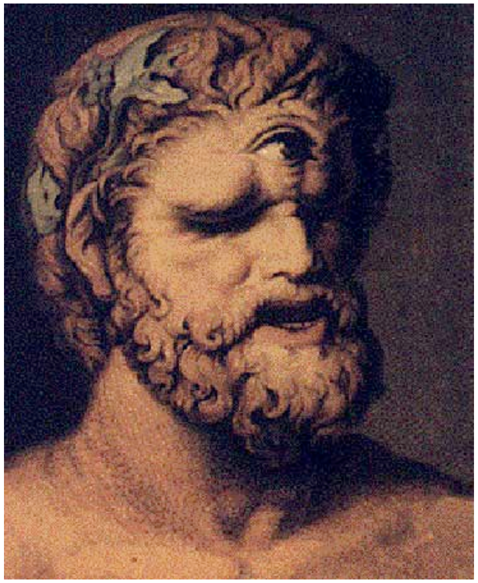
Is a neuron worth a thousand pixels?

Joëlle Barral
PSY 221
Winter, 2008

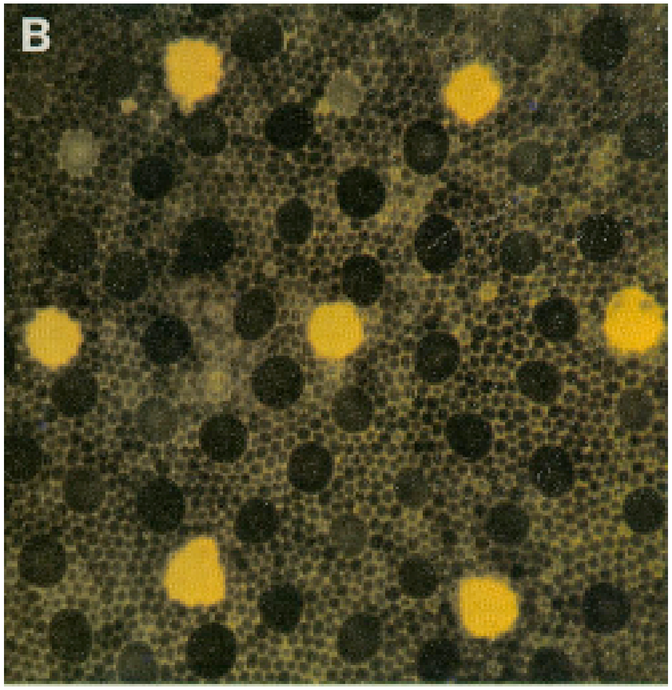


Outline

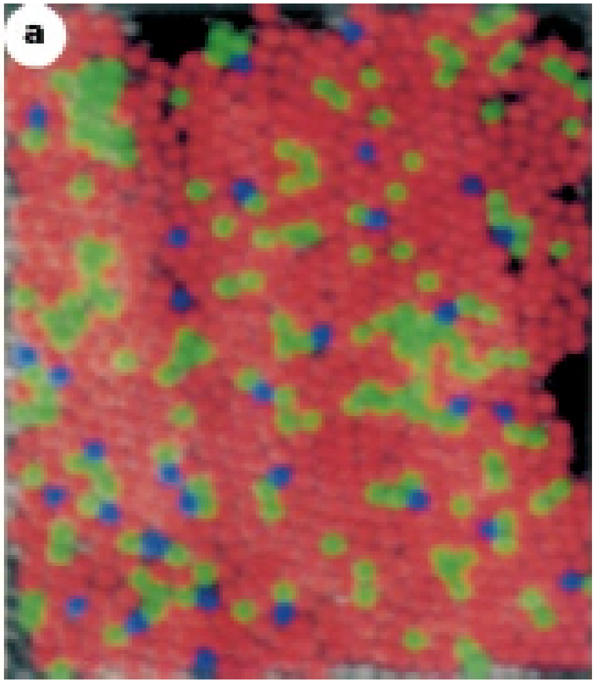
- Sparsity in the Visual System
- Compressive Sensing
- An Example: the Single-pixel Camera

Sparsity in the Visual System

Cones



Regular?



Random?

