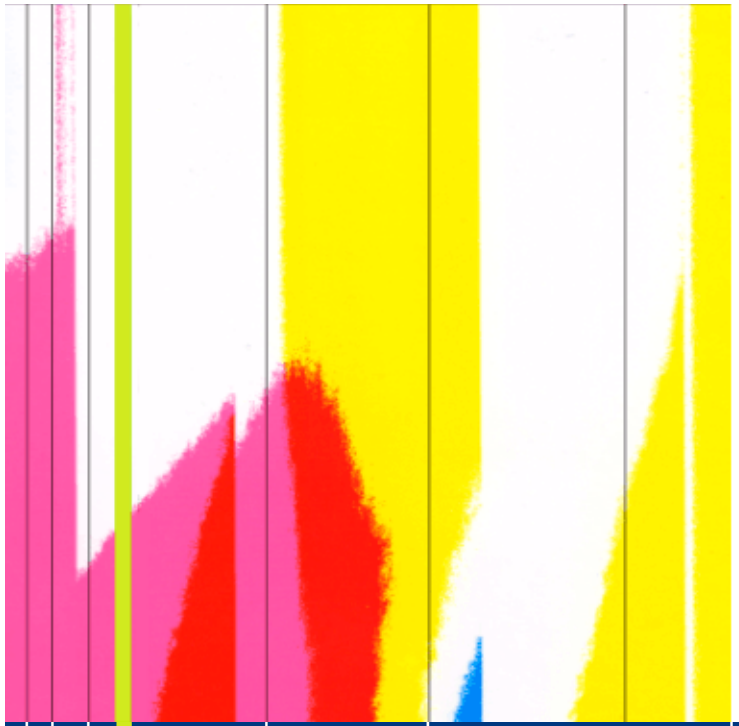


The Internship Report

Xueping Yao

July 15, 2009

INSTITUT NATIONAL
DE RECHERCHE
EN INFORMATIQUE
ET EN AUTOMATIQUE

INRIA

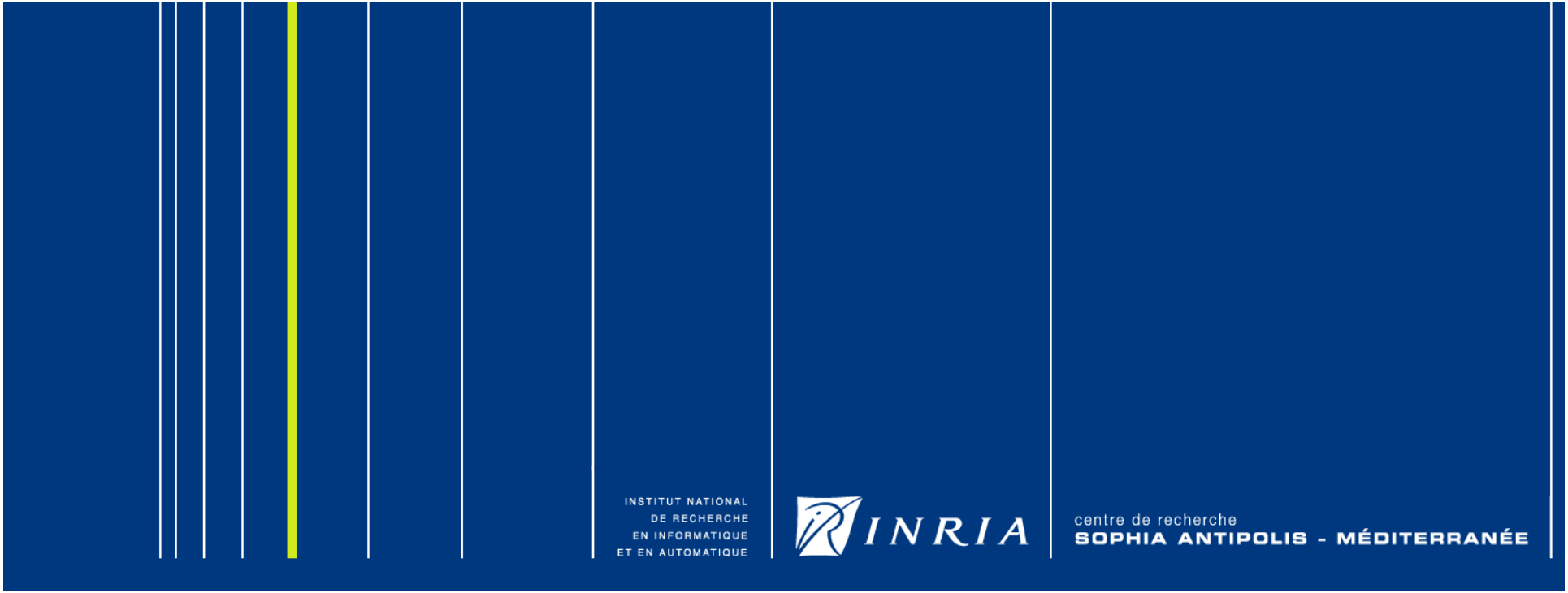
centre de recherche
SOPHIA ANTIPOLIS - MÉDITERRANÉE

