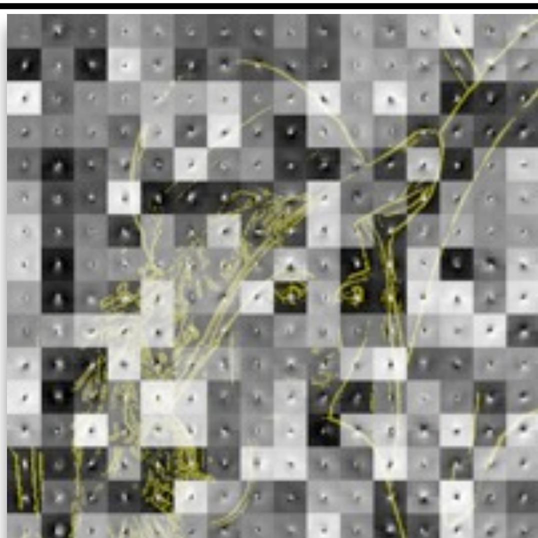
Beyond bits

Reconstructing Images from Local Binary Descriptors



Emmanuel d'Angelo

Alexandre Alahi (Stanford)

Pierre Vandergheynst

ICPR'12, Tsukuba Science City, Japan , Nov. 2012

Outline

- **Some context**
  - Motivations
  - Local Binary Descriptors
- **LBD reconstruction as an inverse problem**
  - TV-L1, non-binarized case
  - Some examples
- **Ongoing work: L1, binarized reconstruction**
  - A glimpse at our first results
- **Future work and perspectives**

Motivations

- Mobile image recognition services mostly happening «in the cloud»

http://www.kooaba.com

Motivations

- **Typical workflow:**
  - Extract features locally, send them over the network
  - «Cloud» matching
  - Send the results back
- **Possible privacy issue**
  - «feature encryption» required ?
- **But there is more:**
  - Smart cameras scenarios
  - Compressed Sensing...

Prior art: inverting SIFT

- Atypical paper, not much related work...
- **One inspiring paper (CVPR'11)**
  - SIFT + learning database + Poisson reconstruction

Weinzaepfel, P., Jegou, H., & Pérez, P. (2011). *Reconstructing an image from its local descriptors.*

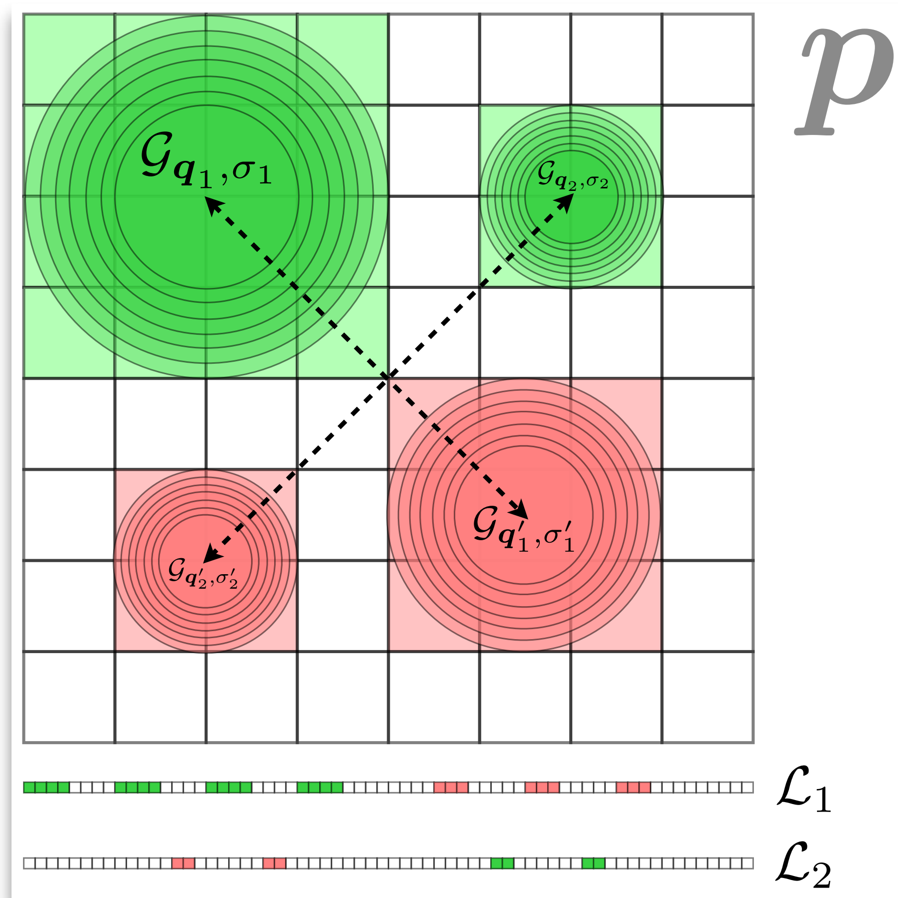
Local Binary Descriptors (LBDs)

