Visual object recognition in machine intelligence

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Summary of the tutorial

Machine intelligence is a very broad area consisting of several components, methods and approaches. One of its most important part is understanding visual information. A key task of image understanding is an automatic recognition of objects in the visual field of the camera/robot. The aim of the tutorial is to present a general background of supervised learning and classification techniques (on the introductory level) and selected feature-based techniques for object description.

The tutorial consists of two following parts.

Supervised classification techniques

In the first part we explain the idea of supervised machine learning and review all major techniques - NN and k-NN classifiers, linear classifiers, support vector machines (SVM) and Bayessian classifier. This part has an introductory character but contains also some techniques which are not commonly known.

At the end of this part the audience should understand that object recognition is a classification problem in a proper metric feature space and should know how basic classification approaches work.

Features for object description

In the second part, the attention is paid to proper object representation, i.e. to the definition of the feature space in which the recognition will be carried out. We start with the explanation of the basic requirements imposed on the features – *invariance* and *discriminability*.

Invariance means that the features are insensitive to object deformations and other intra-class variations. Discriminability, on the other hand, ensures that objects belonging to different classes, must have significantly different feature values. Clearly, these two requirements are antagonistic – the broader the invariance, the less discrimination power and vice versa. Choosing a proper trade-off between invariance and discrimination power is a very important task in feature-based object recognition.

The existing invariant features used for describing 2D objects can be categorized from various points of view. Categorization according to the mathematical tools used may be as follows.

- *Simple shape descriptors* – compactness, convexity, elongation, etc.

- *Transform coefficient features* are calculated from a certain transform of the image – Fourier descriptors, Hadamard descriptors, Radon transform coefficients, and wavelet-based features.
- *Point set invariants* use positions of dominant points.
- *Differential invariants* employ derivatives of the object boundary.
- *Moment invariants* are special functions of image moments.

Another viewpoint reflects what part of the object is needed to calculate the invariant.

- *Global* invariants are calculated from the whole image (including background if no segmentation was performed). Most of them include projections of the image onto certain basis functions and are calculated by integration. Comparing to local invariants, global invariants are much more robust with respect to noise, inaccurate boundary detection and other similar factors. On the other hand, their serious drawback is the fact, that a local change of the image influences values of all invariants and is not "localized" in a few components only. This is why global invariants cannot be used when the studied object is partially occluded by another object and/or when a part of it is out of the visual field.
- *Local* invariants are, on the contrary, calculated from a certain neighborhood of dominant points only.

After a brief review of the main feature categories, we will pay a special attention to *moment invariants*. Moment invariants have become one of the most important and most frequently used shape descriptors. Even though they suffer from certain intrinsic limitations (the worst of which is their globalness, which prevents direct utilization for occluded object recognition), they frequently serve as "first-choice descriptors" and as a reference method for evaluating the performance of other shape descriptors.

In this tutorial, many practical examples and results from various application areas will be presented. We will show the applications in robot vision, remote sensing, character and logo recognition, medicine, and others.

Required knowledge

There is no specific required knowledge of the tutorial participants except standard undergraduate courses. The tutorial is mostly self-contained.

Target audience and time allocation

The target audience of the tutorial are researchers and practitioners from various application areas who are interested in automatic object recognition. Time allocation is three hours.

Supplementary reading

The first part of the tutorial is well covered by the following books.

- Duda, Hart, Stork, *Pattern Classification*, (2nd ed.), John Wiley, New York, 2001,
- Theodoridis, Koutroumbas, *Pattern Recognition*, (4th ed.), Academic Press, 2009.

The second part is based on the book authored by the presenter

- Flusser J., Suk T., Zitová B. : *Moments and Moment Invariants in Pattern Recognition*, Wiley, 2009.

The speaker's qualification

Jan Flusser received the M.Sc. degree in mathematical engineering from the Czech Technical University, Prague, Czech Republic in 1985 and the Ph.D. degree in computer science from the Czechoslovak Academy of Sciences in 1990. Since 1985 he has been with the Institute of Information Theory and Automation, Academy of Sciences of the Czech Republic, Prague. In 1995-2007 he was holding the position of a head of Department of Image Processing. In 2007 he was appointed the Director of the Institute. Since 1991 he has been also affiliated with the Faculty of Mathematics and Physics, Charles University, Prague and with the Czech Technical University, Prague (full professorship in 2004), where he gives undergraduate and graduate courses on Digital Image Processing and Pattern Recognition and specialized graduate course on Invariants and wavelets. He has research and teaching experience from many universities and institutions worldwide.

