Image Processing Activities

Guillermo Sapiro
University of Minnesota

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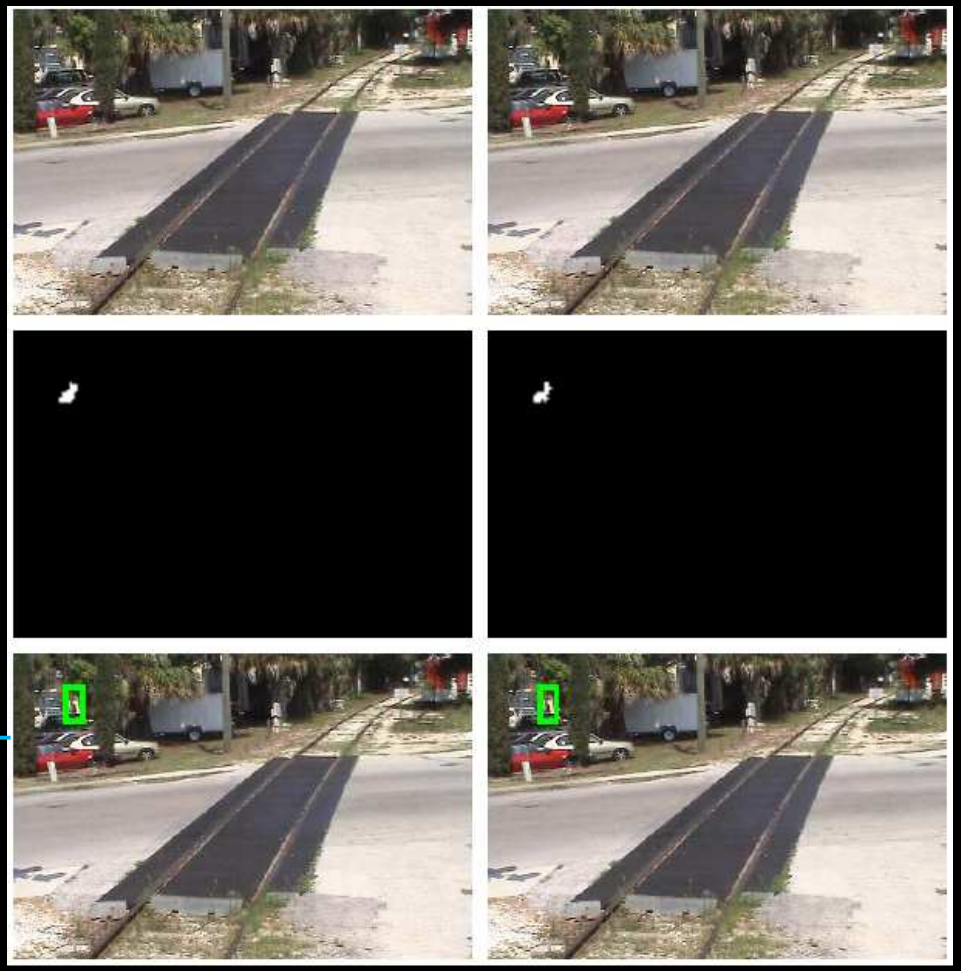
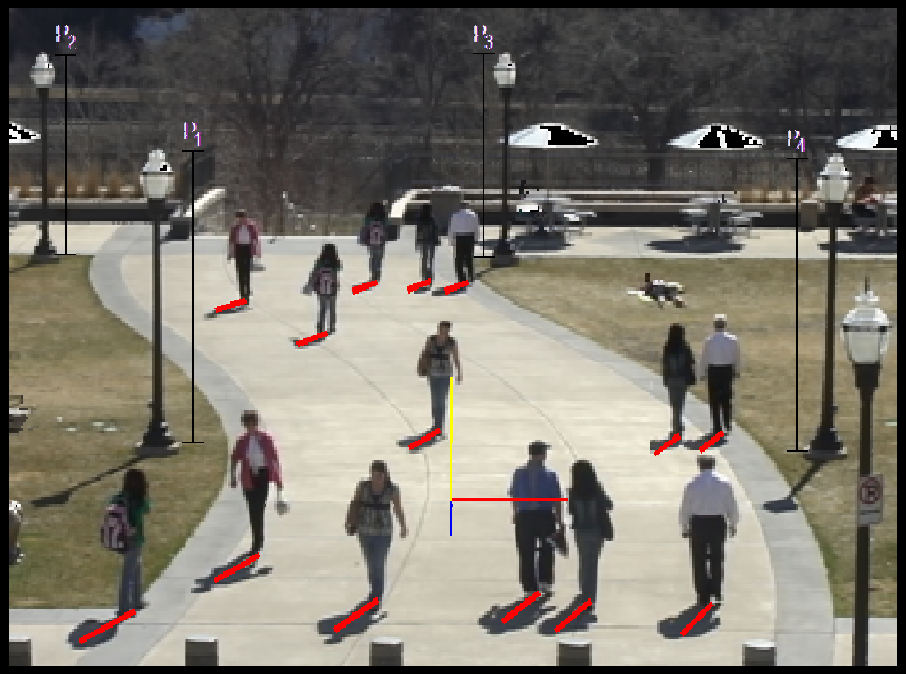
Surveillance: Gotcha!

