Ravi Ramamoorthi

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EDUCATION

6/98-8/02 **Stanford University**
Ph.D in Computer Science
Thesis: *A Signal-Processing Framework for Forward and Inverse Rendering*

9/94-6/98 **California Institute of Technology**
BS in Engineering and Applied Science, MS in Computer Science, MS in Physics

EMPLOYMENT

1/07-present **Columbia University**, Associate Professor of Computer Science

9/02-12/06 **Columbia University**, Assistant Professor of Computer Science

RESEARCH INTERESTS

The goal of my research is to develop the *theoretical foundations*, *mathematical representations*, and *computational algorithms* for the *visual appearance* of objects, digitally recreating or *rendering* the complexity of natural appearance. My work explores practical applications in a variety of areas in *computer graphics* rendering and related topics in computer vision, including

mathematical foundations of rendering and visual appearance

real-time photorealistic rendering

acquisition, representation and rendering with measured appearance

complex illumination, materials and shadows in computer vision

HONORS

ACM SIGGRAPH Significant New Researcher Award (highest early career award for computer graphics researchers; 1 award made per year among all "new" academic/industrial researchers), Aug 2007.

ONR Young Investigator Award "Mathematical Models of Illumination and Reflectance for Image Understanding and Machine Vision" (2 awards per year in computer science), Office of Naval Research, Mar 2007.

Sloan Fellowship in Computer Science (14 awards per year in computer science to junior faculty; only award in computer graphics in 2005), Alfred P. Sloan Foundation, Sep 2005.

NSF CAREER award, "Mathematical and Computational Fundamentals of Visual Appearance for Computer Graphics" (3 awards per year in computer graphics), National Science Foundation, Feb 2005.

Stanford Graduate Fellowship (awarded to 1% of PhD applicants), 1998-2002.

Green Prize for creative Scholarship, California Institute of Techonology (1 or 2 awards made per year among all undergraduates for outstanding research), 1997.

RECENT INVITED TALKS

Nov 2006 "High Quality Real-Time Rendering", *Princeton University*

May-June 2006 "Representations of Visual Appearance for Computer Graphics", *University of California at Berkeley, University of Washington, Microsoft Research, Cornell University*

June 2006 "Data-Driven Appearance Representations", *Mitsubishi Electric Research Laboratories, Carnegie Mellon University*

May 2006 "Spherical Convolution in Computer Graphics and Vision", *SIAM Imaging Science Conference, Minneapolis*

Apr-Oct. 2005 "Signal-Theoretic Representations of Visual Appearance", *Carnegie Mellon University, Massachussetts Institute of Technology, Stevens Institute of Technology, University of California San Diego, IIIT Hyderabad, Harvard University*

Oct. 2004 "Signal-Theoretic Representations of Appearance", *University of Maryland, Siemens, Rutgers University [Dec. 2003]*

Aug. 2004 "Real-Time Rendering and Interaction with Complex Illumination and Materials", *Intel*

MAJOR PUBLICATIONS

SIGGRAPH[1]

1. "A Theory of Locally Low Dimensional Light Transport" by D. Mahajan, I. Kemelmacher, R. Ramamoorthi and P. Belhumeur. *ACM Transactions on Graphics 26(3) [SIGGRAPH 2007], to appear.*

2. "Frequency Domain Normal Map Filtering" by C. Han, B. Sun, R. Ramamoorthi and E. Grinspun. *ACM Transactions on Graphics 26(3) [SIGGRAPH 2007], to appear.*

3. "Real-Time BRDF Editing in Complex Lighting" by A. Ben-Artzi, R. Overbeck and R. Ramamoorthi. *ACM Transactions on Graphics 25(3) [SIGGRAPH 2006], pages 945–954.*

4. "Inverse Shade Trees for Non-Parametric Material Representation and Editing" by J. Lawrence, A. Ben-Artzi, C. Decoro, W. Matusik, H. Pfister, R. Ramamoorthi and S. Rusinkiewicz. *ACM Transactions on Graphics 25(3) [SIGGRAPH 2006], pages 735–745.*