NeuroMathComp project team
(INRIA, ENS Paris, UNSA LJAD)

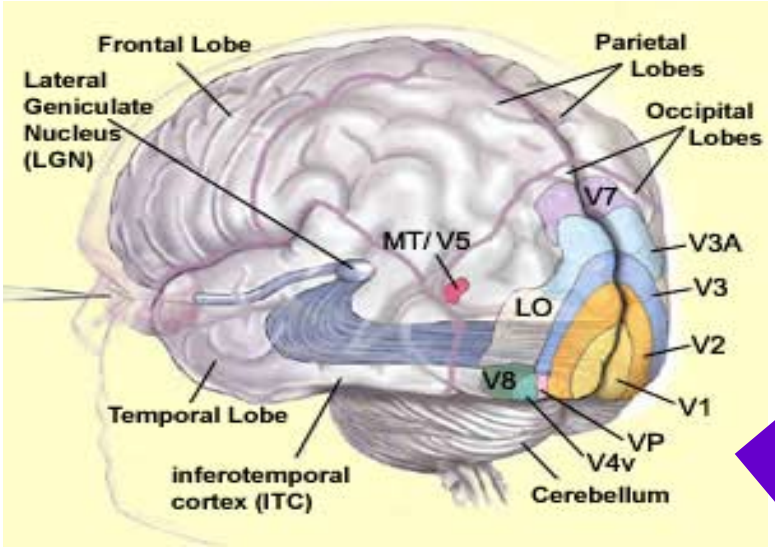
Modeling the Nature of Centre-Surround Interactions in Early Visual Cortex

