# Scale Normalized Radial Fourier Transform as a Robust Image Descriptor

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## Abstract

We present a new visual descriptor that combines a multi-scale Laplacian Profile (**LP**) with a Radial Discrete Fourier Transform (**RDFT**). This descriptor can be defined at every position and scale in an image and provides a local feature vector that is both discriminant and robust to changes in orientation and scale.

## Ingredients of LP-RDFT

*A. Laplacian profile (LP)*

A Half-Octave Gaussian pyramid [1] is composed of K resampled images (pyramid levels), P(x, y, k), with k∊Z, each of which has been convolved with a Gaussian filter $G(x, y, 2^{k/2})$ and resampled with a sample distance of $s_k = 2^{(k-1)/2}$.

The LP is a vector of second order Gaussian derivatives $\nabla^2 p(x, y)$ collected on adjacent levels of the pyramid. The LP function over a range of σ is:

$$LP_{xy}(\sigma_k) = < \nabla^2 G(x, y, \sigma_k), P(x, y) >$$

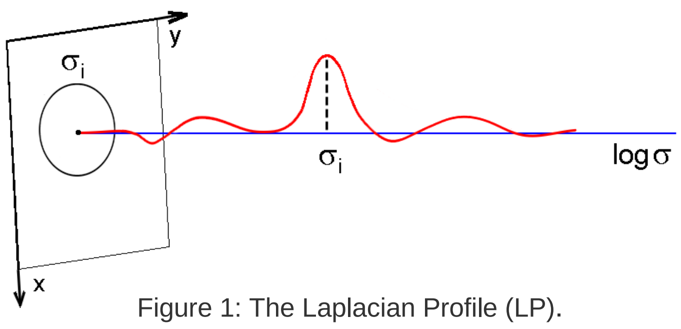


Figure 1: The Laplacian Profile (LP).

Figure 2: A LP vector describes visual appearance simultaneously in several ranges.

*B. Radial Discrete Fourier Transform (RDFT)*

- On a 4 sample neighborhood of radius = 1 in order to create small descriptor vectors for a cascade classifier. Calculate 1D RDFT on a circle of samples.
- On a disk neighborhood of variable radius in order to create more discriminative descriptor vectors for keypoint matching. Calculate 2D RDFT on a disk of samples.

In both case, use the magnitude information of the RDFT coefficients to enhance the descrimination power of the LP with rotation invariant data. Keep phase information as an indication for orientation if necessary.

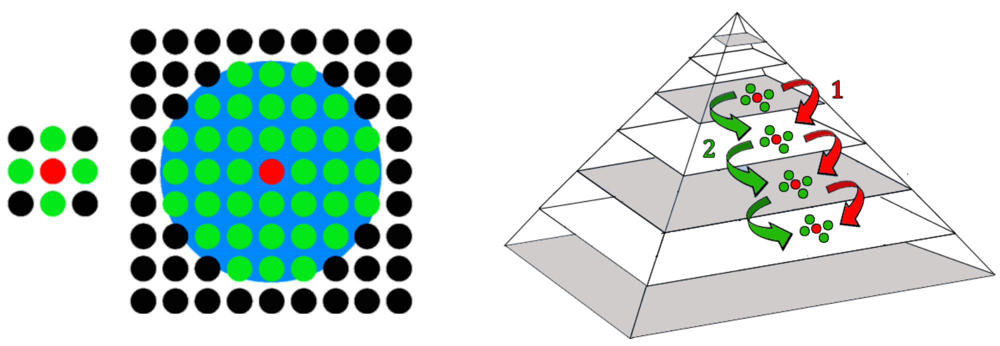


Figure 3: The central red dots represent the LP. The surrounding green dots represent possible areas for sampling for the RDFT. Right: Example of the two steps for extracting a descriptor on an image pyramid. The way is the same for LP-RDFT with either 1D or 2D RDFT.