5. "Time-Varying Surface Appearance: Acquisition, Modeling and Rendering" by J. Gu, C. Tu, R. Ramamoorthi, P. Belhumeur, W. Matusik and S. Nayar. *ACM Transactions on Graphics 25(3) [SIGGRAPH 2006], pages 762–771.*

6. "A Compact Factored Representation of Heterogeneous Subsurface Scattering" by P. Peers, K. von Berge, W. Matusik, R. Ramamoorthi, J. Lawrence, S. Rusinkiewicz and P. Dutre. *ACM Transactions on Graphics 25(3) [SIGGRAPH 2006], pages 746–753.*

7. "Acquiring Scattering Properties of Participating Media by Dilution" by S. Narasimhan, M. Gupta, C. Donner, R. Ramamoorthi, S. Nayar and H. Jensen. *ACM Transactions on Graphics 25(3) [SIGGRAPH 2006], pages 1003–1012.*

8. "A Practical Analytic Single Scattering Model for Real-Time Rendering" by B. Sun, R. Ramamoorthi, S. Narasimhan and S. Nayar. *ACM Transactions on Graphics 24(3) [SIGGRAPH 2005], pages 1040-1049.*

9. "Efficiently Combining Positions and Normals for Precise 3D Geometry" by D. Nehab, S. Rusinkiewicz, J. Davis and R. Ramamoorthi. *ACM Transactions on Graphics 24(3) [SIGGRAPH 2005], pages 536-543.*

10. "Wavelet Triple Product Integrals for All-Frequency Relighting" by R. Ng, R. Ramamoorthi and P. Hanrahan. *ACM Transactions on Graphics 23(3) [SIGGRAPH 2004], pages 475-485.*

11. "Efficient BRDF Importance Sampling Using a Factored Representation" by J. Lawrence, S. Rusinkiewicz and R. Ramamoorthi. *ACM Transactions on Graphics 23(3) [SIGGRAPH 2004], pages 494-503.*

12. "All-Frequency Shadows Using Non-Linear Wavelet Lighting Approximation" by R. Ng, R. Ramamoorthi and P. Hanrahan. *ACM Transactions on Graphics 22(3) [SIGGRAPH 2003], pages 376-381.*

13. "Structured Importance Sampling of Environment Maps" by S. Agarwal, R. Ramamoorthi, S. Belongie and H. Jensen. *ACM Transactions on Graphics 22(3) [SIGGRAPH 2003], pages 605-612.*

14. "Frequency Space Environment Map Rendering" by R. Ramamoorthi and P. Hanrahan. *ACM Transactions on Graphics 21(3) [SIGGRAPH 2002], pages 517-526.*

15. "A Signal-Processing Framework for Inverse Rendering" by R. Ramamoorthi and P. Hanrahan. *In proceedings of SIGGRAPH 2001, pages 117–128.*

16. "An Efficient Representation for Irradiance Environment Maps" by R. Ramamoorthi and P. Hanrahan. *In proceedings of SIGGRAPH 2001, pages 497–500.*

17. "Efficient Image-Based Methods for Rendering Soft Shadows" by M. Agrawala, R. Ramamoorthi, A. Heirich and L. Moll. *In proceedings of SIGGRAPH 2000, pages 375–384.*

18. "Creating Generative Models from Range Images" by R. Ramamoorthi and J. Arvo. *In proceedings of SIGGRAPH 1999, pages 195–204.*

19. "Fast Construction of Accurate Quaternion Splines" by R. Ramamoorthi and A. Barr. *In proceedings of SIGGRAPH 1997, pages 287–292.*