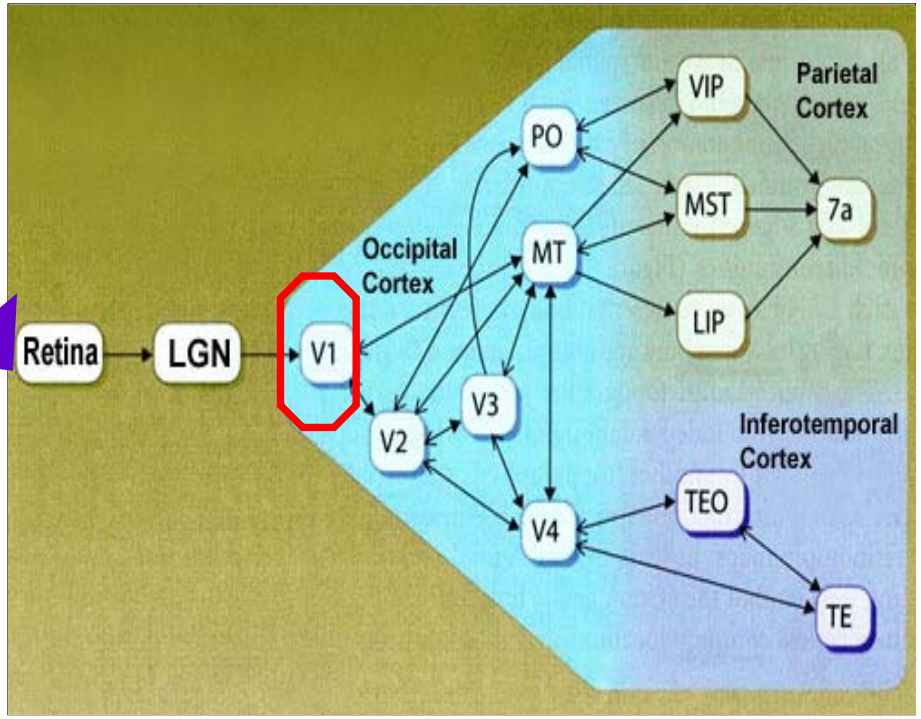
Xueping Yao

July 15, 2009

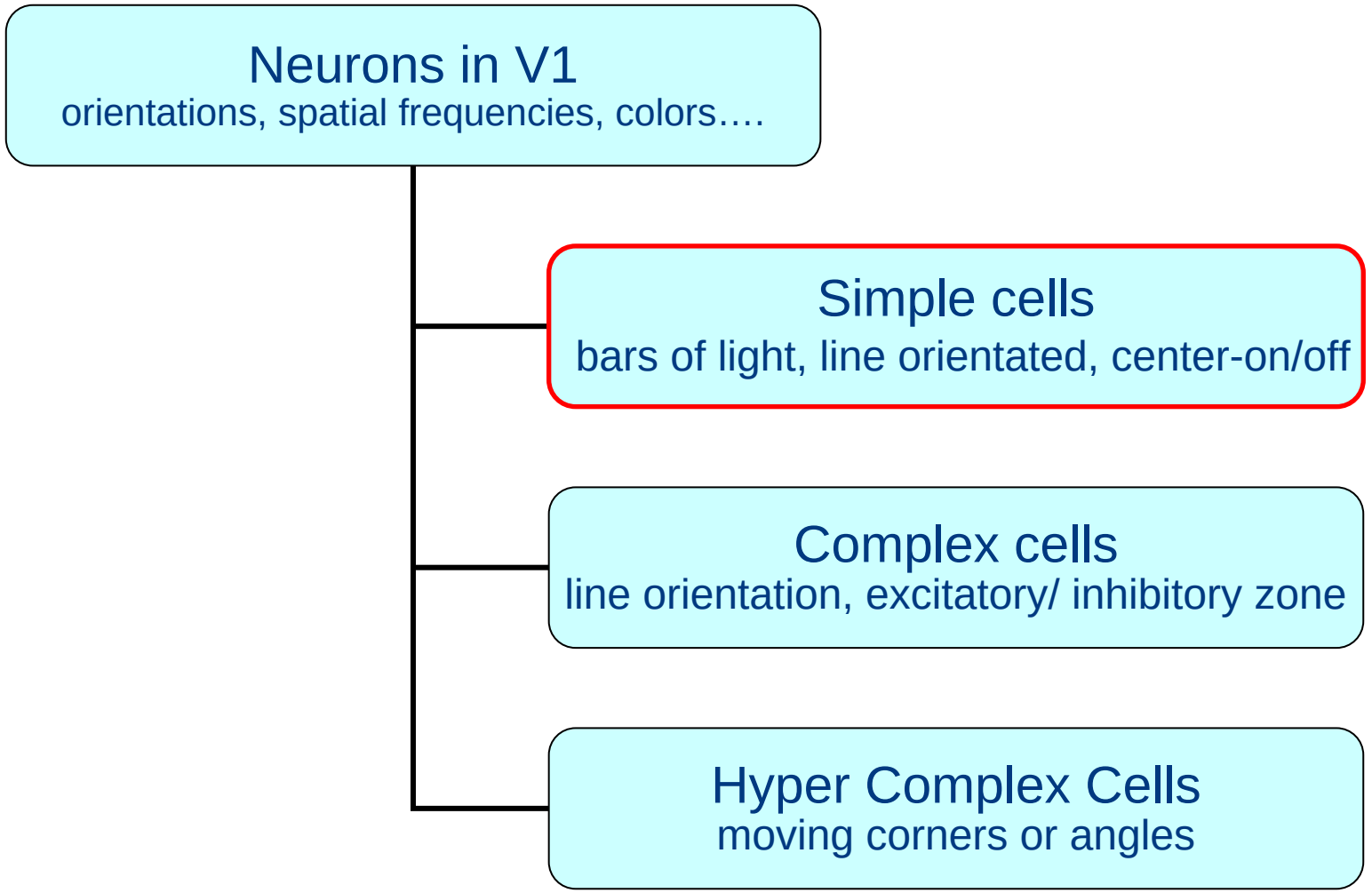


Primary Visual Cortex V1

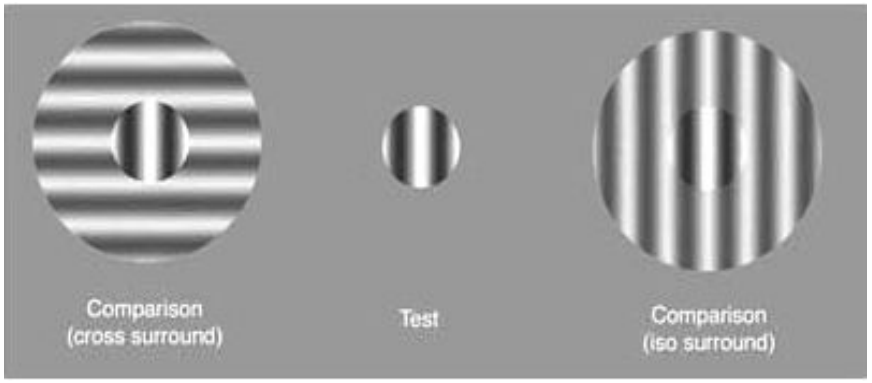




Primary Visual Cortex V1



