Bio - ML

TASKS RELATED TO BIOLOGICAL VISION

Ask Jesús!

(Kick off meeting MINECO sept. 2021)

NEW THEORETICAL AND EXPERIMENTAL METHODS

1.3 Improving biological models through experiments driven by statistics

* Psychophysics - Noise
  - MAximum Differentiation (MAD)
* fMRI - information transfer and connectivity between voxel regions

EXTENSION OF CONVENTIONAL TECHNIQUES

2.1 Bio-inspired architectures. Divisive Normalization (DN) versus dynamical models (Wilson-Cowan/Amari) and Intrinsically Nonlinear Receptive Fields (INRF)

2.3 Noise in natural and artificial networks. Estimated noise and Fisher information.

RELATIONS BETWEEN BRAIN AND STATISTICS

3.2 Similarities and differences between artificial and natural NN

* Contrast Sensitivity Functions
* Visual Illusions
* Distortion metrics
* Nets with natural noise induce human behavior?

3.3 Information theory in the visual system

* Information flow
* Brain connectivity
* Information-based distortion metrics

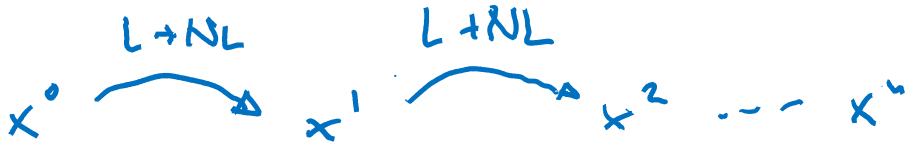
1.3 New experiments to improve biological vision models

- Bio vision models

- Psychopysics

- fMRI

1.3 New experiments to improve biological vision models

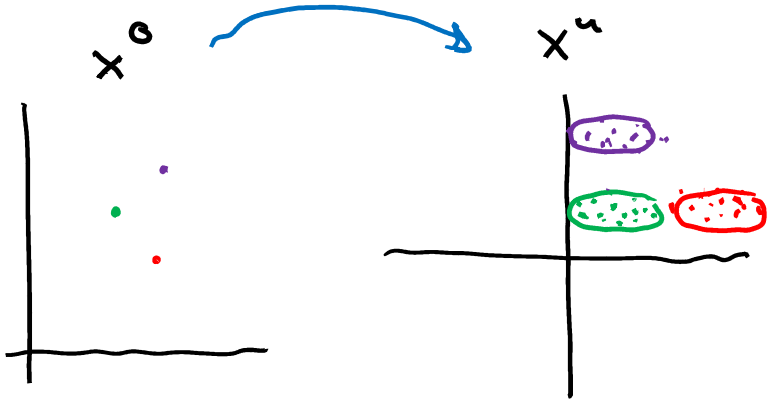


- Bio Vision models

L ≡ Chromatic oppoency / center-surround / wavelets } convolutional invariance via pooling

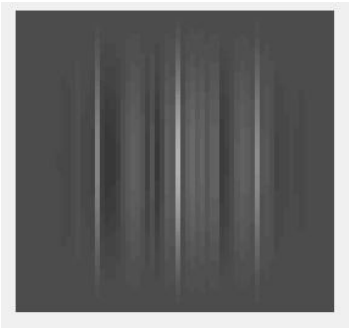
NL ≡ Saturation (activation)
Adaptive (similar to batch normalization) } invariance to contrast texture & illumination

Long tradition in fitting the parameters of L+NL



IEEE TIP 06a		https://ieeexplore.ieee.org/document/1556625
IEEE TIP 06b		https://ieeexplore.ieee.org/document/1556637
JOSA A	10	https://www.osapublishing.org/josaa/abstract.cfm?uri=josaa-27-4-852
JOSA A	17	https://www.osapublishing.org/josaa/abstract.cfm?uri=josaa-34-9-1511
PLOS	18	https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0201326
Frontiers	19	https://www.frontiersin.org/articles/10.3389/fnins.2019.00008/full
Scient. Rep.	20	https://www.nature.com/articles/s41598-020-73113-0
J. Neurophysiol.	20	https://journals.physiology.org/doi/full/10.1152/jn.00487.2019
J. Math. Neurosci.	20	https://mathematical-neuroscience.springeropen.com/articles/10.1186/s13408-020-00095-8