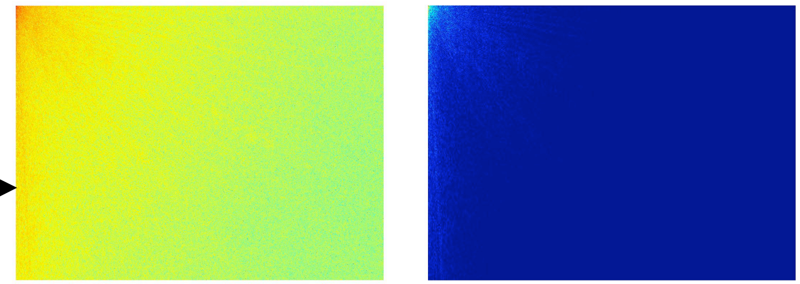
De Monasterio, 1981
Roorda, 1999

Sparsity in the Visual System

Natural Scenes

DCT

Throw away 88%

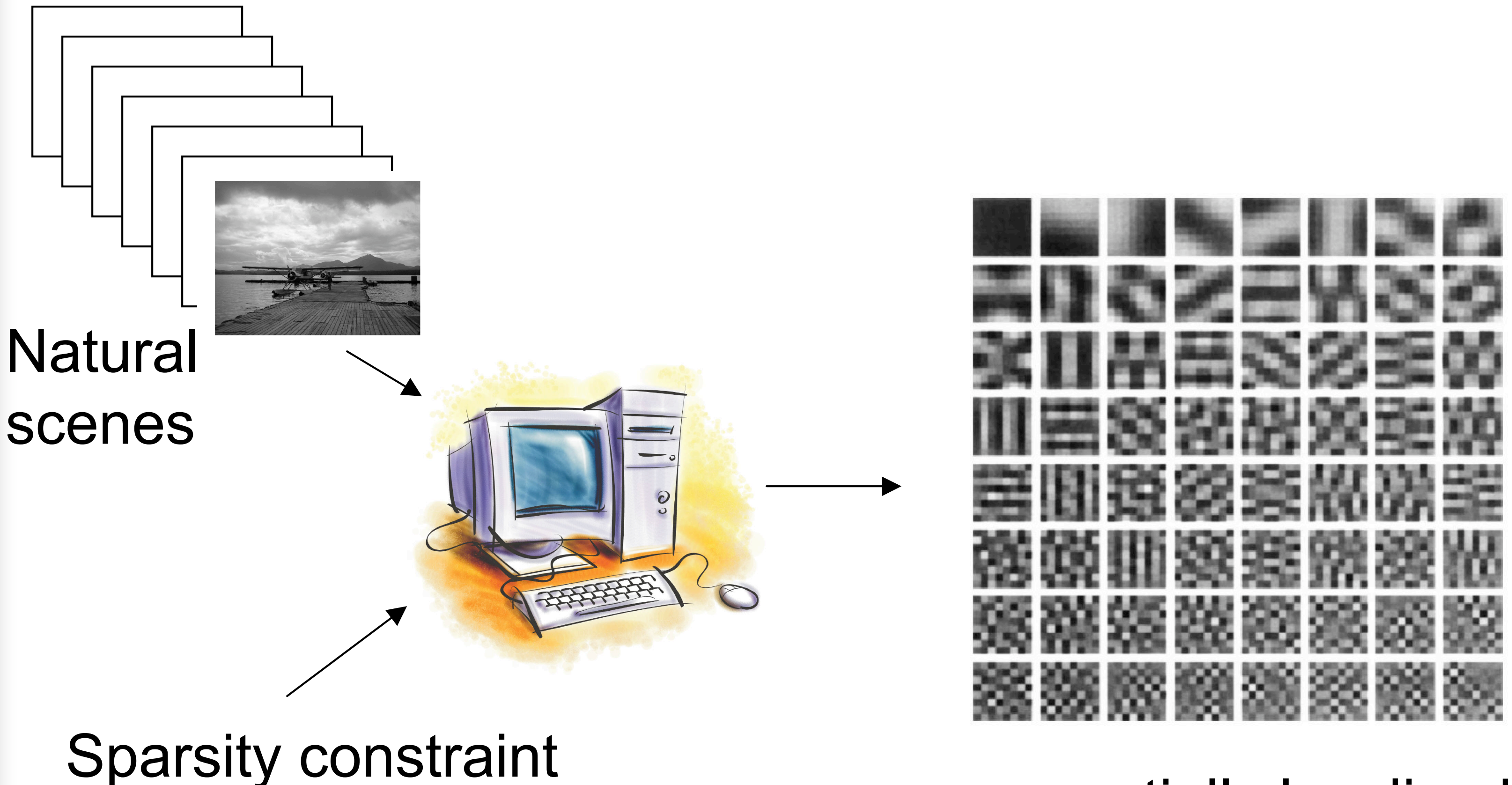


IDCT

difference

Sparsity in the Visual System

Learning Algorithms

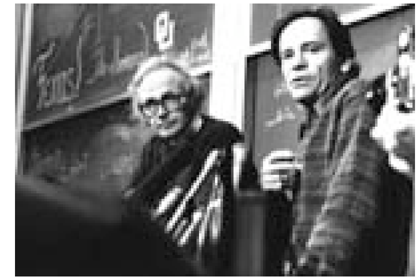


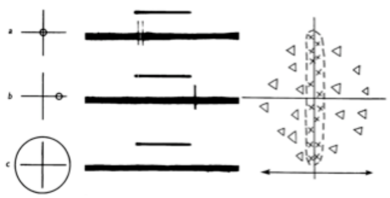
- spatially localized
- oriented
- bandpass