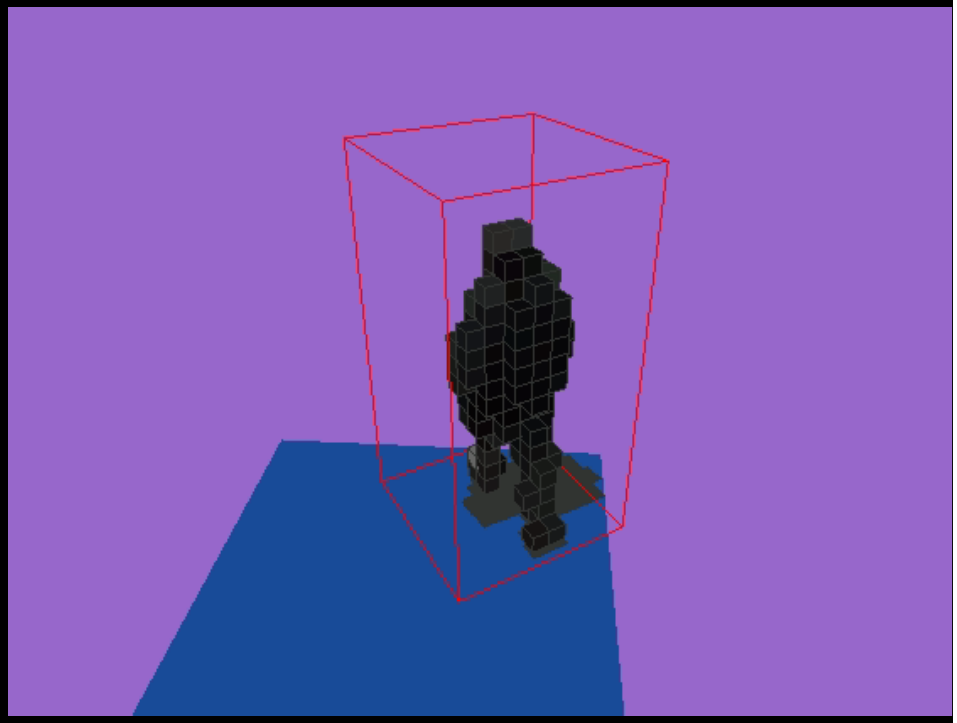


Tracking

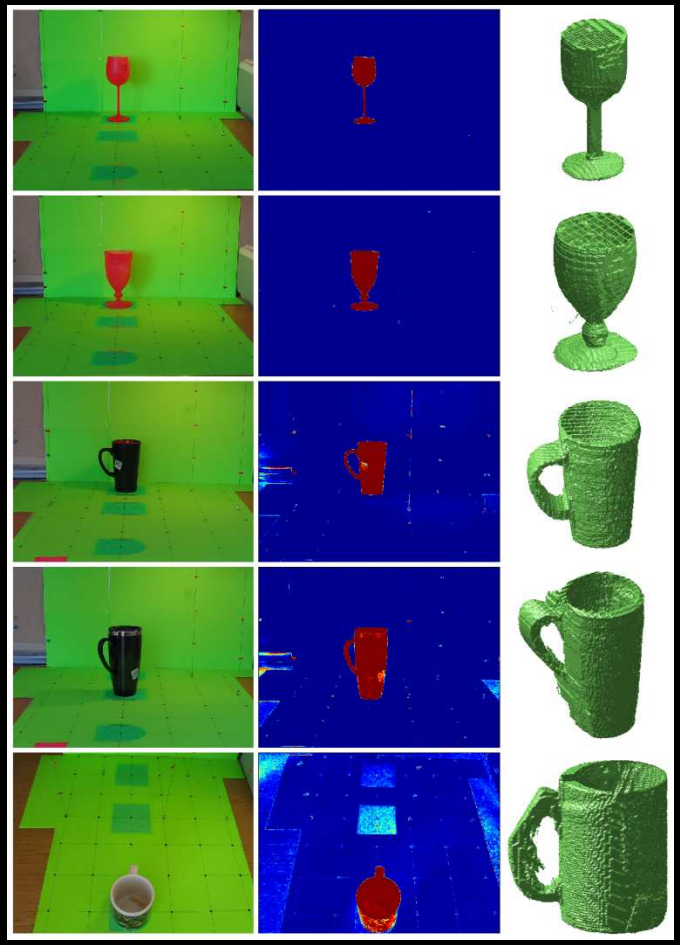
3D from single image/view

Estimated Horizon

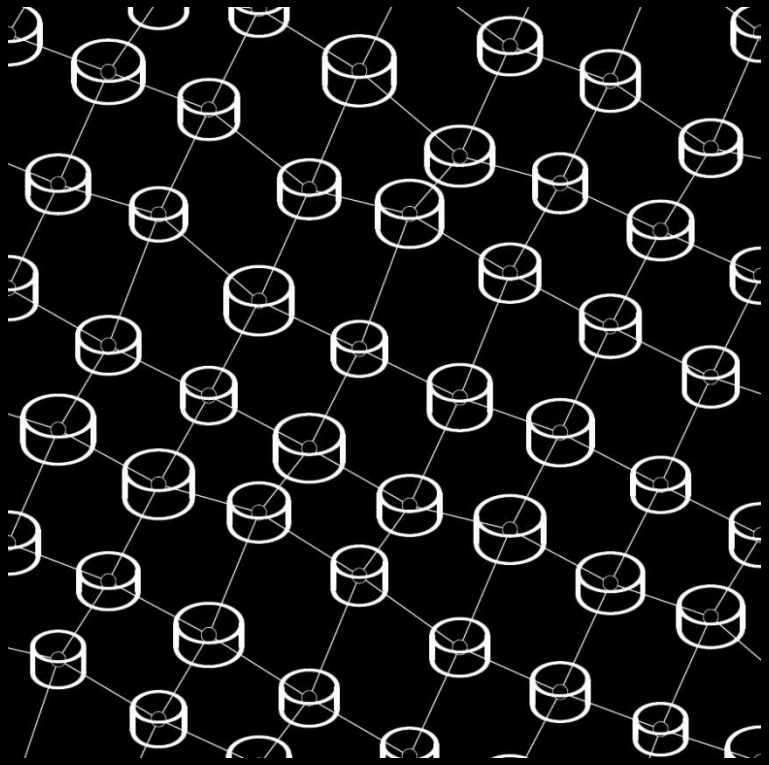


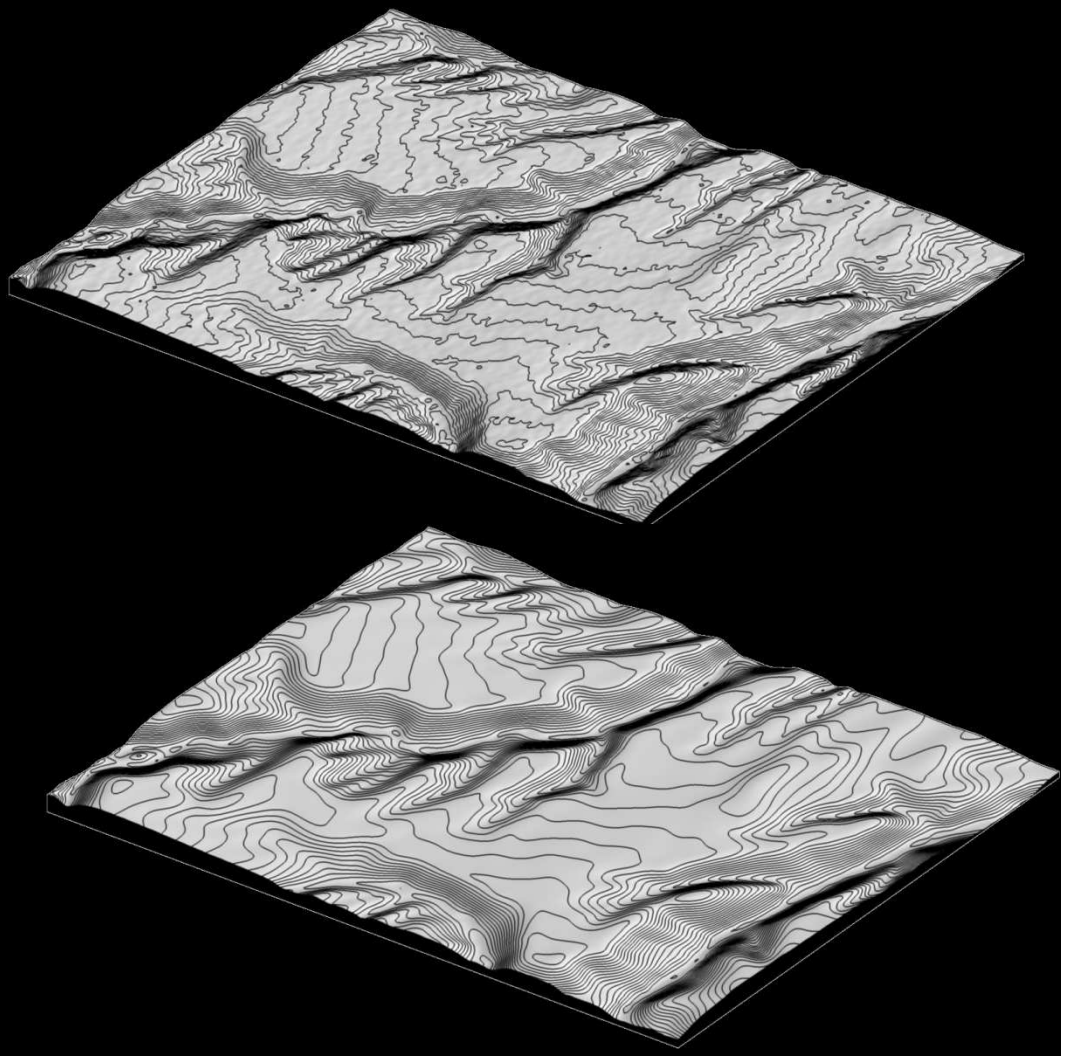


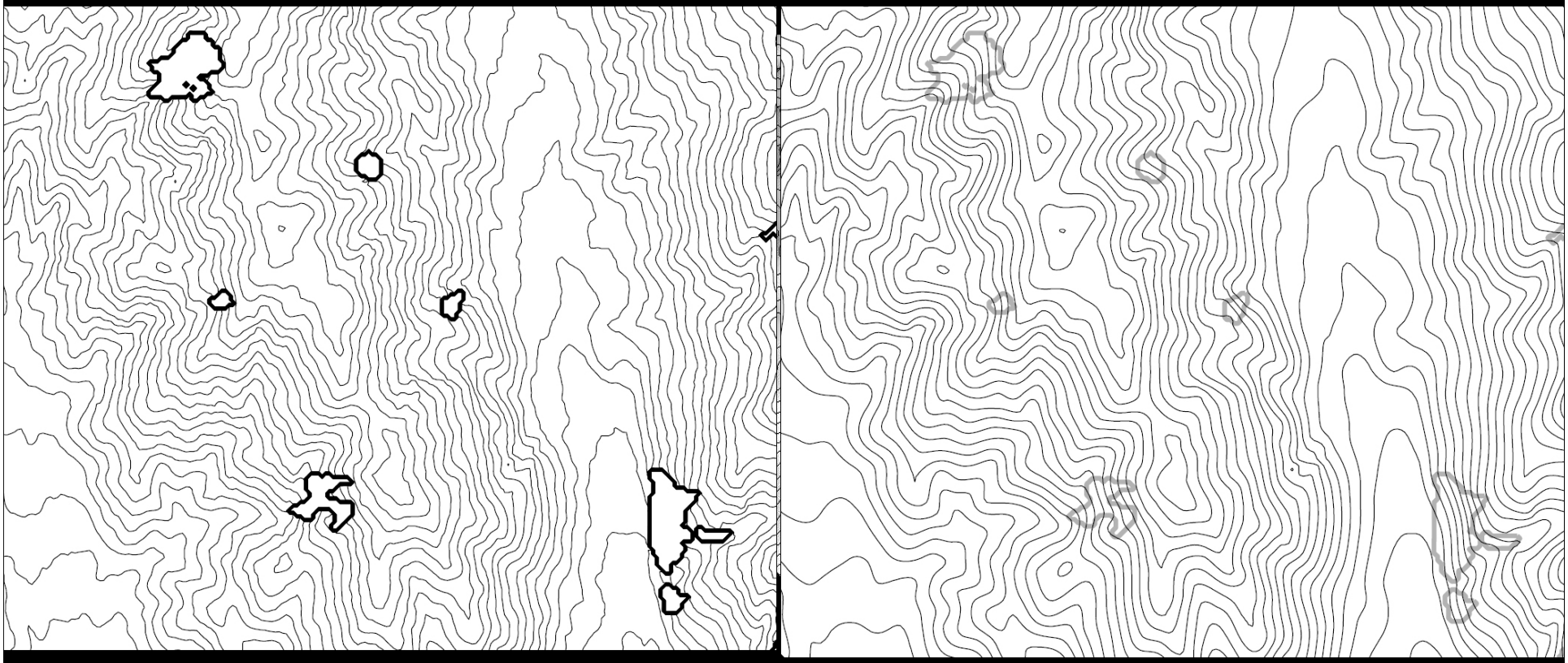
3D from a Single View/Image



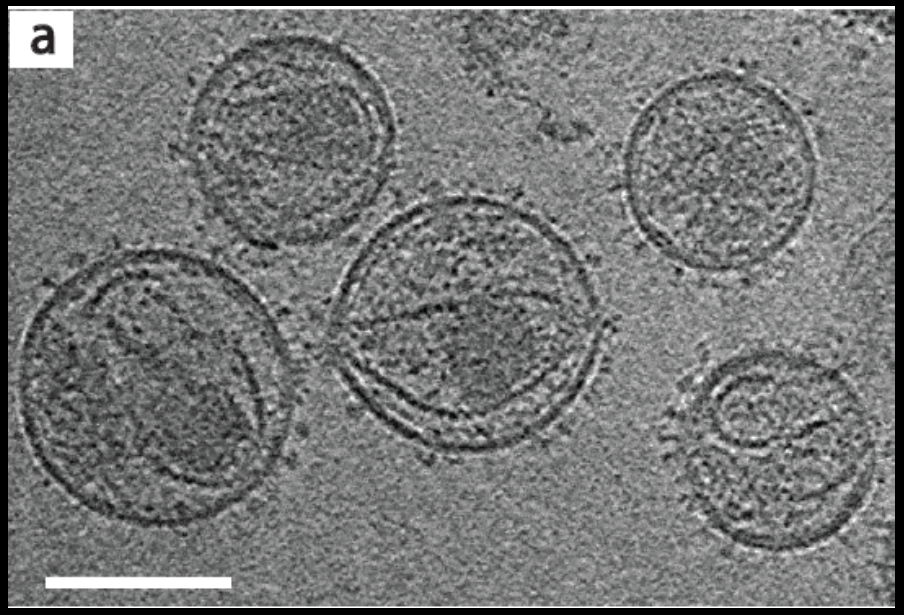
Processing of Elevation Maps

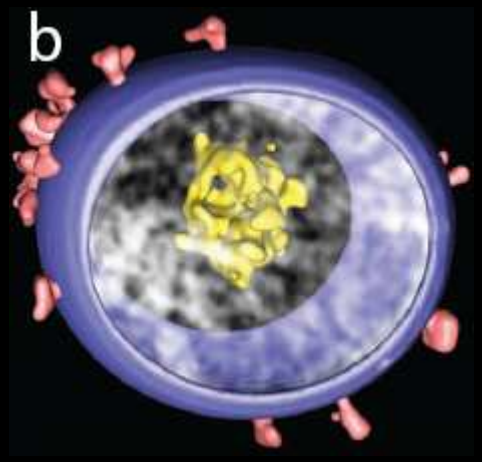


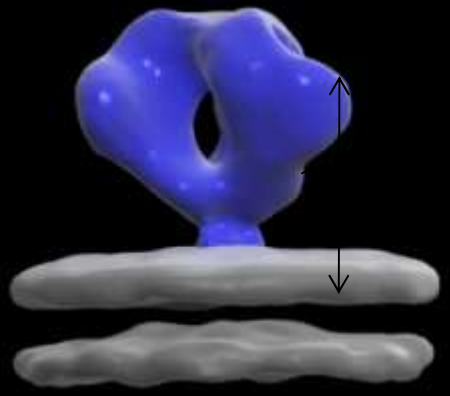


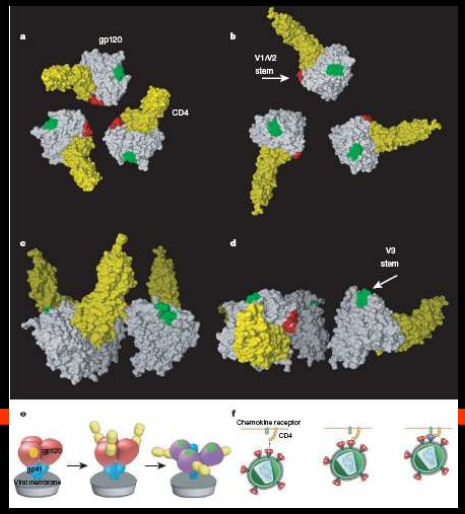


