Edge co-occurrences and categorizing images

Implications for understanding adaptation of the function of V1 with respect to the environment

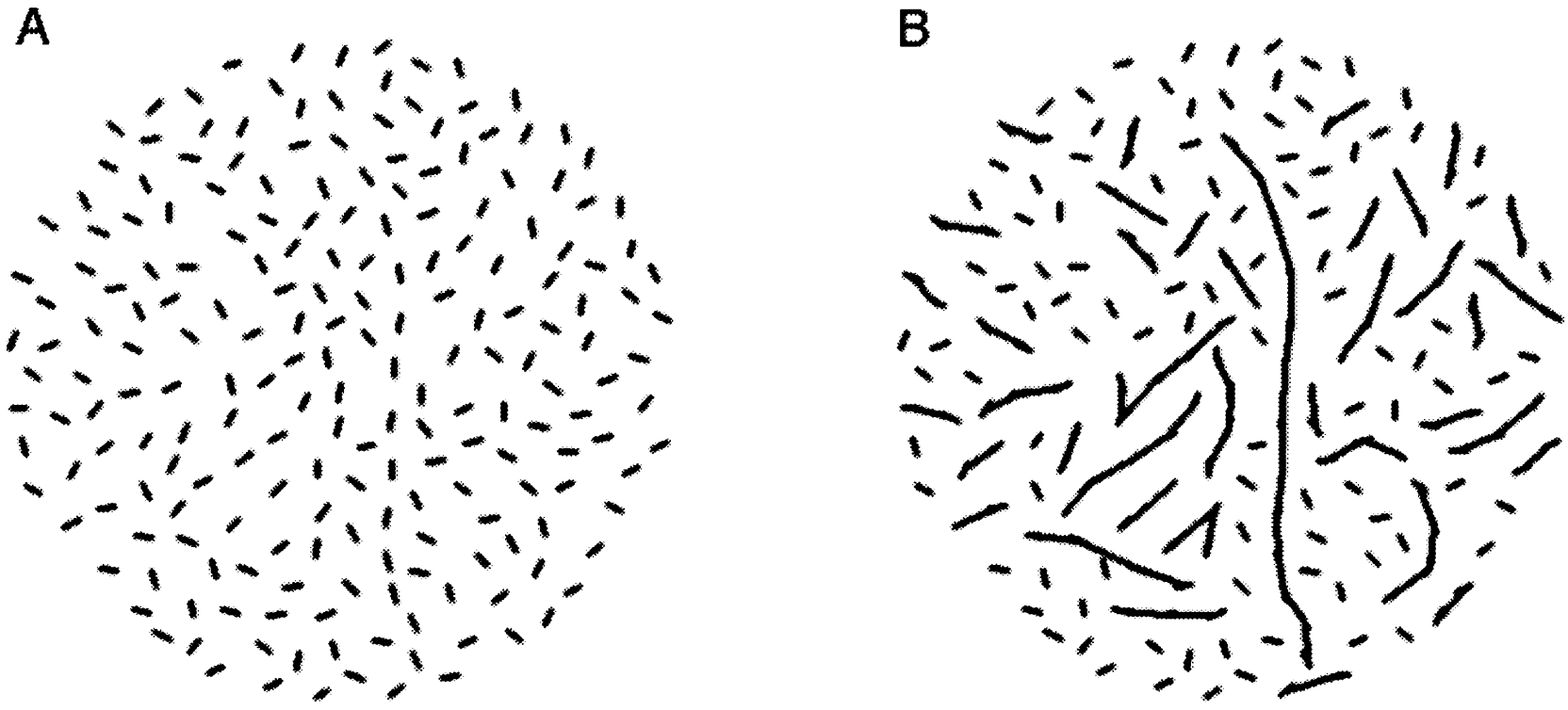
Laurent U. Perrinet[1,2], David Fitzpatrick[3] and James A. Bednar[4]

1 - InViBe, Institut de Neurosciences de la Timone
CNRS / Université de la Méditérrannée, Marseille, France.
2 - The Wellcome Trust Centre for Neuroimaging
University College London, UK.
3 - Max Planck Florida Institute, Jupiter, Florida
4 - Institute for Adaptive and Neural Computation, University of Edinburgh

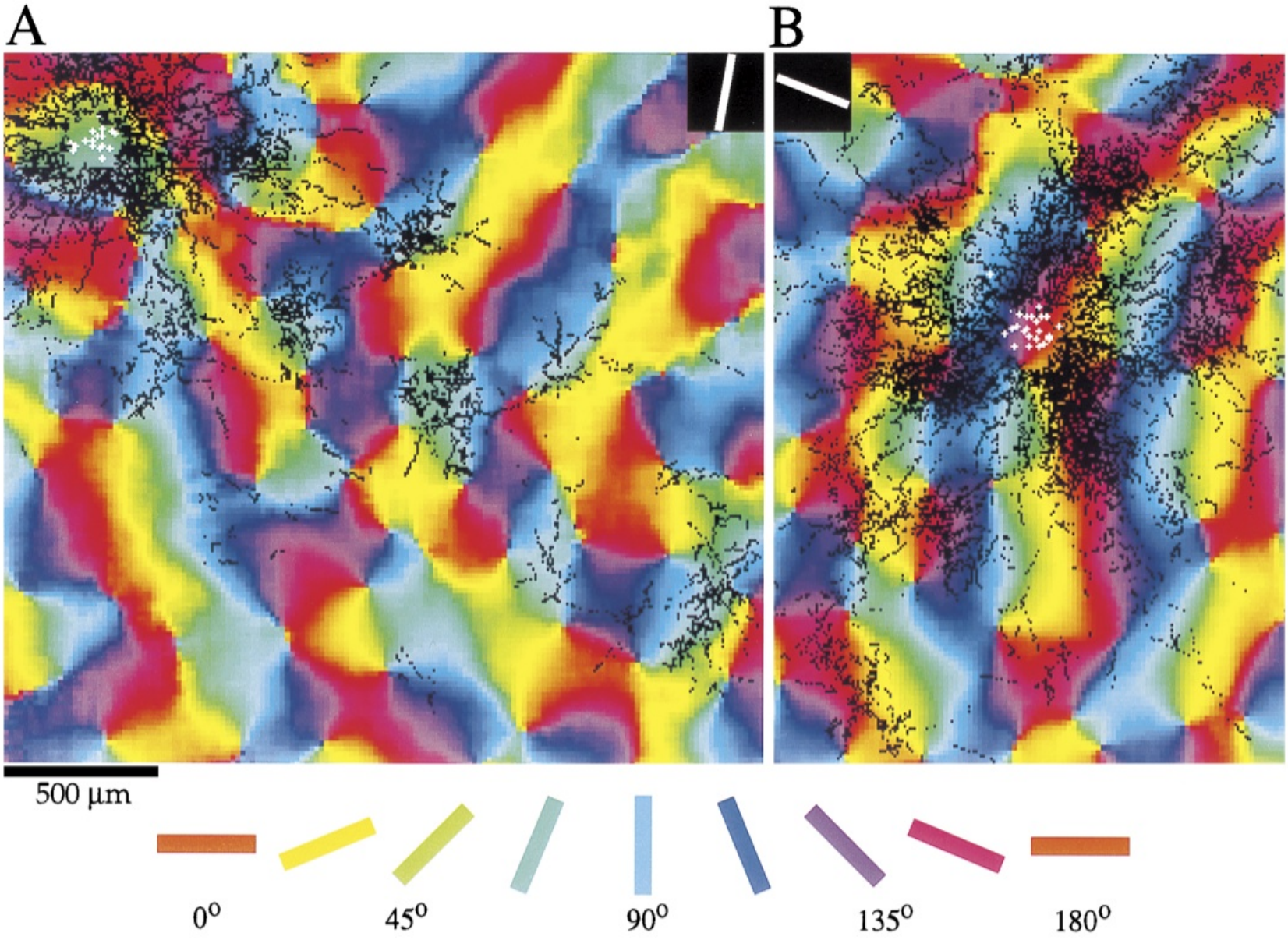
Friday 5th July, 2013

CerCo's 20th anniversary, Toulouse, France.

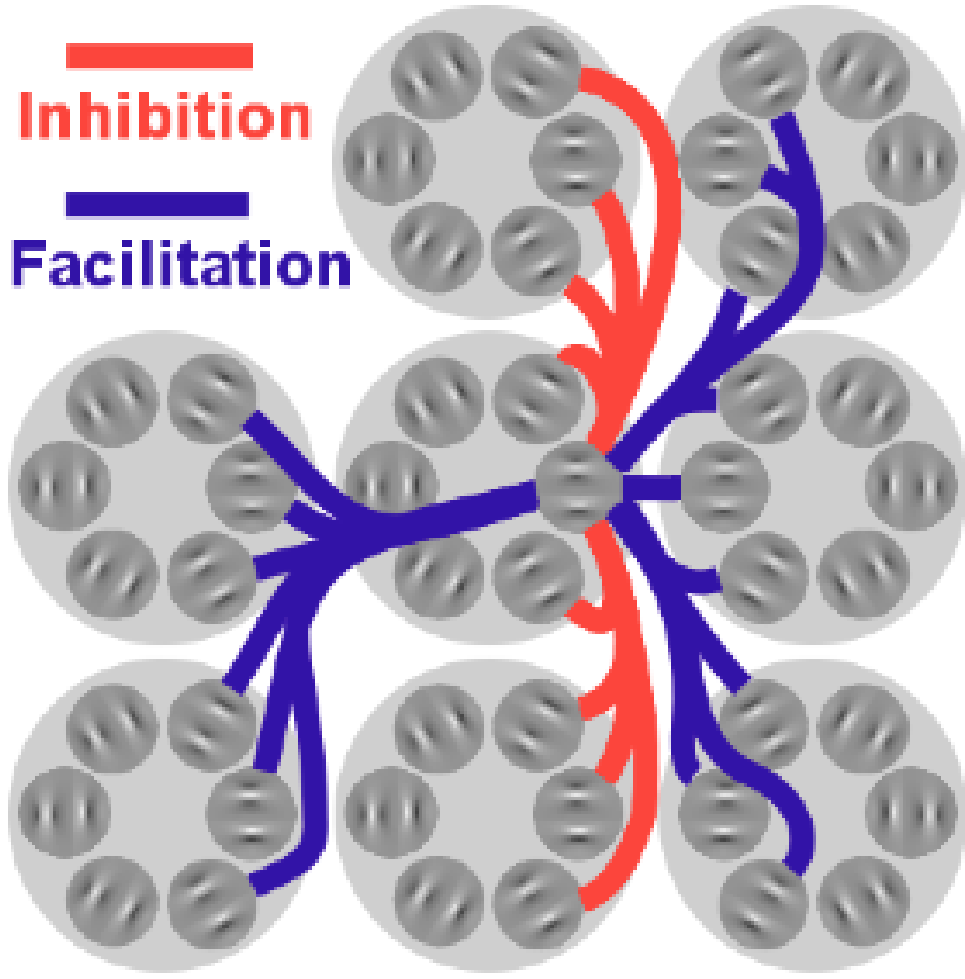
This work is supported by projects ``BrainScaleS'' (EU funding, grant number FP7-269921).



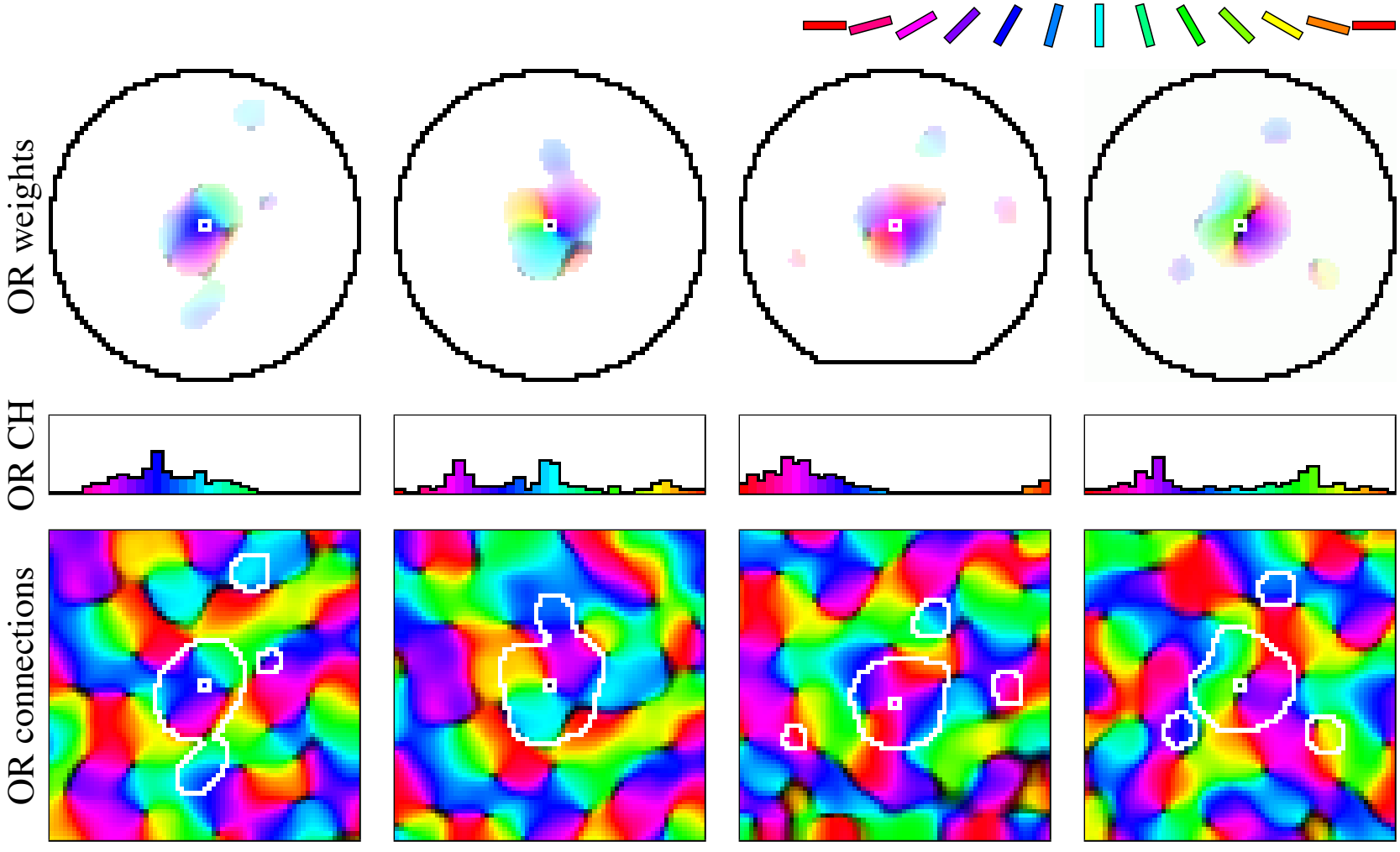
(Geisler et al., 2001, Vision Research)



(Bosking et al, 1997, Journal of Neuroscience)



(Fischer et al., 2007)



(*a*) Connections in iso-OR patches

(*b*) Connections in OR pinwheels

(*c*) Connections in OR saddles

(*d*) Connections in OR fractures

(Choe et al. 2004; Miikkulainen et al., 2005)

Outline: Edge co-occurrences and categorizing images

Introduction: linking neural structure to natural scenes

- Geisler et al, 2001
- Bosking et al, 1997
- Problem statement

Method: detection of edges

- Geisler et al, 2001
- Log Gabor representation / Sparse coding

Results: natural vs. laboratory images

- Some examples of edge extraction
- Second-order statistics
- Quantitative difference using classification

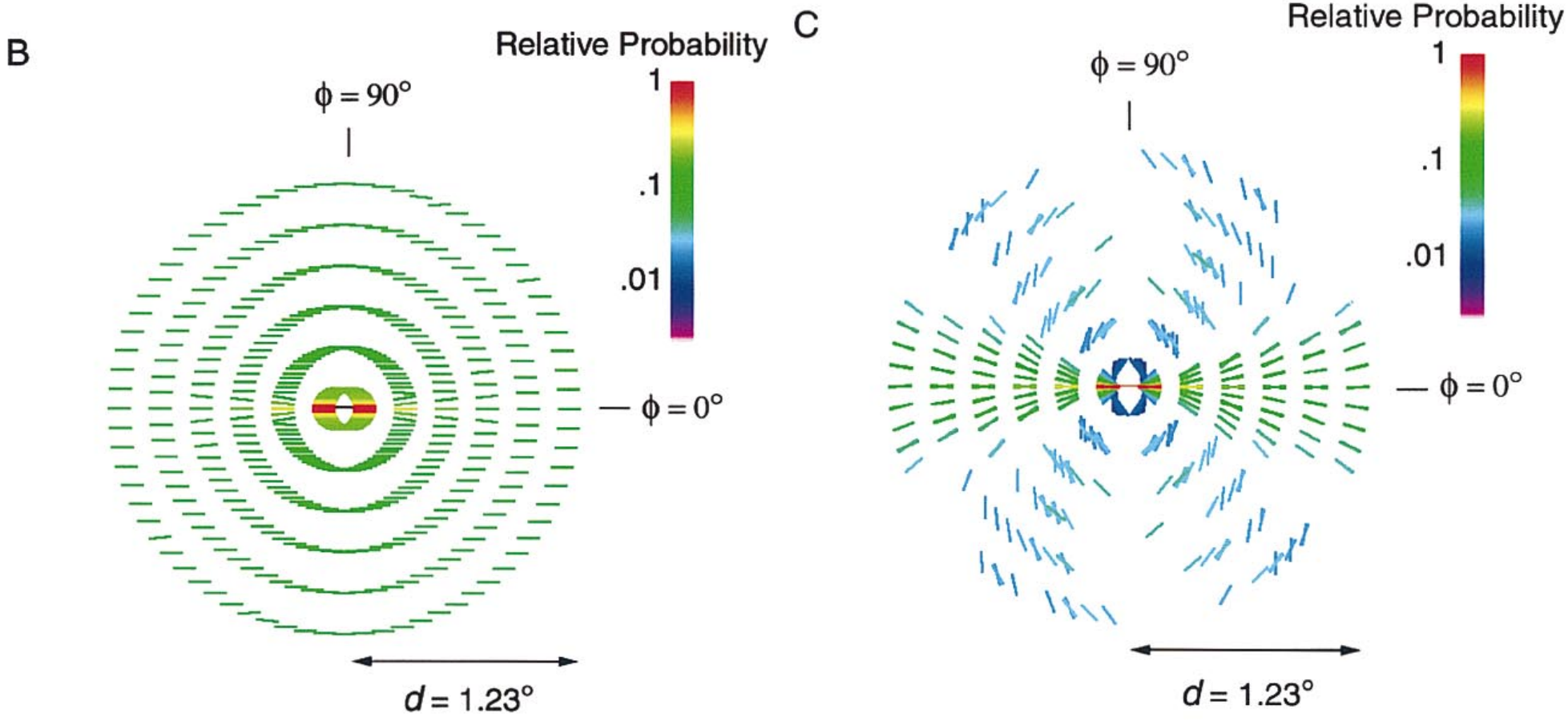
Take-home message

Categorizing animals vs animals

Outline: Edge co-occurrences and categorizing images

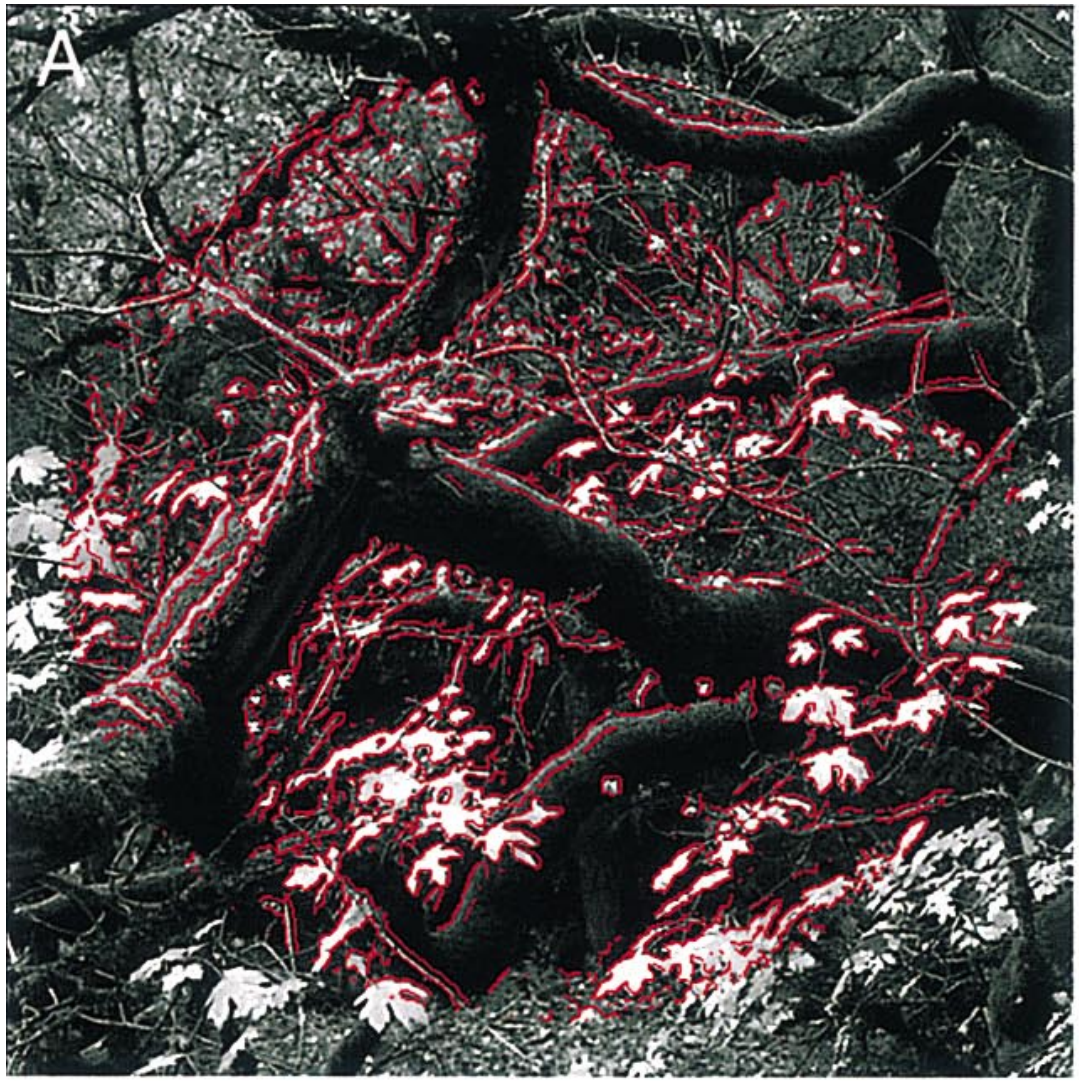
- Introduction: linking neural structure to natural scenes
  - Geisler et al, 2001
  - Bosking et al, 1997
  - Problem statement
- Method: detection of edges
  - Geisler et al, 2001
  - Log Gabor representation / Sparse coding
- Results: natural vs. laboratory images
  - Some examples of edge extraction
  - Second-order statistics
  - Quantitative difference using classification
- Take-home message
- Categorizing animals vs animals