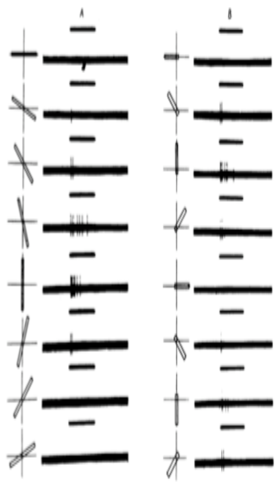
Olshausen and Field, 1996

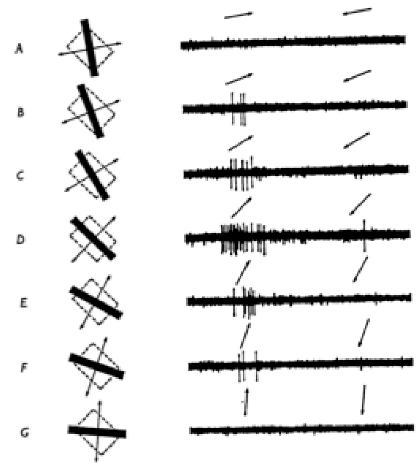
Sparsity in the Visual System

Receptive Fields





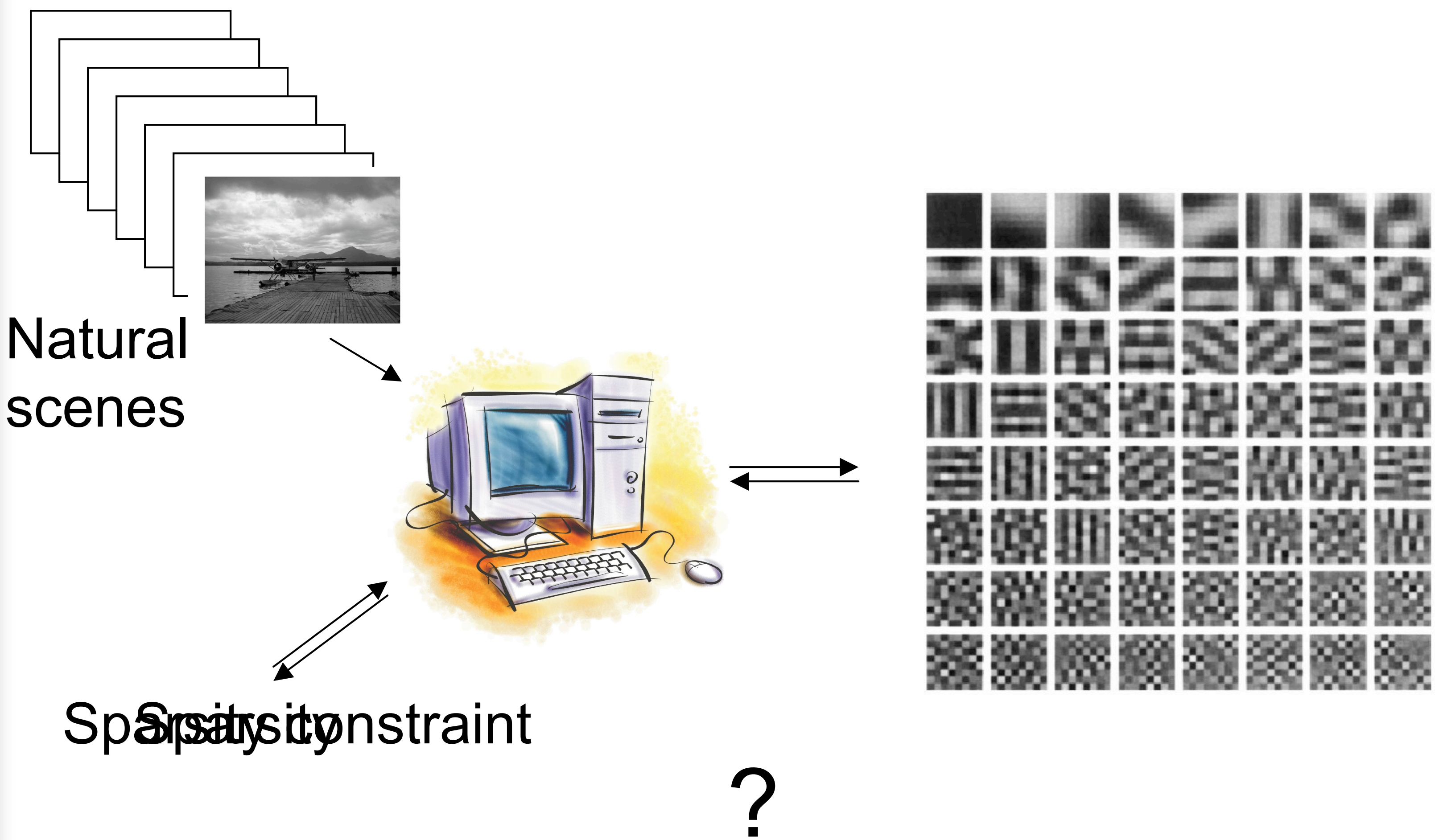




“These observations made in 1958 had not been predicted and came as a complete surprise” Hubel, 1995