Primary Visual Cortex V1



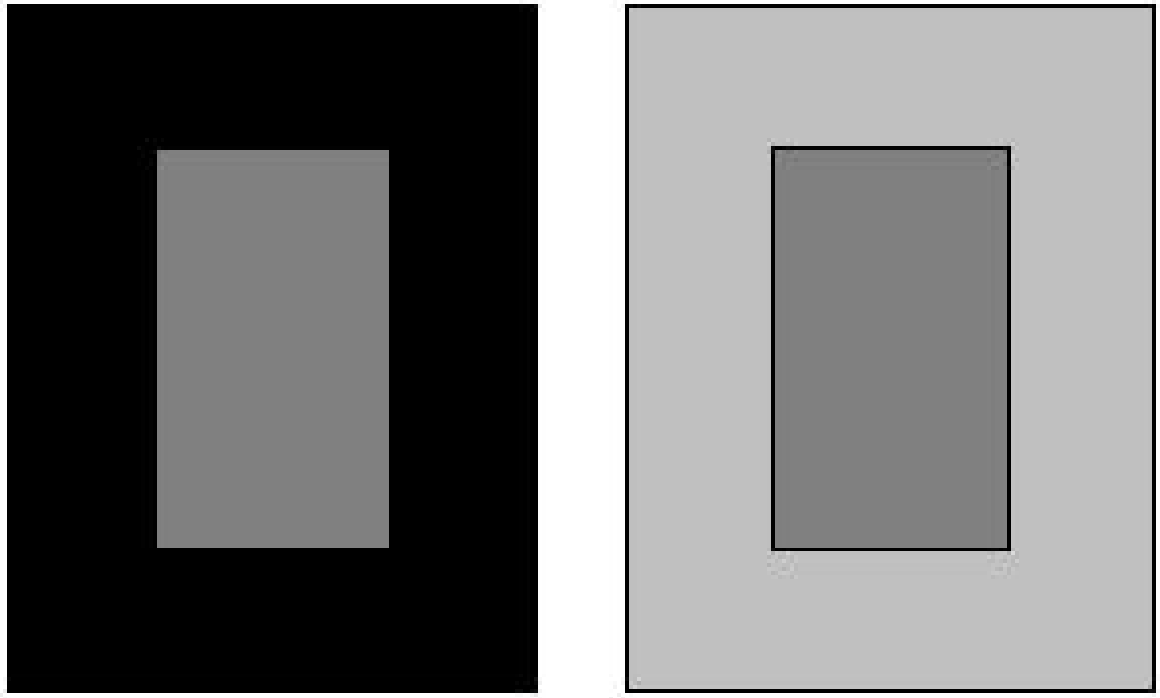
Drifting oriented luminance spots

V1 neurons spatial frequency, **orientation selectivities (1st),**

motion, direction, speed…..

