Shubao Liu

Research Scientist
GE Global Research

Mailing Address: 1 Research Circle,
Niskayuna, NY 12309
Phone: (401) 419-9656
Email: shubao.liu@gmail.com
Homepage: http://www.lems.brown.edu/~sbliu

Education

- Ph.D. in Computer Vision — Sep. 2005 – Feb. 2011
  Brown University, Providence, RI
  Thesis: *Statistical Inverse Ray Tracing for Image-Based 3D Modeling*
  Advisor: Professor David B. Cooper
- M.Phil. in Computational Intelligence — Aug. 2003 – Aug. 2005
  The Chinese University of Hong Kong, Hong Kong
  Thesis: *Continuous-Time Recurrent Neural Networks for Quadratic Programming — Theory and Engineering Applications*
  Advisor: Professor Jun Wang
- B.E. in Automation — Sep. 1999 – Jul. 2003
  University of Science and Technology of China, Hefei, China

Work Experience

- Lead Scientist, GE Global Research, March 2011 – present
- Intern, Google Inc., May–August 2008

Research Interests

I am interested in developing statistical methods for various computer vision problems, and their practical applications. More specifically, I am interested in the following sub-topics in computer vision and machine learning:

Low-level Vision computational photography, higher-order MRF and efficient inference, multi-view stereo, vision-based graphics

Image Understanding scene graph parsing, visual recognition and retrieval, hierarchical segmentation

Machine Learning efficient learning and inference algorithms for graphical models, hierarchical graphical models

PhD Dissertation / Main Research Achievements during PhD Study

Title: **Statistical Inverse Ray Tracing for Image-Based 3D Modeling**
Abstract: Capturing 3D geometry and appearance from multiple 2D images taken from different views is a classic problem in computer vision and has applications in virtual reality, entertainment, human-computer interface, surveillance, navigation, and high-level vision tasks, etc. In this thesis, we present

an *inverse ray tracing* approach based on statistical inference. Instead of matching features/pixels across images, the inverse ray tracing approach models the volumetric ray-tracing based image generation process directly and searches for the best 3D geometry and surface reflectance model to explain all the observations. *It can better handle difficult problems in multi-view stereo, including large camera baseline, occlusion, matching ambiguities, etc., than traditional methods, without additional information and assumptions, such as initial surface estimate or simple background assumption.* Here the image generation process is modeled through volumetric ray tracing, where the *occlusion/visibility is accurately modeled*. All the constraints (including ray constraints and prior knowledge about the geometry) are put into the *Ray Markov Random Field* (Ray MRF) formulation. This MRF model is unusual in the sense that the ray clique, which models the ray-tracing process, consists of thousands of random variables, instead of two to dozens as in typical MRFs. This presents a big challenge to the inference algorithm, because of the combinatorial explosion of possible configurations. In this work an algorithm with *linear computational complexity* is developed to solve the estimation problem. More specifically, we show that a highly optimized belief propagation algorithm, *deep belief propagation* (DBP), can tackle the challenging problem effectively and efficiently, by exploring the deep factorization structure of the ray clique energy. Then the DBP algorithm is also extended to solve the inference problem for a broader class of *higher-order MRFs*. *The algorithm developed is capable of handling general and complex scenes of large varieties, general camera configurations (both small and large baselines), and can generate accurate and photo-realistic 3D models*. These have been verified by extensive experiments on standard and home-grown challenging datasets. More information is available at `http://www.lems.brown.edu/~sbliu/projects/iray2/iray2.html`, and `http://www.lems.brown.edu/~sbliu/projects/iray/iray.html`.