Hubel and Wiesel, 1959, 1968

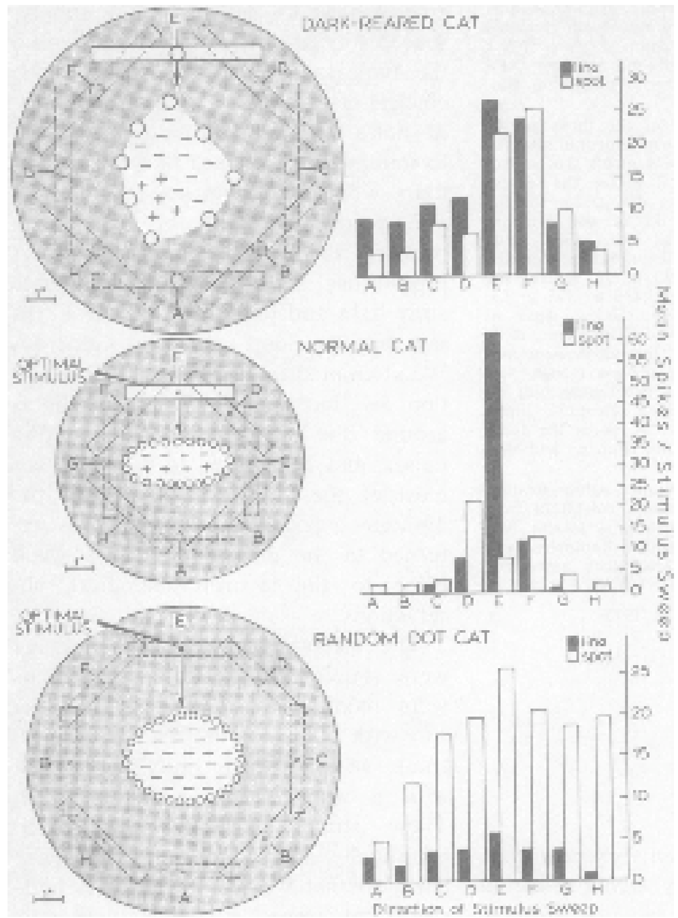
Learning Algorithms



Olshausen and Field, 1996

Sparsity in the Visual System

Development/Evolution



Pettigrew and Freeman, 1973

Sparsity of the Visual System

- Information-efficient

  coding of natural images

- Energy-efficient

  metabolism

Barlow, 1961
Quiroga, 2005

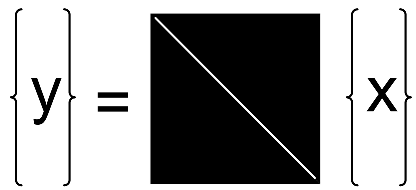
Compressive Sensing

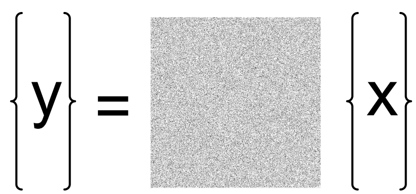
