Evolving estimators of the pointwise Hölder exponent with GP

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Our Paper

- Leonardo Trujillo, Pierrick Legrand, Gustavo Olague, and Jacques Levy-Vehel. 2012. **Evolving estimators of the pointwise Hölder exponent with Genetic Programming**. *Inf. Sci.* 209 (November 2012), 61-79.

Signal Regularity

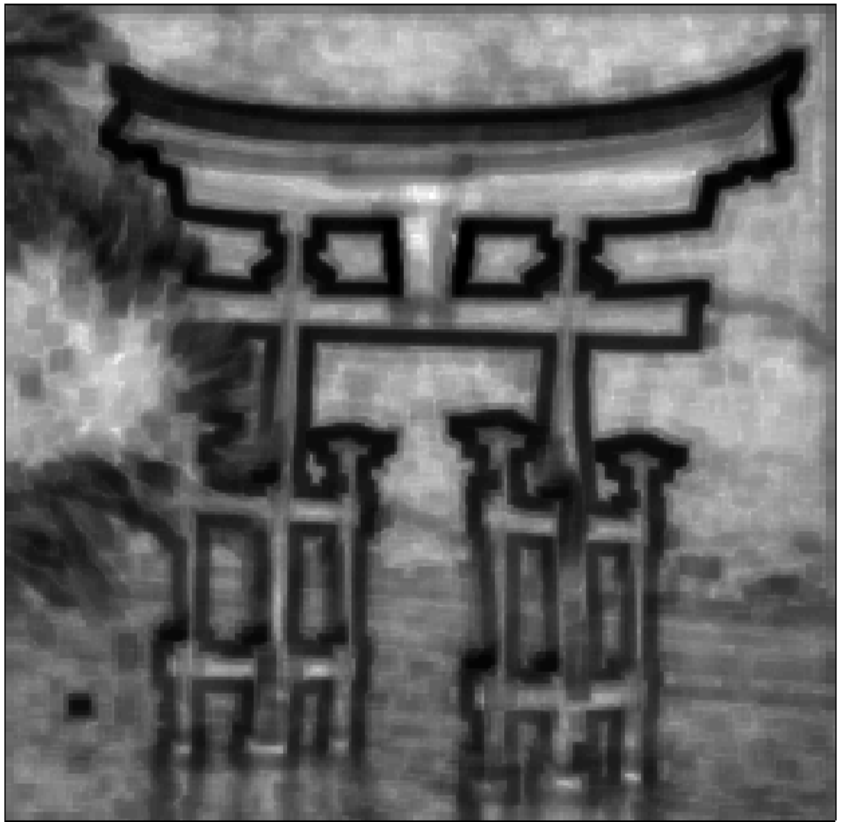
- In science and engineering there is one fundamental task: Analyzing and processing signals (natural or artificial) to extract useful information.
- However, signals can be to BIG; where is the information located?
- Usually its smart to focus where signal variation is high (for visual data, you can think of borders, corners and textured areas)

O. Le Meur, P. Le Callet, D. Barba, and D. Thoreau. 2006. A Coherent Computational Approach to Model Bottom-Up Visual Attention. IEEE Trans. Pattern Anal. Mach. Intell. 28, 5 (May 2006), 802-817.

Hölder Exponents

- Mathematical tool that measures the regularity (or smoothness) of a signal around each point.