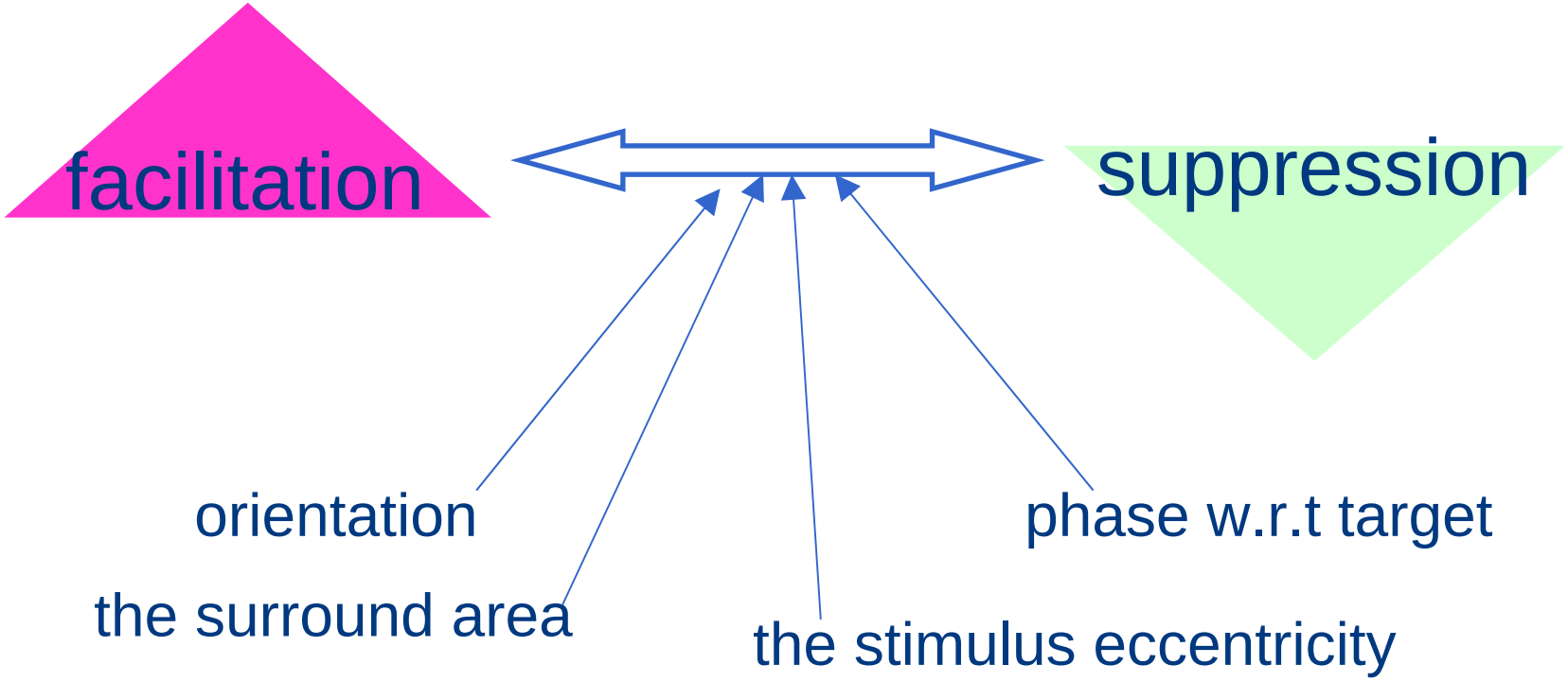
code local contrast

Center-surround Interactions

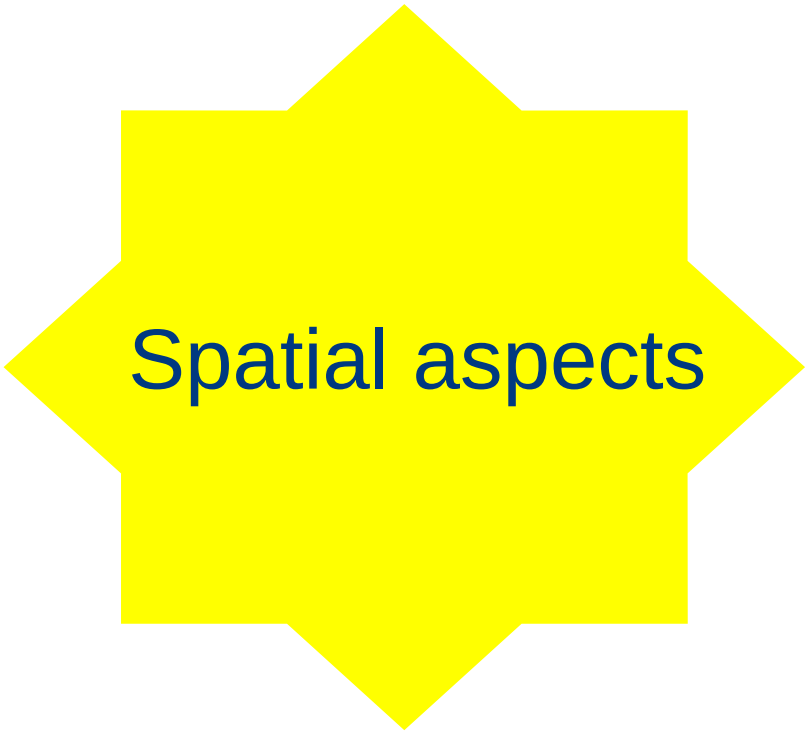


Simultaneous Contrast

Center-surround Interactions



Center-surround Interactions



Center-surround Interactions

one aspect