Classical Paradigm

K ≥(2)B

Number of measurements → K

Bandwidth → B

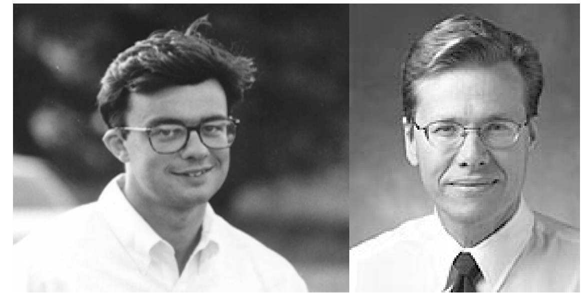




Measurement matrix N*N

Compressive Sensing

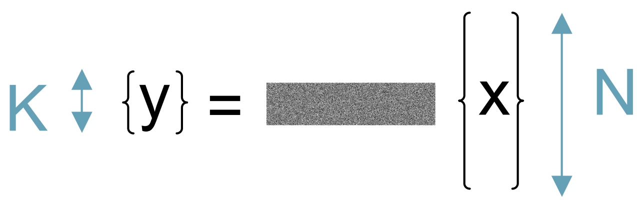
New Paradigm

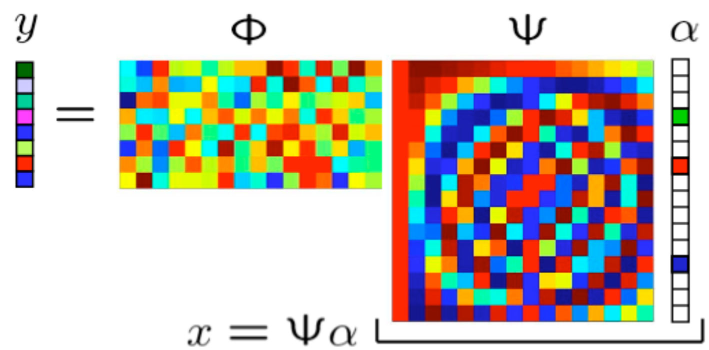


$K \geq C\ S \log(N)$

Number of measurements

Sparsity

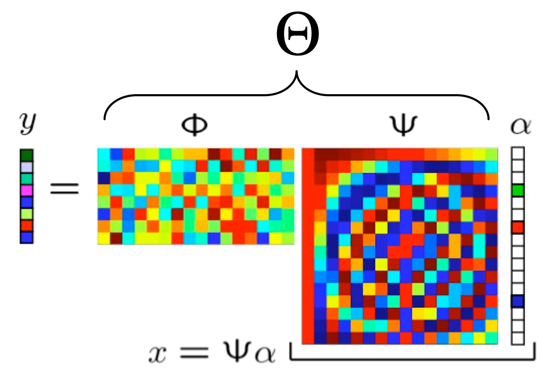




Measurement matrix K*N

Compressive Sensing

Reconstruction



~~**s** = argmin $||s'||_2$ s.t. Θs' = y~~