Research Experience

- **Deep Belief Propagation for Efficient Higher-Order MRF Inference**,
  Advisor: Professor David B. Cooper, Brown University, 2010–present
  - Developed an efficient algorithm, deep belief propagation, for the inference of a class of higher-order MRFs, by exploring the "deep" factorization structure of these cliques and extending the (loopy) belief propagation algorithm.
- **Statistical Inverse Ray Tracing for 3D Modeling from Multiple Images: Ray Markov Random Fields and Efficient Inference**,
  Advisor: Professor David B. Cooper, Brown University, 2008–present
  - Proposed to tackle the image-based 3D modeling problem from the inverse problem perspective: modeling the ray-tracing based image generation process, and then searching for the best 3D model to explain the observed images.
  - Developed the Ray Markov Random Field formulation of the problem, which is unique in the sense that the ray clique, which models the ray-tracing process, consists of thousands of random variables, instead of two to dozens as in typical MRFs.
  - Developed a highly optimized belief propagation algorithm for inferring the RayMRF to estimate the volume occupancies and colors.
  - Built a prototype system that can handle general and complex scenes, general camera configurations (both small and large baselines), and can generate photo-realistic 3D models. These have been verified by extensive experiments on varieties of standard and home-grown datasets.
  - Earlier results have been published in IEEE Conference on Computer Vision and Pattern Recognition (CVPR), 2010.
  - More recent results have been accepted by IEEE Conference on Computer Vision and Pattern Recognition (CVPR), 2011.

  - Demos: `http://www.lems.brown.edu/~sbliu/projects/iray2/iray2.html` and `http://www.lems.brown.edu/~sbliu/projects/iray/iray.html`

- **Text Detection from Natural Images**,
  Advisors: Dr. Raquel Romano, Dr. Dar-Shyang Lee and Dr. Ranjith Unnikrishnan, Google Inc., May–August, 2008

  - Designed and implemented a maximum pseudo-likelihood based learning algorithm for text detection in natural images using Conditional Random Fields;
  - Prototyped a novel hierarchical-MRF based text detection algorithm.

- **Distributed Volumetric Scene Reconstruction with a Randomly Configured Camera Network**,
  Advisor: Professor David B. Cooper, Brown University, 2007–2009

  - Studied the problem of reconstructing a scene's 3D structure from a network of randomly and sparsely placed cameras.
  - Explored the gradient information (soft edge) of the image to get a 3D reconstruction by optimizing the consistency between the surface's occluding contours and the image gradients.
  - Designed a distributed algorithm that adaptively balances the cameras' load and reduces the communication cost among cameras by exploring the locality property of the surface occluding contour.
  - This work has been published in IEEE Conference on Computer Vision and Pattern Recognition (CVPR), 2009.

- **Free-form Object Reconstruction from Silhouettes, Occluding Edges and Texture Edges: A Unified Approach based on Duality**,
  Advisors: Professor David B. Cooper, Dr. Kongbin Kang and Dr. Jean-Philippe Tarel, Brown University, 2005–2007

  - Extended the *duality in differential form* theorem between a 3D primal surface and the dual manifold formed by the surface's tangent planes. The theorem shows that each tangent plane of the dual manifold corresponds to a point on the original 3D surface, i.e., the "dual" of the "dual" goes back to the "primal".
  - Developed an algorithm to reconstruct 3D surfaces from image edges by estimating the dual manifold.
  - This work has been published in IEEE Transactions on Pattern Analysis and Machine Intelligence (TPAMI), 2008.

Publications

Peer-Reviewed Journal Articles

1. **Shubao Liu**, Kongbin Kang, Jean-Philippe Tarel and David B. Cooper, "Free-form Object Reconstruction from Silhouettes, Occluding Edges and Texture Edges: A Unified and Robust Operator Based on Duality", *IEEE Transactions on Pattern Analysis and Machine Intelligence* (**TPAMI**), vol. 30, no. 1, pp. 131–146, January 2008.

2. **Shubao Liu** and Jun Wang, "A Simplified Dual Neural Network for Quadratic Programming with Application for K-Winners-Take-All Operation", *IEEE Transactions on Neural Networks* (**TNN**), vol. 17, no. 6, pp. 1500-1510, 2006.