Orientation tuning

Schwartz and Simoncelli, 2001

Surround suppression is locally anisotropic

Schwartz & Simoncelli, 2001

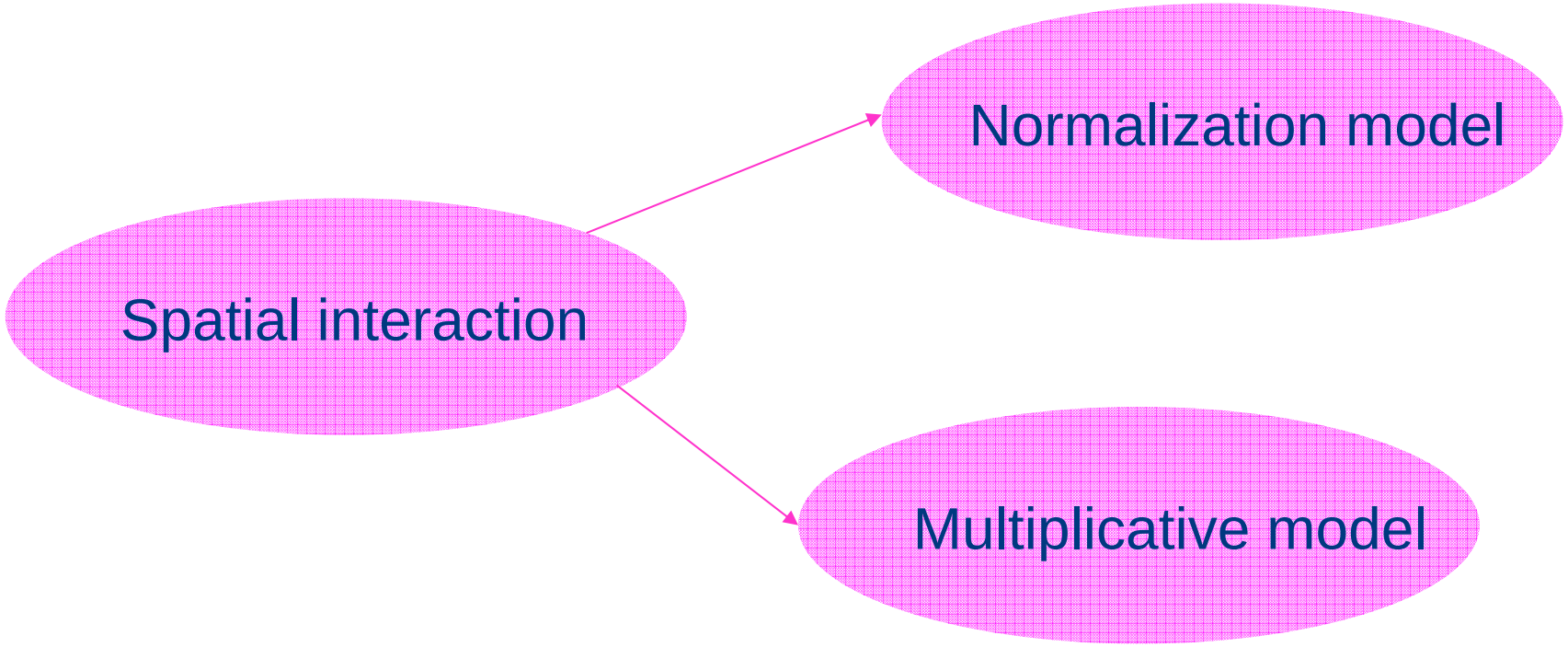
Modeling surrond suppression in V1 neurons with a statistically-derived normalization model