Medical and Bio Imaging



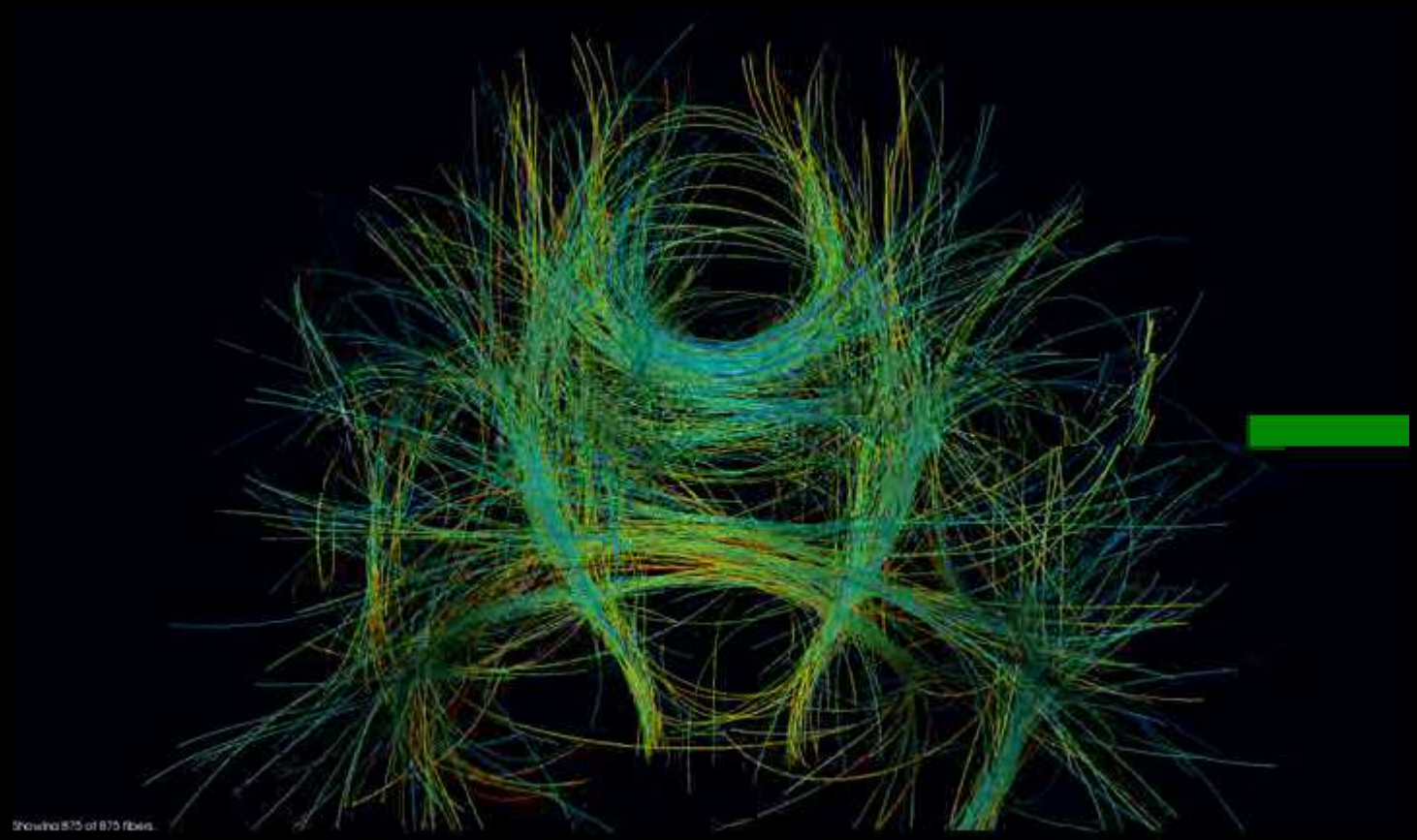






HIV structure, Nature, 9/2008
In collaboration with CCR/NIH

Diffusion tensor imaging



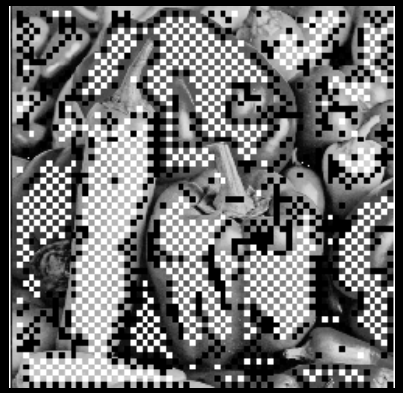
Compression

- For consumer images: JPEG
- For scientific data: More open question

Rock in MARS, compressed with JPEG-LS
(Weinberger, Seroussi, Sapiro)
Courtesy of JPL/NASA

Enhance/Change

Inpainting



mountains.ece.umn.edu/~guille/inpainting.htm

Video Inpainting