Peer-Reviewed Conference Papers

1. **Shubao Liu** and David B. Cooper, "A Complete Statistical Inverse Ray Tracing Approach to Multi-view Stereo", Proceedings of IEEE Conference on Computer Vision and Pattern Recognition (**CVPR**'11), pp.913-920, Colorado Springs, CO, 2011.
2. **Shubao Liu** and David B. Cooper, "Ray Markov Random Fields for Image-Based 3D Modeling: Model and Efficient Inference", Proceedings of IEEE Conference on Computer Vision and Pattern Recognition (**CVPR**'10), pp.1530–1537, San Francisco, CA, 2010.
3. Eben Gay, David Cooper, Benjamin Kimia, Gabriel Taubin, Daniel Cabrini, Suman Karumuri, Will Doutre, **Shubao Liu**, Katarina Galor, Donald Sanders, Andrew Willis, "REVEAL intermediate report", 2010 IEEE Computer Society Conference on Computer Vision and Pattern Recognition Workshops (CVPRW), San Francisco, CA, 2010.
4. **Shubao Liu**, Kongbin Kang, Jean-Philippe Tarel and David B. Cooper, "Distributed Volumetric Scene Geometry Reconstruction With a Network of Distributed Smart Cameras", Proceedings of IEEE Conference on Computer Vision and Pattern Recognition (**CVPR**'09), pp.2334–2341, Miami, FL, 2009.
5. **Shubao Liu**, Xiaolin Hu and Jun Wang, "Obstacle avoidance for kinematically redundant manipulators based on an improved problem formulation and the simplified dual neural network", Proc. IEEE Three-Rivers Workshop on Soft Computing in Industrial Applications, pp. 67–72, Passau, Germany, 2007.
6. **Shubao Liu** and Jun Wang, "A New K-Winners-Take-All Neural Network," International Joint Conference on Neural Networks (**IJCNN**), pp. 712-716, Montreal, Canada, 2005.
7. **Shubao Liu** and Jun Wang, Obstacle Avoidance for Kinematically Redundant Manipulators Using the Deterministic Annealing Neural Network, International Symposium on Neural Networks (**ISNN**), pp. 240-246, May 2005.
8. **Shubao Liu** and Jun Wang, A Dual Neural Network for Bi-Criteria Torque Optimization of Redundant Robot Manipulators, Proceedings of International Conference on Neural Information Processing (**ICNIP**), pp. 1142-1147, November 2004.
9. **Shubao Liu** and Jun Wang, "Blind Adaptive Multiuser Detection Using a Recurrent Neural Network", International Conference on Communications, Circuits and Systems (**ICCCS**), pp. 1071-1075, June 2004.

Articles in Submission

1. **Shubao Liu** and David B. Cooper, "Statistical Inverse Ray Tracing for Multi-view 3D Modeling: Ray Markov Random Fields and Deep Belief Propagation", In submission.

Academic Activities

- "Image Parsing," seminar talk at GE Global Research, 2012.
- Presented a paper at CVPR'11, Colorado Springs, CO, 2011.
- "Statistical Inverse Ray Tracing for Image-Based 3D Modeling," seminar talk at MIT CSAIL, GE Global Research, Siemens Corporate Research, 2011.
- Presented a paper at CVPR'10, San Francisco, CA, 2010.

- Presented a paper at CVPR'09, Miami, FL, 2009.
- Attended the Graduate Summer School: Probabilistic Models of Cognition: The Mathematics of Mind, Institute of Pure and Applied Mathematics, UCLA, July 9 – 26, 2007.
- Reviewed papers for major journals and conferences on computer vision and neural networks, including IEEE Transactions on Pattern Analysis and Machine Intelligence, ISPRS Journal of Photogrammetry and Remote Sensing, Neural Computation, Neurocomputing, Neural Processing Letters, Journal of Inequalities and Applications, IEEE Transactions on Multimedia, etc.
- Served as programme committee member on several international conferences (ICICIP 2012, ICACI 2012, ISIEA 2012, ISNN 2013)

Awards

- GE Genius of the Day, GE Global Research, 2011
- Research Assistantship, Brown University, 06/2006-2010
- University Fellowship, Brown University, 09/2005-05/2006
- Postgraduate Scholarship, The Chinese University of Hong Kong, 08/2003-08/2005
- CAST Scholarship, University of Science and Technology of China, 2001
- Outstanding Student Scholarship, University of Science and Technology of China, 1999, 2000, 2002

Programming Skills

- highly proficient and 10+ years of experience in C, C++ and Matlab.
- familiar with Java, Python, Javascript.
- experience with common libraries in numerical computing, computer vision and computer graphics, including OpenCV, OpenGL, VTK, VXL, BLAS, LAPACK, ARPACK, GSL, Bundler, etc.