1. Differences

$$\mathcal{L}_i = \langle \mathcal{G}_{x_i,\sigma_i}, p \rangle - \langle \mathcal{G}_{x_i',\sigma_i'}, p \rangle$$

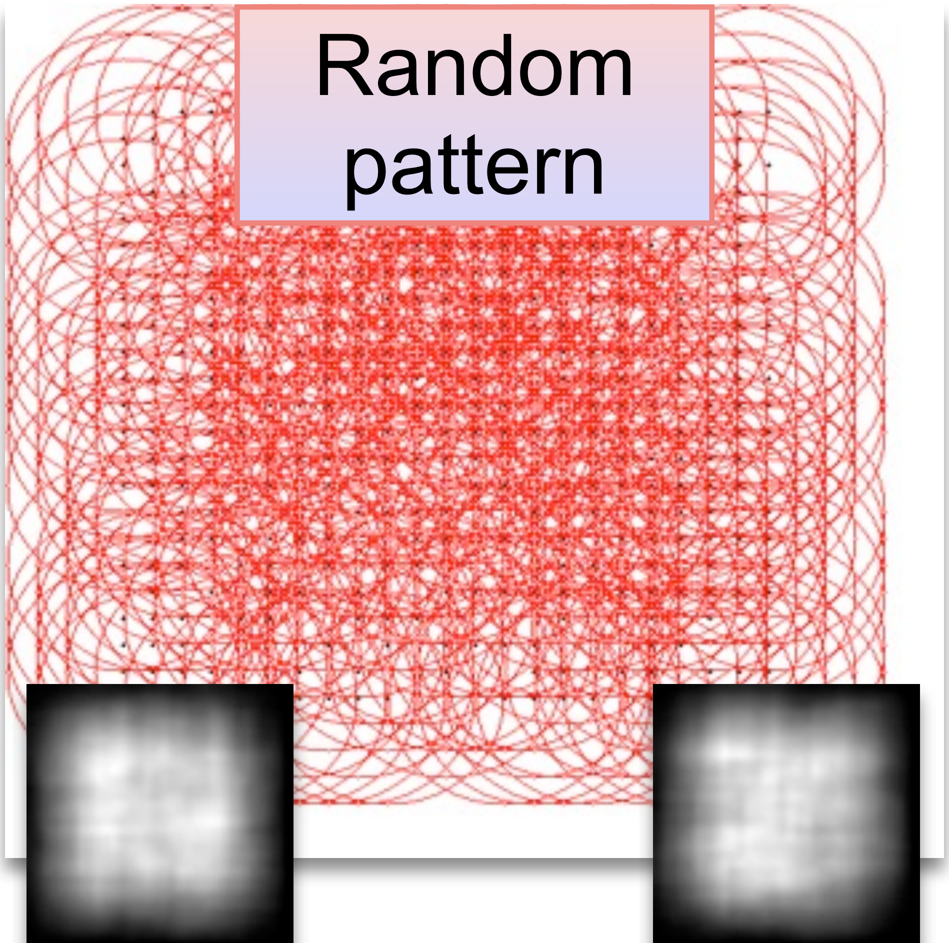
2. Binarization

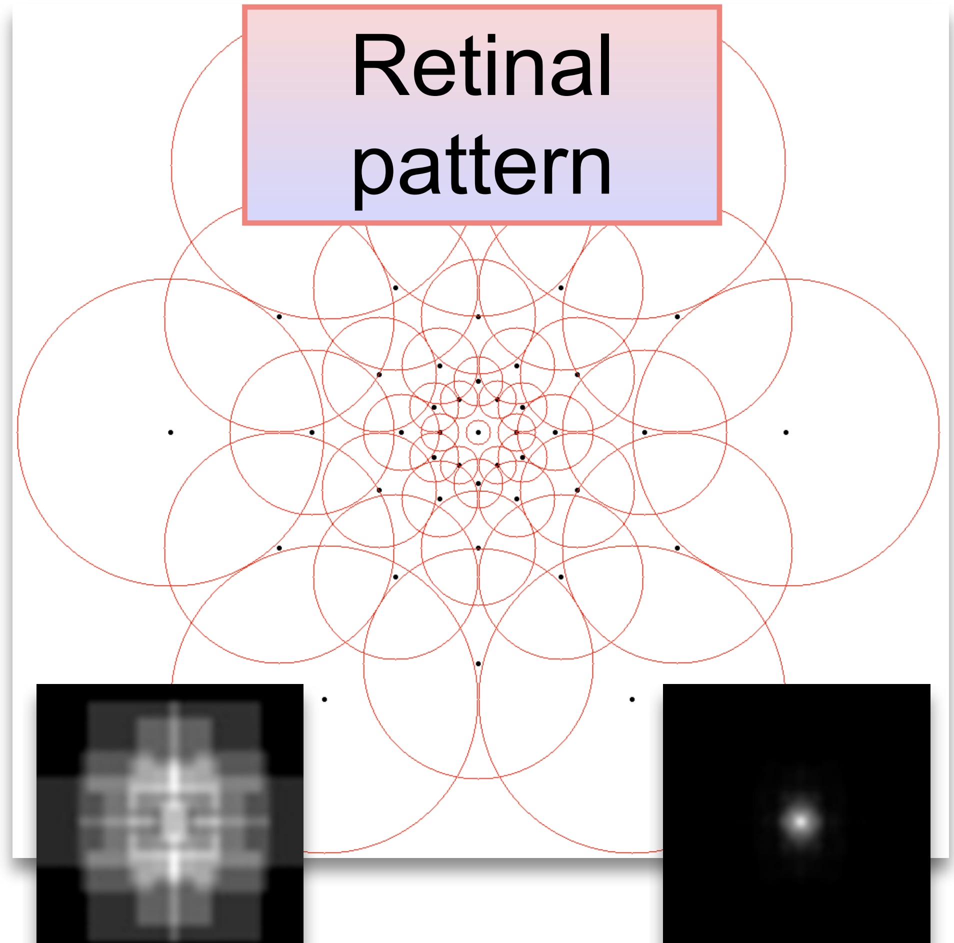
$$\mathrm{LBD}_i = \mathcal{B}(\mathcal{L}_i)$$



Calonder et al. (2010). *BRIEF: Binary Robust Independent Elementary Features.*

LBDs: BRIEF vs. FREAK





Alahi et al. (2012). *FREAK: Fast Retina Keypoint.*

Variational reconstruction

Better than wavelets!

- What did we measure ? What is our pr

$$\hat{p} = \operatorname*{argmin}_p \underbrace{\lambda \| A_{\mathcal{L}} p - g \|_1}_{\text{data term}} + \underbrace{\|p\|_{\mathrm{TV}} + \delta_{\mathcal{S}}(p)}_{\text{regularization}}$$

- Fitting the data: robust ℓ_1-norm of the error
- Prior 1: a patch is piecewise smooth
- Prior 2: mean + dynamic range

Chambolle-Pock primal-dual solver

- Solves a convex functional of the form:

$$\hat{x} = \underset{x}{\operatorname{argmin}} \; F(Kx) + G(x)$$

- Idea: recast as a saddle point on the primal x and the dual y :

$$\min_x \max_y \langle Kx, y \rangle_Y + G(x) - F^*(y).$$

- No derivatives involved, but needs the proximal mappings of G and F^*

Chambolle & Pock (2010). *A First-Order Primal-Dual Algorithm for Convex Problems with Applications to Imaging.*

TV-L1 reconstruction algorithm

- Using «cross-and-bouquet» leads to decoupling but 2 unknowns (y, z) s.t. $y = A_{\mathcal{L}} p, z = \nabla p$