Geisler et al, 2001



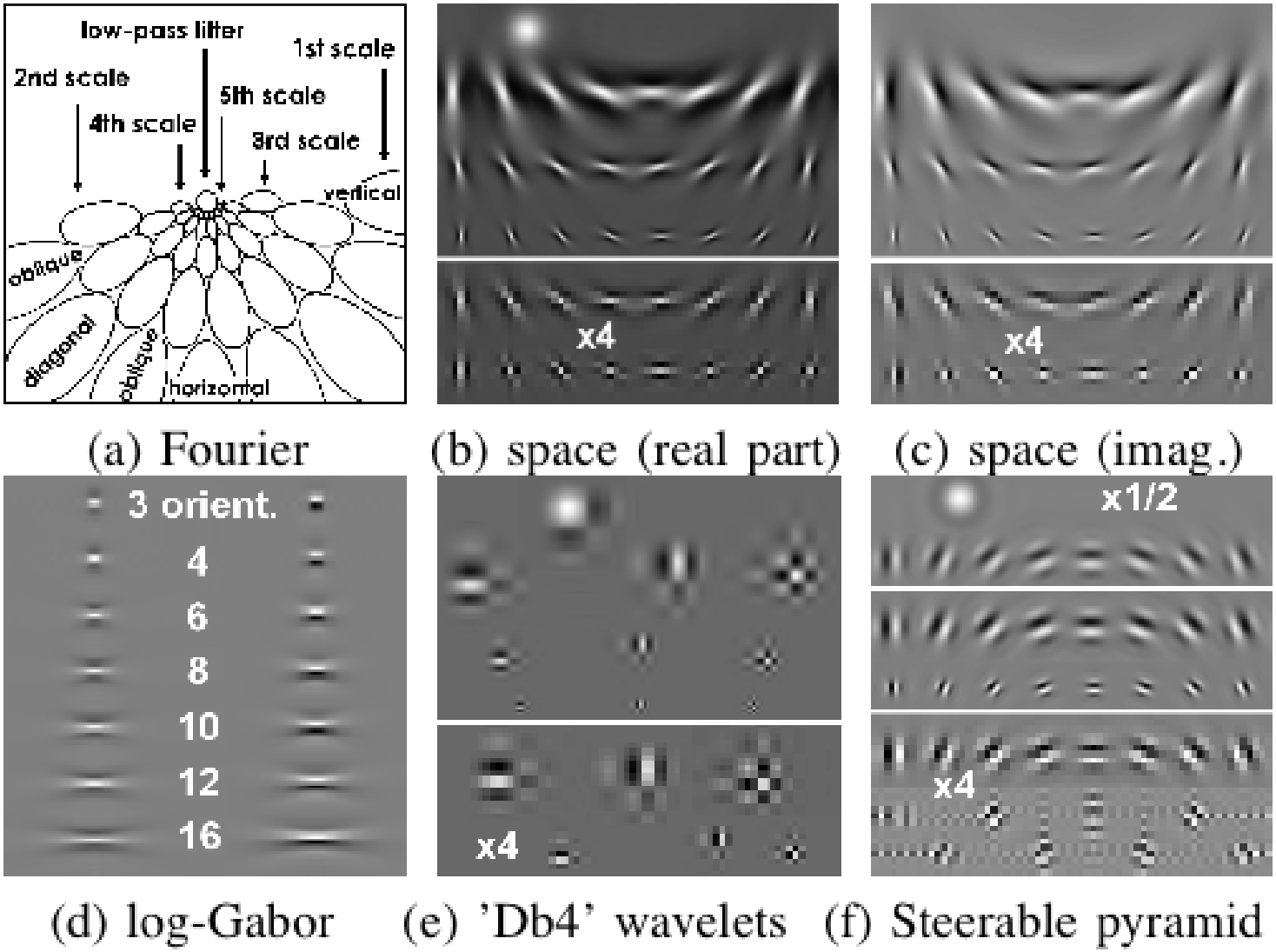
(Geisler et al., 2001, Vision Research)

Geisler et al, 2001



(Geisler et al., 2001, Vision Research)

Log Gabor representation / Sparse coding



(a) Fourier (b) space (real part) (c) space (imag.)

(d) log-Gabor (e) 'Db4' wavelets (f) Steerable pyramid

(Fischer et al, 2007, International Journal of Computer Vision)

(Perrinet, 2010, Neural Computation)

Outline: Edge co-occurrences and categorizing images

Introduction: linking neural structure to natural scenes
- Geisler et al, 2001
- Bosking et al, 1997
- Problem statement

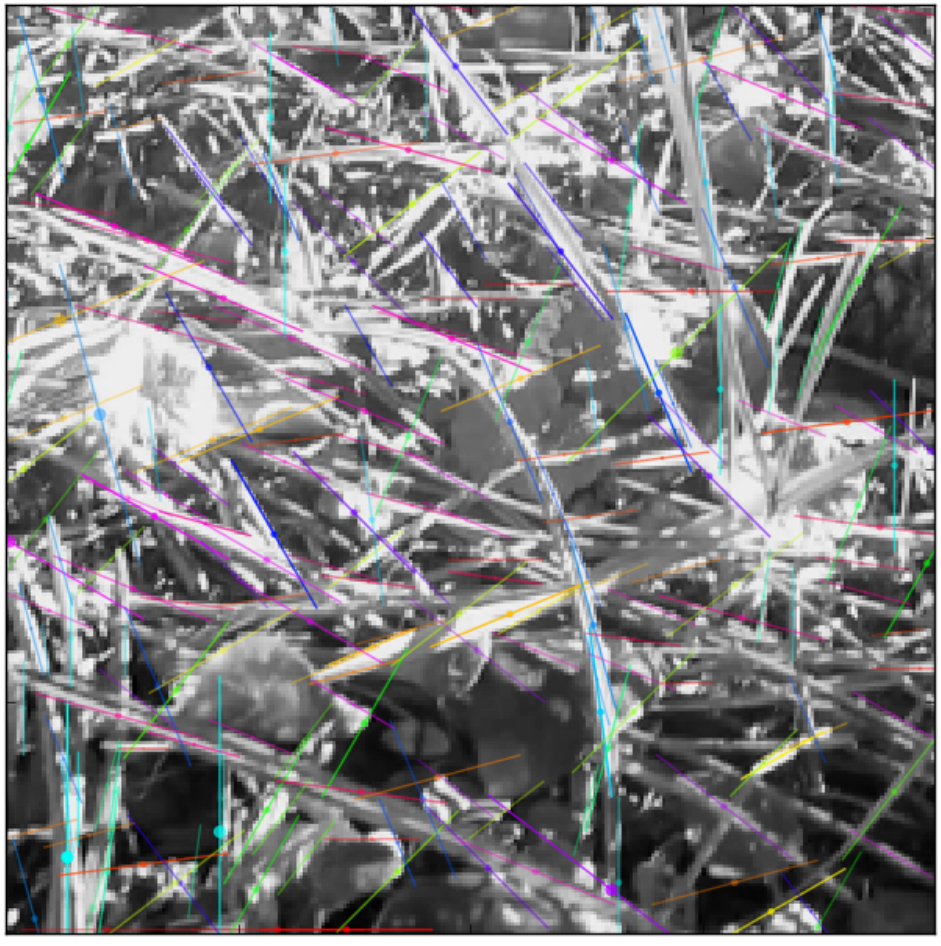
Method: detection of edges
- Geisler et al, 2001
- Log Gabor representation / Sparse coding

Results: natural vs. laboratory images
- Some examples of edge extraction
- Second-order statistics
- Quantitative difference using classification

