Noise Robust Local Phase Coherence Based Method for Image Sharpness Assessment

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http://www.fer.unizg.hr/_download/repository/LPCcode.zip

1. Introduction

Image sharpness assessment is a very important issue in image acquisition and processing. Novel approaches in no-reference image sharpness assessment methods are based on **local phase coherence (LPC)**, rather than edge or frequency content analysis. It has been shown that the LPC based methods are closer to human observer assessments.

We propose *carefully designed complex wavelets* that provide a good tool for the local phase estimation. Moreover, we take a *special care of noise*. We apply thresholding in the wavelet domain and *merge several estimates* to achieve statistical robustness in the presence of noise. It results in the sharpness index that over-performs previously reported methods.

2. Robust Local Phase Coherence

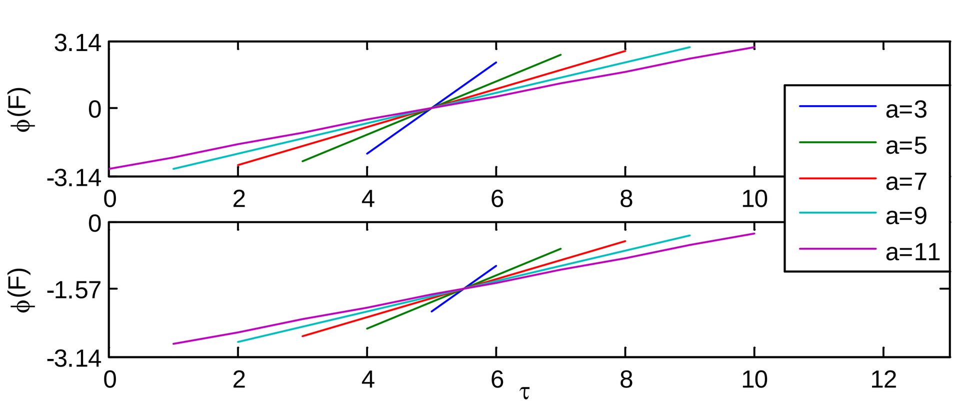
Human observer assessment of sharpness is focused on **impulses** and **steps** of 1D signals, or on **points** and **edges** in images.
Complex wavelet analysis of sharp edges across a set of scales results in locally linear phase segments that intersect in a single point → strong local linear phase coherence → LPC can be used for sharpness assessment.
We use continuous complex mother wavelet

$$\psi(t) = \left[\mu\left(t+\frac{\pi}{\omega_0}\right) - \mu\left(t-\frac{\pi}{\omega_0}\right)\right] e^{j\omega_0 t}$$

that is sampled on unit circle to produce discrete wavelet function:

$$\psi_N(n) = [\mu(n+(N-1)/2) - \mu(n-(N-1)/2)]e^{j2\pi/N\cdot n}$$

where $N \in [3,5,7,9,11]$ and $n \in \mathbb{Z}$.



→ phase of the impulse $\delta(t-5)$ in the complex wavelet domain for different scales

→ phase of the step function $\mu(t-6)$ in the complex wavelet domain for different scales

In 2D:

$$\psi_o(m,n) = \psi_k(m) \times \psi_l(n)$$

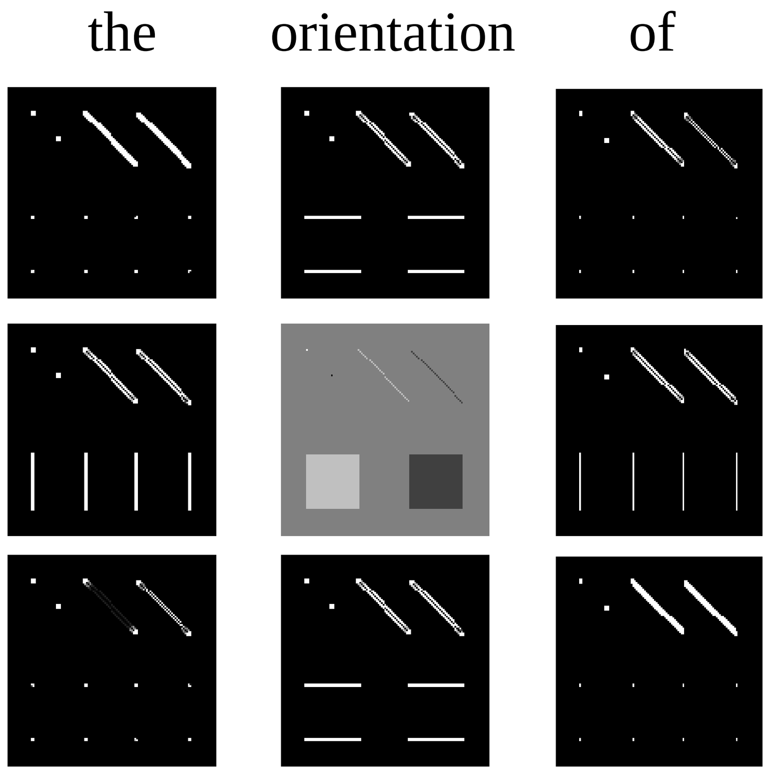
where $k, l \in \{-,0,+\}$ correspond to 9 spatial orientations o.
We propose LPC strength measure:

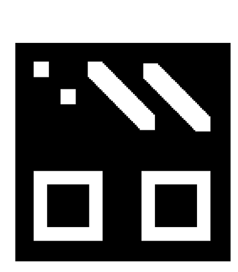
$$S_{LPC}^{\{o,k\}} = (\pi - |\mathbf{w}^T\boldsymbol{\Phi}|)/\pi$$

where $\boldsymbol{\Phi}$ is a vector of the measured phases and $\mathbf{w}$ are weights. The weights using 5 scales are: $\mathbf{w}_{\{5\}}$=[1 -2.10 -0.44 0.48 1.06]^T,
using 4 scales are: $\mathbf{w}_{\{4\}}$=[1 -2.06 -0.10 1.16]^T,
and using 3 scales are: $\mathbf{w}_{\{3\}}$=[1 -2.57 1.57]^T.

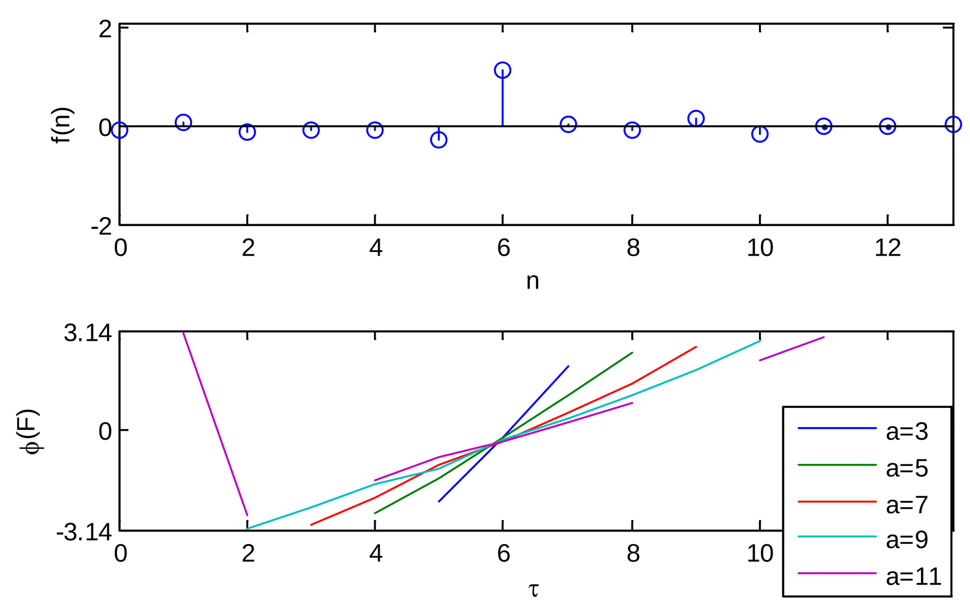
LPC strength measure is calculated for each orientation o and for each position k in the 1D signal or in the image → results strongly depend on the orientation of edges in images → Spatial LPC map is a collection of all LPC strength maps:

$$S_{LPC}^{\{k\}} = \max\left(S_{LPC}^{\{o,k\}}\right)$$





3. Phase Prediction in the Presence of Noise



in the presence of noise, the estimation of phase is not ideal

⇩

→ noisy impulse

→ phase estimates for different scales

⇩

our solution

⇩

Thresholding in the wavelet domain
if amplitude is smaller than a threshold → phase estimate is non-accurate → do not take it into the account

⬇

if phase estimates are available for all 5 scales → calculate $S_{LPC,\{5\}}$ using weights $\mathbf{w}_{\{5\}}$
if phase estimates are available for 4 scales → calculate $S_{LPC,\{4\}}$ using weights $\mathbf{w}_{\{4\}}$
if phase estimates are available only for 3 scales → calculate $S_{LPC,\{5\}}$ using weights $\mathbf{w}_{\{3\}}$

⬇

Averaged LPC strength maps S_{LPC}
weighted moving average of the LPC strength maps with 5, 4 or 3 scales