Colorization

Colorization

Video SnapCut: Video Segmentation in Real Life

Xue Bai[1] Jue Wang[2] David Simons[2] Guillermo Sapiro[1]

1.University of Minnesota
2.Adobe Systems

With additional contributions by Daniel Wilk (Adobe Systems)

Goal

Let us see it in action:

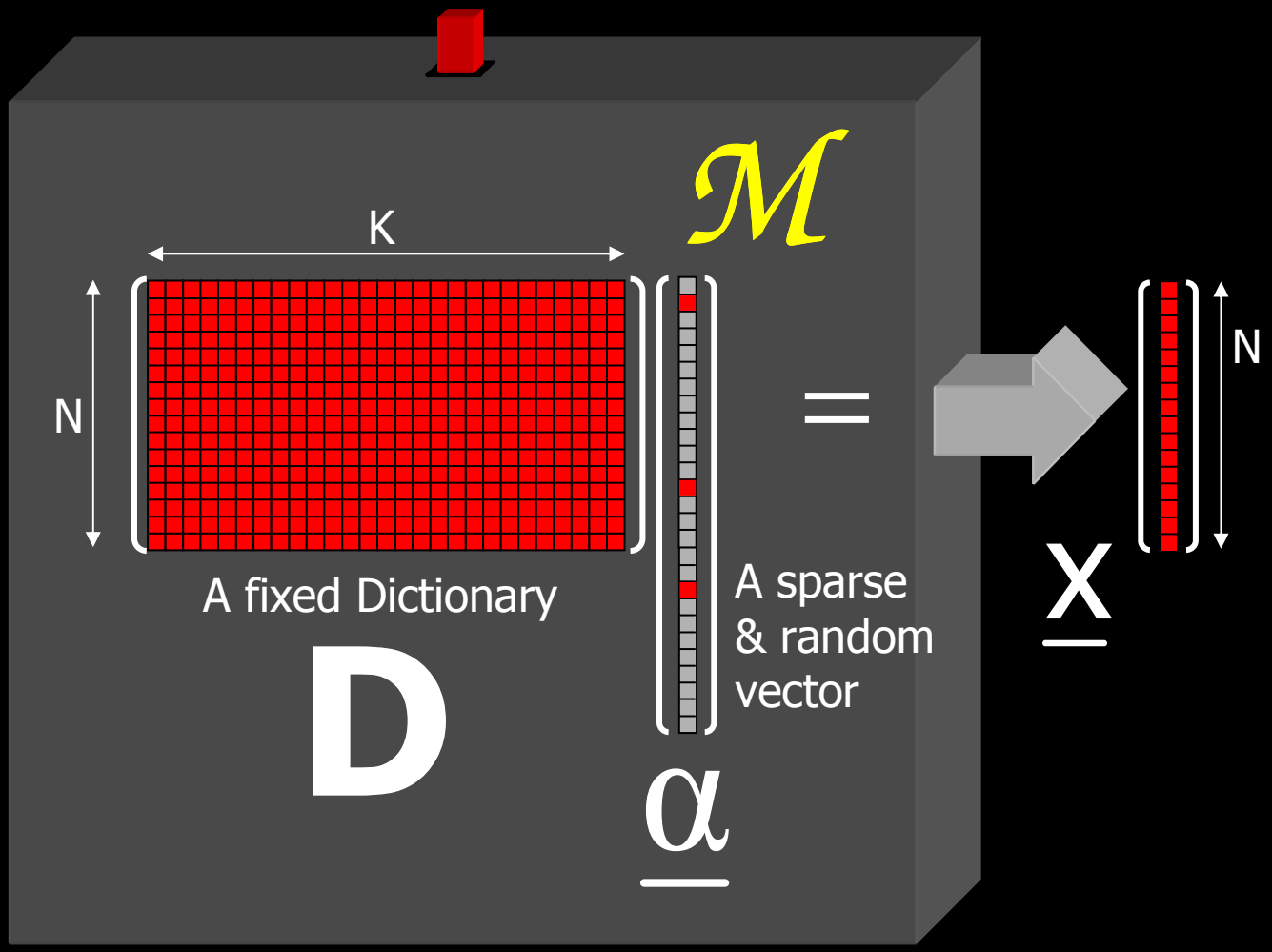
Adobe *After* Effects Plug-In

Dictionary Learning and Sparse Coding: New Models and Applications

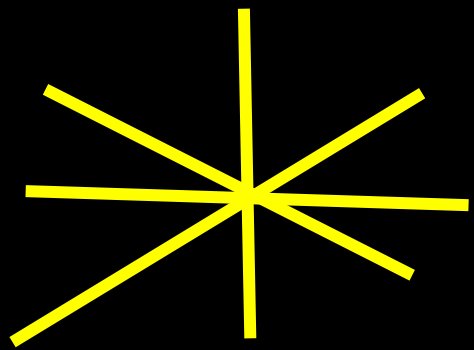
Guillermo Sapiro
University of Minnesota