1.3 New experiments to improve biological vision models



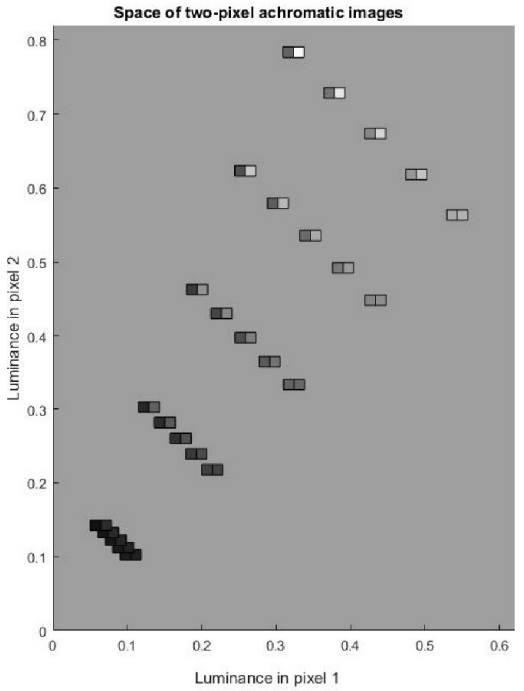
Noise

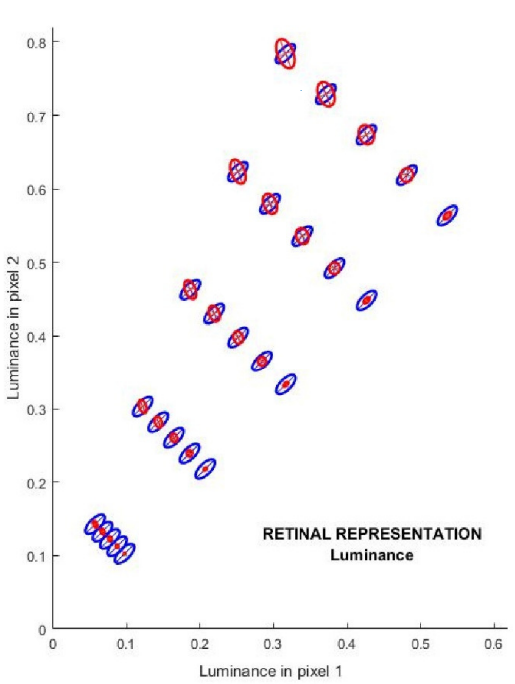
- Psychopysics

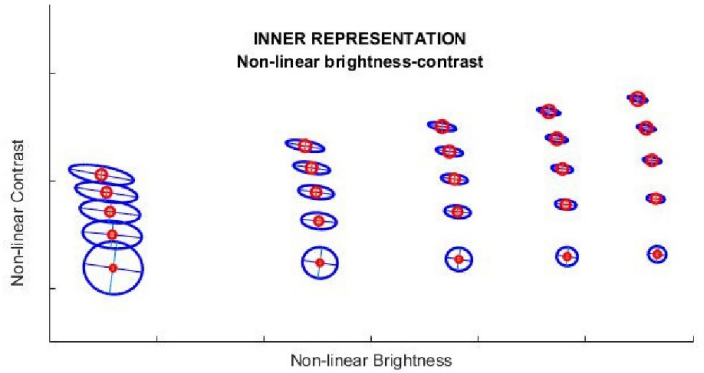
https://arxiv.org/abs/2012.06608

We are starting to measure the noise!