s = argmin $||s'||_0$ s.t. Θs' = y

(Donoho, 2006) ↕

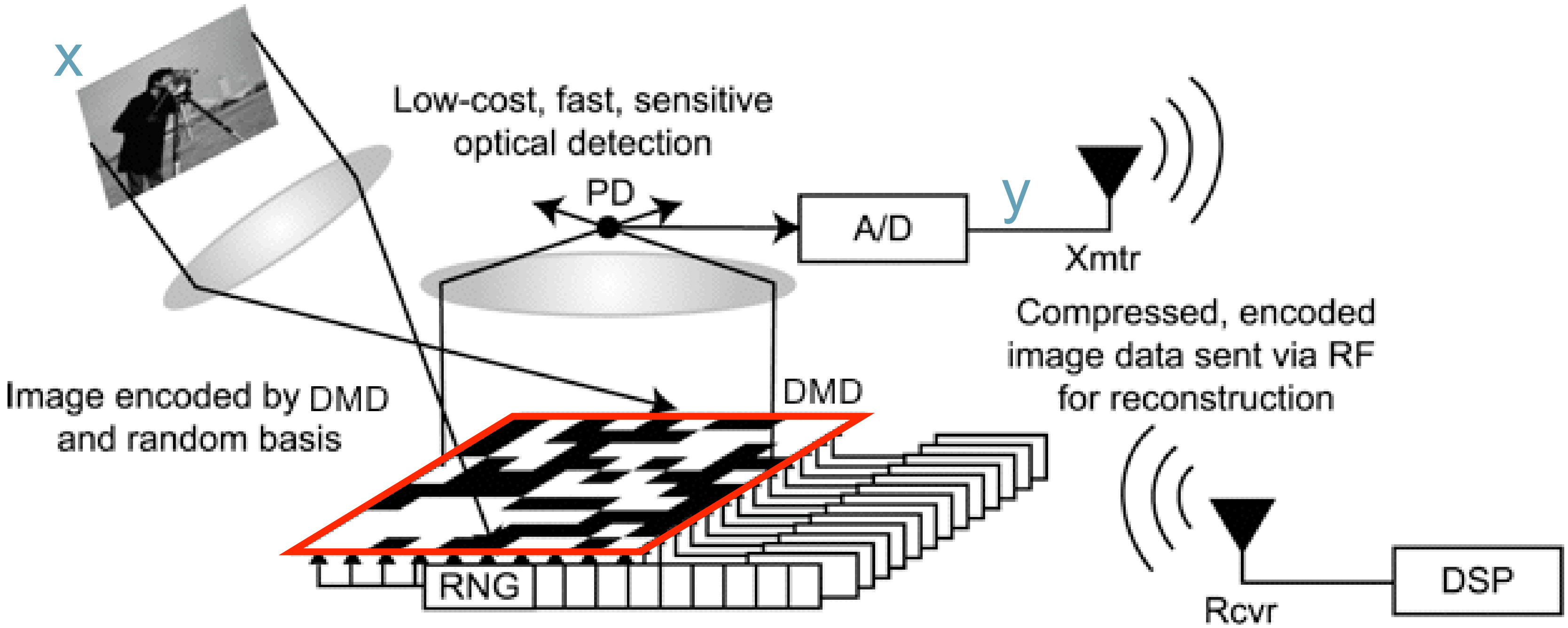
s = argmin $||s'||_1$ s.t. Θs' = y

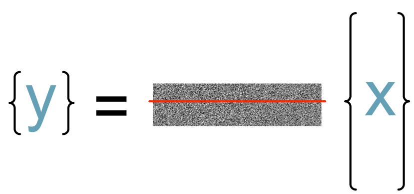
http://www.acm.caltech.edu/l1magic/

Compressive Sensing

- Accurate reconstruction of randomly undersampled ‘somewhere’ sparse signals

Single-pixel Camera





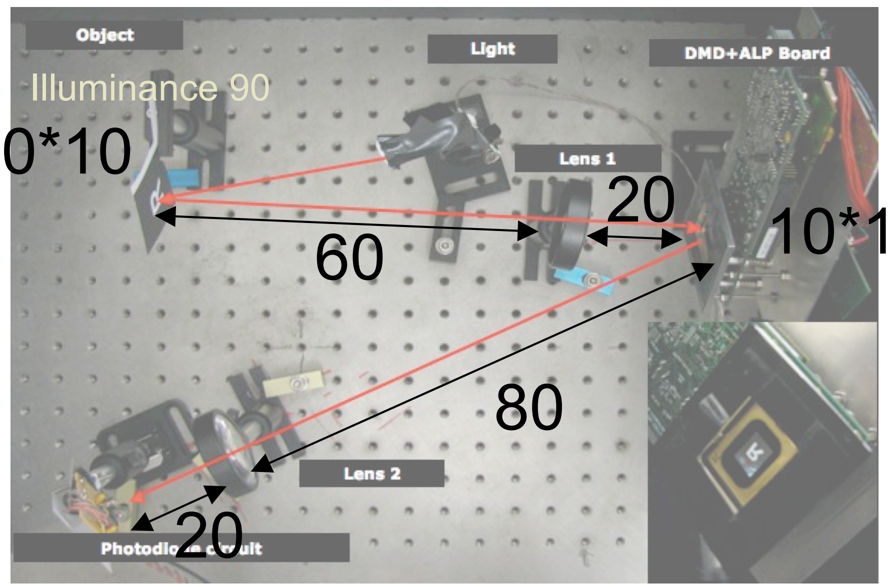
http://www.dsp.ece.rice.edu/cscamera

Single-pixel Camera

Monochrome

Lens 1
