

# CVPR 2011 Tutorial

## Tools and Methods for Image Registration

(Regular, Full Day)

### Abstract

This tutorial covers the fundamentals of image registration, including similarity and affine invariant point detectors and descriptors, design of image descriptors for various vision tasks, similarity and affine invariant features, feature learning and optimal features, point correspondence algorithms under various geometric constraints, and various transformation functions for image registration. Also to be covered are registration of temporal, multiview, and multimodality images, as well as applications of image registration in medical imaging and remote sensing.

### Motivation

Image registration is a basic capability required to analyze two or more images of a scene. It puts into correspondence image points and regions, facilitating analysis of the images. Image registration tools and methods are required in various vision tasks, such as stereo depth perception, motion analysis, object tracking, object localization and recognition. In addition to covering the fundamentals of image registration, this tutorial identifies those tools and methods that are suitable for the registration of images with local geometric differences.

### Target Audience

Presentation of the materials will be at the intermediate level, skipping very basic materials as well as very advanced materials that require in-depth knowledge in a domain. Materials covered in this tutorial require basic knowledge of computer vision. Because the tutorial covers the fundamentals of image registration including tools and methods applicable to various vision tasks, it will be of interest to a wide range of audiences. In addition to computer vision researchers, this tutorial is believed to be of interest to researchers in medical imaging and remote sensing.

### Topics

1. Introduction: *A. Goshtasby*
2. Point detectors, point descriptors, and image features
  - a. Similarity and affine invariant point detectors and descriptors: *J. Morel, G. Yu*
  - b. Design and use of local descriptors in matching: *G. Carneiro*
  - c. Learning optimal features: *M. Brown*
3. Point pattern matching:

- a. Viewpoint invariant matching and repeated patterns: *F. Sur*
- b. State-of-the-art RANSAC: *J. Matas*
- c. Graph spectral matching: *E. Hancock*
4. Transformation models for image registration: *A. Goshtasby*
5. Applications
  - a. Elastic registration of topological surfaces in volumetric brain images: *A. Farag*
  - b. Robust feature-based registration of remotely sensed data: *N. Netanyahu*
6. Summary and Conclusions: *A. Goshtasby*

## Organizer

A. Goshtasby, Professor, Department of Computer Science and Engineering, Wright State University, Dayton, OH 45435, USA; *E-mail*: [arthur.goshtasby@wright.edu](mailto:arthur.goshtasby@wright.edu); *Phone*: (937)-775-5170; *Fax*: (937)-775-5133

## Speakers

**Matthew Brown** is a Postdoctoral Fellow at the Ecole Polytechnique Fédérale de Lausanne. He holds an M.Eng. in Electrical and Information Sciences (Cambridge, 2000) and a Ph.D. in Computer Science (UBC, 2005). He has worked with the Computer Vision and Robotics group at Cambridge University, the Vision Technology groups at Microsoft Research in Redmond (2006–2007) and Cambridge, and the Computational Intelligence Lab. at UBC. He currently works with the Computer Vision and Audiovisual Communications laboratories at EPFL. His presentation covers some of his most recent published work on optimal feature learning. *Address*: EPFL IC – CVLAB, BS 316, Station 14, 1015 Lausanne, Switzerland; *E-mail*: [matthew.brown@epfl.ch](mailto:matthew.brown@epfl.ch)

**Gustavo Carneiro** received his Ph.D. degree in Computer Science from the University of Toronto under the supervision of Prof. Allan Jepson in 2004. He is an Assistant Professor in the Department of Electrical and Computer Engineering and a Marie Curie International Incoming Fellow (IIF) at the Technical University of Lisbon (Instituto Superior Tecnico, Institute for Systems and Robotics). Previously, he was a senior research scientist at the Integrated Data Systems Department at Siemens Corporate Research. Dr. Carneiro also worked as an NSERC Post-doctoral Fellow at the Laboratory for Computational Intelligence at the University of British Columbia with Prof. David Lowe. Before that he worked as a Post-doctoral Fellow at the Statistical Visual Computing Laboratory, University of California at San Diego with Prof. Nuno Vasconcelos. He has been a regular contributor to CVPR. His presentation covers some of his most recent research results on automatic design of feature spaces for local image descriptors using an ensemble of nonlinear feature extractors. *Address*: Department of Electrical and Computer Engineering, Technical University of Lisbon, ISR-IST-Torre Norte 7 Piso Av. Rovisco Pais, 1049-001 Lisbon, Portugal; *E-mail*: [gcarneiro@isr.ist.utl.pt](mailto:gcarneiro@isr.ist.utl.pt)