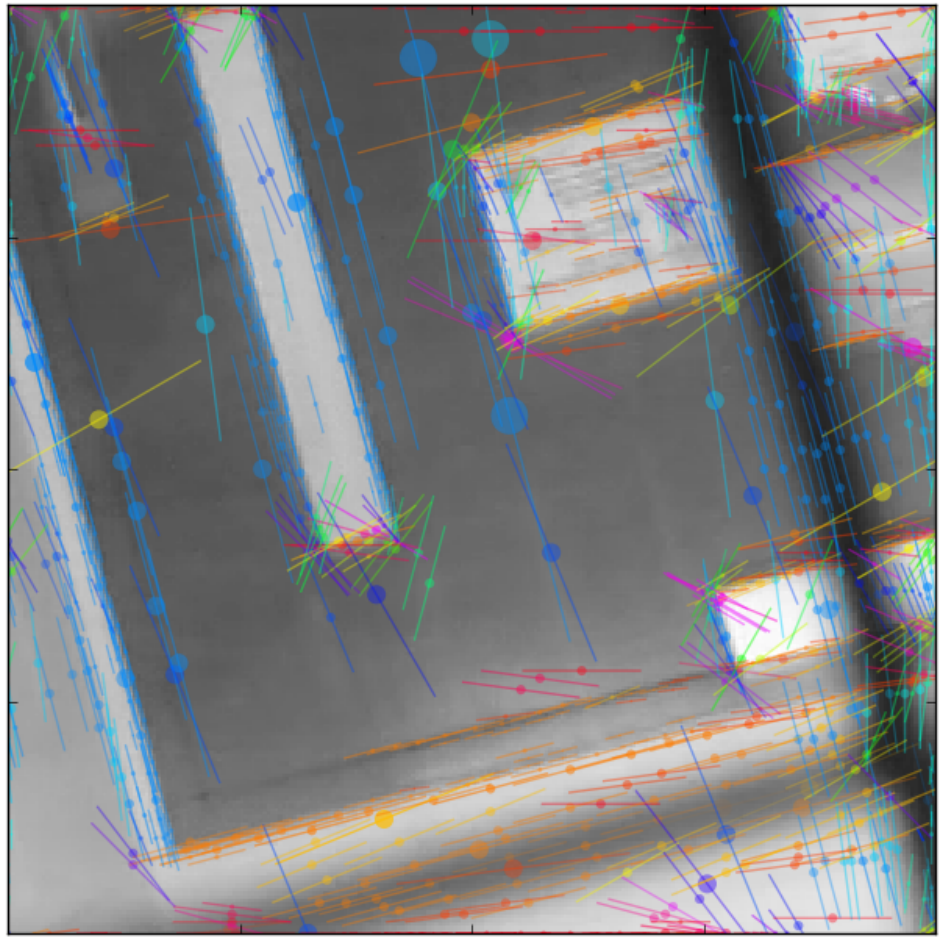
Take-home message

Categorizing animals vs animals

Some examples of edge extraction



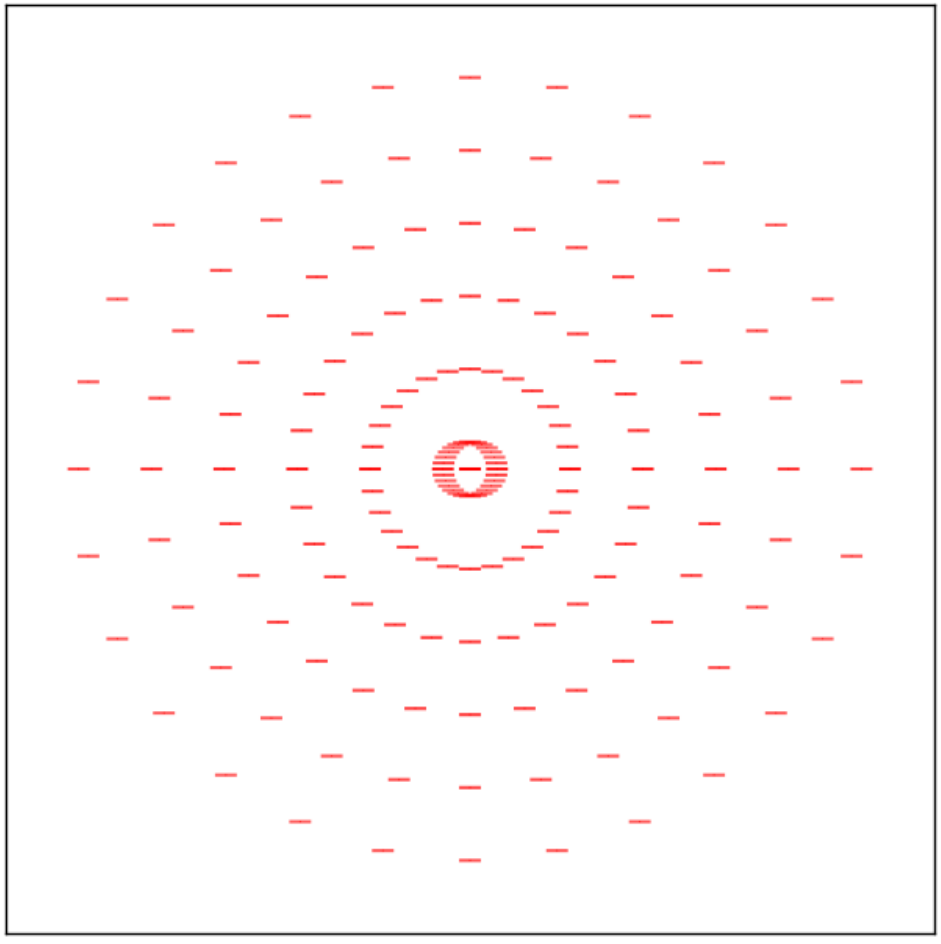
Natural



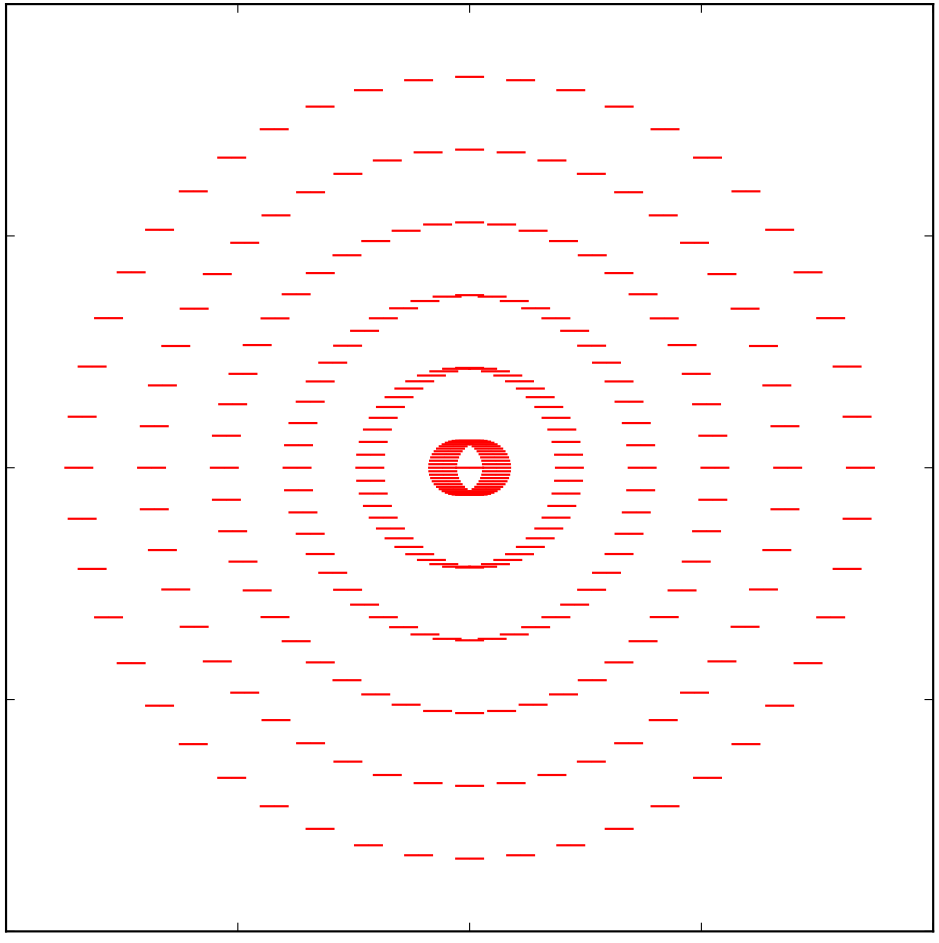
Laboratory

Second-order statistics

$$\arg\max_{\theta} p(\theta|d, \phi, \sigma, \pi_0)$$



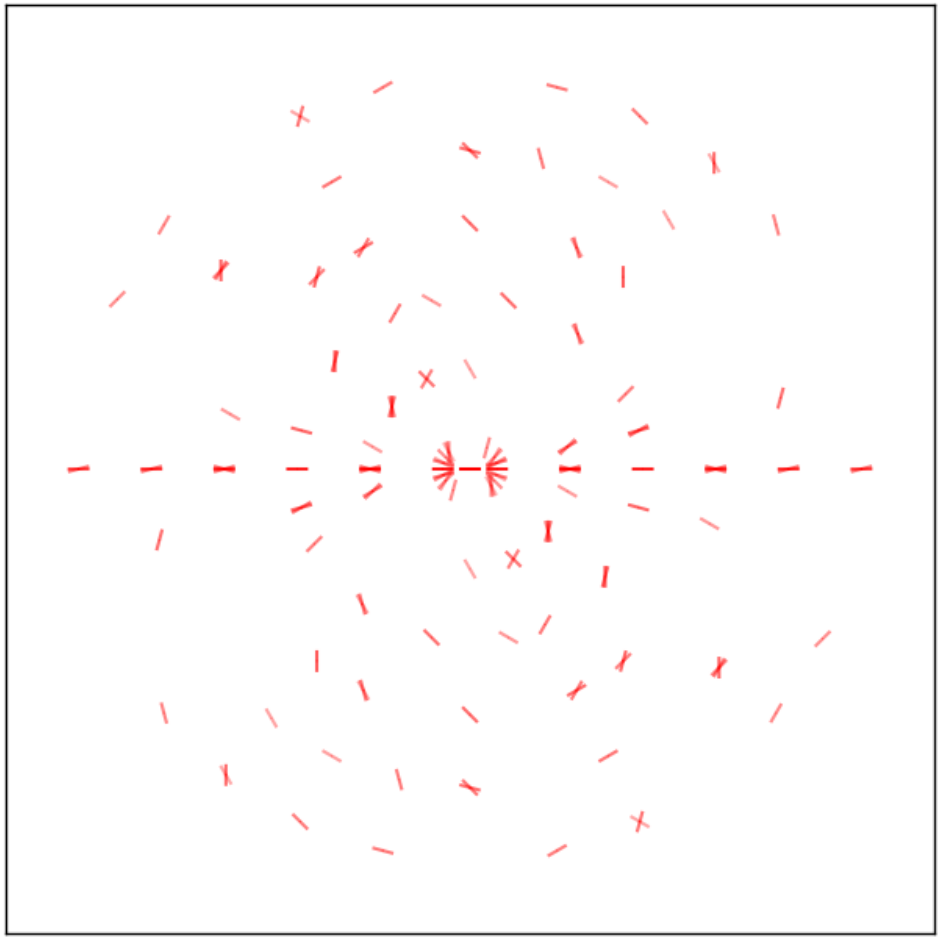
Natural



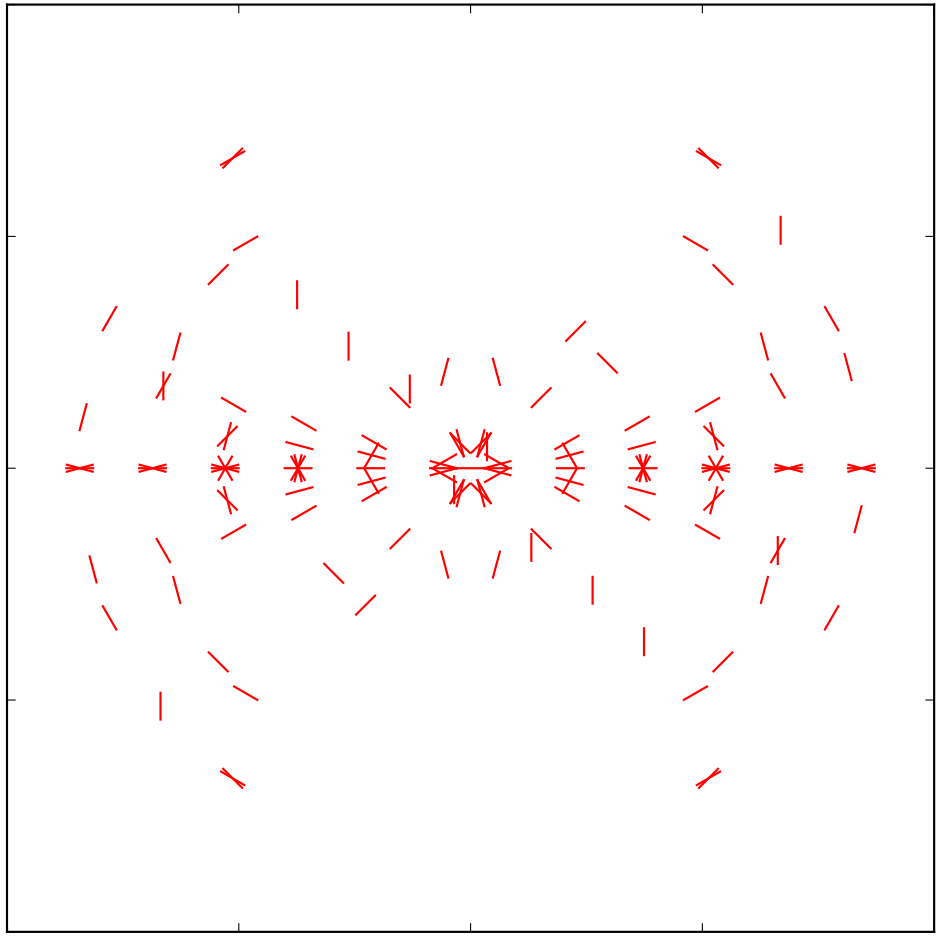
Laboratory

Second-order statistics

$$\arg\max_{\phi} p(\phi|d,\theta,\sigma,\pi_0)$$



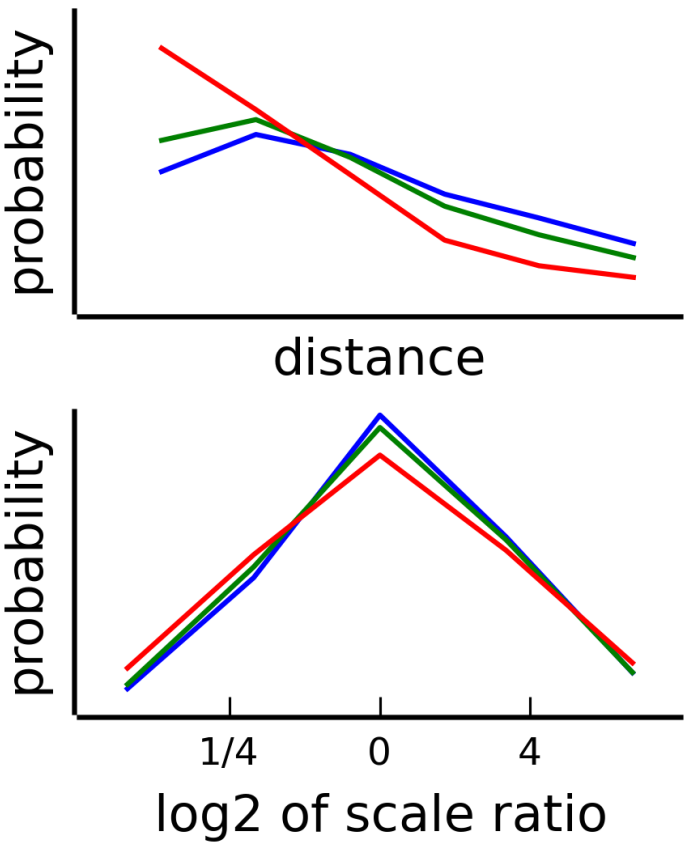
Natural

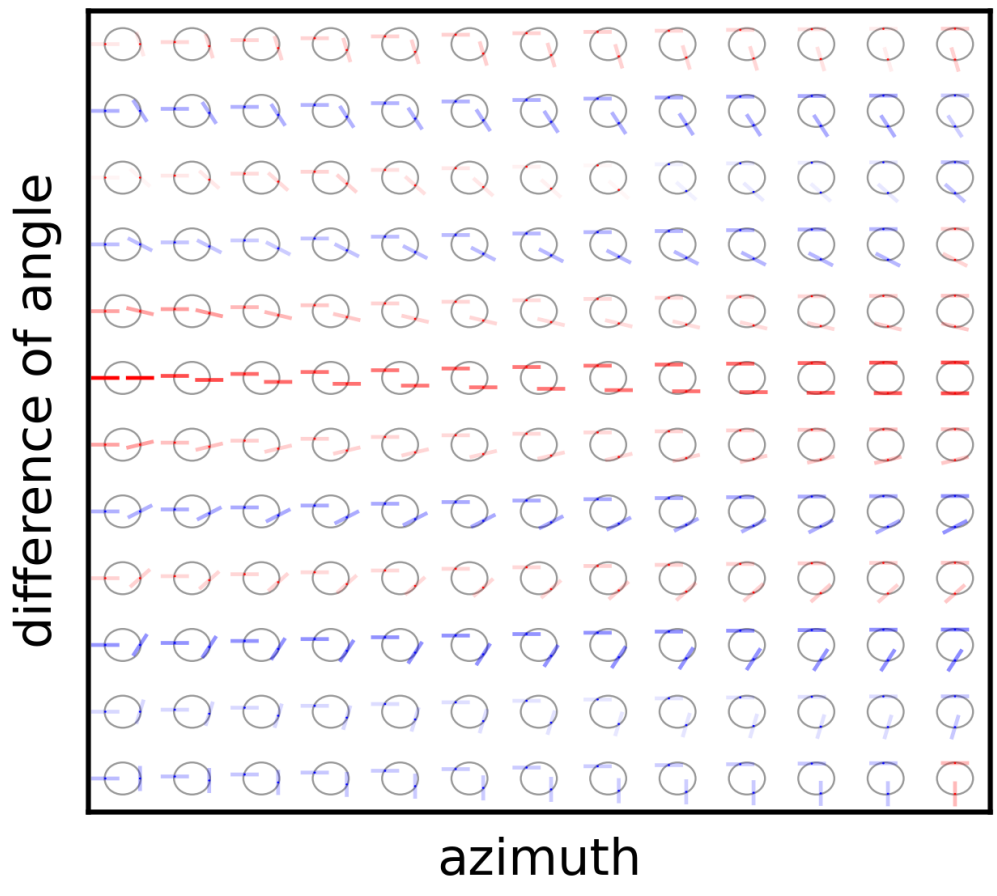


Laboratory

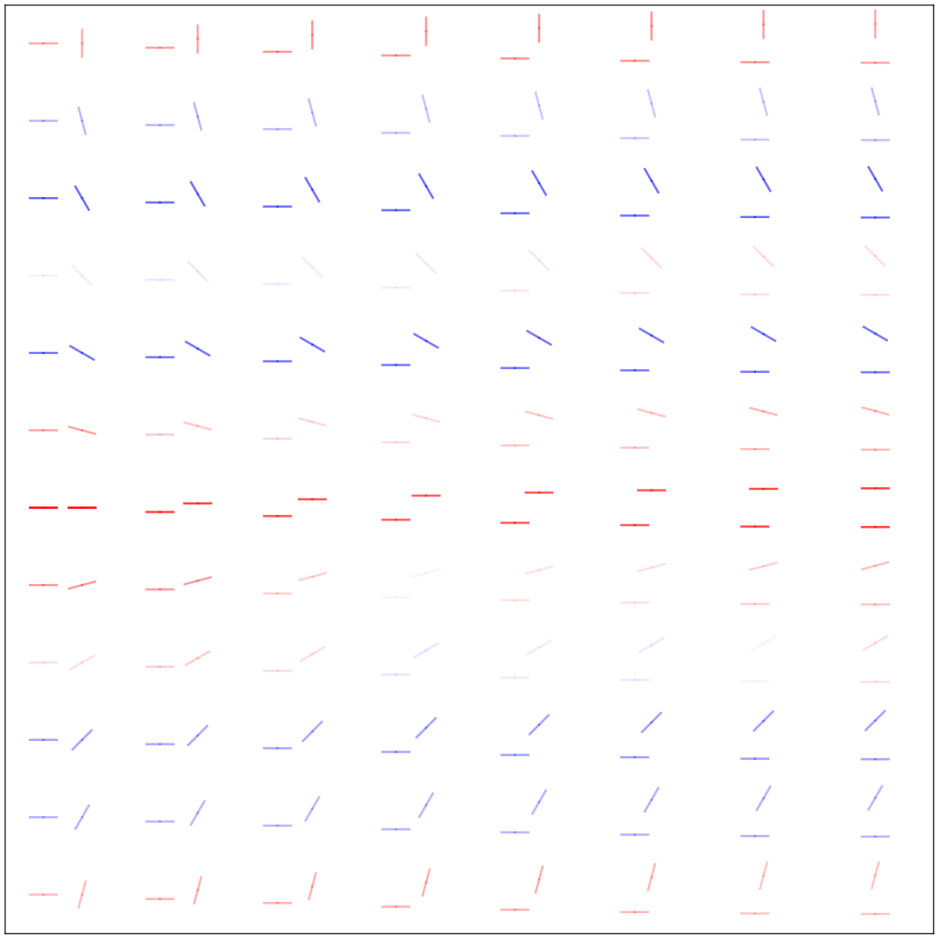
Second-order statistics

$$p(d, \phi, \theta, \sigma|\pi_0) \approx p(d, \sigma|\pi_0)p(\theta, \phi|\pi_0)$$

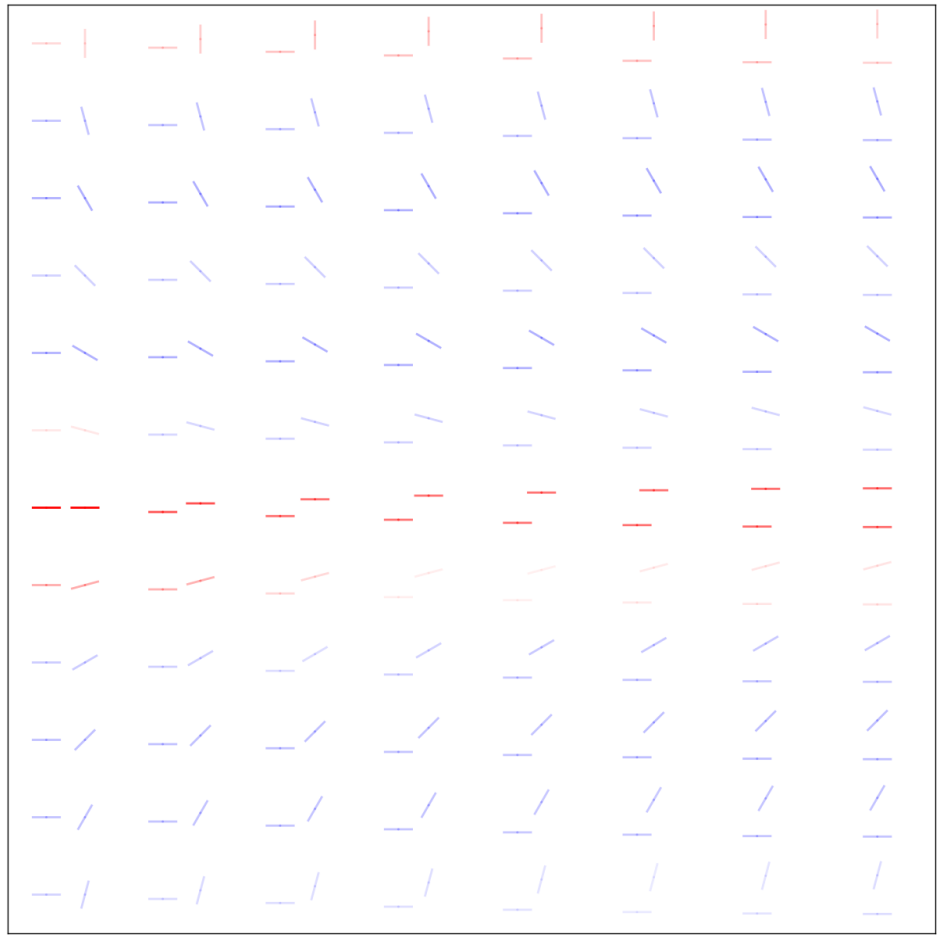




Second-order statistics



Natural

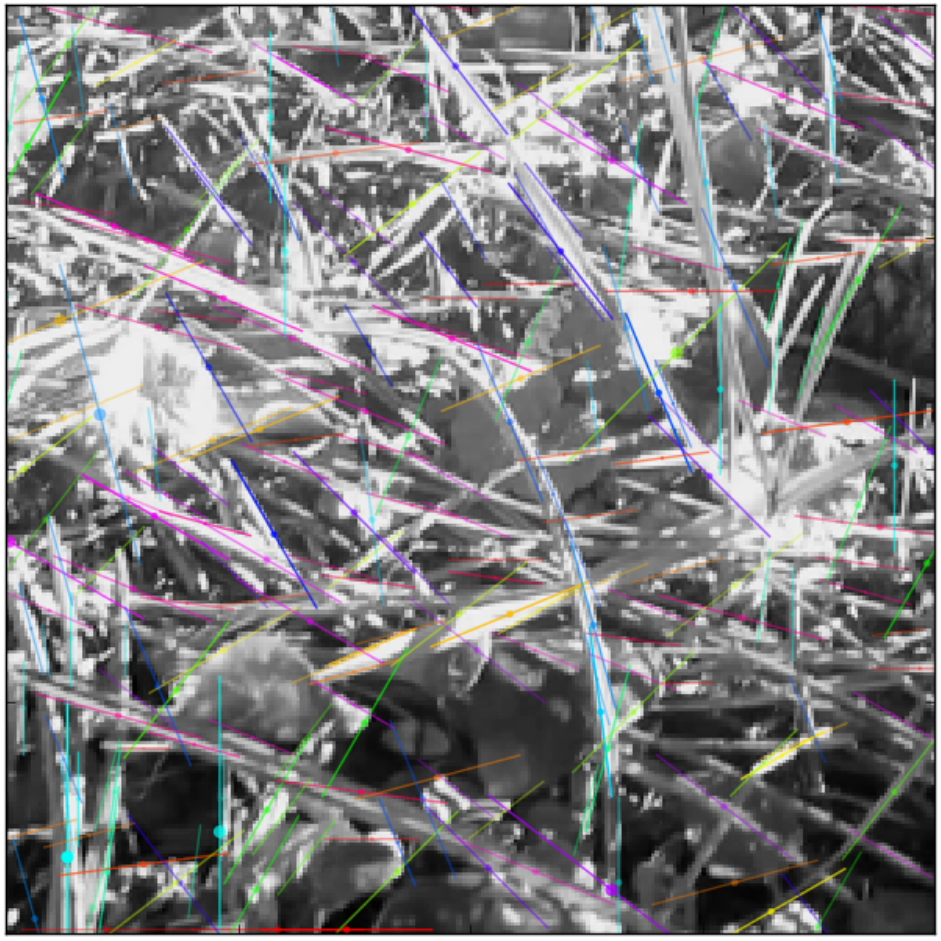


Laboratory

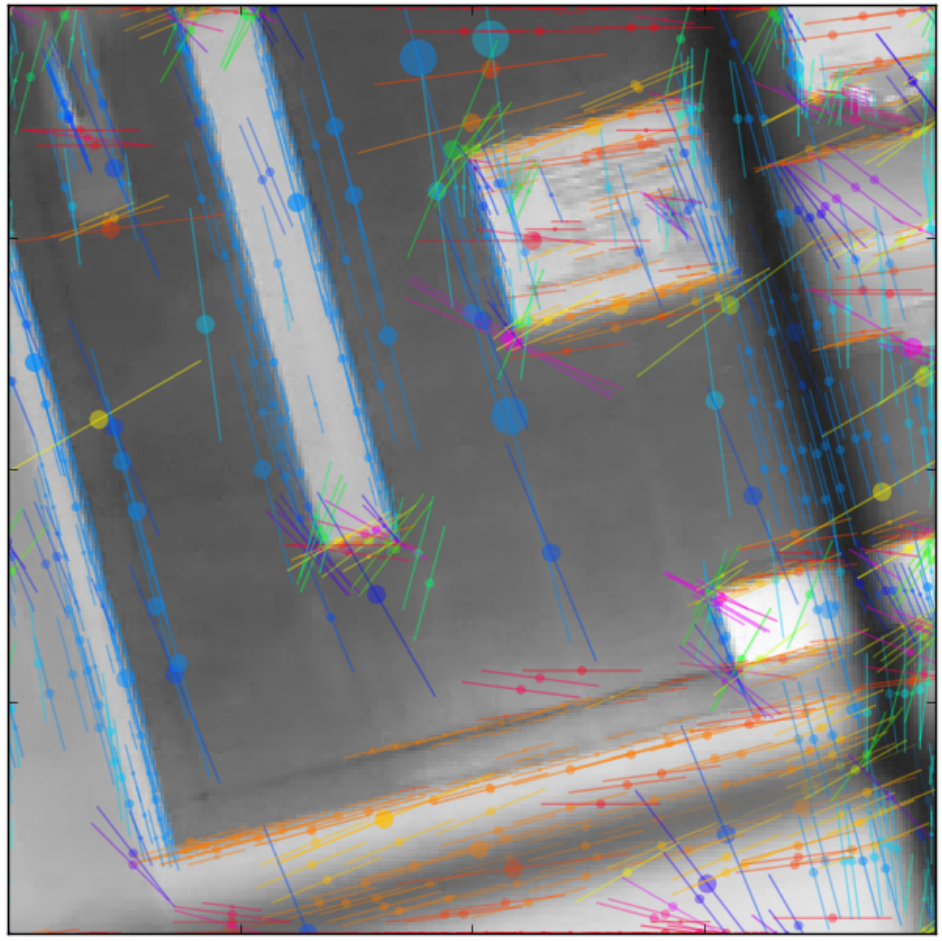
Quantitative difference using classification