f = 0.08 m
F= 4

DMD 13.68*13.68 um
1024*768
Optics of the DMD not simulated

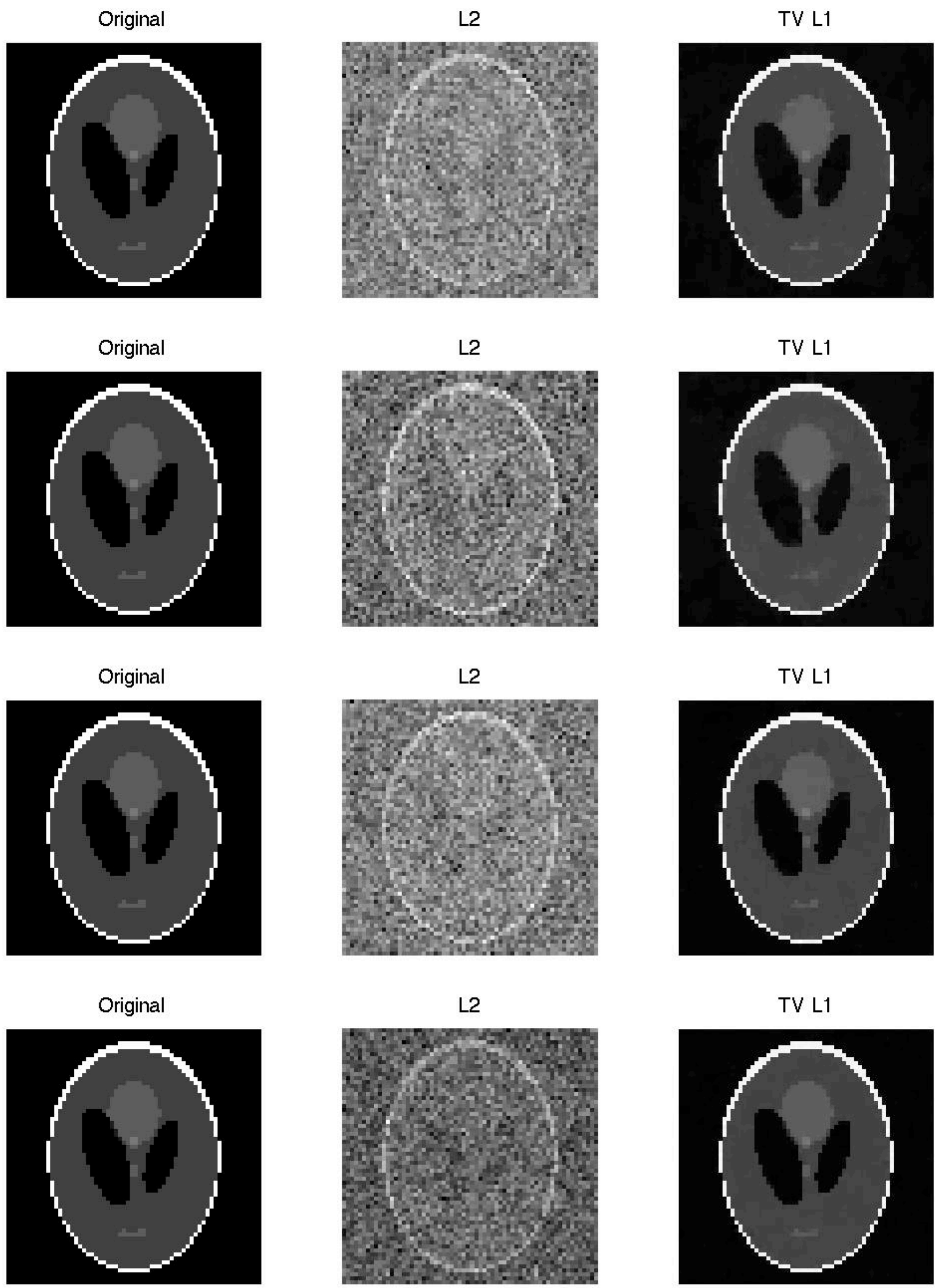


mm

Photodiode:
2.8*2.8 um,
integration time 0.101 s
Geometric efficiency 85%
Digitization 12 bit

Lens 2
f = 0.1 m
F= 4

http://www.dsp.ece.rice.edu/cscamera



ϕ

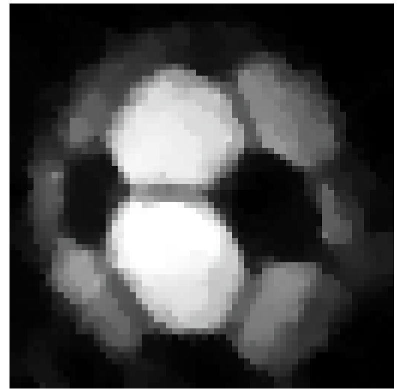
Gaussian

Hadamard
(the one Rice used)

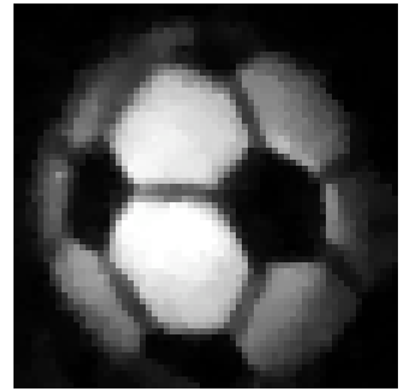
Random Bernoulli

Random sparse
(Berinde, 2008)