**Aly A. Farag** received his bachelor's degree from Cairo University, Egypt, and his PhD from Purdue University, both in Electrical Engineering. He joined the University of Louisville in August 1990, where he is currently a Professor of Electrical and Computer Engineering. At the University of Louisville, Dr. Farag founded the Computer Vision and Image Processing

Laboratory (CVIP Lab) which focuses on imaging science, computer vision, and biomedical imaging. His main research focus is scene analysis, object reconstruction from multimodality imaging, statistical and variational methods for object segmentation, and registration.

Dr. Farag has co-authored over 250 technical papers in image understanding, and he has co-edited a two-volume collection of papers on Deformable Models for Biomedical Applications (Springer, 2007). He is also the author of two upcoming textbooks: *A Course on Digital Signal Processing* (Springer) and *Statistical Models in Biomedical Image Analysis* (Cambridge University Press). Address: Department of Electrical and Computer Engineering, University of Louisville, Louisville, KY 40292; E-mail: aly.farag@louisville.edu

**Edwin Hancock** is a Professor of Computer Vision at the University of York. He obtained his B.Sc., Ph.D. and D.Sc. degrees from the University of Durham, in 1977, 1981 and 2008 respectively. He is the Editor in Chief of the *IET Computer Vision Journal*, Area (i.e. deputy) Editor for *Pattern Recognition*, Area Editor for *Computer Vision and Image Understanding*, and Associate Editor of *Image and Vision Computing*. He is the fellow of the IAPR, IET, BCS and Institute of Physics. In 2009 he was awarded a Royal Society Wolfson Research Merit Award. His research interests are in statistical/structural pattern recognition, machine learning, and 3D shape reconstruction. This presentation covers some of his recent published work on graph spectral point pattern matching. Address: Department of Computer Science, University of York, Deramore Lane, York YO10 5GH, UK; E-mail: erh@cs.york.ac.uk

**Arthur A. Goshtasby** received his B.E. in Electronics Engineering from the University of Tokyo, Japan, in 1974; his M.S. in Computer Science from the University of Kentucky, Lexington, Kentucky, in 1975, and his Ph.D. in Computer Science from Michigan State University, East Lansing, Michigan, in 1983. He is currently a professor of Computer Science and Engineering at Wright State University. His areas of research are image registration, image fusion, medical image analysis, and curves and surfaces. He is the author of *2-D and 3-D Image Registration for Medical, Remote Sensing, and Industrial Applications* (Wiley Press, 2005). He organized tutorials on the same topic in CVPR 2004 and 2008 attracting large audiences. Address: Department of Computer Science and Engineering, Wright State University, Dayton, OH 45434; E-mail: arthur.goshtasby@wright.edu

**Jiri Matas** received his M.S. in Cybernetics (with honors) from the Czech Technical University, Prague, Czech Republic, in 1987 and his Ph.D. from the University of Surrey, UK, in 1995. Since 1997 he has been with the Center for Machine Perception at the Czech Technical University in Prague. He has published more than 150 papers in refereed journals and conferences. His publications have more than 3500 citations in the ISI Thomson-Reuters Science Citation Index, and his SCI H-index is 21. He received the best paper prize at the British Machine Vision Conferences in 2002 and 2005 and at the Asian Conference on Computer Vision in 2007.