Database 1	Database 2	2-means	SVM 1	SVM 2	SVM C
Natural	Artificial	98%	88%	99%	98%

Summary



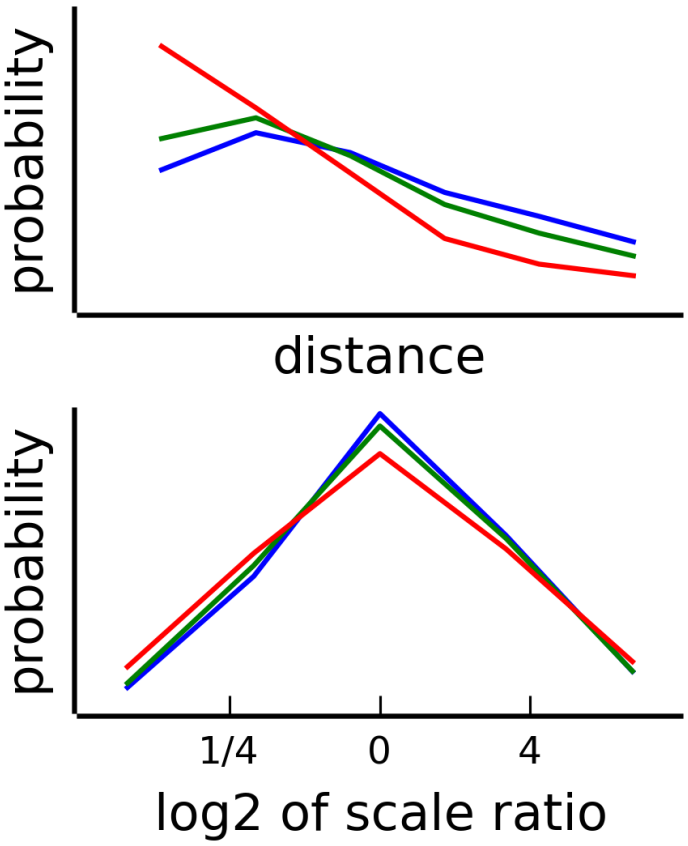
Natural

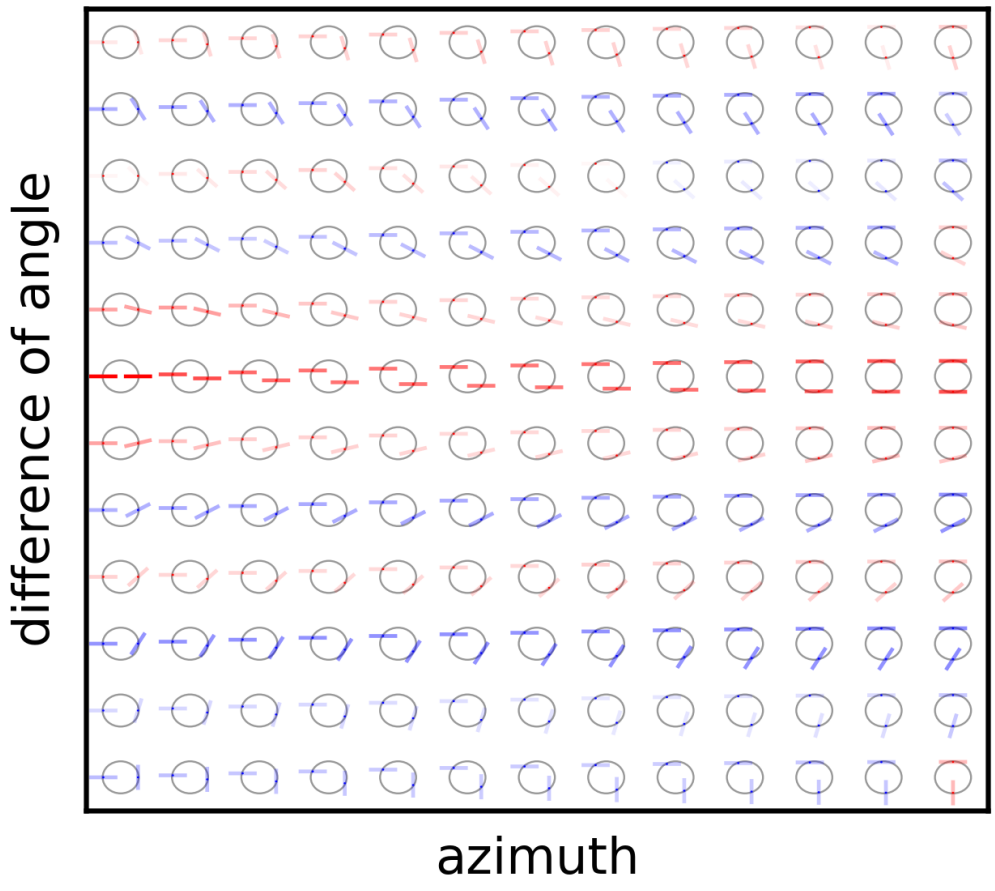


Laboratory

Summary

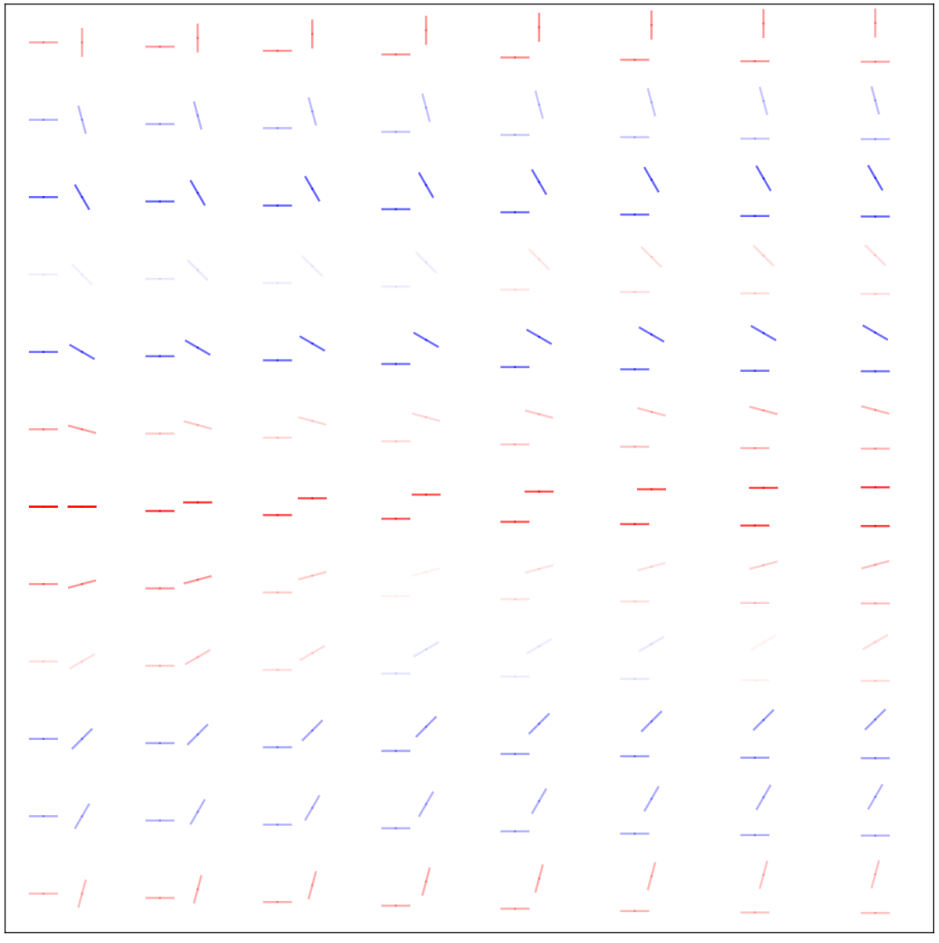
$$p(d, \phi, \theta, \sigma|\pi_0) \approx p(d, \sigma|\pi_0)p(\theta, \phi|\pi_0)$$



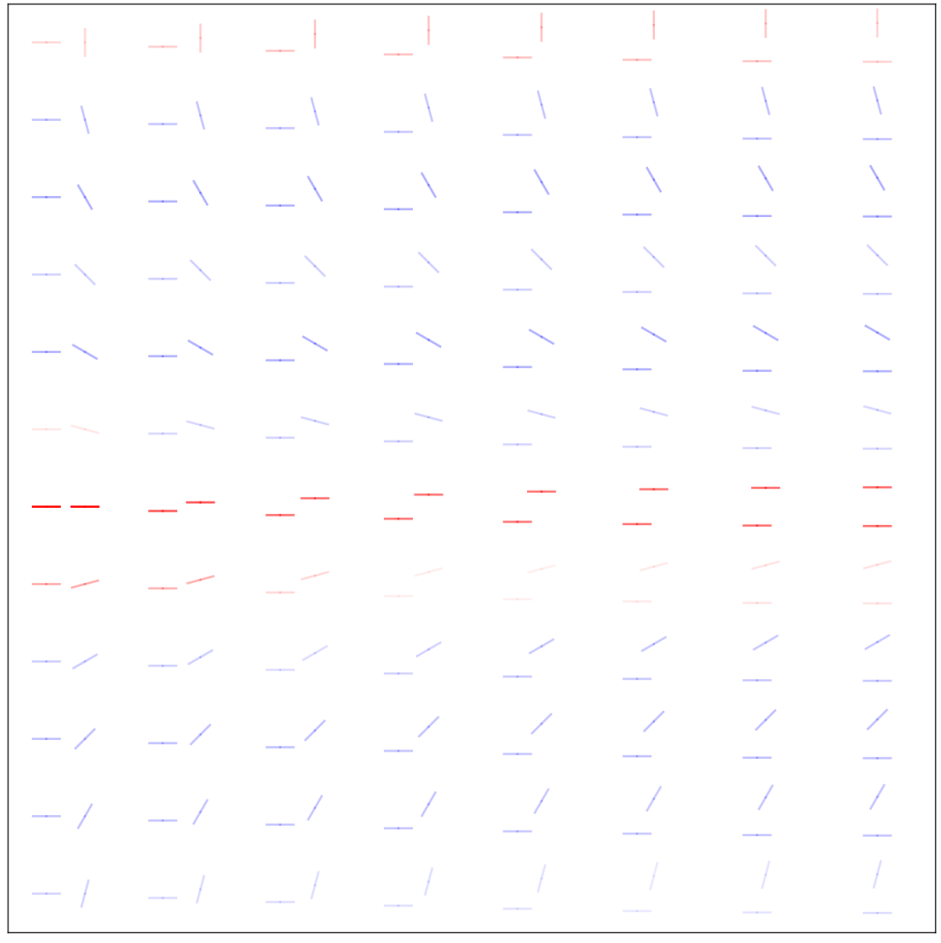


Summary

$$p(d, \phi, \theta, \sigma|\pi_0) \approx p(d, \sigma|\pi_0)p(\theta, \phi|\pi_0)$$