Jan Flusser has a 25-years experience in basic and applied research on the field of image analysis, pattern recognition, and machine learning. He has been involved in applications in remote sensing, medicine, and astronomy. He has authored and coauthored more than 200 research publications in these areas. He has presented more than 20 tutorials and invited/keynote talks at international conferences (ICIP'05, ICIP'07, EUSIPCO'07, CVPR'08, FUSION'08, SPPRA'09, SCIA'09, ICIP'09, SPPRA'10 and CGIM'10, ICCS'06, COMPSTAT'06, WIO'06, DICTA'07, CGIM'10, AIA'14). Some of his journal papers became classical and are frequently cited (Google Scholar lists more than 10 000 citations of J. Flusser's publications).

Selected publications

Book

Flusser J., Suk T., Zitová B. : *Moments and Moment Invariants in Pattern Recognition*, Wiley & Sons Ltd., 2009, 317 pp., ISBN 978-0-470-69987-4, http://zoi.utia.cas.cz/moment_invariants

Journal papers

Flusser J. : "An Adaptive Method for Image Registration", *Pattern Recognition*, vol. 25, pp. 45-54, 1992

Flusser J., Suk T. : "Pattern Recognition by Affine Moment Invariants", *Pattern Recognition*, vol. 26, pp. 167-174, 1993

Matúš F., Flusser J. : "Image Representations via a Finite Radon Transform", *IEEE Trans. Pattern Anal. Mach. Intell.*, vol. 15, pp. 996-1006, 1993

Flusser J., Suk T. : "Affine Moment Invariants: A New Tool for Character Recognition", *Pattern Recognition Letters*, vol. 15, pp. 433-436, 1994

Flusser J., Suk T. : "A Moment-Based Approach to Registration of Images with Affine Geometric Distortion", *IEEE Trans. Geosci. Remote Sensing*, vol. 32, pp. 382-387, 1994

Flusser J. : "Object Matching by means of Matching Likelihood Coefficients", *Pattern Recognition Letters*, vol. 16, pp. 893-900, 1995

Flusser J., Suk T., Saic S. : Image Features Invariant with Respect to Blur", *Pattern Recognition*, vol. 28, pp. 1723-1732, 1995

Flusser J., Suk T., Saic S. : "Recognition of Blurred Images by the Method of Moments", *IEEE Trans. Image Proc.*, vol. 5, pp. 533-538, 1996

Suk T., Flusser J. : "Vertex-Based Features for Recognition of Projectively Deformed Polygons", *Pattern Recognition*, vol. 29, pp. 361-368, 1996

Flusser J., Suk T. : "Classification of Degraded Signals by the Method of Invariants", *Signal Processing*, vol. 60, pp. 243-249, 1997

Flusser J., Suk T. : "Degraded Image Analysis: An Invariant Approach", *IEEE Trans. Pattern Anal. Mach. Intell.*, vol. 20, pp. 590-603, 1998

Zitová B., Flusser J. : "Landmark Recognition using Invariant Features", *Pattern Recognition Letters*, vol. 20, pp. 541-547, 1999

Flusser J., Zitová B. : "Combined Invariants to Linear Filtering and Rotation", *Int'l. J. Pattern Recognition Art. Intell.*, vol. 13, pp. 1123-1136, 1999

Suk T., Flusser J. : "Point-Based Projective Invariants", *Pattern Recognition*, vol. 33, pp. 251-261, 2000

Flusser J. : "On the Independence of Rotation Moment Invariants", *Pattern Recognition*, vol. 33, pp. 1405-1410, 2000

Flusser J. : "Refined Moment Calculation using Image Block Representation", *IEEE Trans. Image Proc.*, vol. 9, pp. 1977-1978, 2000

Flusser J., Boldyš J., Zitová B. : "Invariants to Convolution in Arbitrary Dimensions", *J. Mathematical Imaging and Vision*, vol. 13, pp. 101-113, 2000

Kautsky J., Flusser J., Zitová B., Šimberová S. : "A New Wavelet-Based Measure of Image Focus", *Pattern Recognition Letters*, vol. 23, pp. 1785-1794, 2002

Flusser J. : "On the Inverse Problem of Rotation Moment Invariants", *Pattern Recognition*, vol. 35, pp. 3015-3017, 2002

Flusser J. : "Affine Invariants of Convex Polygons", *IEEE Trans. Image Proc.*, vol. 11, pp. 1117-1118, 2002

Flusser J., Boldyš J., Zitová B. : "Moment Forms Invariant to Rotation and Blur in Arbitrary Number of Dimensions", *IEEE Trans. Pattern Anal. Mach. Intell.*, vol. 25, pp. 234-246, 2003

