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Speeded-Up Robust Features (SURF)

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Abstract

This article presents a novel scale- and rotation-invariant detector and descriptor, coined SURF (Speeded-Up Robust Features). SURF approximates or even outperforms previously proposed schemes with respect to repeatability, distinctiveness, and robustness, yet can be computed and compared much faster.

This is achieved by relying on integral images for image convolutions; by building on the strengths of the leading existing detectors and descriptors (specifically, using a Hessian matrix-based measure for the detector, and a distribution-based descriptor); and by simplifying these methods to the essential. This leads to a combination of novel detection, description, and matching steps.

The paper encompasses a detailed description of the detector and descriptor and then explores the effects of the most important parameters. We conclude the article with SURF's application to two challenging, yet converse goals: camera calibration as a special case of image registration, and object recognition. Our experiments underline SURF's usefulness in a broad range of topics in computer vision.

Keywords: Interest points; Local features; Feature description; Camera calibration; Object recognition

1. Introduction

The task of finding point correspondences between two images of the same scene or object is part of many computer vision applications. Image registration, camera calibration, object recognition, and image retrieval are just a few.

The search for discrete image point correspondences can be divided into three main steps. First, 'interest points' are selected at distinctive locations in the image, such as corners, blobs, and T-junctions. The most valuable property of an interest point *detector* is its repeatability. The repeatability expresses the reliability of a detector for finding the same physical interest points under different viewing conditions. Next, the neighbourhood of every interest point is represented by a feature vector. This *descriptor* has to be distinctive and at the same time robust to noise, detection displacements and geometric and photometric deformations. Finally, the descriptor vectors are *matched* between different images. The matching is based on a distance between the vectors, e.g. the Mahalanobis or Euclidean distance. The dimension of the descriptor has a direct impact on the time this takes, and less dimensions are desirable for fast interest point matching. However, lower dimensional feature vectors are in general less distinctive than their high-dimensional counterparts.

It has been our goal to develop both a detector and descriptor that, in comparison to the state-of-the-art, are fast to compute while not sacrificing performance. In order to succeed, one has to strike a balance between the above requirements like simplifying the detection scheme while keeping it accurate, and reducing the descriptor's size while keeping it sufficiently distinctive.

A wide variety of detectors and descriptors have already been proposed in the literature (e.g. [21,24,27,39,25]). Also, detailed comparisons and evaluations on benchmarking datasets have been performed [28,30,31]. Our fast detector and descriptor, called SURF (Speeded-Up Robust

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