[1]The SIGGRAPH conference is the leading venue for publishing research in computer graphics, with acceptance rates ranging from $15\% - 20\%$ depending on the year. Since 2002, the proceedings have also been published as a special issue of the ACM Transactions on Graphics (TOG). TOG (and also the IEEE Transactions on Visualization and Computer Graphics or TVCG) are the top journals in graphics. In particular, TOG is especially suited for fundamental theoretical ideas that may be inappropriate because of length or theoretical content for SIGGRAPH. Some of my papers also appear in the EuroGraphics Symposium on Rendering (EGSR), which is the leading venue for rendering research (second only to the SIGGRAPH conference), and has a competitive acceptance rate of $25-35\%$. Both SIGGRAPH and EGSR papers are fully reviewed, and considered terminal publications. In computer vision, the leading journals are the IEEE Transactions on Pattern Analysis and Machine Intelligence (PAMI), and for more physics-based work, the Journal of the Optical Society of America (JOSA). Leading conferences are IEEE CVPR, ICCV and ECCV. Papers in these conferences are rigorously reviewed, with acceptance rates around 20%. Oral presentation is particularly competitive, with acceptance rates currently below 5%.

LEADING INTERNATIONAL JOURNALS

20. "A Precomputed Polynomial Representation for Interactive BRDF Editing with Global Illumination" by A. Ben-Artzi, K. Egan, R. Ramamoorthi and F. Durand. *ACM TOG, accepted with major revisions.*

21. "A Theory of Frequency Domain Invariants: Spherical Harmonic Identities for BRDF/Lighting Transfer and Image Consistency" by D. Mahajan, R. Ramamoorthi and B. Curless. *IEEE Transactions on Pattern Analysis and Machine Intelligence, to appear.*

22. "Time-Varying BRDFs" by B. Sun, K. Sunkavalli, R. Ramamoorthi, P. Belhumeur and S. Nayar. *IEEE Transactions on Visualization and Computer Graphics, to appear.*

23. "A First Order Analysis of Lighting, Shading, and Shadows" by R. Ramamoorthi, D. Mahajan and P. Belhumeur. *ACM Transactions on Graphics (TOG), 26(1), Article 2, 1–21, Jan 2007.*

24. "Reflectance Sharing: Predicting Appearance from a Sparse Set of Images of a Known Shape" by T. Zickler, R. Ramamoorthi, S. Enrique and P. Belhumeur. *IEEE Transactions on Pattern Analysis and Machine Intelligence, 28(8), 1287–1302, Aug 2006.*

25. "A Fourier Theory for Cast Shadows" by R. Ramamoorthi, M. Koudelka and P. Belhumeur. *IEEE Transactions on Pattern Analysis and Machine Intelligence, 27(2), 288–295, Feb 2005.*

26. "Spacetime Stereo: A Unifying Framework for Depth from Triangulation" by J. Davis, D. Nehab, R. Ramamoorthi and S. Rusinkiewicz. *IEEE Transactions on Pattern Analysis and Machine Intelligence, 27(2), 296–302, Feb 2005.*

27. "A Signal-Processing Framework for Reflection" by R. Ramamoorthi and P. Hanrahan. *ACM Transactions on Graphics, 23(4), 1004–1042, Oct 2004.*

28. "Analytic PCA Construction for Theoretical Analysis of Lighting Variability in Images of a Lambertian Object" by R. Ramamoorthi. *IEEE Transactions on Pattern Analysis and Machine Intelligence, 24(10), 1322–1333, Oct 2002.*

29. "On the Relationship between Radiance and Irradiance: Determining the Illumination from Images of a Convex Lambertian Object" by R. Ramamoorthi and P. Hanrahan. *Journal of the Optical Society of America A, volume 18(10), Oct 2001, pages 2448–2459.*

REVIEWED INTERNATIONAL CONFERENCES AND JOURNALS

30. "Viewpoint-Coded Structured Light" by M. Young, E. Beeson, J. Davis, S. Rusinkiewicz and R. Ramamoorthi. *IEEE Conference on Computer Vision and Pattern Recognition (CVPR) 2007, to appear.*

31. "4D Compression and Relighting with High-Resolution Light Transport Matrices" by E. Cheslack-Postava, N. Goodnight, R. Ng, R. Ramamoorthi and G. Humphreys. *ACM Symposium on Interactive 3D Graphics and Games 2007*.