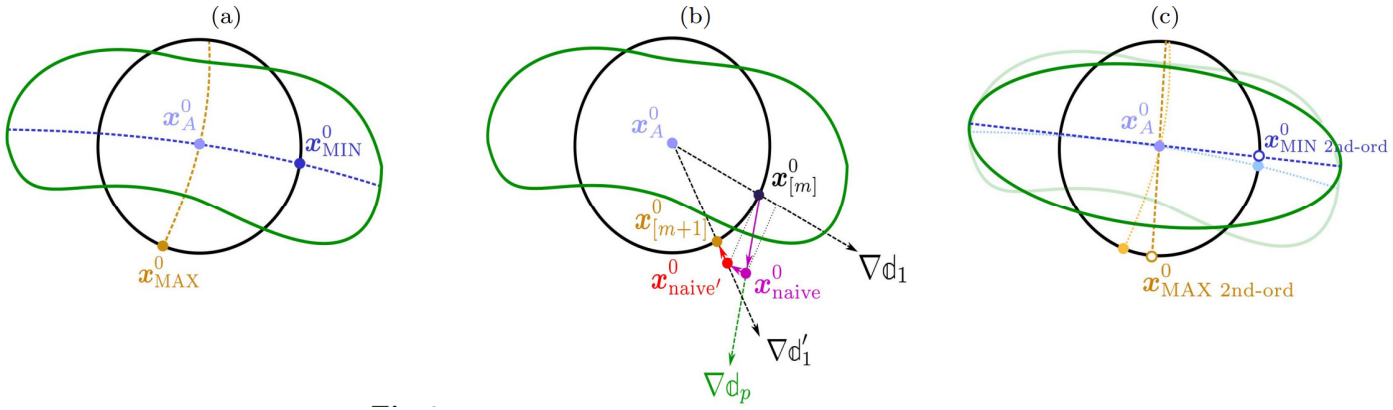
(not only the parameters of the transform L + NL)





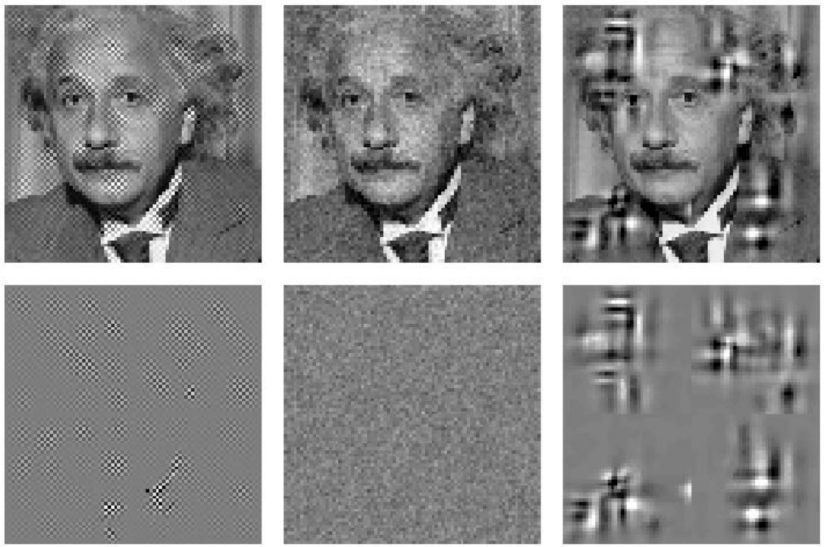


1.3 New experiments to improve biological vision models



- Psychopysics

MAximum Differentiation (MAD)



https://sci-hub.st/https://doi.org/10.1117/12.2085653

https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0201326

MAD can be used to determine the parameters better!

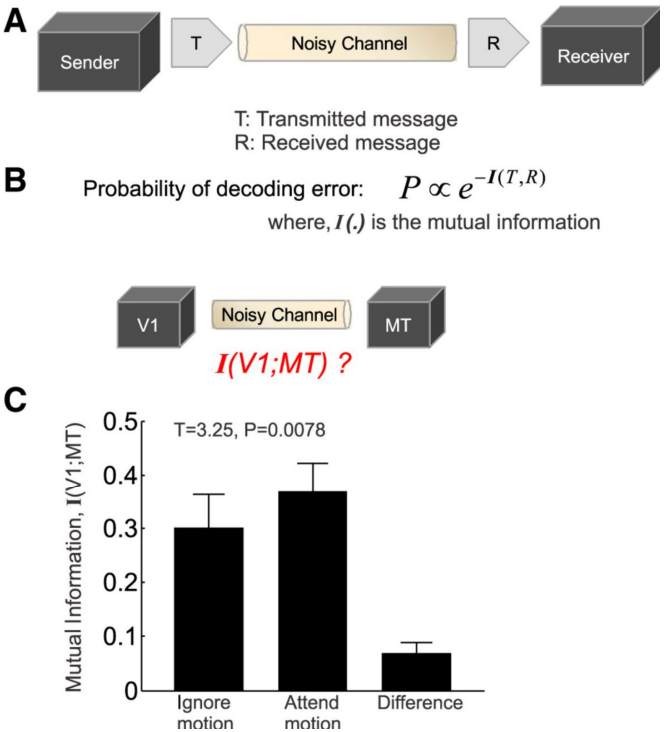
1.3 New experiments to improve biological vision models

