  
ACTIVITIES

- Program Committee: ICCV 2007
- Reviewer: CVPR 2007, IEEE Transactions on Pattern Analysis and Machine Intelligence, IEEE Transactions on Image Processing, IEEE Transactions on Information Forensics and Security, IEEE Transactions on Pervasive Computing

TALKS

- ACM SIGGRAPH 2007 - 'Dappled Photography- Mask Enhanced Cameras for Coded Aperture and Light field heterodyning'
- IEEE CVPR 2006 - 'Function Space of Activities - Learning the space of time warping functions for Activity Recognition'
- Snowbird Learning Workshop 2005 - 'Simultaneous Tracking and Behaviour Analysis of Bee Dances'
- Australian National University: Research School of Biological Sciences - 'Multiple Camera based Simultaneous Tracking and Behavior Analysis'

RELEVANT  
COURSEWORK

Statistical Pattern Recognition	Digital Image Processing
Image Understanding	Advanced Digital Signal Processing
Information Theory	Estimation and Detection Theory
Artificial Neural Networks	Probability and Random Processes
Adaptive Control Systems	Geometric and Information Control
Image Segmentation	Linear Control Systems

REFERENCES

**Prof. Rama Chellappa**, Professor, Department of Electrical and Computer Engineering, University of Maryland, College Park, MD 20742. (rama (AT) umiacs (DOT) umd (DOT) edu)

**Prof. Ramesh Raskar**, Associate Professor, MIT Media Labs, Massachusetts Institute of Technology (MIT) Cambridge, MA 02139, (raskar (AT) media (DOT) mit (DOT) edu)

**Prof. P.S. Krishnaprasad**, Professor, Electrical and Computer Engineering Department, University of Maryland, College Park, MD 20742-3285, (krishna (AT) isr (DOT) umd (DOT) edu)

**Prof. Mandyam Srinivasan**, Professor and Head of Visual Neuroscience, Queensland Brain Institute, The University of Queensland, Australia, (m.srinivasan (AT) uq (DOT) edu (DOT) au)

**Prof. Jack Tumblin**, Associate Professor, EECS Department, Northwestern University, Evanston, IL 60208, (jet (AT) cs (DOT) northwestern (DOT) edu)

**Prof. Amit K. Roy-Chowdhury**, Assistant Professor, Department of Electrical Engineering, Cooperating Faculty, Dept. of Computer Science and Engineering, University of California, Riverside, CA 92521 (amitrc (AT) ee (DOT) ucr (DOT) edu)