32. "A Theory of Spherical Harmonic Identities for BRDF/Lighting Transfer and Image Consistency" by D. Mahajan, R. Ramamoorthi and B. Curless. *European Conference on Computer Vision (ECCV) 2006, vol IV, pages 41–55 (Early version of [21]).* **Oral presentation $<$ 5% accepted**.

33. "Exploiting Temporal Coherence for Incremental All-Frequency Relighting" by R. Overbeck, A. Ben-Artzi, R. Ramamoorthi and E. Grinspun. *Eurographics Symposium on Rendering 2006.*.

34. "Time Varying BRDFs" by B. Sun, K. Sunkavalli, R. Ramamoorthi, P. Belhumeur and S. Nayar. *Eurographics Workshop on Natural Phenomena 2006. (Early version of [22]).*

35. "First Steps Toward an Electronic Field Guide for Plants" by G. Agarwal, P. Belhumeur, S. Feiner, D. Jacobs, W. Kress, R. Ramamoorthi, N. Dixit, D. Mahajan, H. Ling, R. Russell, S. Shirdhonkar, K. Sunkavalli and S. White. *Taxon, 55(3), 597–610, Aug 2006.*.

36. "Efficient Shadows from Sampled Environment Maps" by A. Ben-Artzi, R. Ramamoorthi and M. Agrawala. *Journal of Graphics Tools, 11(1), 13–36, Jan 2006.*

37. "Reflectance Sharing: Image-Based Rendering from a Sparse Set of Images" by T. Zickler, S. Enrique, R. Ramamoorthi and P. Belhumeur. *Eurographics Symposium on Rendering 2005, pages 253–264.*

38. "Adaptive Numerical Cumulative Distribution Functions for Efficient Importance Sampling" by J. Lawrence, S. Rusinkiewicz and R. Ramamoorthi. *Eurographics Symposium on Rendering 2005, pages 11–20.*

39. "Practical Rendering of Multiple Scattering in Participating Media" by S. Premoze, M. Ashikhmin, J. Tesendorf, R. Ramamoorthi and S. Nayar. *Eurographics Symposium on Rendering 2004, pages 363–374.*

40. "A Fourier Theory for Cast Shadows" by R. Ramamoorthi, M. Koudelka and P. Belhumeur. *European Conference on Computer Vision (ECCV) 2004, pages I-146–I-162 (Early version of [25]).*

41. "Using Specularities for Recognition" by M. Osadchy, D. Jacobs and R. Ramamoorthi. *International Conference on Computer Vision (ICCV) 2003, pages 1512-1519.* **Oral presentation $<$ 5% accepted**.

42. "Spacetime Stereo: A Unifying Framework for Depth from Triangulation" by J. Davis, R. Ramamoorthi and S. Rusinkiewicz. *IEEE Conference on Computer Vision and Pattern Recognition (CVPR) 2003, pages II-359–II-366 (Early version of [26]).*

BOOK CHAPTER

43. "Modeling Illumination Variation with Spherical Harmonics" by R. Ramamoorthi in *Face Processing: Advanced Modeling Methods (edited by Rama Chellappa and Wenyi Zhao), Acad. Press 2006, pp 385–424.*

OTHER CONFERENCE PAPERS AND TECHNICAL REPORTS

44. "Acquiring Material Models Using Inverse Rendering" by R. Ramamoorthi, S. Marschner, S. Boivin, G. Drettakis, H. Lensch, Y. Yu. *SIGGRAPH 2002 course 39 (note chapter on Inverse rendering under complex illumination by R. Ramamoorthi).*