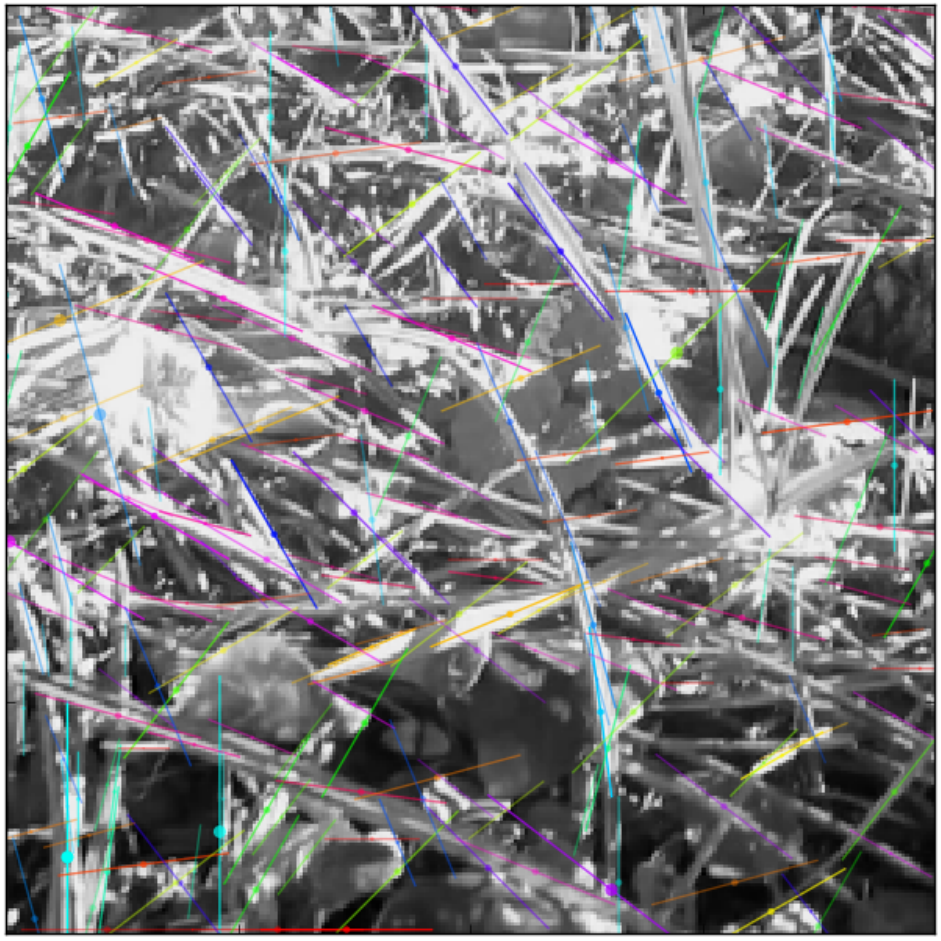


Natural

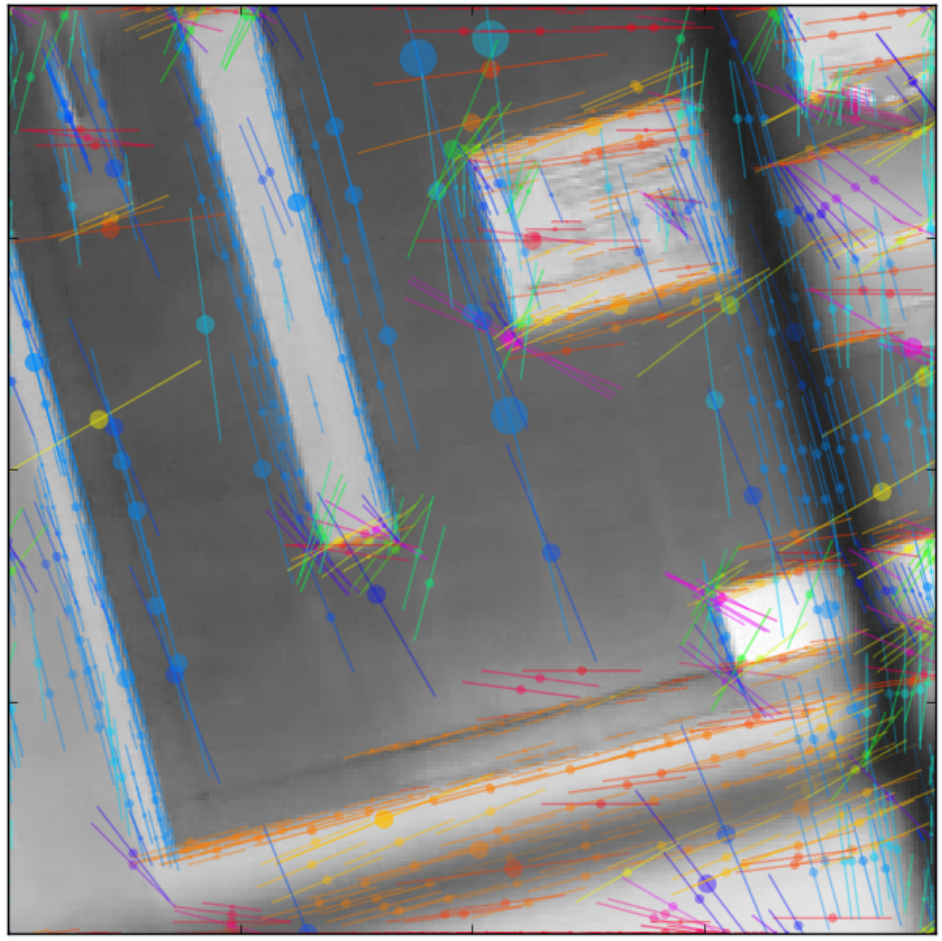


Laboratory

Categorizing animals vs animals

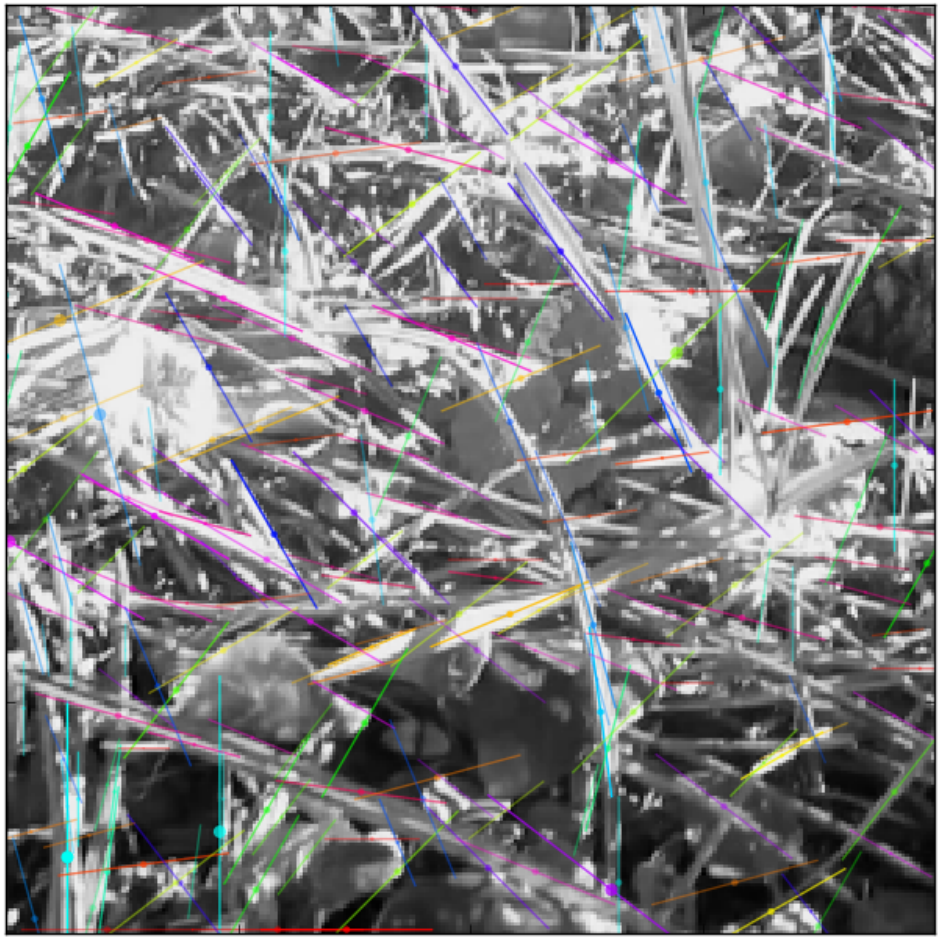


Natural

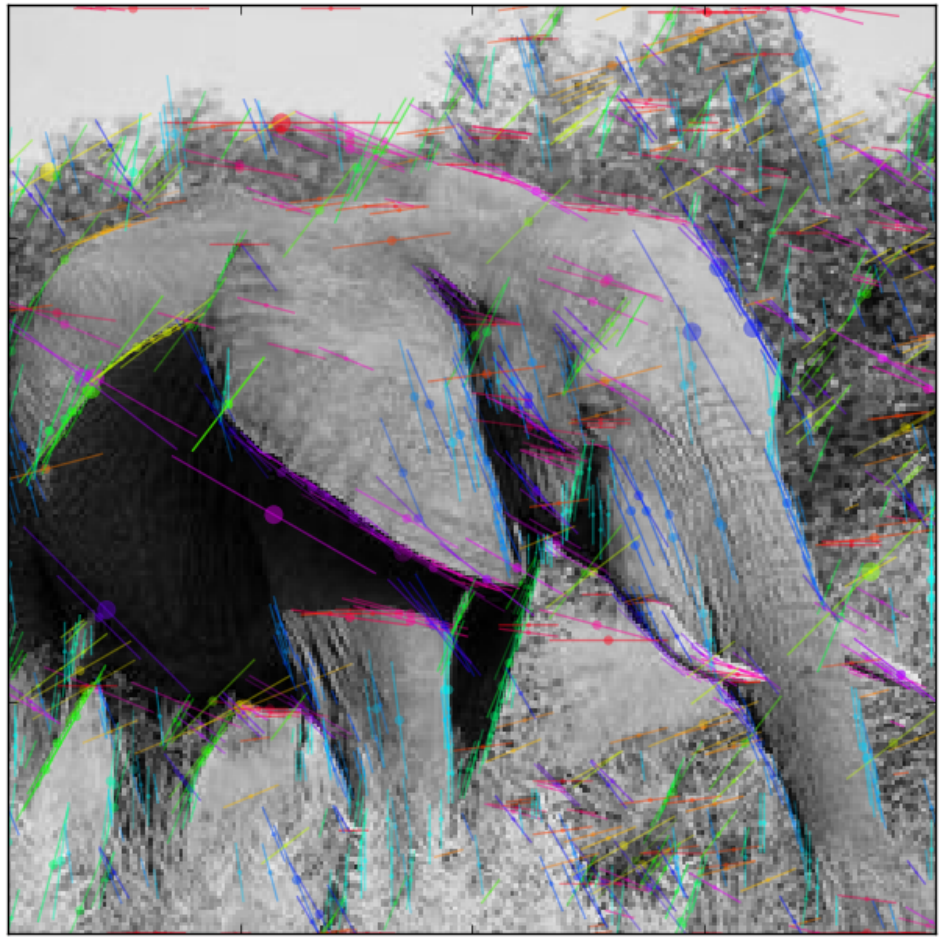


Laboratory

Categorizing animals vs animals

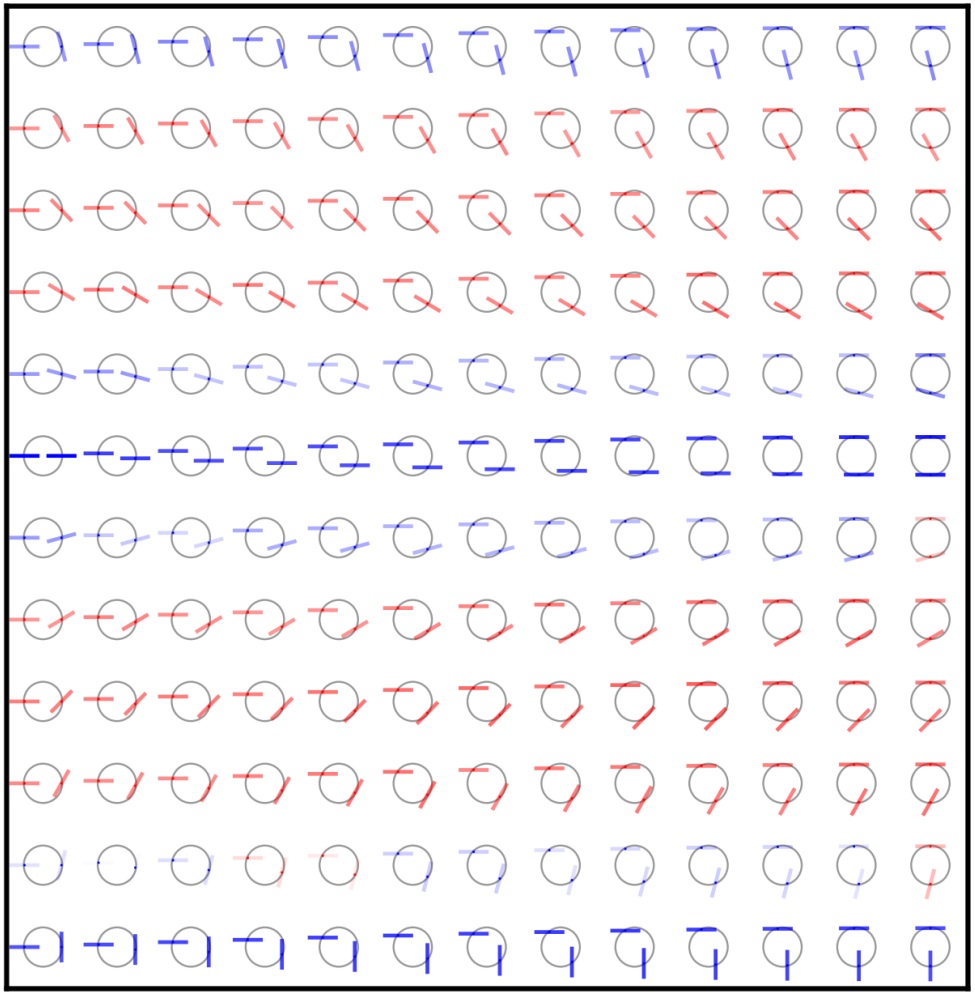


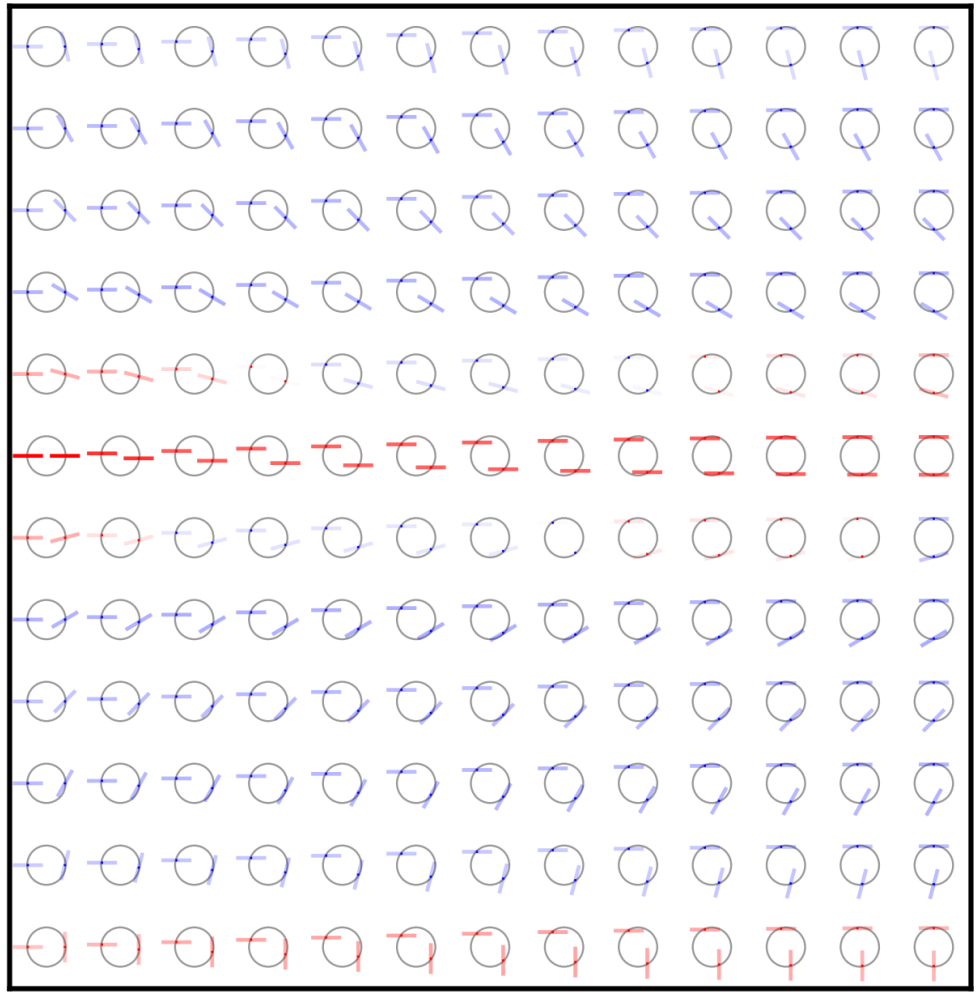
Natural



Animal

Categorizing animals vs animals





Categorizing animals vs animals

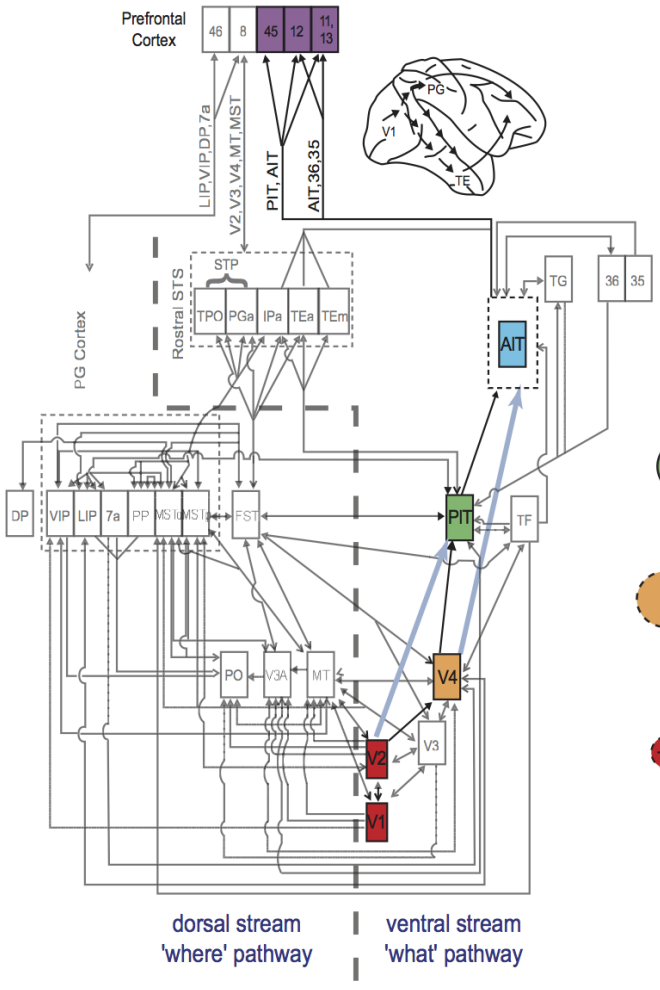
Database 1	Database 2	2-means	SVM 1	SVM 2	SVM C
Natural	Natural	50%	50%	50%	50%
Natural (noise)	Animal (noise)	64%	71%	77%	77%
Natural	Animal	65%	68%	82%	81%
Natural	Artificial	98%	88%	99%	98%

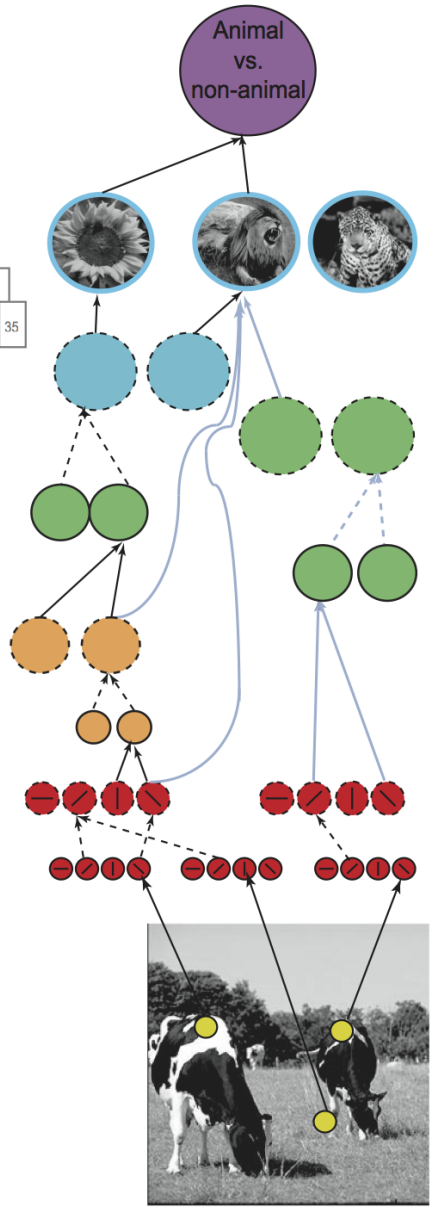
Categorizing animals vs animals

Best

Worst

Categorizing animals vs animals





Model layers	RF sizes	Num. units
classification units		10^0
S4	7 °	10^2
C3	7 °	10^3
C2b	7 °	10^3
S3	1.2°- 3.2°	10^4
S2b	0.9°- 4.4°	10^7
C2	1.1°- 3.0°	10^5
S2	0.6°- 2.4°	10^7
C1	0.4°- 1.6°	10^4
S1	0.2°- 1.1°	10^6

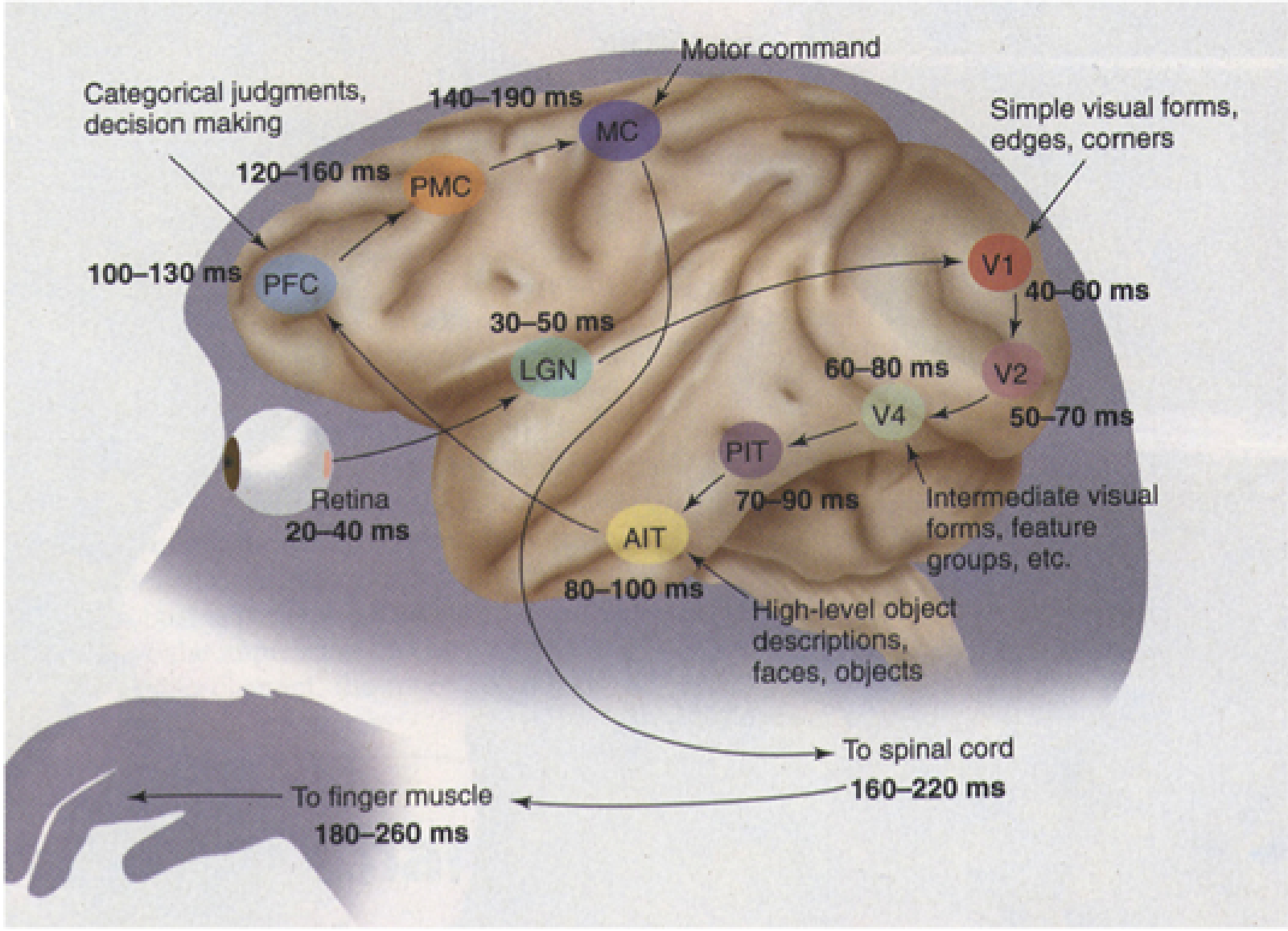
Supervised task-dependent learning

Unsupervised task-independent learning

Increase in complexity (number of subunits), RF size and invariance

Simple cells
Complex cells
Tuning
MAX
Main routes
Bypass routes

Categorizing animals vs animals



References

W. Geisler, J. Perry, B. Super, D. Gallogly

Edge co-occurence in natural images predicts contour grouping performance.
Vision Research, 41:711--24, 2001.

D. Field and A. Hayes and R. Hess

Contour integration by the human visual system: evidence for a local "association field".
Vision Research, 33(2):173--93, 1993.

Y. Choe and R. Miikkulainen

Contour integration and segmentation with self-organized lateral connections.
Biological Cybernetics, 90(2):75--88, 2004.

W. Bosking, Y. Zhang, B. Schofield, and D. Fitzpatrick

Orientation selectivity and the arrangement of horizontal connections in tree shrew striate cortex
The Journal of Neuroscience, 17(6):2112-27, March 15, 1997.

E. Callaway and L. Katz

Emergence and refinement of clustered horizontal connections in cat striate cortex.
The Journal of Neuroscience, 10(4):1134--53, 1990.

S. Fischer, F. Šroubek, L. U. Perrinet, R. Redondo, and G. Cristóbal.

Self-Invertible 2D Log-Gabor Wavelets.
International Journal of Computer Vision, 75(2):231--246, 2007.

L. U. Perrinet.

Role of homeostasis in learning sparse representations.
Neural Computation, 22(7):1812--36, July 2010.

L. U. Perrinet, D. Fitzpatrick, and J. Bednar

Edge co-occurrences and categorizing images.
CerCo's 20th anniversary, Toulouse, France., 2013.
URL `http://invibe.net/LaurentPerrinet/Presentations/13-07-05_CerCo`

P. Seriès, S. Georges, J. Lorenceau, and Y. Frégnac.

Orientation dependent modulation of apparent speed: a model based on the dynamics of feed-forward and horizontal connectivity in V1 cortex.
Vision Research, 42(25):2781--97, Nov 2002.

