Fast Explicit Diffusion for Accelerated Features in Nonlinear Scale Spaces

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We propose a novel and fast multiscale feature detection and description approach that exploits the benefits of nonlinear scale spaces. Previous attempts to detect and describe features in nonlinear scale spaces such as KAZE [1] and BFSIFT [6] are highly time consuming due to the computational burden of creating the nonlinear scale space. In this paper we propose to use recent numerical schemes called *Fast Explicit Diffusion* (FED) [3, 4] embedded in a pyramidal framework to dramatically speed-up feature detection in nonlinear scale spaces. In addition, we introduce a *Modified-Local Difference Binary* (M-LDB) descriptor that is highly efficient, exploits gradient information from the nonlinear scale space, is scale and rotation invariant and has low storage requirements. Our features are called *Accelerated-KAZE* (A-KAZE) due to the dramatic speed-up introduced by FED schemes embedded in a pyramidal framework.

1 Accelerated KAZE Features

Building the nonlinear scale space. We use FED schemes for building a nonlinear scale space from which we can detect and describe features. By means of FED schemes, a nonlinear scale space can be built much faster than with any other kind of discretization scheme. Furthermore, FED schemes are extremely easy to implement and are more accurate than revious approaches such as *Additive Operator Splitting* (AOS) [7]. The main idea is to perform M cycles of n explicit diffusion steps with varying step sizes τ_j that originate from the factorization of a box filter:

$$\tau_j = \frac{\tau_{max}}{2\cos^2\left(\pi\frac{2j+1}{4n+2}\right)} \tag{1}$$

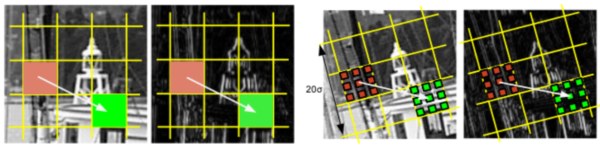
Feature Detection. We compute the determinant of the Hessian for each of the filtered images L^i in the nonlinear scale space. The set of differential multiscale operators are normalized with respect to scale, using a normalized scale factor that takes into account the octave of each particular image in the nonlinear scale space. Then, we search for maxima of the detector response in scale and spatial location.

$$L^i_{Hessian} = \sigma^2_{i,norm}\left(L^i_{xx}L^i_{yy} - L^i_{xy}L^i_{xy}\right) . \tag{2}$$

Feature Description. We propose a *Modified-Local Difference Binary* (M-LDB) that exploits gradient and intensity information from the nonlinear scale space. The LDB descriptor was introduced in [8] and follows the same principle as BRIEF [2], but using binary tests between the average of areas instead of single pixels for additional robustness. In addition to the intensity values, the mean of the horizontal and vertical derivatives in the areas being compared is used, resulting in 3 bits per comparison. Rotation invariance is obtained by estimating the main orientation of the keypoint as in KAZE, and the grid of LDB rotated accordingly. Instead of using the average of all pixels inside each subdivision of the grid, we subsample the grids in steps that are a function of the scale σ of the feature. The scale-dependent sampling in turn makes the descriptor robust to changes in scale.

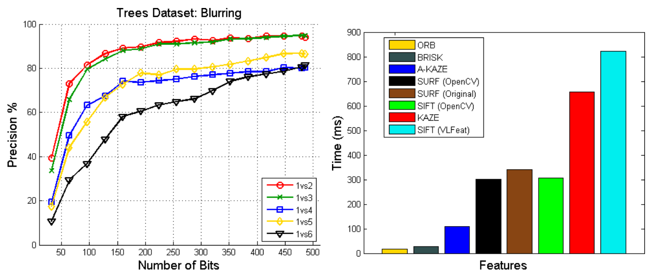
2 Evaluation

We present an extensive evaluation based on the standard Oxford benchmark [5] that shows the excellent compromise between speed and performance of our approach compared to state-of-the-art methods such as BRISK, ORB, SURF, SIFT and KAZE. While A-KAZE is more expensive to compute than BRISK and ORB, it is faster than SURF, SIFT and KAZE. More specifically, A-KAZE is several orders of magnitude faster than KAZE while providing similar or even better performance in some scenarios. In addition, due to the use of binary descriptors the matching step can be computed very efficiently using the Hamming distance.



(a) LDB binary test (b) M-LDB binary test

Figure 1: LDB [8] and proposed M-LDB binary tests between grid divisions around a keypoint, shown for the intensity and the gradients in x. M-LDB includes rotation and subsampling that depends on the scale.



(a) (b)

Figure 2: Descriptor and timing evaluation. (a) Precision vs # Bits (b) Timing evaluation for the joint method (detection and description) considering 1000 features from the first image of the Graffiti dataset.

Open Source Code. The code of the A-KAZE features is implemented in C++ using some functionalities from the OpenCV library. An open source implementation can be downloaded from: `www.robesafe.com/personal/pablo.alcantarilla/kaze.html`.

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