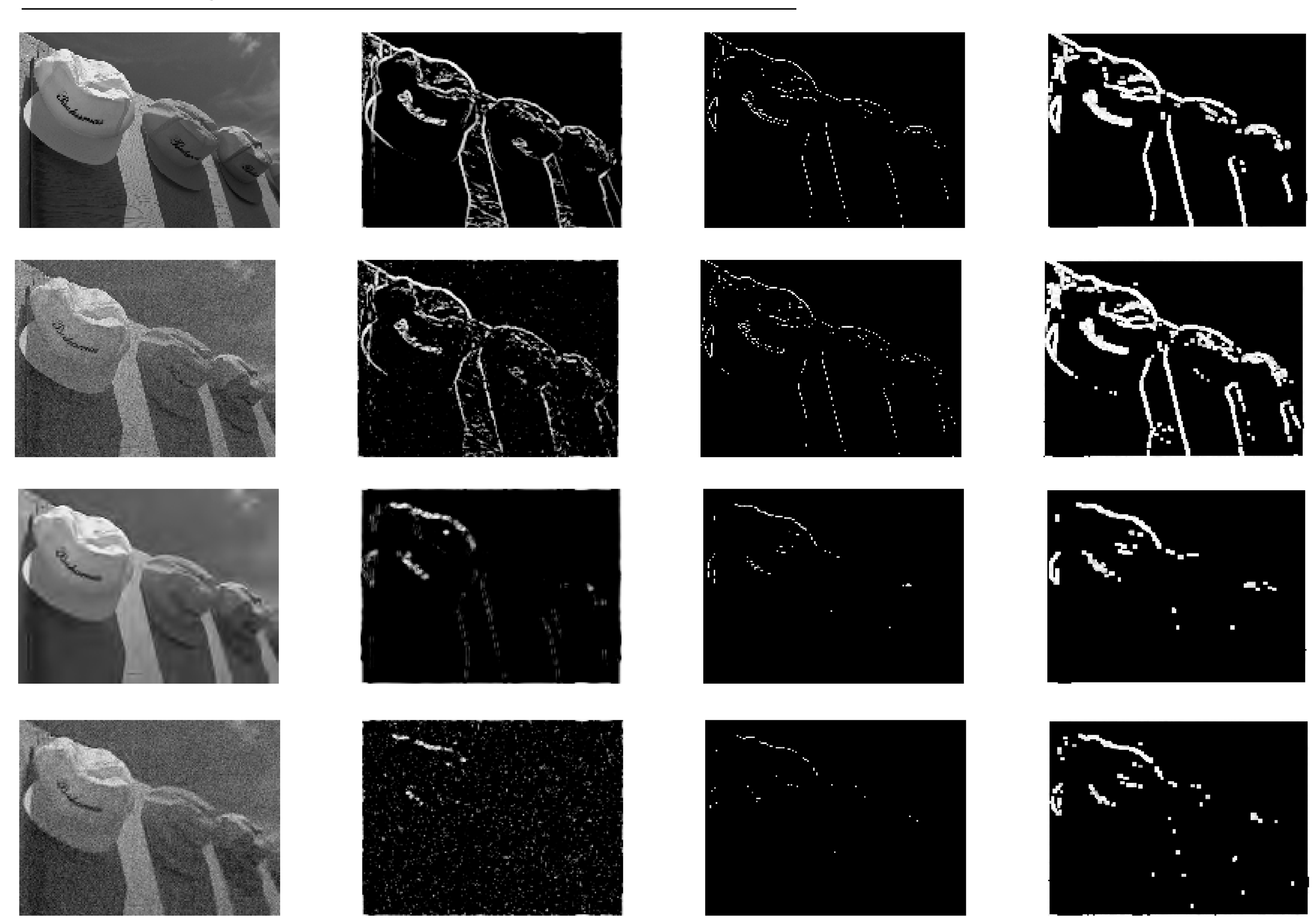
4. Results

The method is applied on real world images → rows top to bottom: hats, noisy hats, blurred hats, blurred and noisy hats.
LPC maps are found using three different methods → columns left to right: noisy real-world image, LPC map using [1], LPC map using $S_{LPC,\{5\}}$ only, LPC map using averaged S_{LPC}.

[1] R. Hassen, Z. Wang, and M. Salama, "Image sharpness assessment based on local phase coherence," *IEEE Transactions on Image Processing*, vol. 22, no. 7, pp. 2798 – 2810, 2013.

	S_{LPC} form [1]	$S_{LPC,\{5\}}$	S_{LPC}
hats	0.923	0.243	0.871
noisy hats	0.914	0.255	0.917
blurred hats	0.904	0.091	0.451
blurred noisy hats	0.879	0.056	0.431

Sharpness index [1] for image sharpness assessment:
→ 1 for totally sharp and
→ 0 for totally blurred images.



Benefits of the proposed wavelets: the resulting LPC maps are sharp, precisely reflecting the image edges and fine details → noise robust LPC estimate can be used as an edge detector, too.

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