- **Outline of the iterations:**
  1. Update the dual variable of y
  $$\operatorname{prox}_\sigma F_1^*(q) = \operatorname{sign}(q - \sigma g) \cdot \max(\lambda, |q - \sigma g|)$$
  2. Update the dual variable of z
  $$(\operatorname{prox}_\sigma F_2^*)_i = r_i / \max(1, |r_i|)$$
  3. Update the primal unknown by applying the equality and feasible domain constraints

A few remarks

- Why is TV «better» than wavelets ?
  - (+) translation invariant, fast (parallel)
  - (-) flattening effect
- The solver seems complicated...
  - Actually, mostly pointwise / parallel operations
- Why the C-P primal-dual and not... ?
  - Mostly a matter of taste and available code !

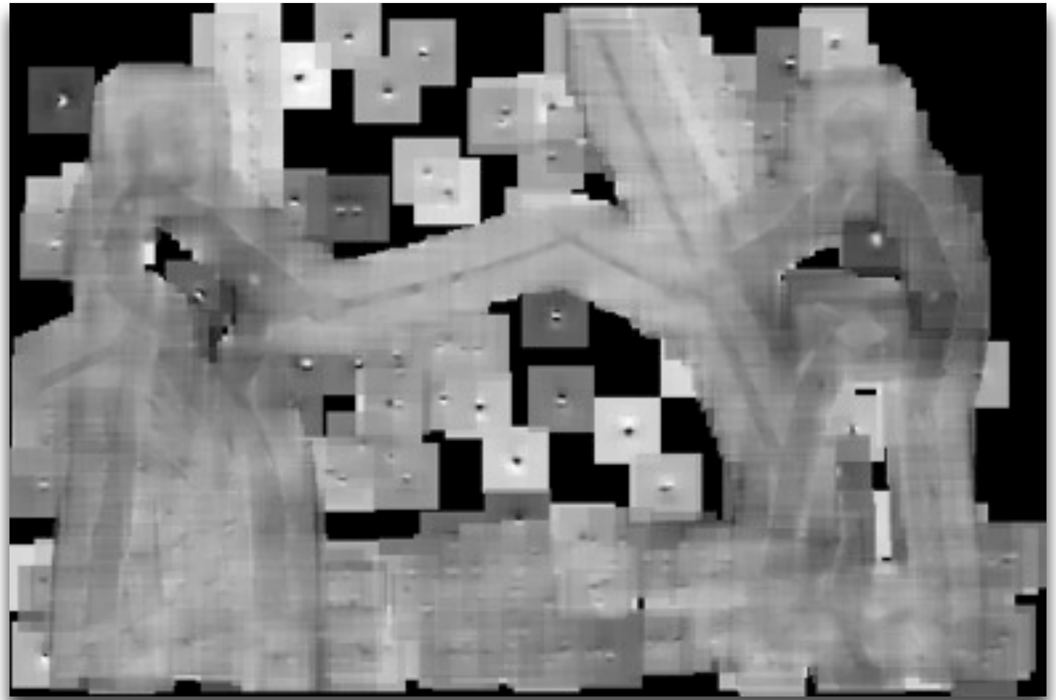
What about 1-bit LBDs ?

- **Spoiler alert: it works !**
- Ongoing work with A. Alahi, P. Vandergheynst and Laurent Jacques (UC Louvain)
- **Inverse problem with sparsity constraint**
  - No binary prox: Primal-dual (C-P) replaced by Binary Iterative Hard Thresholding (Jacques et al.)
  - TV dropped for wavelet analysis sparsity (sic)
- **Submitted** ! Pre-print available on arXiv.org

Jacques et al. (2011). *Robust 1-Bit Compressive Sensing via Binary Stable Embeddings of Sparse Vectors.*

