Int J Comput Vis
DOI 10.1007/s11263-013-0634-z

Rotation-Invariant HOG Descriptors Using Fourier Analysis in Polar and Spherical Coordinates

Kun Liu · Henrik Skibbe · Thorsten Schmidt · Thomas Blein · Klaus Palme · Thomas Brox · Olaf Ronneberger

Received: 30 September 2012 / Accepted: 21 May 2013

Abstract The histogram of oriented gradients (HOG) is widely used for image description and proves to be very effective. In many vision problems, rotation-invariant analysis is necessary or preferred. Popular solutions are mainly based on pose normalization or learning, neglecting some intrinsic properties of rotations. This paper presents a method to build rotation-invariant HOG descriptors using Fourier analysis in polar/spherical coordinates, which are closely related to the irreducible representation of the 2D/3D rotation groups. This is achieved by considering a gradient histogram as a continuous angular signal which can be well represented by the Fourier basis (2D) or spherical harmonics (3D). As rotation-invariance is established in an analytical way, we can avoid discretization artifacts and create a continuous mapping from the image to the feature space. In the experiments, we first show that our method outperforms the state-of-the-art in a public dataset for a car detection task in aerial images. We further use the Princeton Shape Benchmark and the SHREC 2009 Generic Shape Benchmark to demonstrate the high performance of our method for similarity measures of 3D shapes. Finally, we show an application on microscopic volumetric data.

Keywords Rotation-invariance · Image descriptor · Fourier analysis · Spherical harmonics · Histogram of oriented gradients · Feature design · Volumetric data

All authors are part of the BIOSS Centre for Biological Signalling Studies, University of Freiburg.

K. Liu (✉) · H. Skibbe · T. Schmidt · T. Brox · O. Ronneberger
Department of Computer Science, University of Freiburg,
79110 Freiburg, Germany
e-mail: liu@cs.uni-freiburg.de
URL: http://lmb.informatik.uni-freiburg.de/

H. Skibbe
e-mail: skibbe-h@sys.i.kyoto-u.ac.jp

T. Schmidt
e-mail: tschmidt@cs.uni-freiburg.de

T. Brox
e-mail: brox@cs.uni-freiburg.de

O. Ronneberger
e-mail: ronneber@cs.uni-freiburg.de

Present address:
H. Skibbe
Integrated Systems Biology Lab., Department of Systems Science,
Kyoto University, Kyoto 611-0011, Japan

T. Blein · K. Palme
Institute of Biology II (Botany), University of Freiburg,
79104 Freiburg, Germany
e-mail: thomas.blein@versailles.inra.fr

K. Palme
e-mail: klaus.palme@biologie.uni-freiburg.de

Present address:
T. Blein
Institut Jean-Pierre Bourgin, INRA Centre de Versailles-Grignon,
78026 Versailles, France

1 Introduction

A good image descriptor should be able to capture substantial image patterns and be robust to object deformation or other common transformations. Gradient histogram based features, like HOG (Histogram-of-Oriented-Gradients, Dalal and Triggs 2005), are widely used for 2D image description. They prove to be very robust, and work as a key component of state-of-the-art object recognition frameworks (*e.g.,* Felzenszwalb et al. 2010; Bourdev and Malik 2009). The HOG descriptor employs a histogram binning on the gradient orientation and a spatial aggregation with soft binning. The spatial aggregation cancels out fine details of spatial place-

Published online: 07 June 2013