45. "Analytic PCA construction for theoretical analysis of lighting variability, including attached shadows, in a single image of a convex Lambertian object" by R. Ramamoorthi. *CVPR 01, workshop on Identifying Objects Across Variations in Lighting (early version of [28]).*

46. "Analysis of Planar Light Fields from Homogeneous Convex Curved Surfaces under Distant Illumination" by R. Ramamoorthi and P. Hanrahan. *Human Vision and Electronic Imaging VI 2001, pages 195–208.*

47. "A General Resource Reservation Framework for Scientific Computing" by R. Ramamoorthi, A. Rifkin, B. Dimitrov and K. Chandy. *ISCOPE 97, pages 283–290.*

48. "Dynamic Splines with Constraints for Animation" by R. Ramamoorthi, C. Ball and A. Barr. *Caltech Tech. Report CS-TR-97-03.*

FUNDING

"Mathematical Models of Illumination and Reflectance for Image Understanding and Machine Vision", ONR Young Investigator Program $350,000 + $30,000 matching funds Jun 1, 2007 - May 31, 2010.

"Fast and Accurate Volumetric Rendering of Scattering Phenomena in Computer Graphics" with S. Nayar, S. Narasimhan (CMU), NSF CPA $400,000 Mar 1, 2006 - Feb 28, 2009.

"Sloan Fellowship in Computer Science", Alfred P. Sloan Foundation $45,000 Sep 1, 2005 - Aug 31, 2007.

"CAREER: Mathematical and Computational Fundamentals of Visual Appearance for Computer Graphics", NSF CCF Graphics and Visualization $425,000 +$45,000 matching funds Feb 1, 2005 - Jan 31, 2010.

"Restore the Trustworthiness of Digital Photographs: Blind Detection of Digital Photograph Tampering" with S. Chang, NSF Cyber Trust program, $740,000 Sep 1, 2004 - Aug 31, 2007.

"Real-Time Rendering and Interaction with Complex Illumination and Materials", Intel Corporation AIM Program, $75000 + $15000 equipment, Dec 1, 2003 – present.

"Real-Time Visualization and Rendering of Complex Scenes" with H. Jensen (UCSD), NSF program on Numeric, Symbolic and Geometric Computation CCF $434,734 Dec 15, 2003 - Nov 30, 2007.

"An Electronic Field Guide: Plant Exploration and Discovery in the 21st Century" with P. Belhumeur, S. Feiner, D. Jacobs (UMD), J. Kress (Smithsonian), NSF ITR $2,224,000 Sep 1, 2003 - Aug 31, 2008.

TEACHING

COMS 4160	Computer Graphics. Redesigned introductory undergraduate graphics course. Intended to be offered yearly in the fall. Spring 2003 (45 students), Fall 2003 (28 students), Fall 2004 (39 students), Fall 2005 (39 students), Fall 2006 (39 students).
COMS 4162	Advanced Computer Graphics. Developed new undergraduate course. Spring 2005 (25 students), Spring 2006 (14 students). Intended to be offered in future in alternate years.
COMS 6160	Topics in Computer Graphics. Developed new graduate course taught every two years (content changes with each offering). Fall 2002 COMS 6998 Appearance Models (9 students), Fall 2004 Real-Time High Quality Rendering (23 students), Spring 2007 Visual Appearance Representations for Rendering (17 students).
CS 148 (Stanford)	Introductory Computer Graphics, Summer 2001. Instructor for course.
SIGGRAPH 2002	Organizer (with Steve Marschner) and lecturer in course on Acquiring Material Models by Inverse Rendering

STUDENT COLLABORATORS AND ADVISEES

Current PhD (co-)advisees

- Aner Ben-Artzi (since Jan 2003: candidacy Jun 2004, proposal Mar 2006, PhD deposit May 11, 2007)
- Bo Sun [Presidential Fellow] (since Jan 2004 : candidacy Jun 2006)
- Jinwei Gu (since Sep 2005, with Shree Nayar and Peter Belhumeur)
- Dhruv Mahajan (since Jan 2006, with Peter Belhumeur)
- Charles Han (since Jan 2006, with Eitan Grinspun)
- Ryan Overbeck (since Sep 2006)
- Kevin Egan [NSF Fellow] (since Sep 2006)