Neuromorphic implementation

P. Seriès et al. / Vision Research 42 (2002) 2781–2797

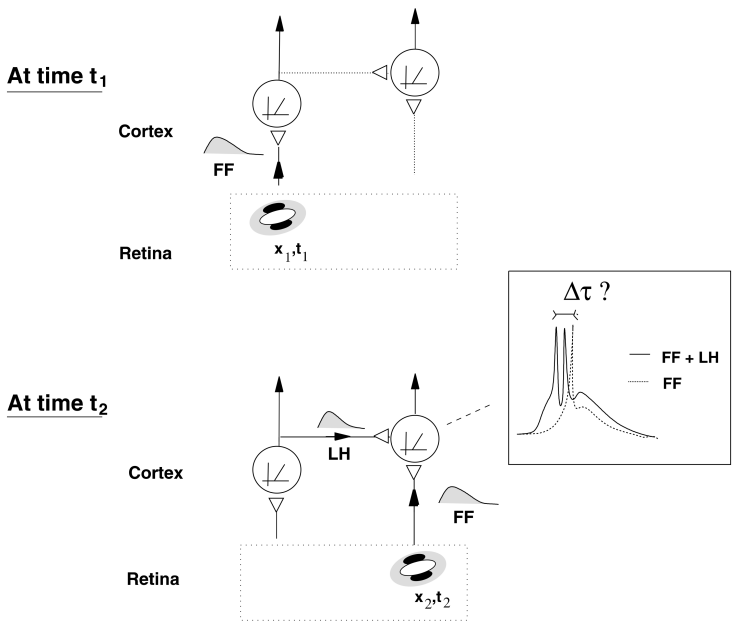
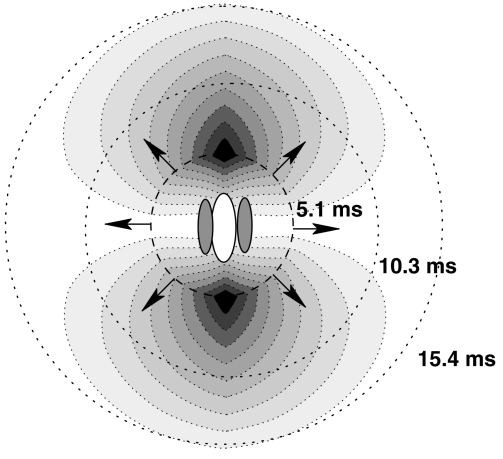


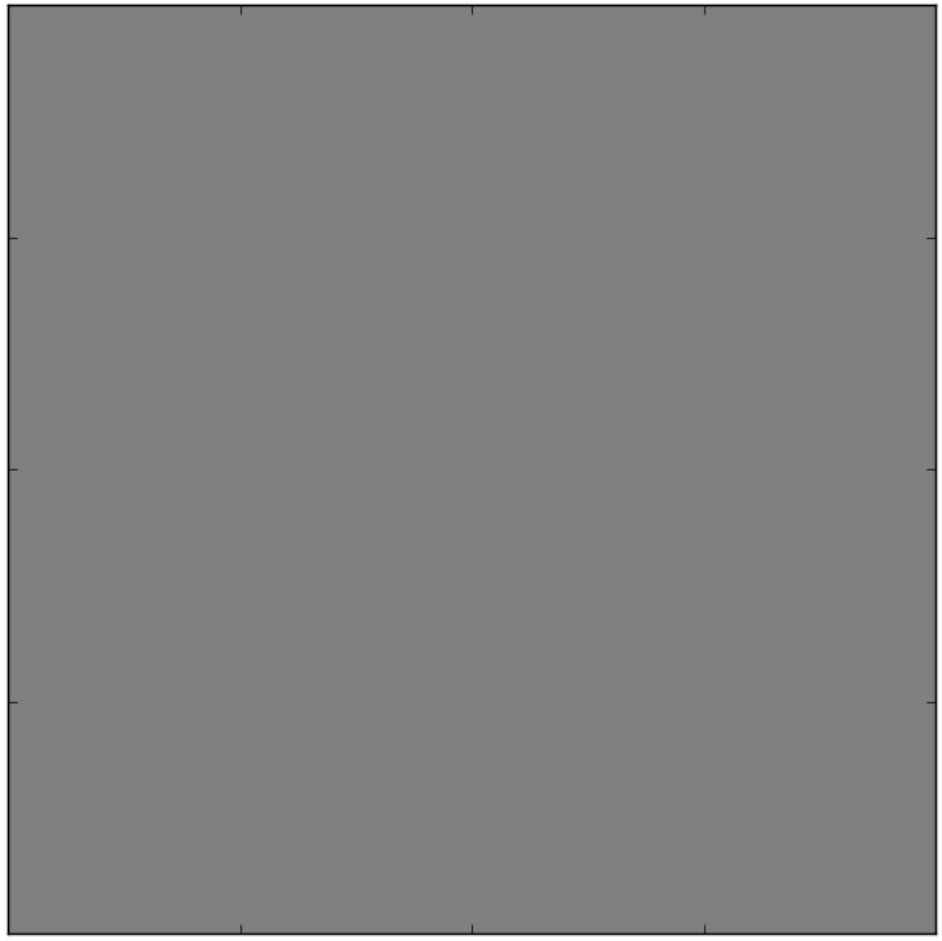
Fig. 1. Cartoon of the V1 model, which represents an array of cortical units



(Series et al., 2002)