+Students and post-docs:
Mairal, Rodriguez, Lecumberry, Duarte-Carvajalino,Sprechmann, Bar, Yu

The *Sparseland* Model for Images



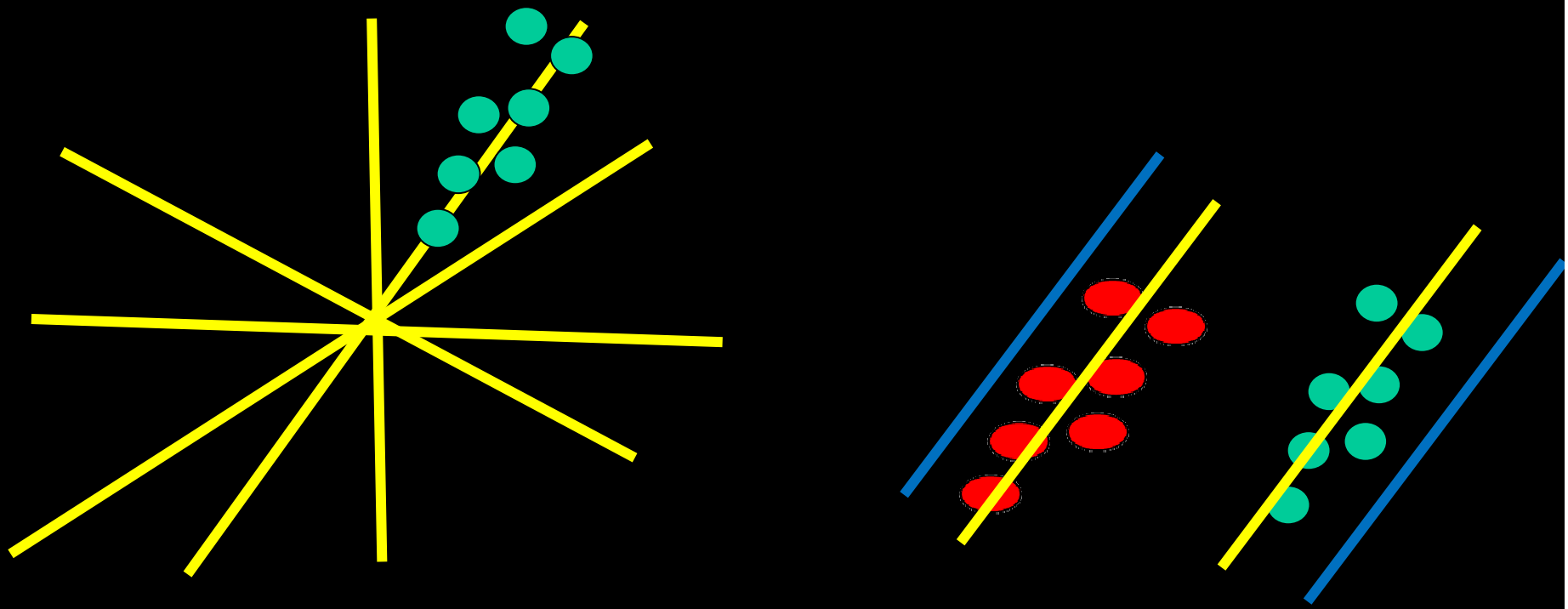
- Every column in **D** (dictionary) is a prototype signal (Atom).
- The vector $\underline{\alpha}$ contains very few (say L) non-zeros.



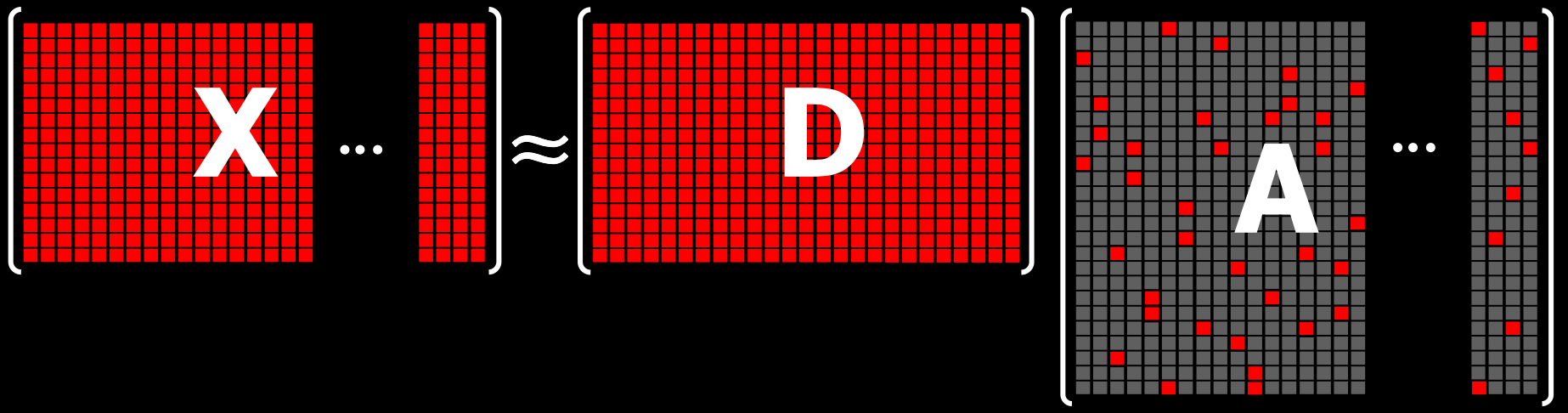
What is sparse coding?

$$\underline{\hat{\alpha}} = \arg\min_{\underline{\alpha}} \frac{1}{2} \left\| \mathbf{D}\underline{\alpha} - \underline{y} \right\|_2^2 \quad \text{s.t.} \quad \left\| \underline{\alpha} \right\|_0^0 \leq L \quad \Rightarrow \quad \underline{\hat{x}} = \mathbf{D}\underline{\hat{\alpha}}$$

What is dictionary learning or sparse modeling?



Learning D (to reconstruct)