PhD student collaborator: Diego Nehab (Princeton, advisor Szymon Rusinkiewicz, since Jun 2003)

Alumni

- *Postdoc:* Simon Premoze [now at ILM] (Oct 2003–Mar 2005)
- *PhD (co-)advisee:* Jason Lawrence [now faculty at Univ. Virginia] (at Princeton, advisor Szymon Rusinkiewicz, since Jun 2003: PhD completed Jun 2006)
- *PhD student collaborators:* Ren Ng [Microsoft Fellow] (Stanford, advisor Pat Hanrahan, May 2002-Jan 2004), Sameer Agarwal (UCSD, advisor Serge Belongie, Jan 2003), Srinivasa Narasimhan [now faculty at CMU] (advisor Shree Nayar, Jan 2003-Jan 2006), Todd Zickler [now faculty at Harvard] (Yale, advisor Peter Belhumeur, Nov 2002–Feb 2005)
- *MS:* Dhruv Mahajan [MS thesis, now PhD] (Sep 2004–Dec 2005), Ryan Overbeck [MS thesis, now PhD] (Sep 2004–Dec 2005), Nandan Dixit [now at Google] (Sep 2005–Dec 2006), Kalyan Sunkavalli [now at MERL] (Sep 2004–Jul 2006), Chien-I Tu [now PhD at Texas A&M] (Jun–Sep 2005), Sebastian Enrique [now at Electronic Arts] (Sep 2003–Jun 2005)
- *BS:* Makiko Yasui [Theodore Bashkow award] (SEAS 2004), Zeyar Htet (SEAS 2005), Ray Ming-Yeh [Computer Science Scholarship award] (SEAS 2005), Matthew Schulkind (SEAS 2006)

PROFESSIONAL SERVICE

Associate Editor, ACM Transactions on Graphics, 2006 -

NSF Panelist and Reviewer, 2005

Proposal Reviewer for Austrian Science Foundation, 2005, 2006

Program Committee, SIGGRAPH conference, 2006, 2007

Program Commitee, EGSR (Eurographics Symposium on Rendering), 2005, 2006, 2007

Program Commitee, CVPR (IEEE Conference on Computer Vision and Pattern Recognition), 2003, 2007

Program Commitee, ICCV (International Conference on Computer Vision), 2003

Program Commitee, ECCV (European Conference on Computer Vision), 2004, 2006

Reviewer for SIGGRAPH, Eurographics, Eurographics Symposium on Rendering, IEEE Computer Graphics and Applications, IEEE TVCG, IEEE PAMI, Computer Vision and Image Understanding, . . .

DEPARTMENTAL SERVICE

- *PhD Admissions:* Served on PhD admissions committee 2002–. Participated actively on discussions to improve process, leading to new departmental fellowships for "general pool admits" chosen early by committee. Responsible for discussions and selection of Presidential and Departmental Fellowships (and before current electronic system, screening and sorting all applications). Responsible for the full schedule of faculty and student meetings for the 2006 PhD visit day.
- *Distinguished Lecture Series:* Organized Distinguished and Departmental Lecture series, 2006–2007.
- *Faculty Recruiting:* Responsible (2002–2004) for screening/interviewing applicants and active recruiting, especially in computer graphics. Continuing service on recruiting committee for 2006 search.
- *Nominations Committee:* Served on nominations committee (2004–) to select departmental nominees for competitive awards, like IBM and Microsoft fellowships.
- *Talks:* Gave talks and participated in 25^{th} anniversary celebrations, PhD admit day, and visit of chair of trustees (and helped with some organization).
- *Advising:* Academic advising of undergraduate and MS students.

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