Šroubek F., Flusser J. : "Multichannel Blind Iterative Image Restoration", *IEEE Trans. Image Proc.*, vol. 12, pp. 1094-1106, 2003

Zitová B., Flusser J. : "Image Registration Methods: A Survey", *Image and Vision Computing*, vol. 21, pp. 977-1000, 2003

Suk T., Flusser J. : "Combined Blur and Affine Moment Invariants and their Use in Pattern Recognition", *Pattern Recognition*, vol. 36, pp. 2895-2907, 2003

Zitová B., Flusser J., Šroubek F. : "An Application of Image Processing in the Medieval Mosaic Conservation", *Pattern Analysis and Applications*, vol. 7, pp. 18-25, 2004

Suk T., Flusser J. : "Projective Moment Invariants", *IEEE Trans. Pattern Anal. Mach. Intell.*, vol. 26, pp. 1364-1367, 2004

Šroubek F., Flusser J. : "Multichannel Blind Deconvolution of Spatially Misaligned Images", *IEEE Trans. Image Processing*, vol. 14, pp. 874-883, 2005

Šroubek F., Flusser J. : "Resolution Enhancement via Probabilistic Deconvolution of Multiple Degraded Images", *Pattern Recognition Letters*, vol. 27, pp. 287-293, 2006

Flusser J., Suk T. : "Rotation Moment Invariants for Recognition of Symmetric Objects", *IEEE Trans. Image Proc.*, vol. 15, pp. 3784-3790, 2006

Šroubek F., Cristobal G., Flusser J., : "A Unified Approach to Superresolution and Multichannel Blind Deconvolution", *IEEE Trans. Image Processing*, vol. 16, pp. 2322-2332, 2007

Krolupper F., Flusser J. : "Polygonal Shape Description for Recognition of Partially Occluded Objects", *Pattern Recognition Letters*, vol. 28, pp. 1002-1011, 2007

Šorel M., Flusser J. : "Space-Variant Restoration of Images Degraded by Camera Motion Blur", *IEEE Trans. Image Proc.*, vol. 17, pp. 105-116, 2008

Horacek O., Kamenicky J., Flusser J. : "Recognition of Partially Occluded and Deformed Binary Objects", *Pattern Recognition Letters*, vol. 29, pp. 360-369, 2008

Boldyš J., Flusser J. : "Extension of Moment Features Invariance to Blur", *J. Mathematical Imaging and Vision*, vol. 32, pp. 227-238, 2008

Šroubek F., Cristobal G., Flusser J., : "Super-Resolution and Blind Deconvolution for Rational Factors with an Application to Color Images", *The Computer Journal*, vol. 52, pp. 142-152, 2009

Bican J., Flusser J. : "3D Rigid Registration by Cylindrical Phase Correlation Method", *Pattern Recognition Letters*, vol. 30, pp. 914-921, 2009

Flusser J., Kautsky J., Šroubek F. : "Implicit Moment Invariants", *Int'l. J. Computer Vision*, vol. 86, pp. 72-86, 2010

Suk T., Flusser J. : "Affine Moment Invariants Generated by Graph Method", *Pattern Recognition*, vol. 44, pp. 20472056, 2011

Kautsky J., Flusser J. : "Blur Invariants Constructed from Arbitrary Moments", *IEEE Trans. Image Proc.*, vol. 20, pp. 3606-3611, 2011

Suk T., Hoschl C., Flusser J. : "Decomposition of Binary Images - A Survey and Comparison", *Pattern Recognition*, vol. 45, No. 12, pp. 42794291, 2012

Pedone M., Flusser J., Heikkila J. : "Blur Invariant Translational Image Registration for N-fold Symmetric Blurs", *IEEE Trans. Image Proc.*, vol. 22, No. 9, pp. 3676-3689, 2013

Yang B., Flusser J., Suk T. : "Steerability of Hermite Kernel", *Int'l. J. Pattern Recognition and Art. Intell.*, vol. 27, No. 4, pp. 1-25, 2013

Honarvar B., Flusser J. : "Fast Computation of Krawtchouk Moments", *Information Sciences*, vol. 288, pp. 7386, 2014

Suk T., Flusser J.: "Recognition of Symmetric 3D Bodies", *Symmetry*, vol. 6, No. 3, pp. 722-757, 2014

Flusser J., Suk T., Boldys J., Zitova B. : "Projection Operators and Moment Invariants to Image Blurring", *IEEE Trans. PAMI*, DOI:10.1109/TPAMI.2014.2353644, 2014