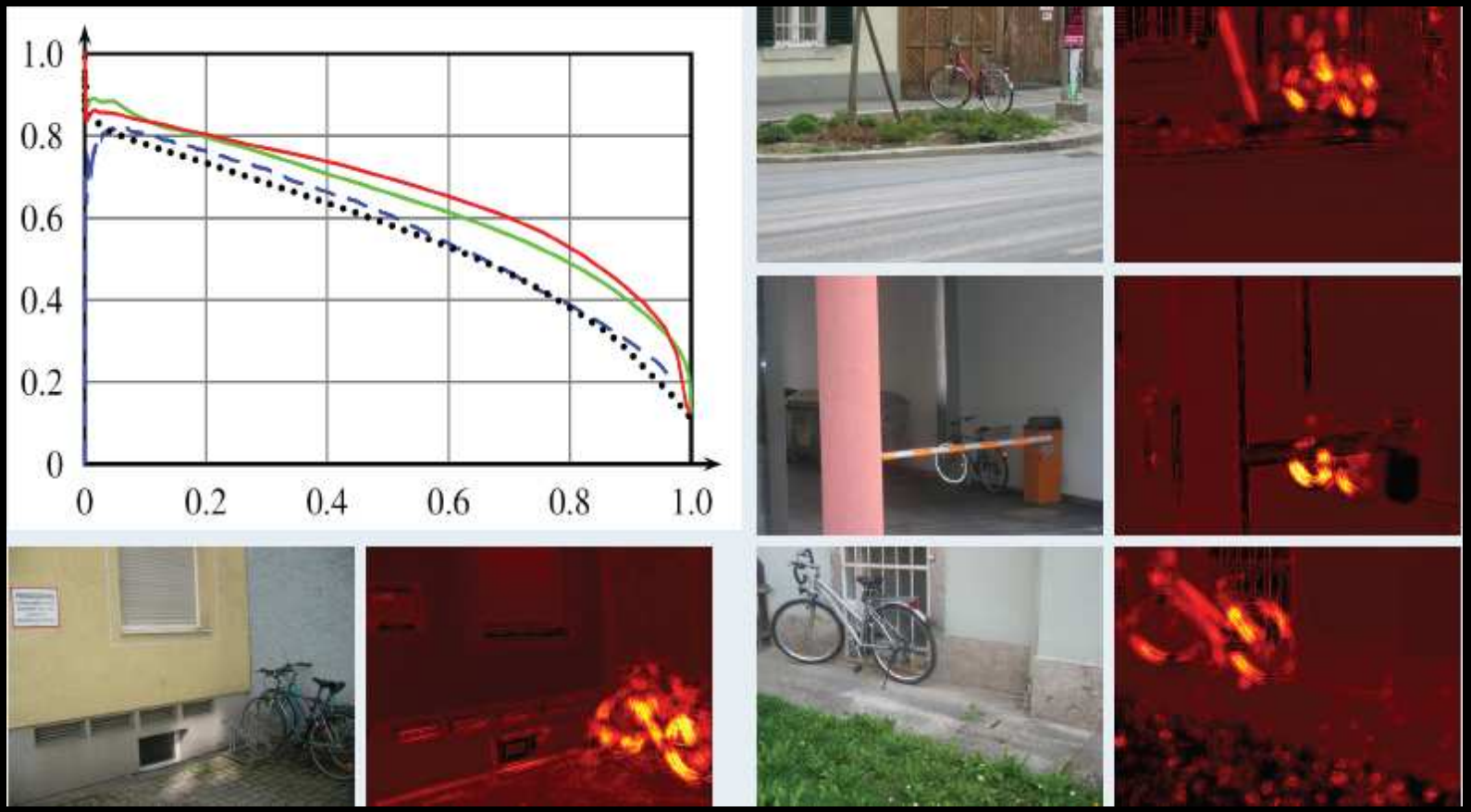
$$(\mathbf{A}^*, \mathbf{D}^*) = \arg\min_{\mathbf{A},\mathbf{D}} \sum_{j=1}^{n} \left\{ \underbrace{\|\mathbf{X}_j - \mathbf{D}\mathbf{A}_j\|^2}_{\text{data fitting}} + \underbrace{\phi(\mathbf{A}_j)}_{\text{regularizer}} \right\}$$

- ℓ_0 "norm": $\|\mathbf{A}_j\|_0 = |\{i : \mathbf{A}_{ij} \neq 0\}|$
- ℓ_1 norm: $\|\mathbf{A}_j\|_1 = \sum |\mathbf{A}_{ij}|$

Field & Olshausen ('96)
Engan et. al. ('99)
Lewicki & Sejnowski ('00)
Cotter et. al. ('03)
Gribonval et. al. ('04)
Aharon, Elad, & Bruckstein ('04)
Aharon, Elad, & Bruckstein ('05)
Ng et al. ('07)
Mairal, Sapiro, Elad ('08)

Example: Inpainting/Denoising

Detection/Classification



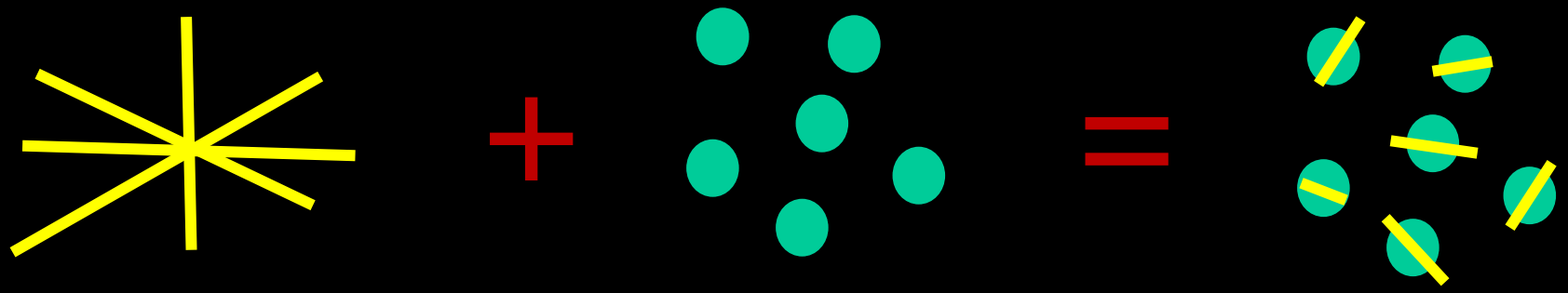
Better Sensing

New Models

Model 1

Sparsity + Self-similarity = Group Sparsity

- Combine the two of the most successful models for images



Sparsity + Self-similarity=Group Sparsity

Adobe Camera Raw

Proposed Method

Model 2: Universal Coding

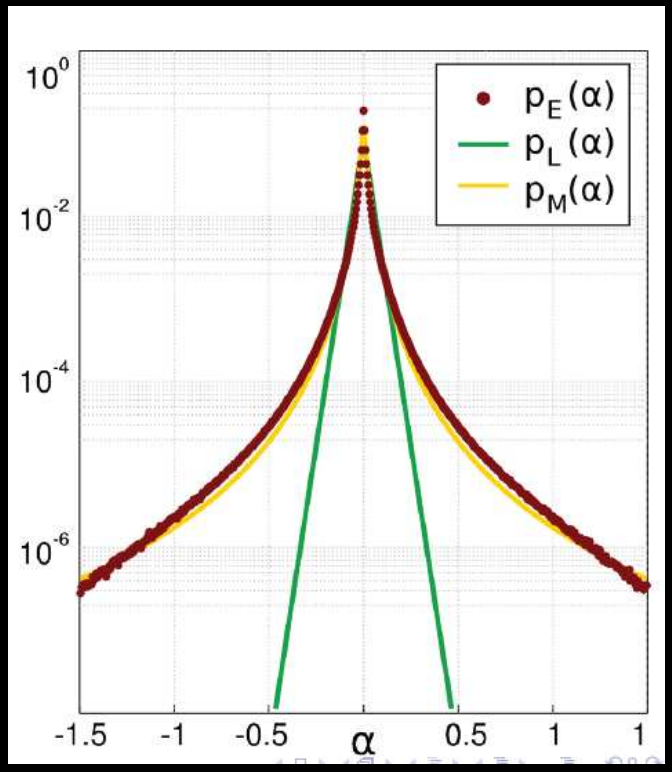
$$(\mathbf{A}^*, \mathbf{D}^*) = \arg\min_{\mathbf{A},\mathbf{D}} \sum_{j=1}^{n} \left\{ \underbrace{\|\mathbf{X}_j - \mathbf{D}\mathbf{A}_j\|^2}_{\text{data fitting}} + \underbrace{\phi(\mathbf{A}_j)}_{\text{regularizer}} \right\}$$