Dr. Matas has served in various roles at major international conferences (e.g., ICCV, CVPR, NIPS, ECCV), co-chairing ECCV 2004 and CVPR 2007. He is on the editorial board of the International Journal of Computer Vision and serves as the Associate Editor-in-Chief of *IEEE Transactions on Pattern Analysis and Machine Intelligence*. His research interests include object recognition,

image retrieval, sequential pattern recognition, ensemble methods, invariant feature detection, and Hough Transform and RANSAC-type optimization, which is the main topic of his presentation in this tutorial. Address: Center for Machine Perception, CVUT Praha, Guilding G, Office 1, Karlovo namesti 13, 121 35 Czech Rep.; E-mail: matas@cmp.felk.cvut.cz

**Jean-Michel Morel** received his PhD in Applied Mathematics from University Pierre et Marie Curie, Paris, France in 1980. He started his career in 1979 as an Assistant Professor in Marseille Luminy. In 1984 he moved to University Paris-Dauphine where he was promoted to the rank of Professor in 1992. He has been a Professor of Applied Mathematics at the Ecole Normale Supérieure de Cachan since 1997. His research focuses on the mathematical aspects of image analysis and processing. He has coauthored with S. Solimini *Variational Methods in Image Segmentation* (Birkhäuser 1994), coauthored with Agnès Desolneux and Lionel Moisan *From Gestalt Theory to Image Analysis: A Probabilistic Approach* (Springer, 2008), and also is a coauthor of *A Theory of shape identification* (Springer LNM, 2008). Address: CMLA, ENS Cachan, 61 Avenue du Prèsident Wilson, F-94230 Cachan, France; E-mail: morel@cmla.ens-cachan.fr

**Nathan S. Netanyahu** is an Associate Professor in the Department of Computer Science at Bar-Ilan University, Israel, and is also affiliated with the Brain Research Center at Bar-Ilan University and the Center for Automation Research at the University of Maryland, College Park. He has previously worked for the Israeli Ministry of Defense, the Space Data and Computing Division at NASA's Goddard Space Flight Center (GSFC), and for the Center for Excellence in Space Data and Information Sciences (CESDIS) at NASA GSFC. Professor Netanyahu's main research interests are in the areas of algorithm design and analysis, computational geometry, image processing, pattern recognition, remote sensing, and robust statistical estimation. He has coauthored nearly 70 refereed papers that appeared in journals, international conference proceedings, and book chapters, has served as Associate Editor for *Pattern Recognition*, and is co-editor of the book, *Image Registration for Remote Sensing*, to be published shortly by Cambridge University Press. Address: Department of Computer Science, Bar Ilan University, Ramat Gan 52900, Israel; E-mail: nathan@cfar.umd.edu

**Frédéric Sur** is an Assistant Professor at Ecole des Mines de Nancy (France) since 2006 and conducts research at INRIA (LORIA laboratory). His research interests include statistical methods for computer vision. He defended his Ph.D. dissertation in Applied Mathematics and Image Analysis in 2004 at Ecole Normale Supérieure de Cachan and then held a postdoctoral position on statistical learning theory at LORIA. He will be presenting some of his published research on view-invariant matching in this tutorial. Address: Loria bat. C – project Magrit, Campus Scientifique – BP 239, 54506 Vandoeuvre-lès-Nancy cedex, France; E-mail: frederic.sur@loria.fr

**Guoshen Yu** received his B.Sc. in Electronics Engineering from Fudan University, Shanghai, China, in 2003 and his Ph.D. in Applied Mathematics from Ecole Polytechnique, Palaiseau, France, in 2009. He is currently a Postdoctoral Fellow in the Department of Electrical and Computer Engineering, University of Minnesota, Minneapolis, MN. In spring 2008, he was a visiting graduate student in the Department of Mechanical Engineering, Massachusetts Institute

of Technology (MIT), Cambridge, MA. Together with Dr. Morel at CMAP Polytechnique, he developed an affine invariant descriptor known as ASIFT, which is the main topic of his presentation in this tutorial. Address: Department of Electrical and Computer Engineering, University of Minnesota, 200 Union St. SE, Minneapolis, MN 55455; E-mail: yu@cmap.polytechnique.fr