## Experiments on detection

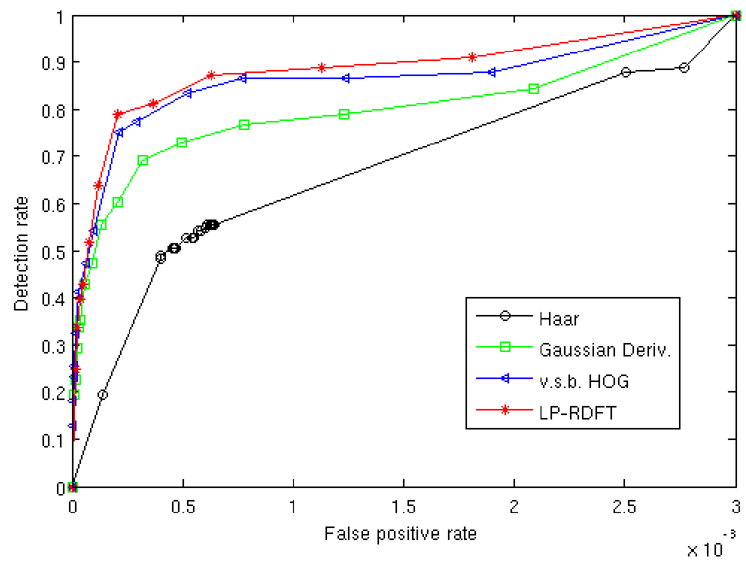


Figure 4: Comparison with Haar wavelets [Viola et al., 2001], Gaussian Derivatives [1], and variable block size HOG [Zhu et al., 2006] descriptors on INRIA Person Dataset using cascade classifiers.

## Testing Robustness for Keypoint Matching under Rotation and Scaling

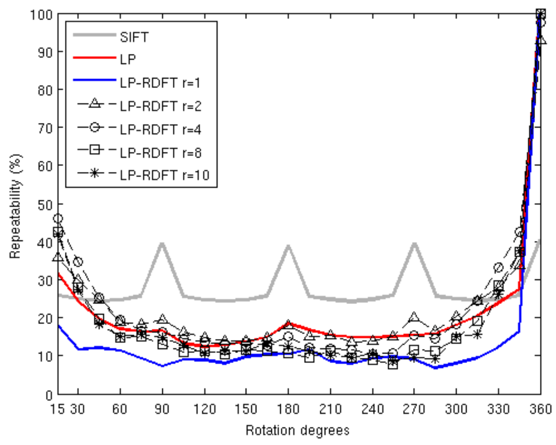


Figure 5: Comparison with SIFT [Lowe, 1999] on rotation, with 50 128×128images from the FERET face dataset.

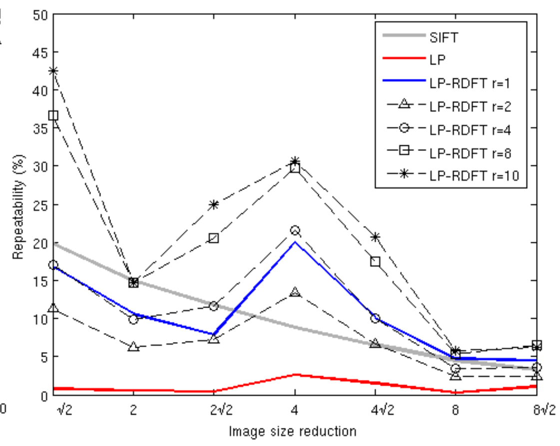


Figure 6: Comparison with SIFT [Lowe, 1999] on scaling with a set of images from the Affine Covariant Features test dataset.

| | |
|---|---|
| SIFT | $< 1$ ms |
| LP | $< 1$ ms |
| LP-RDFT r=1, k=5 | 1 ms |
| LP-RDFT r=1, k=7 | 1 ms |
| LP-RDFT r=2, k=5 | 2 ms |
| LP-RDFT r=2, k=7 | 3 ms |
| LP-RDFT r=4, k=5 | 9 ms |
| LP-RDFT r=4, k=7 | 13 ms |
| LP-RDFT r=8, k=5 | 23 ms |
| LP-RDFT r=10, k=5 | 38 ms |

- where k is the number LP vector length.
- where r is the sampling area radius for RDFT

Table 1: Computational time for one descriptor vector. Rotation tests: LP-RDFT uses k=7 with r=2 and r=4, and k=5 with r=8 and r=10. Scaling tests: LP-RDFT uses k=5 with all r.

Computation time measured on Ubuntu 10.04 LTS computer with 11.8 GiB RAM and Intel Xeon dual core hyperthreading CPU where every processor unit works with 2.33GHz.

## Conclusions

- ✔ This descriptor is an example of a new class of image descriptors that combine a Laplacian Profile with a Radial Fourier Transform.
- ✔ LP-RDFT provides a description of local image neighborhoods that can be made robust and adjustable to a variety of applications, here in particular people recognition and keypoint matching.
- ✔ The experiments showed that LP-RDFT can provide state of the art performance on detection with significantly smaller description length while providing robustness and equivariance to changes in rotation and scale.

[1] J. A. Ruiz-Hernandez, A. Lux, and J. L. Crowley. Face detection by cascade of Gaussian derivates classifiers calculated with a Half-Octave Pyramid. In FG 2008.

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