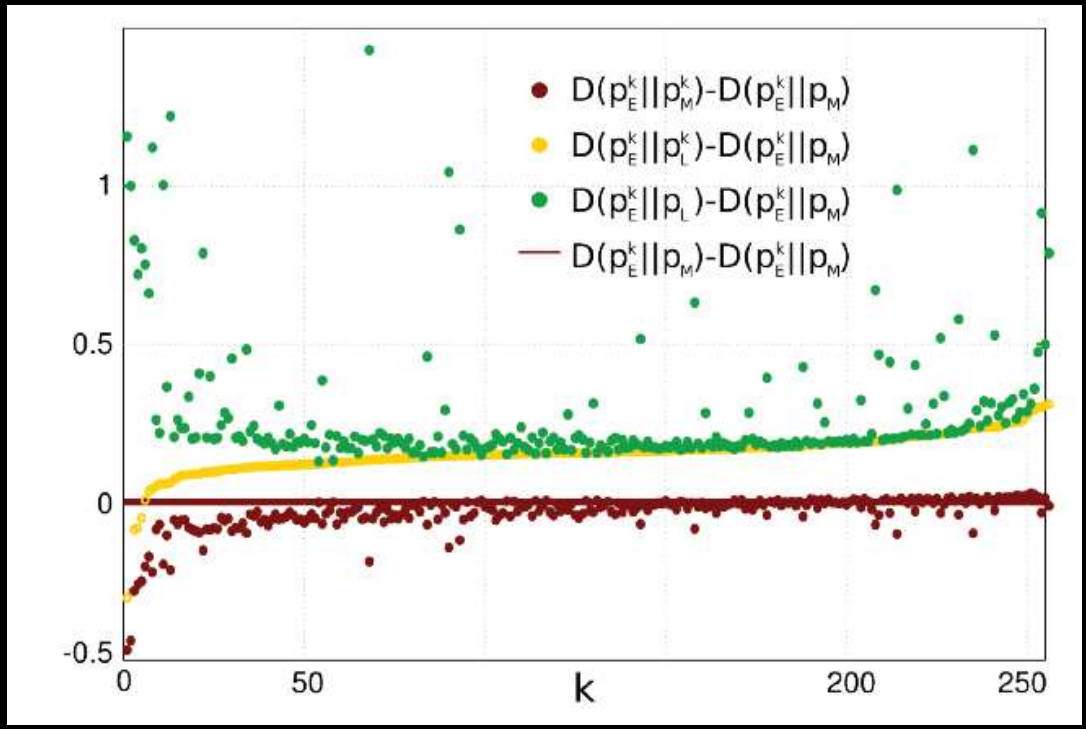
- Are there better sparsifying terms?

$$(\mathbf{A}^*, \mathbf{D}^*) = \arg\min_{\mathbf{A},\mathbf{D}} \sum_{j=1}^{n} \left\{ \|\mathbf{X}_j - \mathbf{D}\mathbf{A}_j\|^2 + \sum_{k=1}^{p} \lambda_k |\alpha_{kj}| \right\}$$

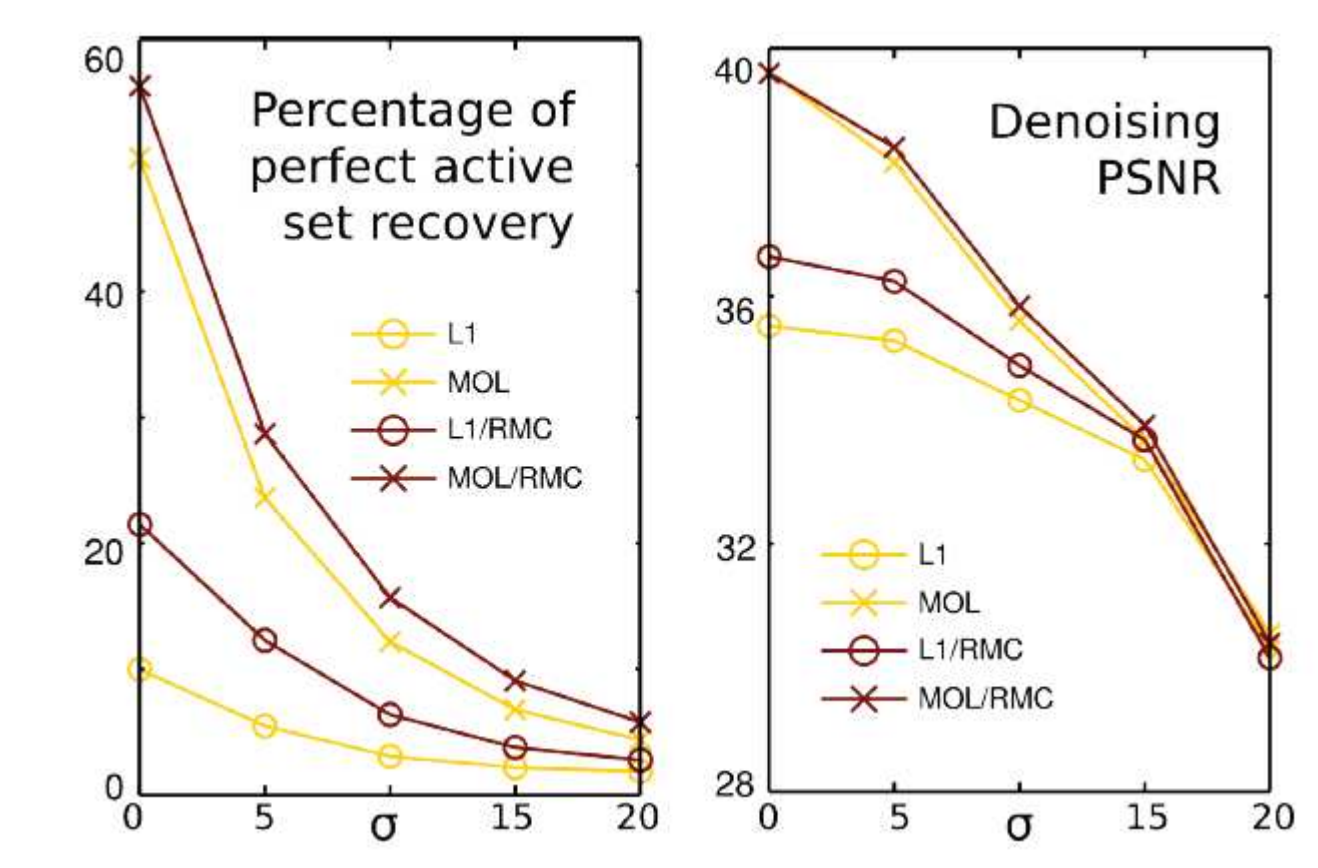
Our Approach: Universal Modeling

- Construct a model almost as good as if we knew the correct parameters





Better Models Work!



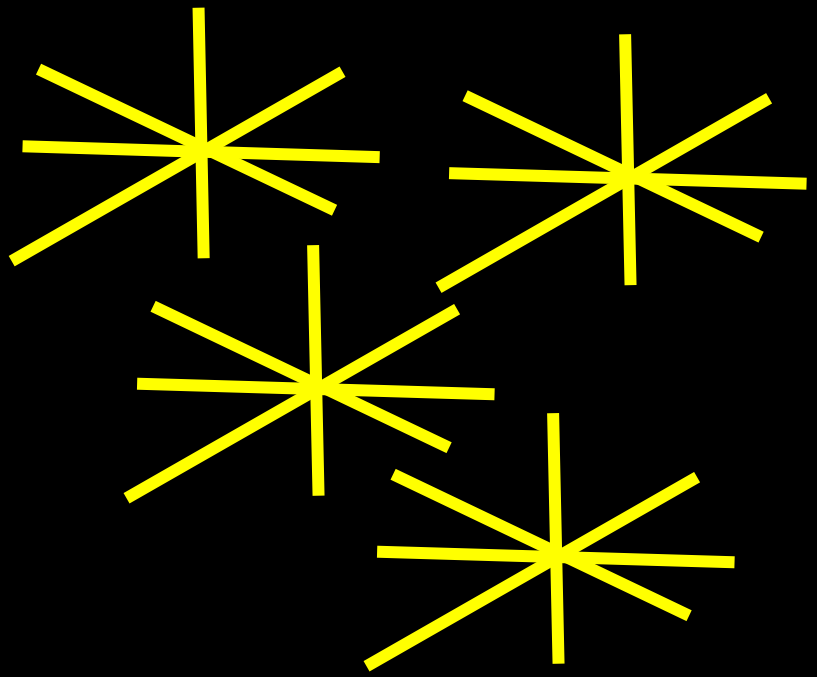
What is the model?