Attention Improves Transfer of Motion Information between V1 and MT

Sameer Saproo and John T. Serences

Journal of Neuroscience 5 March 2014, 34 (10) 3586-3596; DOI: https://doi.org/10.1523/JNEUROSCI.3484-13.2014

JNeurosci
THE JOURNAL OF NEUROSCIENCE



- fMRI

Inform flow & Connectivity from REAL DATA!

2.1 Bio inspired architectures: models of the non-linearity NL

$e \xrightarrow{NL} x$

- Divisive normalization $\quad x = \dfrac{e}{b + H \cdot e} \qquad x_i = \dfrac{e_i}{b_i + H_{ij} c_j}$

- Dynamical models (recurrence) $\quad \dot{x}_i = \alpha_i e_i - W_{ij} f(x_j)$

- Intrinsically Nonlinear Receptive fields $\quad x_i = M_{ij} e_j - W_{ij} f(e_j - G_{jk} e_k)$

J. Neurophysiol. 20 https://journals.physiology.org/doi/full/10.1152/jn.00487.2019

ArXiv 19 https://arxiv.org/abs/1906.08246

Sci. Rep. 20 https://www.nature.com/articles/s41598-020-73113-0

Ready to apply!

2.3 Noise in artificial and natural networks

- NeurIPS 17 https://arxiv.org/abs/1710.02266
  - Covariance back in the input space
  - Fisher information
  - MAD in artificial networks
- J. Math. Neurosci. 20 https://mathematical-neuroscience.springeropen.com/articles/10.1186/s13408-020-00095-8
- Entropy Conference 21 https://arxiv.org/abs/1912.12093
- VSS - J. Vision 21 https://jov.arvojournals.org/article.aspx?articleid=2777344

ALL USED APPROXIMATED ESTIMATES OF NOISE

Now we can do it BETTER with real noise estimates

3.2 Similarities and differences between artificial / biological networks

HOT TOPIC and many ongoing works from us

* Contrast Sensitivity Functions ArXiv 21 https://arxiv.org/abs/2103.00481
  - Tasks (restoration / color constancy) reconstruction)
  - statistics
  - Bottleneck

* Visual illusions Vision Research 20 https://doi.org/10.1016/j.visres.2020.07.010
  ArXiv 21 https://arxiv.org/abs/1911.09599

* Distortion metric
  IEEE ICIP 20 Metric → Masking? https://ieeexplore.ieee.org/document/9190691
  ArXiv 21 Stats → Metric https://arxiv.org/abs/2106.04427

* Networks with natural noise (follow up of NeurIPS 17)

3.3 Information theory in human vision

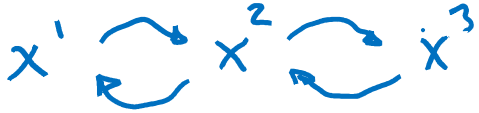
- Information flow

https://mathematical-neuroscience.springeropen.com/articles/10.1186/s13408-020-00095-8

$$I(x,y) = \sum_i h(y_i) - T(y) - h(n)$$

$$I(x,y) = h(x) + E_x\left[\log|\nabla_x s|\right] - h(n) + E_v\left[D_{KL}(s+n|s)\right]$$

- Connectivity



$I(x^i, x^j)$ is widely used

$T(x^1, \ldots, x^N)$ is better (ANALYTIC!)

And we have tools to estimate T (RBIG)

- Extension of Visual Information Fidelity VIF: $\frac{I(x, y_D)}{I(x, y_0)}$ We are doing it Better!

https://jov.arvojournals.org/article.aspx?articleid=2777344