Matching Pursuit

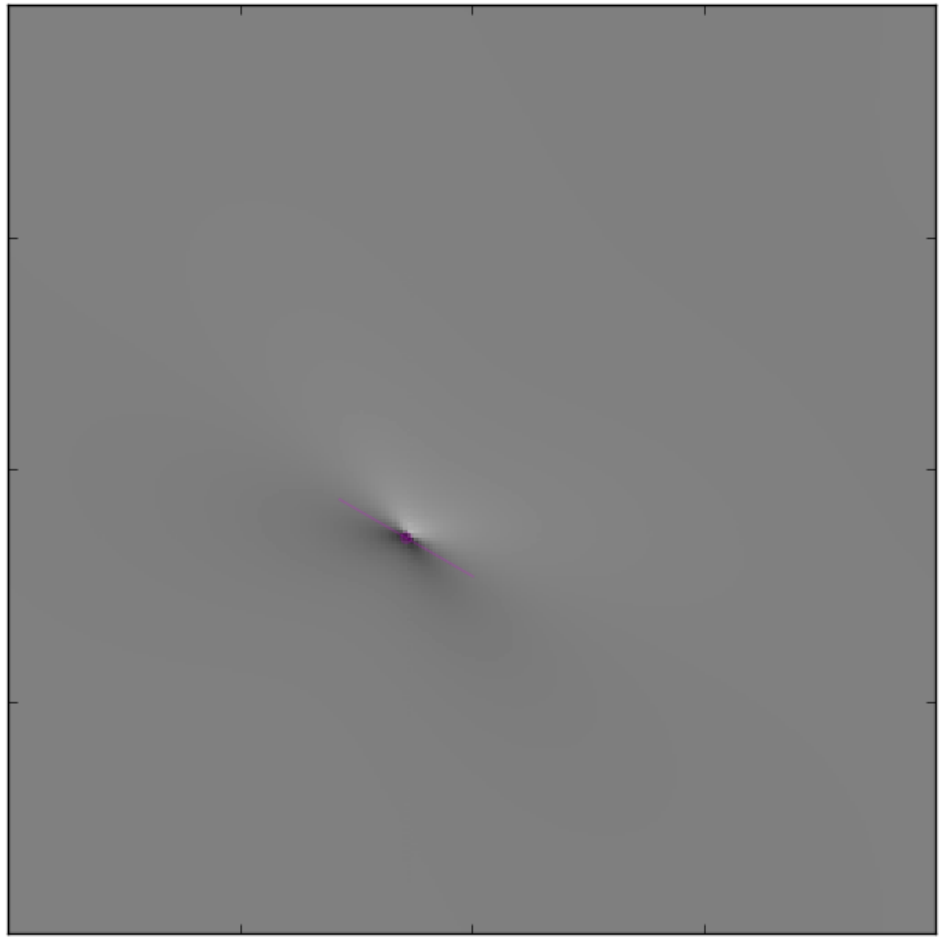
Residual



Edges

Matching Pursuit

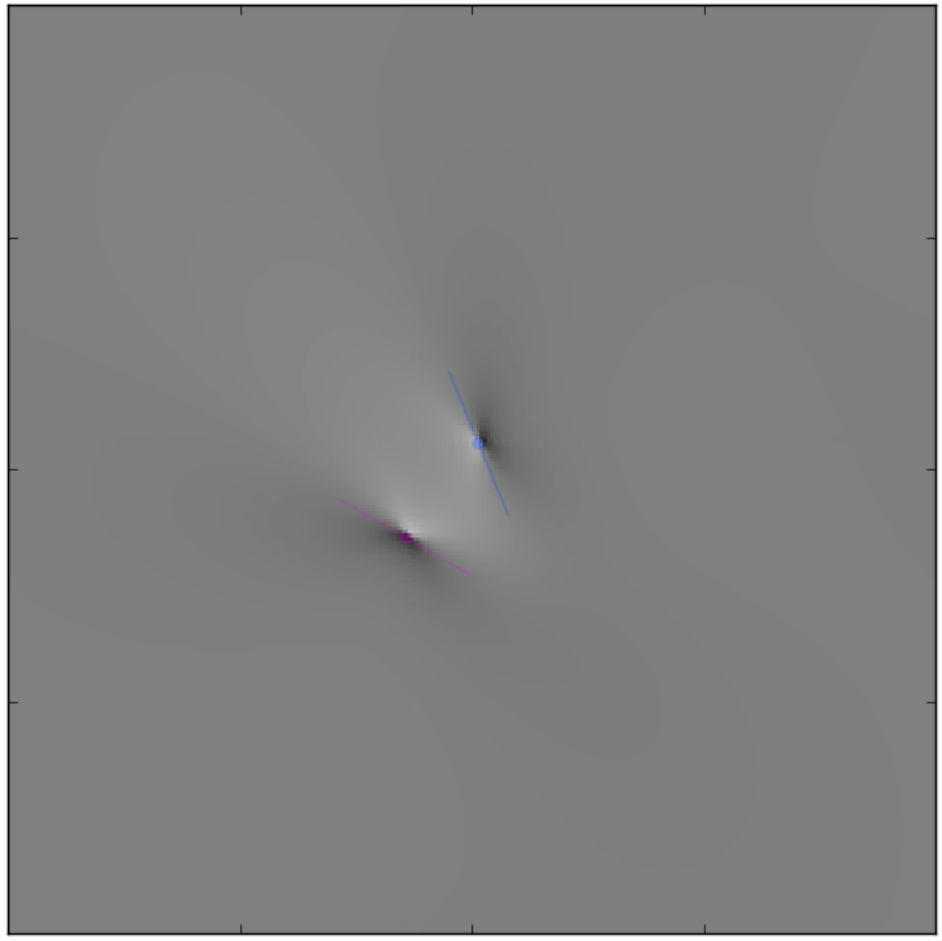
Residual



Edges

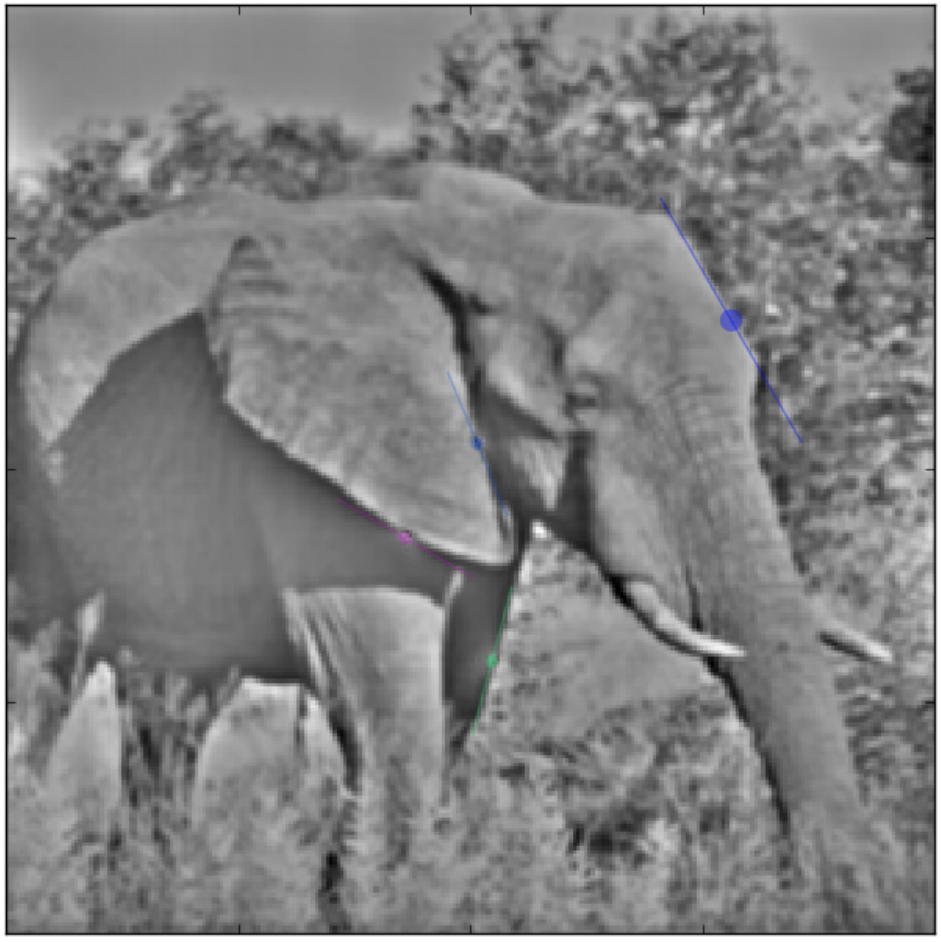
Matching Pursuit

Residual

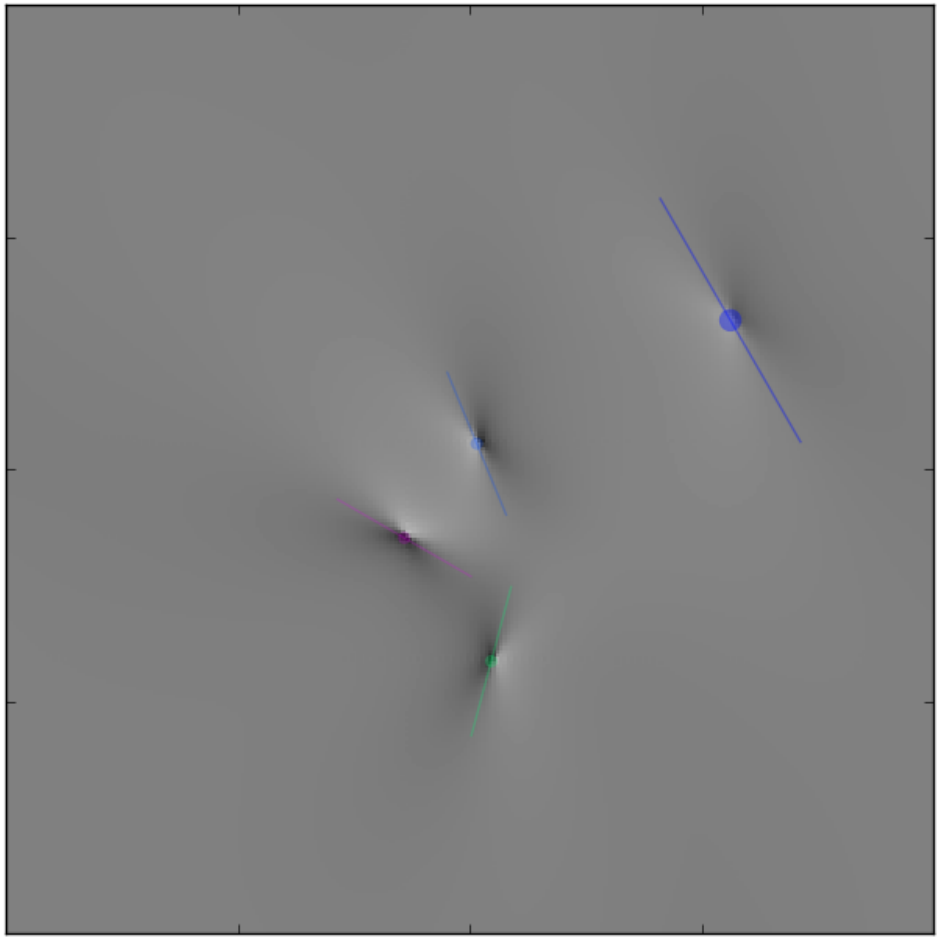


Edges

Matching Pursuit



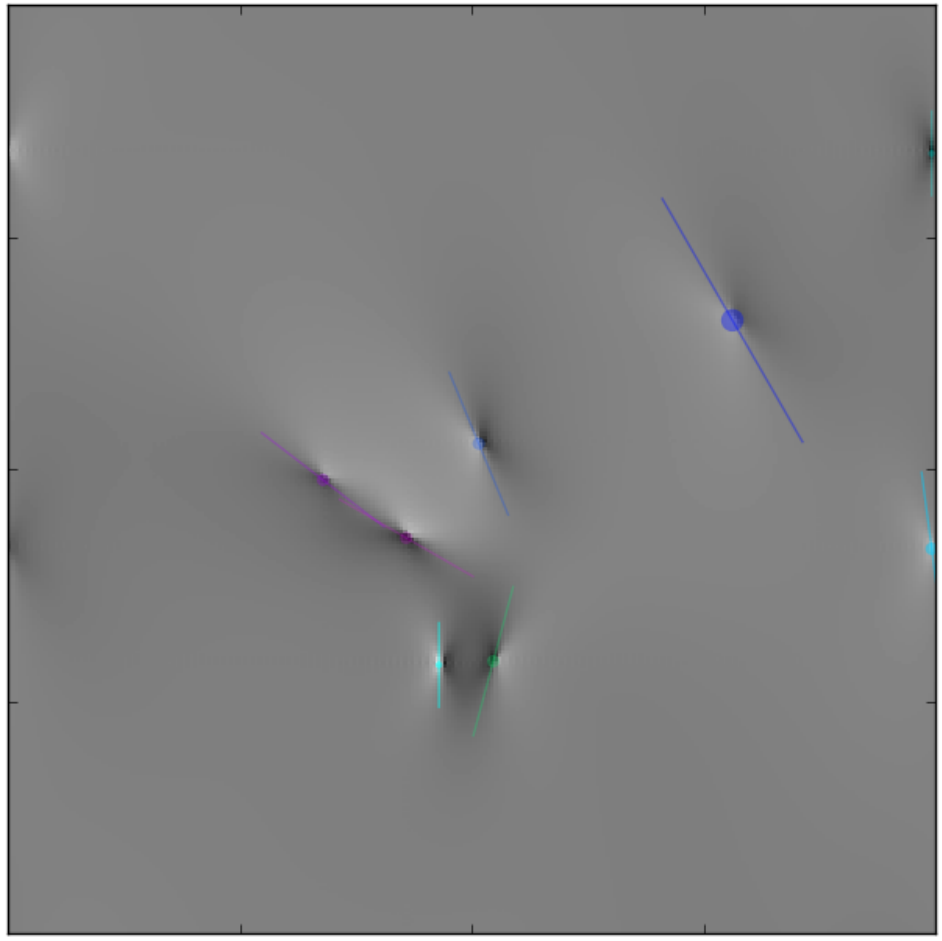
Residual



Edges

Matching Pursuit

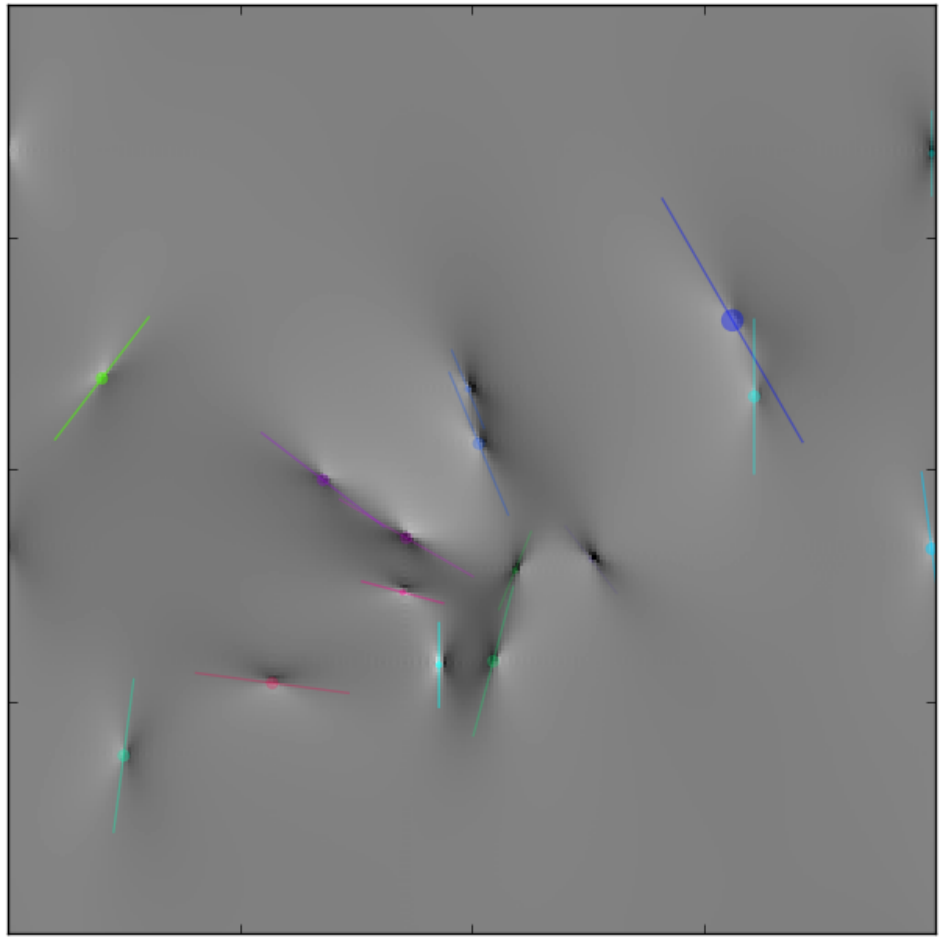
Residual



Edges

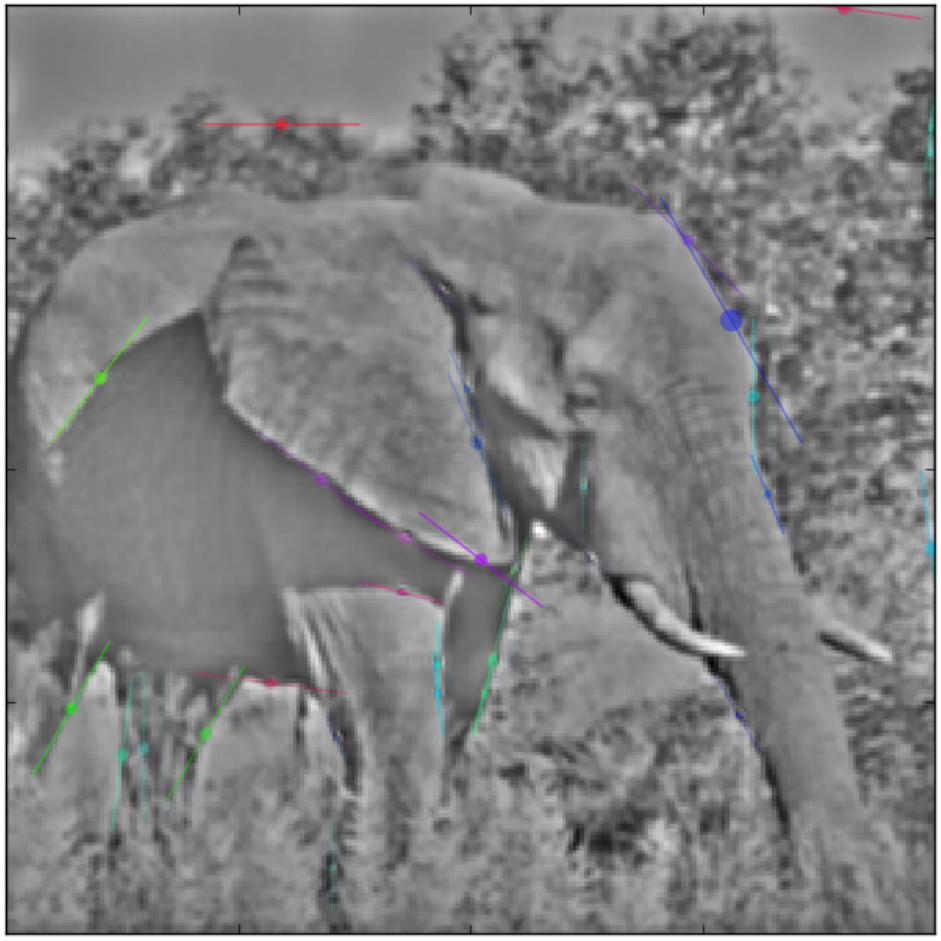
Matching Pursuit

Residual

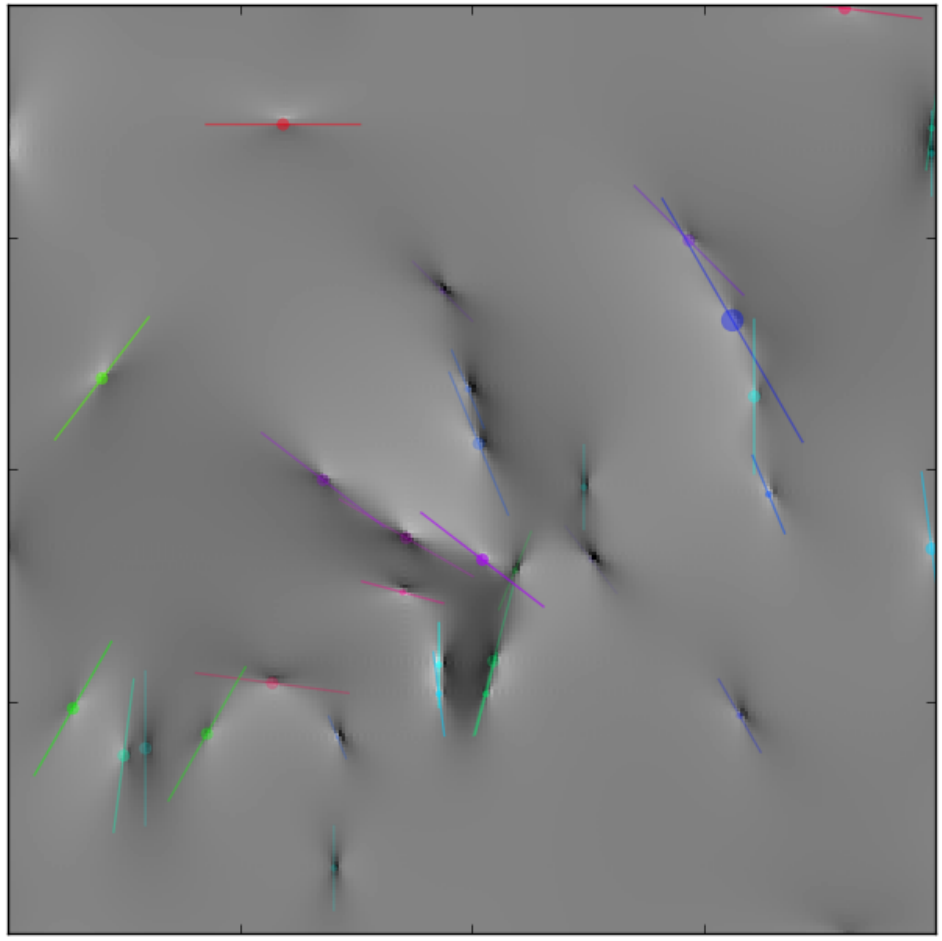


Edges

Matching Pursuit

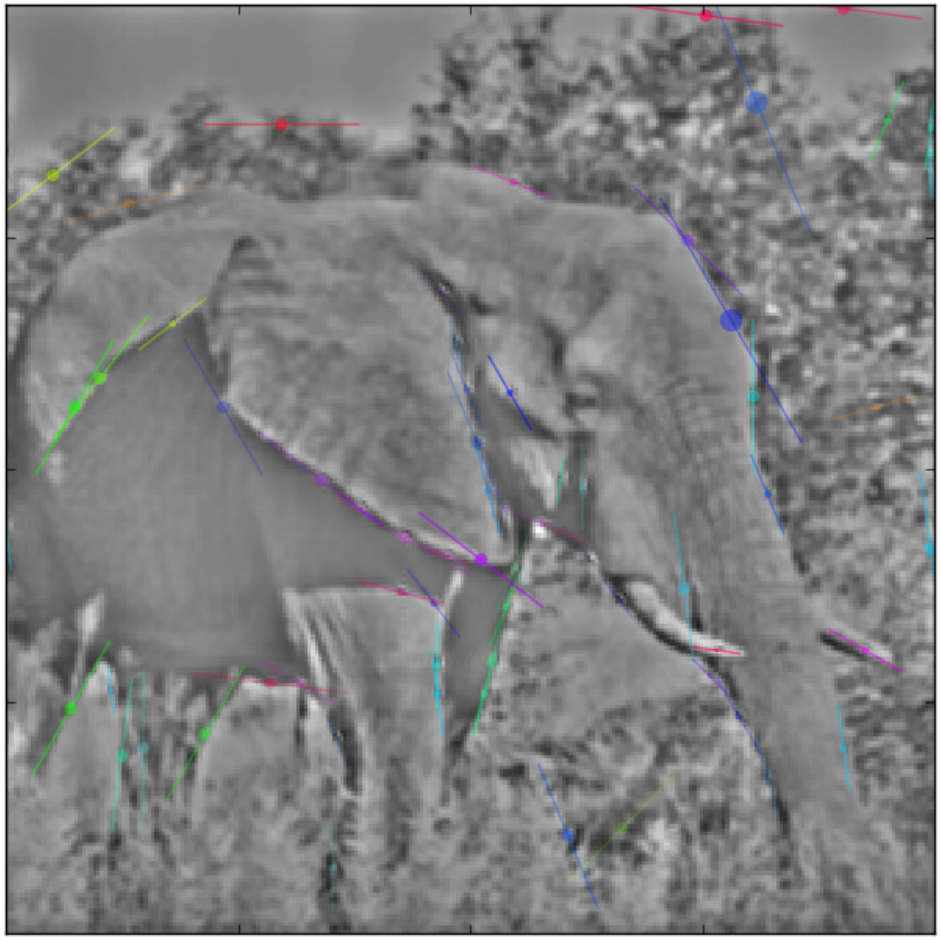


Residual

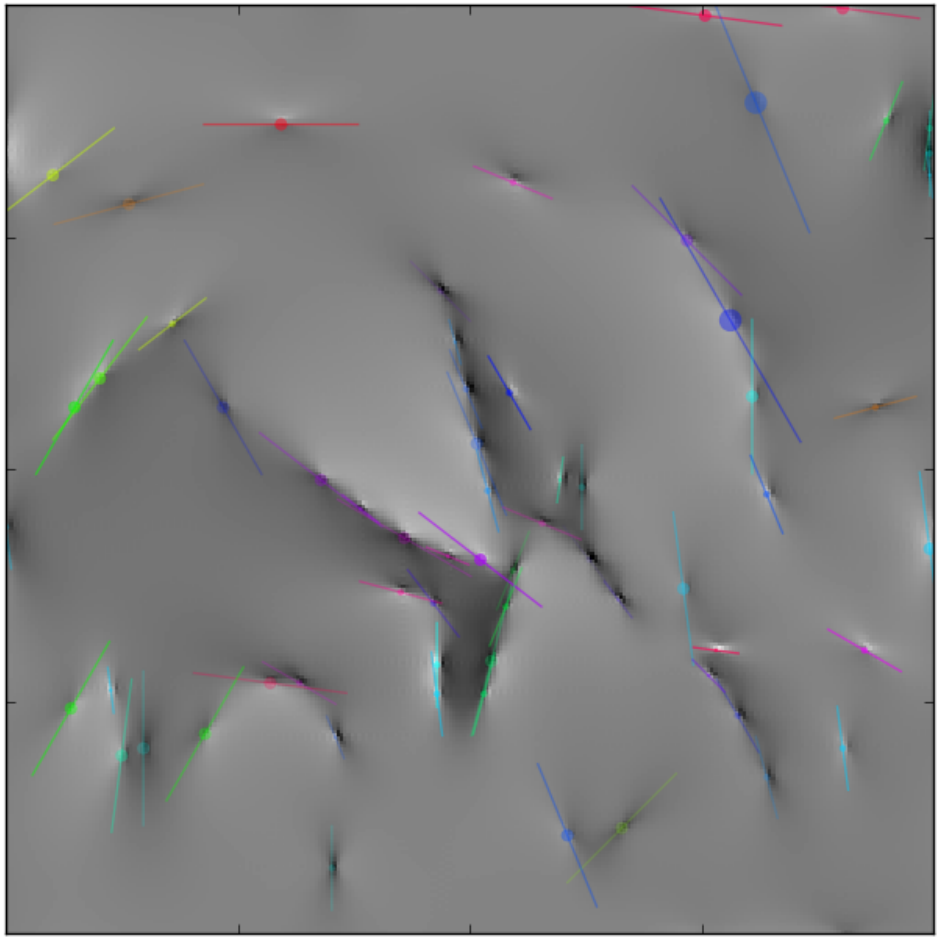