- Following MDL, code length, regret computations, predictive-sequential universal modeling, Jeffreys prior, …

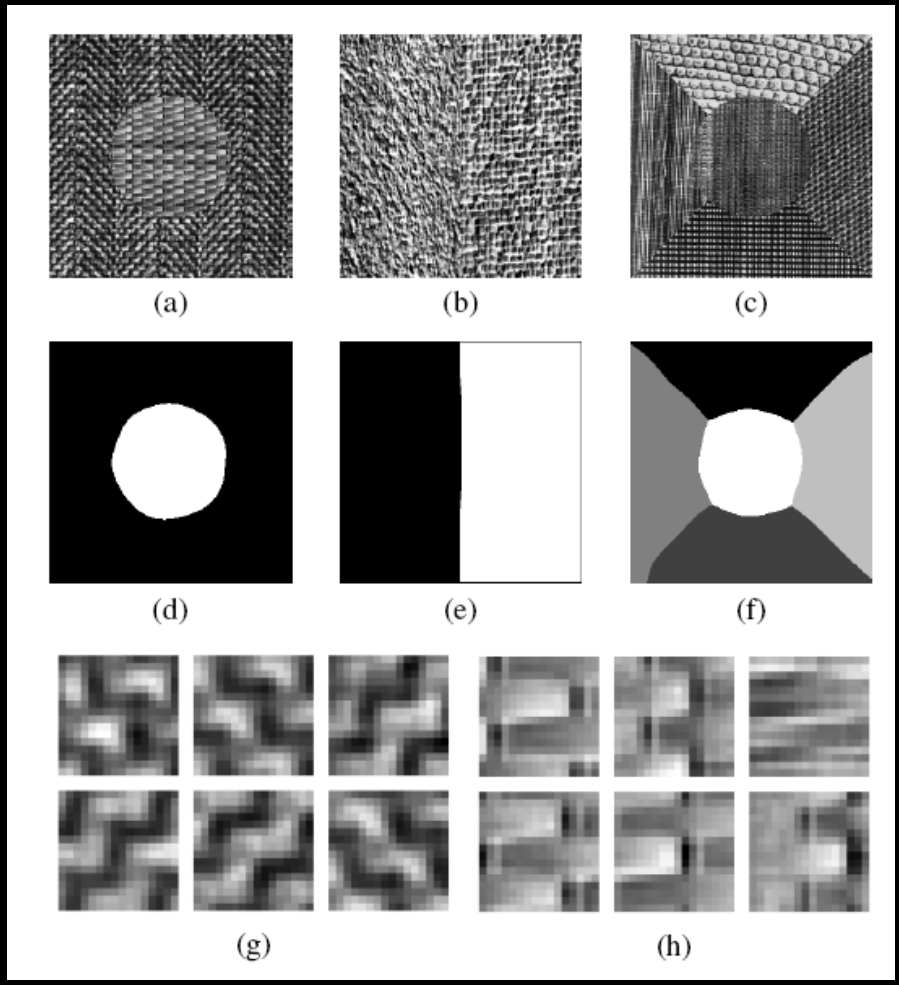
$$\mathbf{A}^* = \arg\min_{\mathbf{A}} \sum_{j=1}^{n} \left\{ \|\mathbf{X}_j - \mathbf{D}\mathbf{A}_j\|^2 + \overbrace{\tau \sum_{k=1}^{p} \log\left(|\alpha_{jk}| + \beta\right)}^{-\log q(\mathbf{A}_j)} \right\}$$

- Actually parameter free!

Model 3: Unsupervised clustering



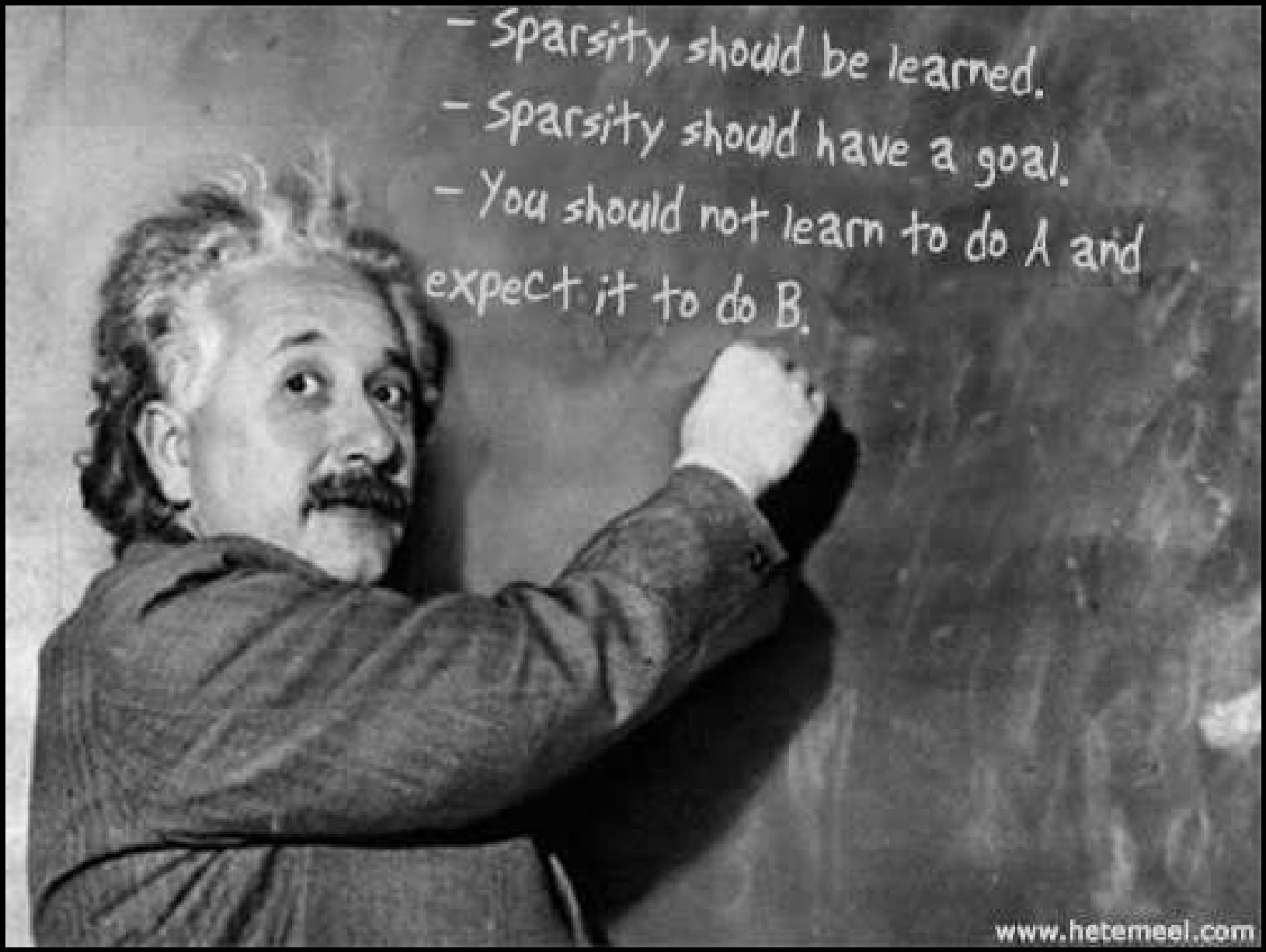
- Learn dictionaries and classify
- Dictionaries with different sizes
- New metric for classification



Conclusions

- New models and applications of dictionary learning and sparse coding
- Much more still coming/to come and open
  - Hierarchical
  - Intrinsic dictionary properties/incoherence
- Dictionary learning code on line:

http://www.di.ens.fr/willow/SPAMS/


- Sparsity should be learned.
- Sparsity should have a goal.
- You should not learn to do A and expect it to do B.
www.hetemeel.com