Original Image



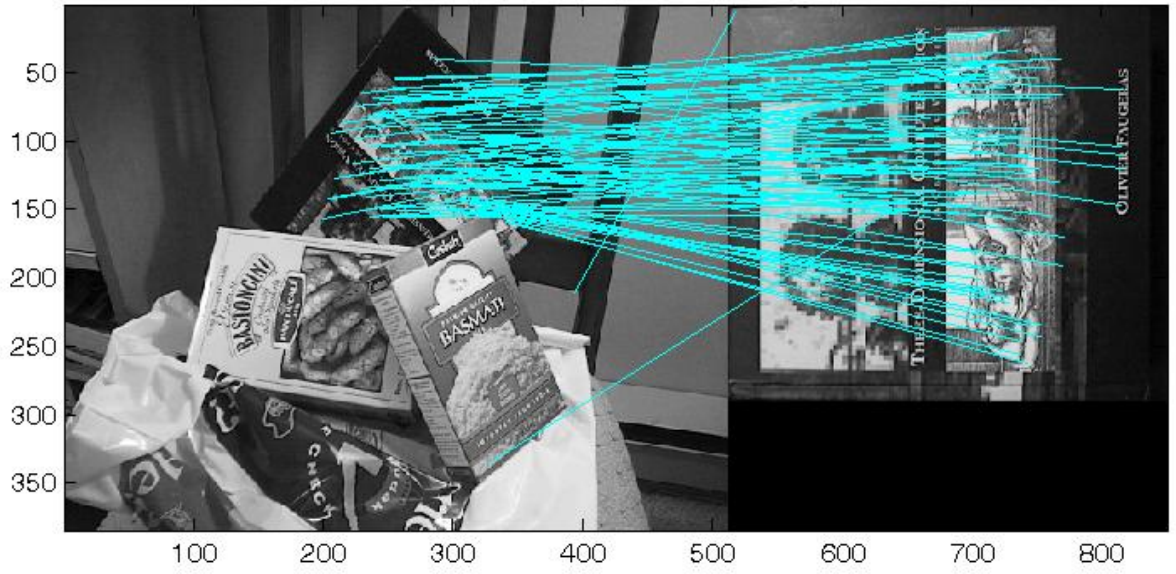
Hölder Image

General Motivation

- For real-world signals the Hölder exponent cannot be calculated, it must be estimated for each point.
- Several estimation methods exist, but most methods are SLOW or highly parameterized; therefore their use is not common (particularly in computer vision applications where speed is usually of importance)

Specific Motivation

- Apply Hölder-based regularity analysis to local image description for object and scene recognition problems in computer vision.



SIFT Features: D. Lowe, http://www.cs.ubc.ca/~lowe/keypoints/

Specific Motivation

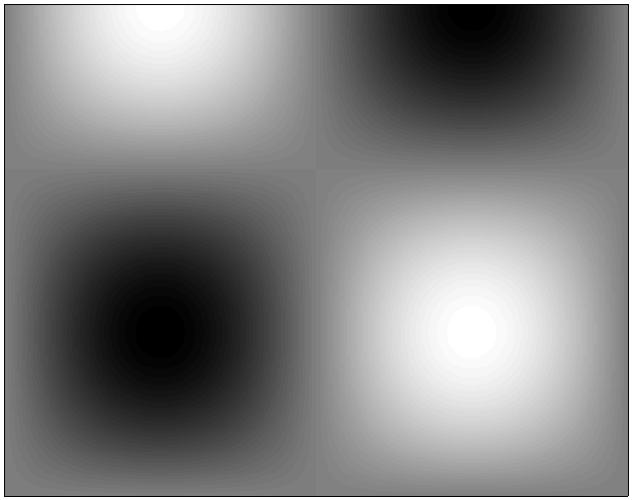
- Local image descriptors are widely used in research and commercial applications!
- Some of the best methods are too slow (SIFT) or patented (SIFT, SURF); which can prohibit their use in some cases (real-time applications or open-source projects).
- Hölder-based descriptors achieve comparable performance, but estimation methods are slow or inaccurate.

Our Work

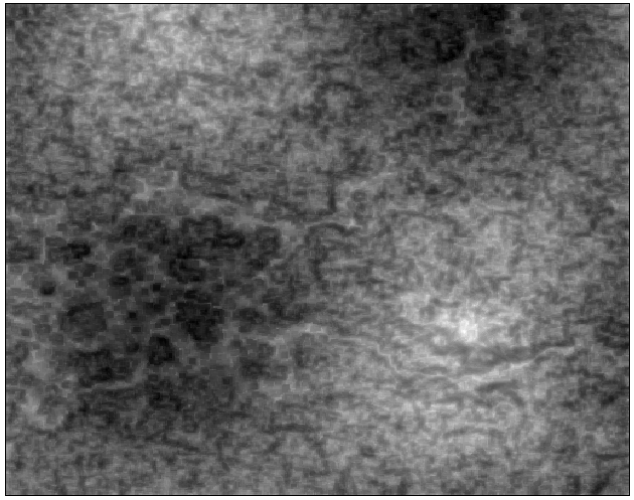
- Evolve estimators of the pointwise Hölder exponent for 2D signals with Genetic Programming!
- GP evolves estimators that are ACCURATE and FAST!
- Evolution is a one-shot process, evolved estimators can be used of-the shelf!