1-bit reconstructions results

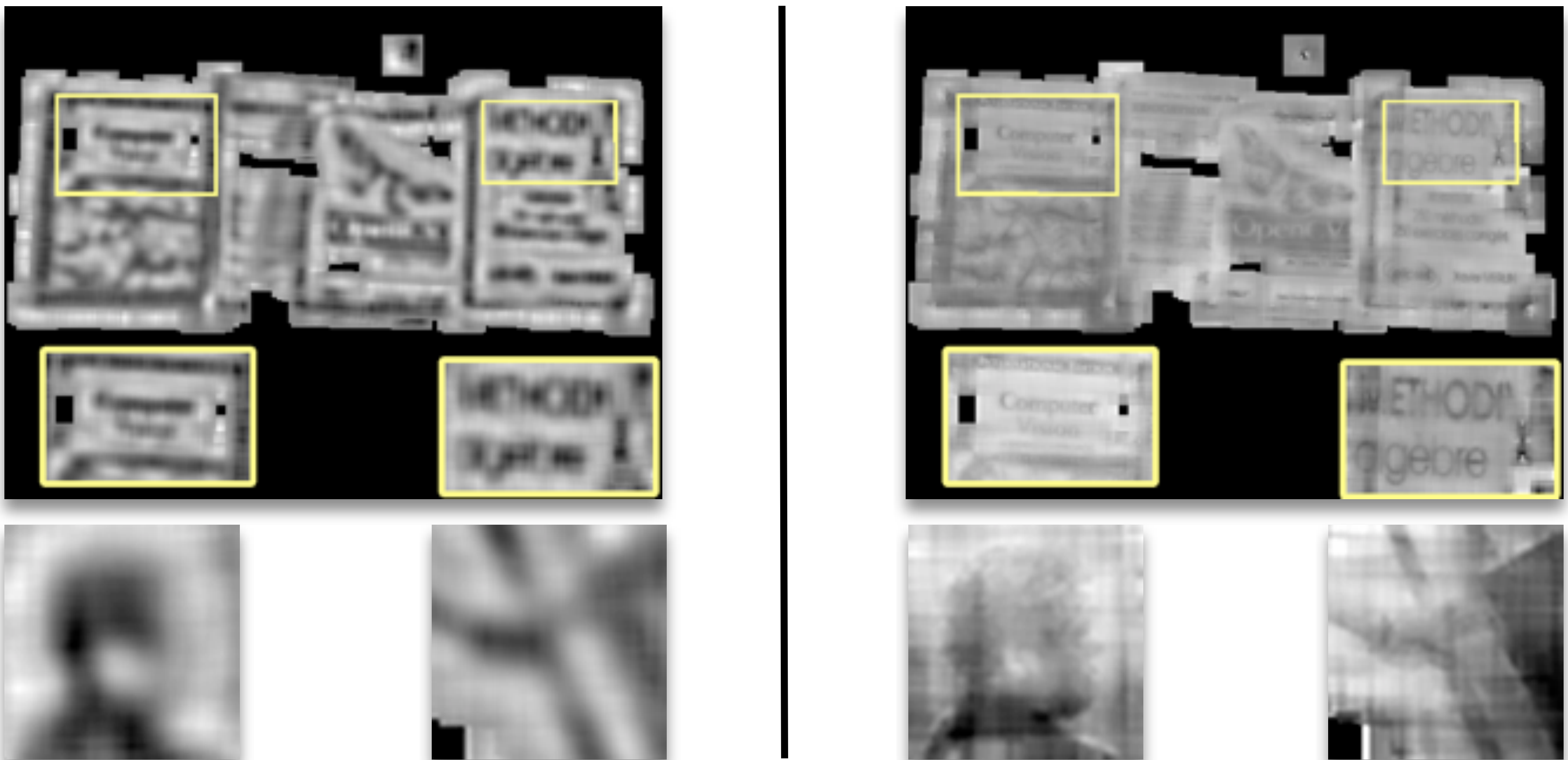
FAST + BRIEF



FAST + FREAK

Bonus: BRIEF vs. FREAK revisited

- They don't encode the same scale !
  - BRIEF captures shapes, FREAK details



Conclusion

- **Wrapping everything up**
  - Reconstruction can be achieved without learning even with binarized features
  - The pattern has to be known.
  - Shows differences between LBDs
- **Privacy matters !**
- **Future work**
  - Hybrid LBD (coarse + fine scale)
  - Better quality using Poisson reconstruction
  - Smart cameras, compression, CS... ?

Thank you !

- **Thank you for your attention**
- Again, thanks to the **reviewers** for their comments about this work
- **1-bit reconstruction links**
  - pre-print: http://arxiv.org/abs/1211.1265
  - code: http://lts2www.epfl.ch/code