N = 64*64 = 4096

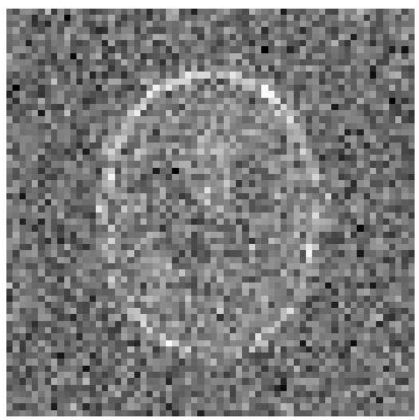


K = 800



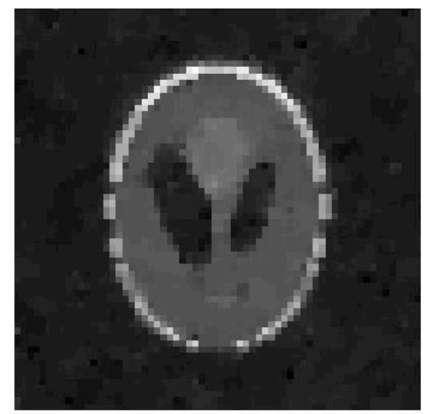
K = 1600

L2



L1 - No quantization

L1 - Quantization



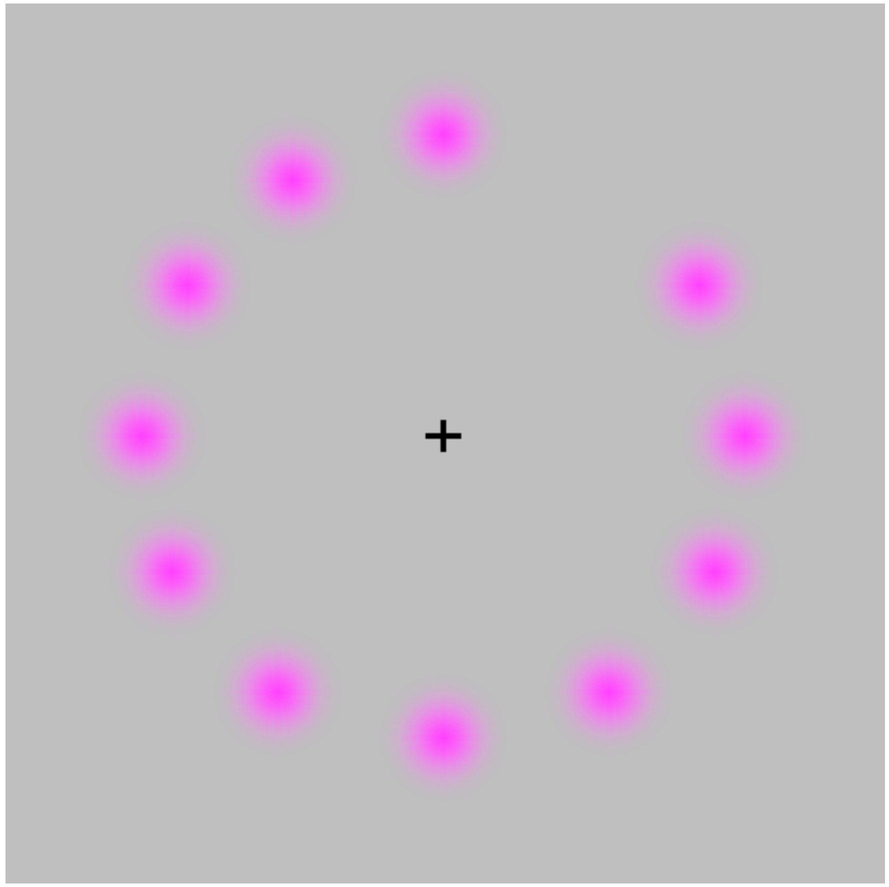
K = 1024

Single-pixel Camera

- Compressive Sensing (Compressed Sampling) shifts the technological burden from the sensor to processing.

Conclusions

- No trivial link between Compressive Sensing and the way the Visual System works.
- Compressive Sensing is not just a measurement paradigm. It provides a broader framework.
  - – Proof of existence and unicity
  - – Plausible alternatives to \
  - – Extension to deterministic or dynamics settings?



Thank you!