Edges

Matching Pursuit

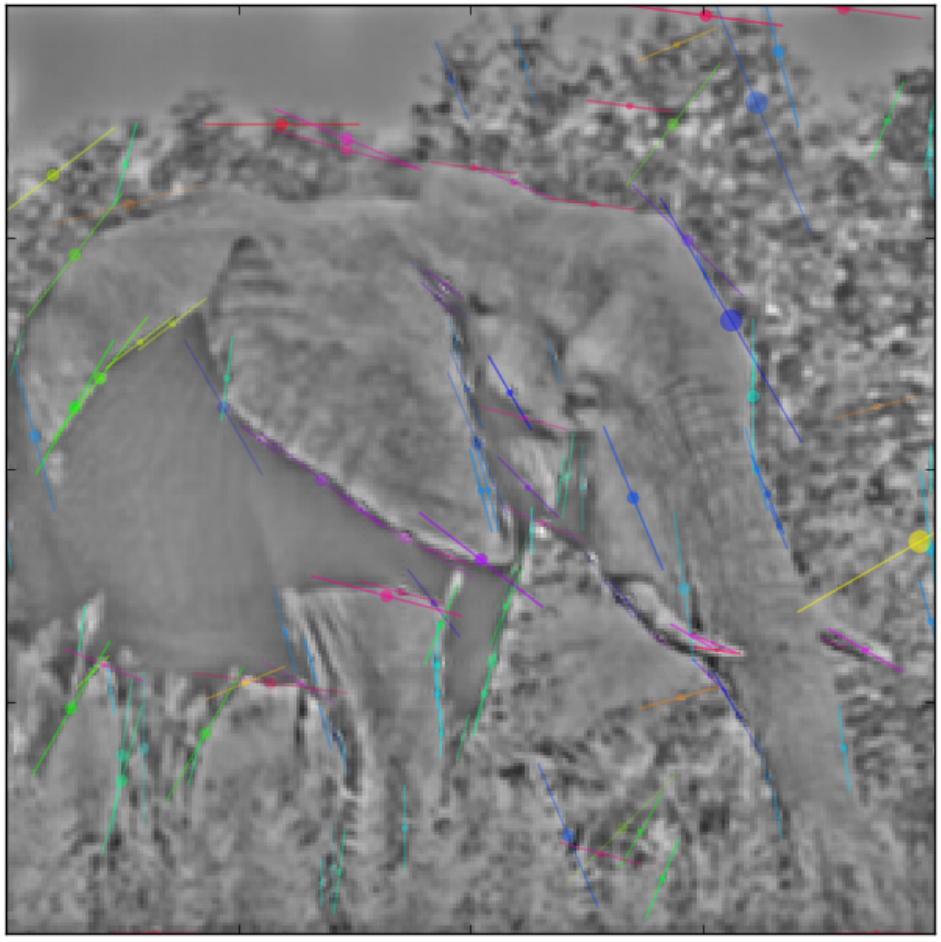


Residual

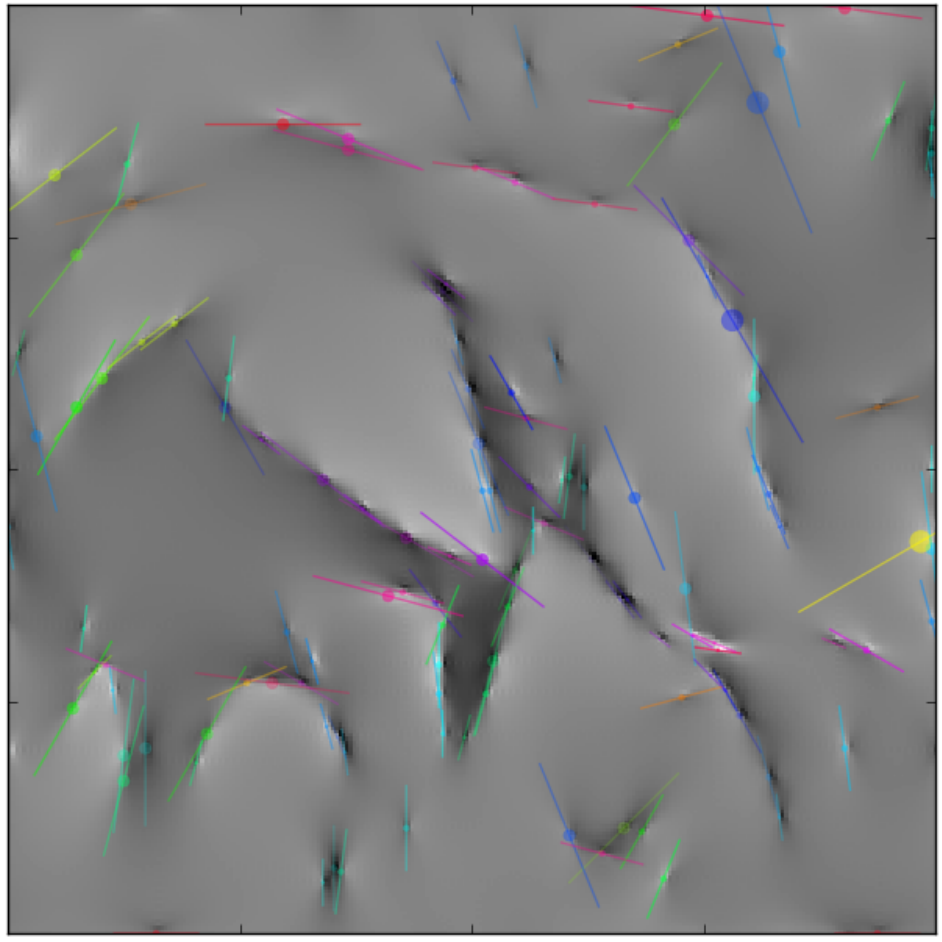


Edges

Matching Pursuit

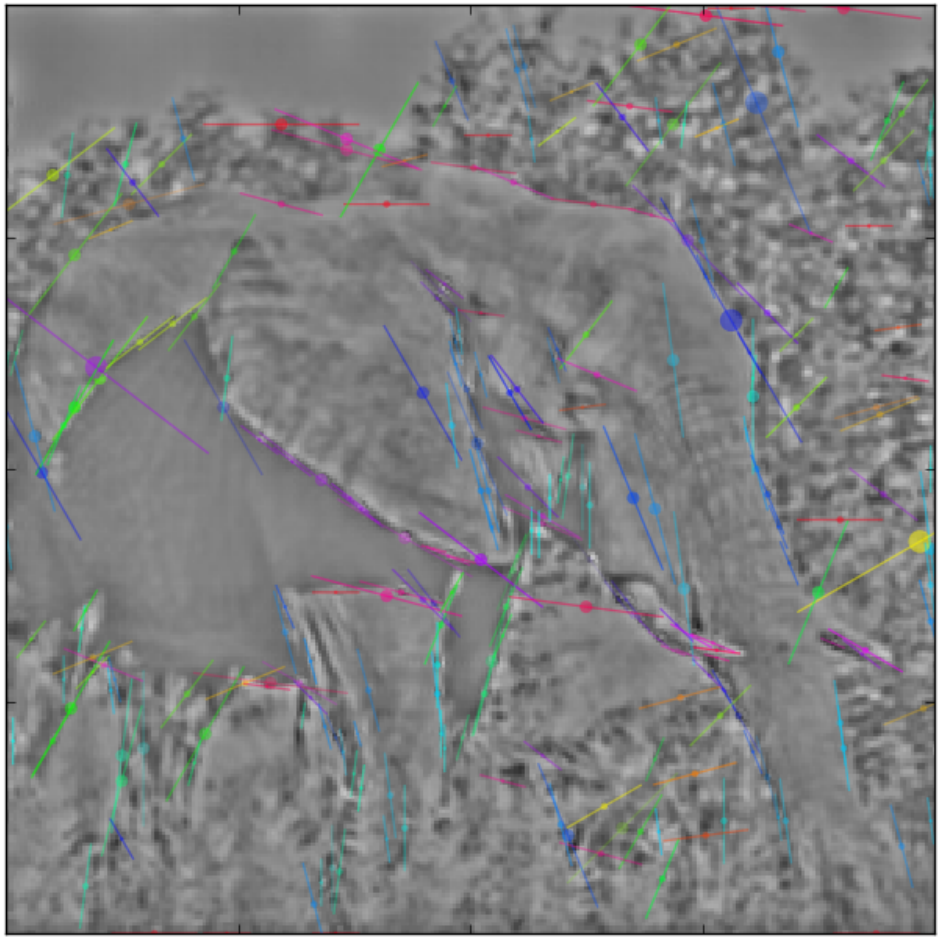


Residual

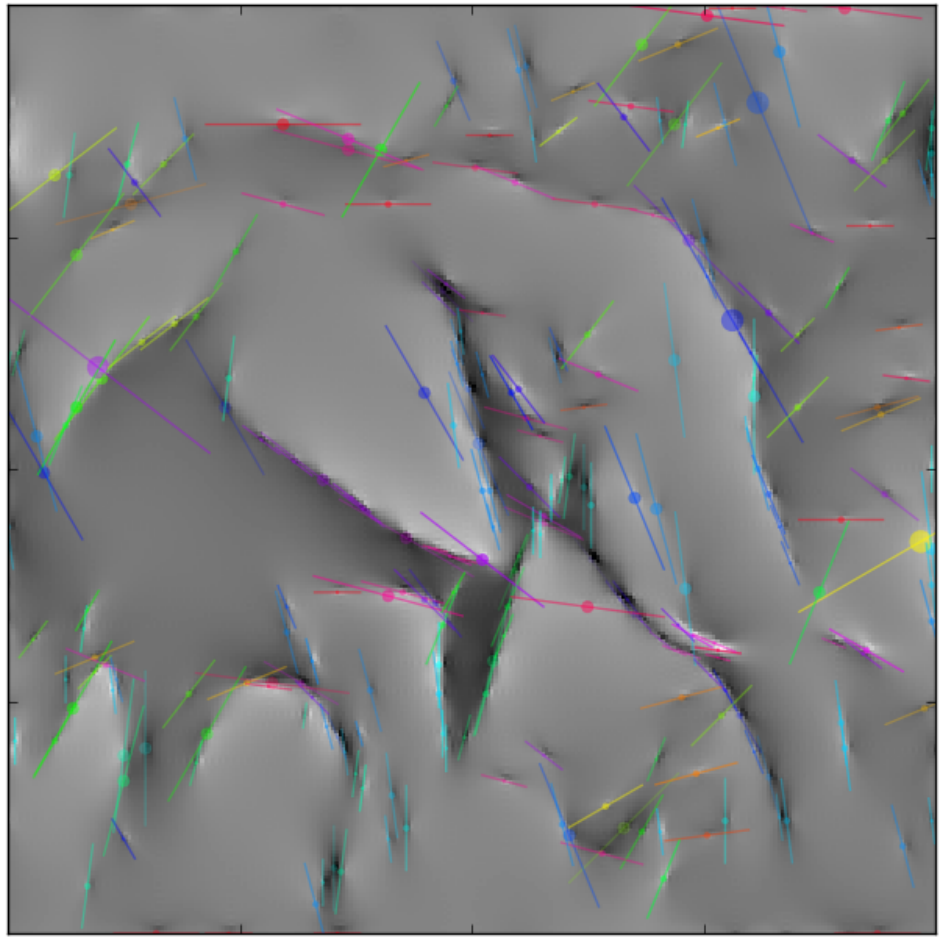


Edges

Matching Pursuit

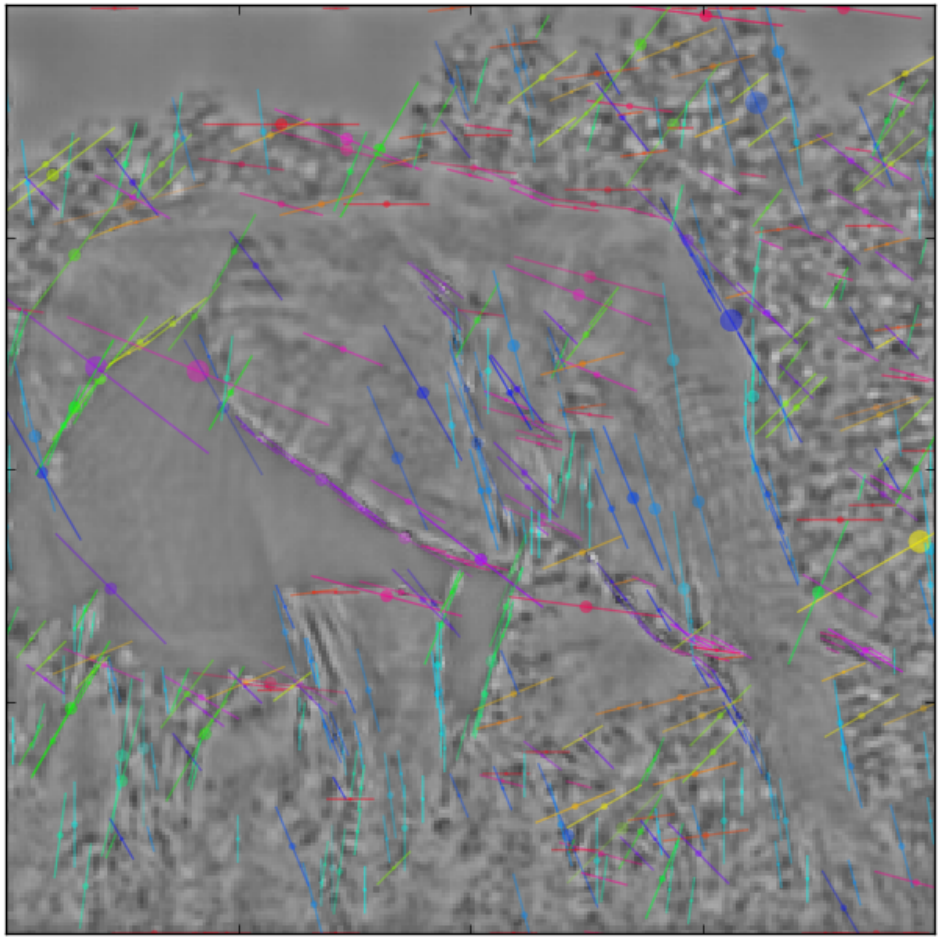


Residual

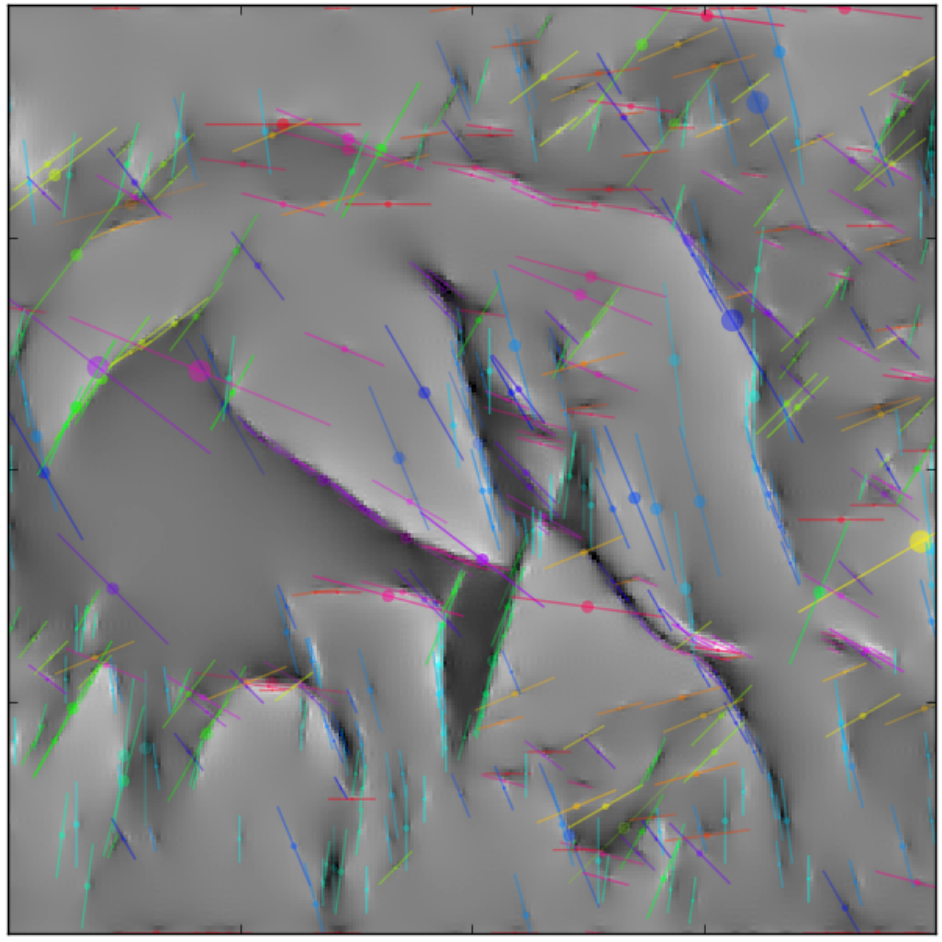


Edges

Matching Pursuit

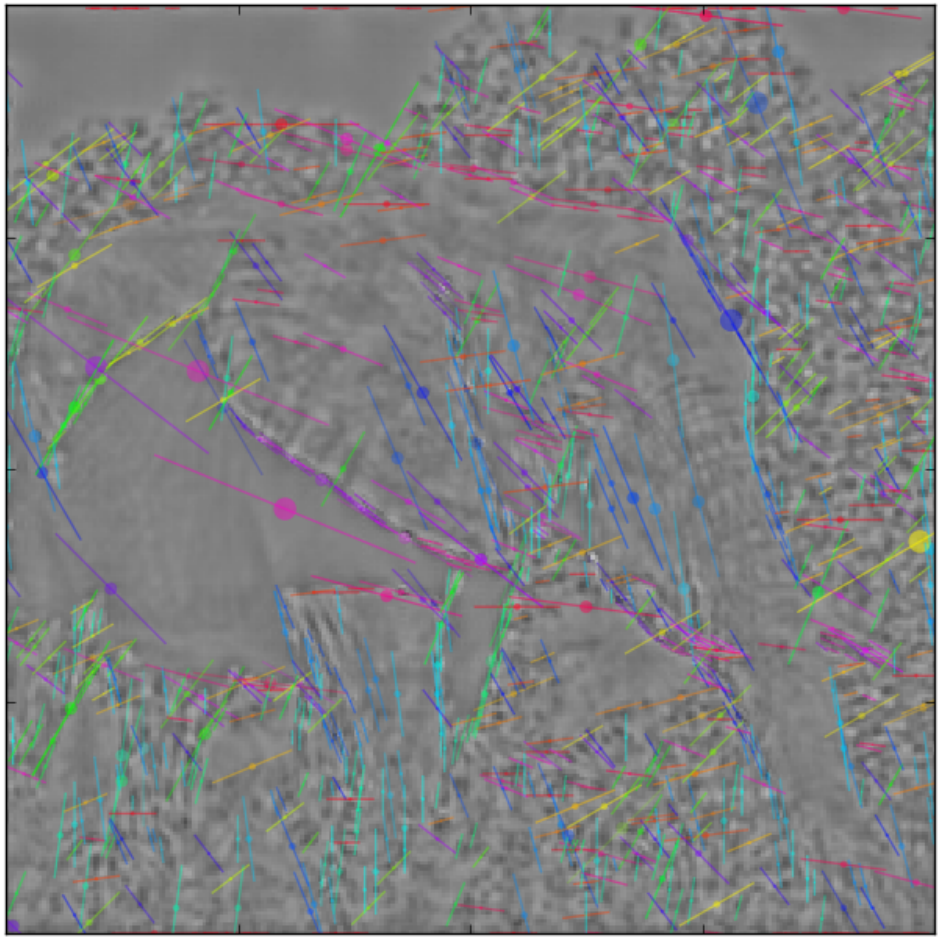


Residual

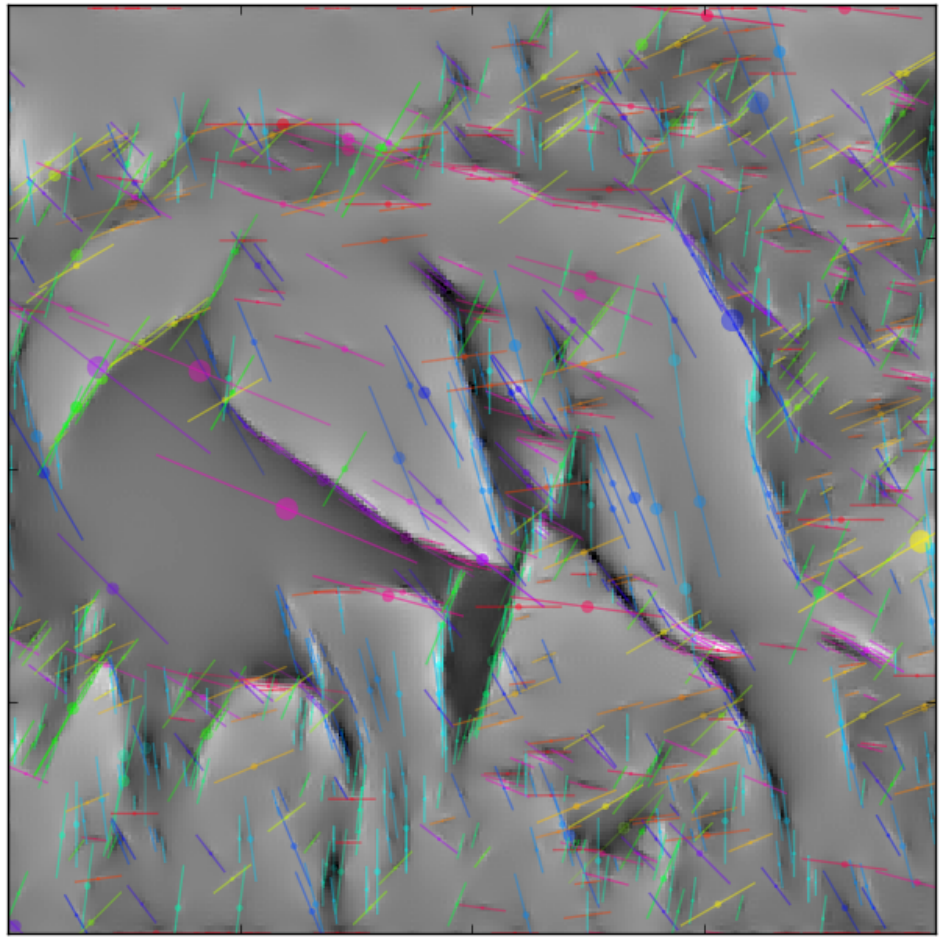


Edges

Matching Pursuit

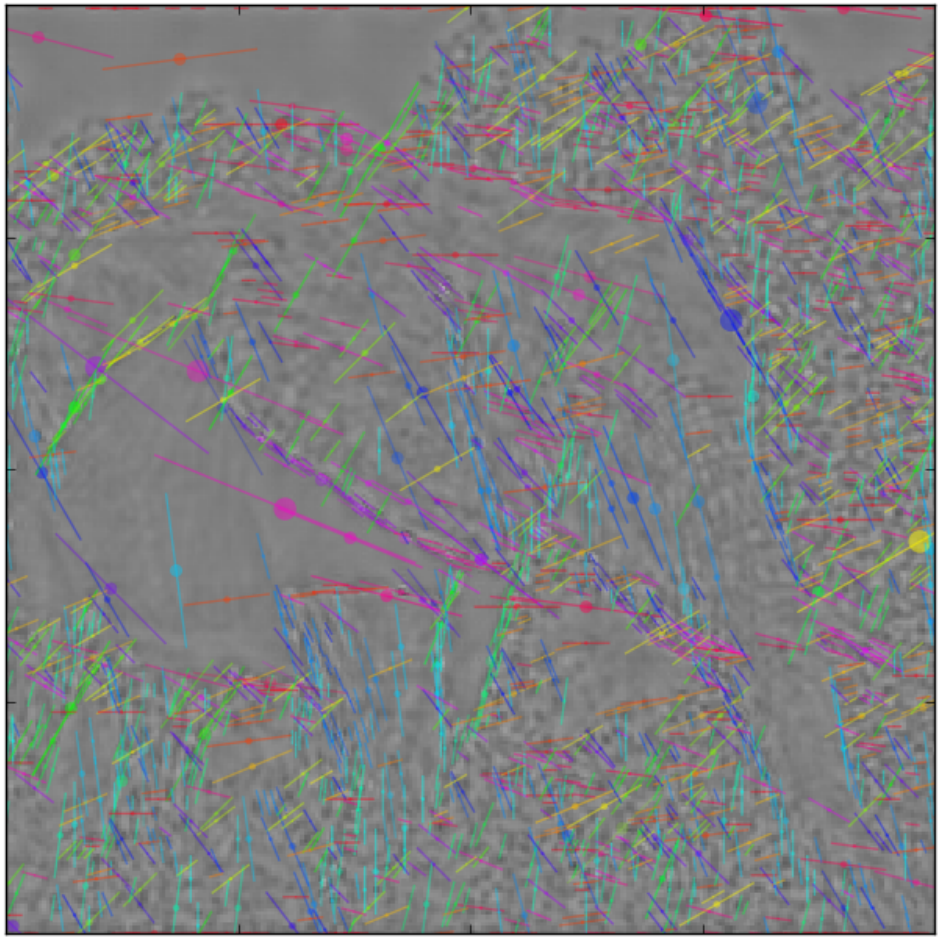


Residual

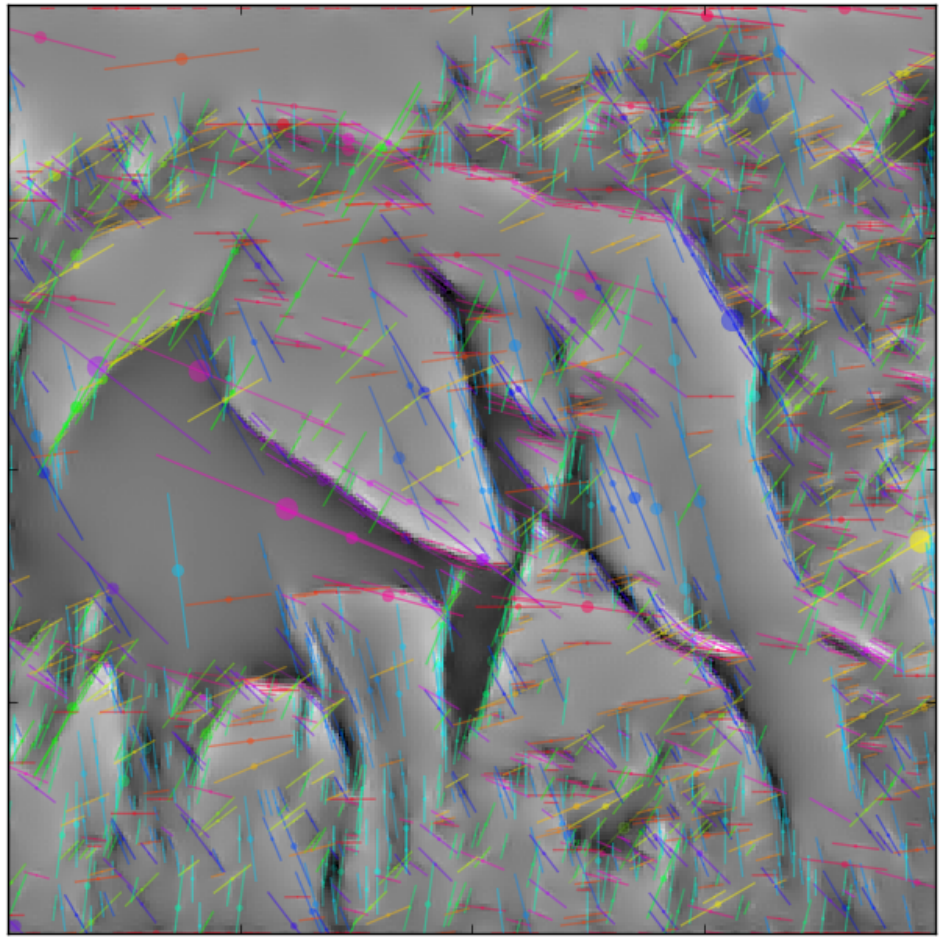


Edges

Matching Pursuit



Residual



Edges