Results: Synthetic Images

Original Image



True Regularity



Traditional Method

GP-Estimator

Results: Real Images

Original Image

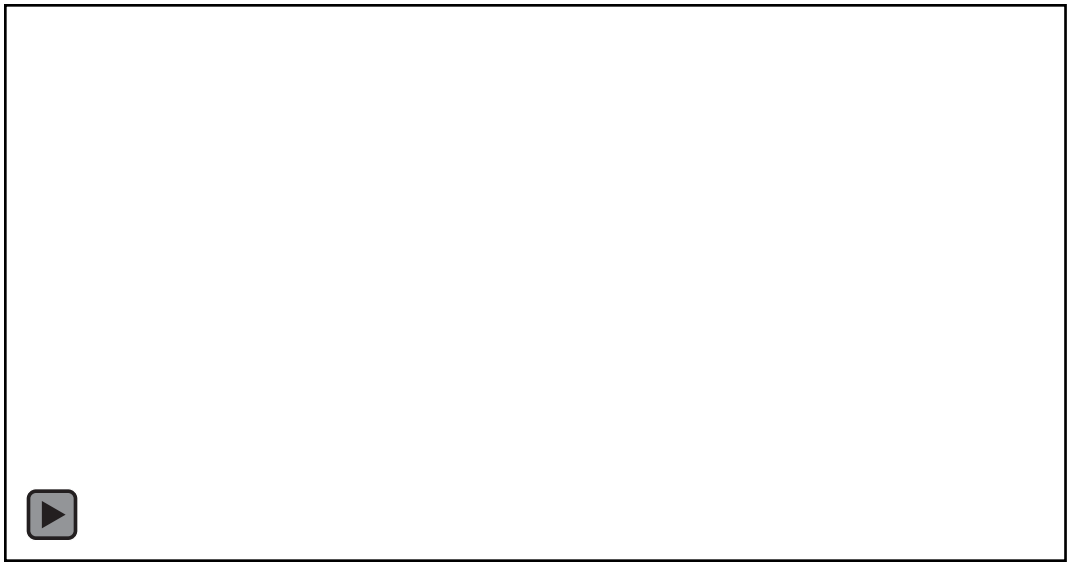
Traditional Method

GP-Estimator

GP-Estimator

Results: Time

- Traditional Methods
  - Accurate approaches (based on oscillation analysis or wavelet decomposition) require dozens or hundreds of seconds.
- Evolved GP-Estimators
  - Require tenths of a second (reported tests are in Matlab (slow), new implementations in C++ run even faster)



Results: Summary

- Evolved estimators can ..
  - Accurately estimate signal regularity (better or equal to all previous methods).
  - Perform regularity estimation in real-time (a first, faster than all previous methods!)
  - Efficiently compute local-image descriptors that are competitive with state of the art methods.

Which Criteria are Satisfied

(B) **The result is equal to or better than a result that was accepted as a new scientific result at the time when it was published in a peer-reviewed scientific journal.**

(D) **The result is publishable in its own right as a new scientific result independent of the fact that the result was mechanically created.**

(F) **The result is equal to or better than a result that was considered an achievement in its field at the time it was first discovered.**

(G) **The result solves a problem of indisputable difficulty in its field.**

Impact

- We present a GP solution to a difficult problem of applied mathematics and signal processing.
- Results allow us to expand the application domain of Hölder regularity, a powerful but mostly unexplored mathematical concept due to its inherent computational costs.
- The application domain is indeed LARGE, computer vision applications are widespread and opportunities are plentiful, in research and commercial use.

THANKS!