Surround suppression should be locally isotropic

Petrov and McKee (2006)

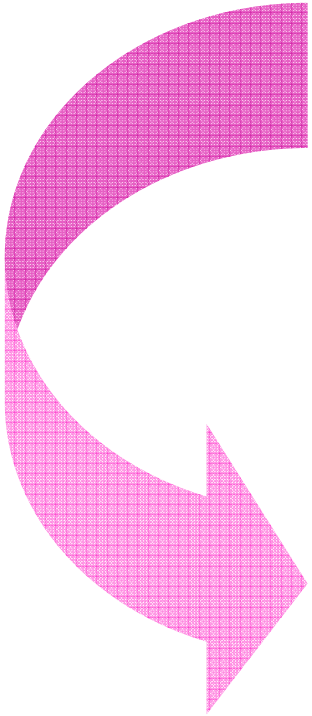
The effect of spatial configuration on surround suppression of contrast sensitivity

Quantitative Models



Normalization Model

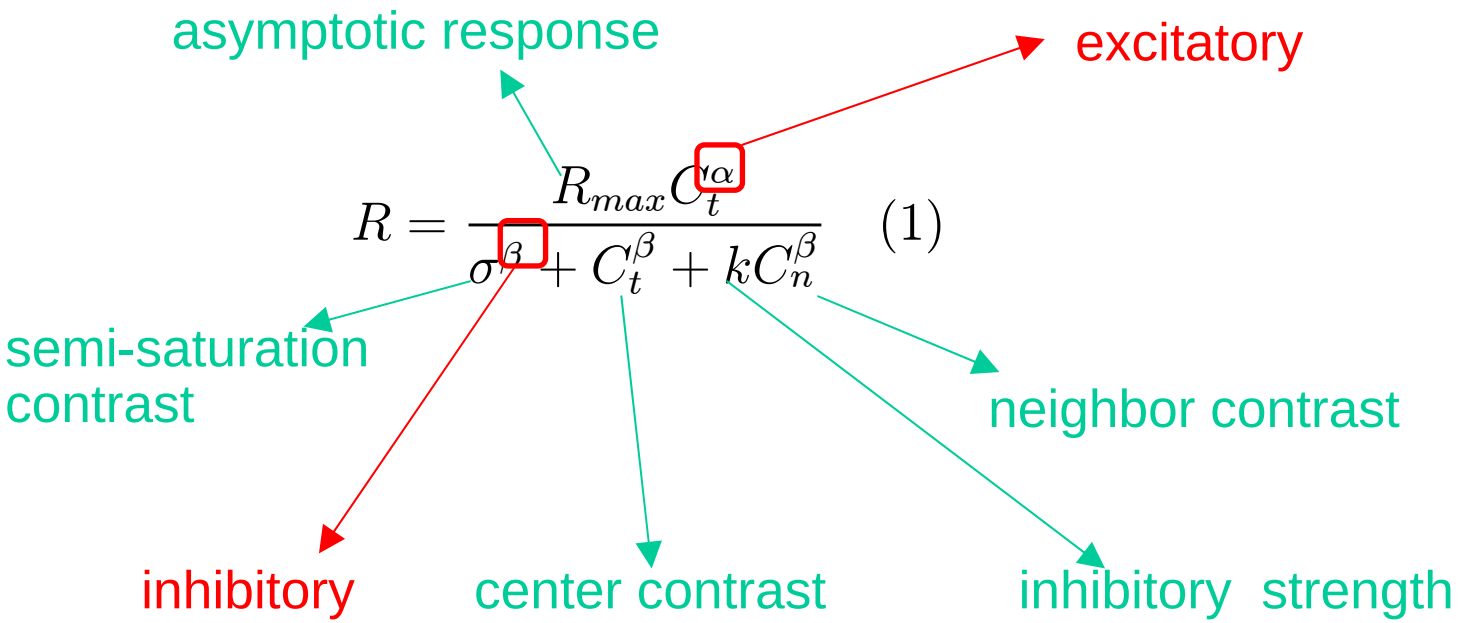
$$R = \frac{R_{max} C_t^{\alpha}}{\sigma^{\beta} + C_t^{\beta} + k C_n^{\beta}} \quad (1)$$



cortical channels interaction

- overlap,
- orientation channel
- spatial frequency channels

Normalization Model



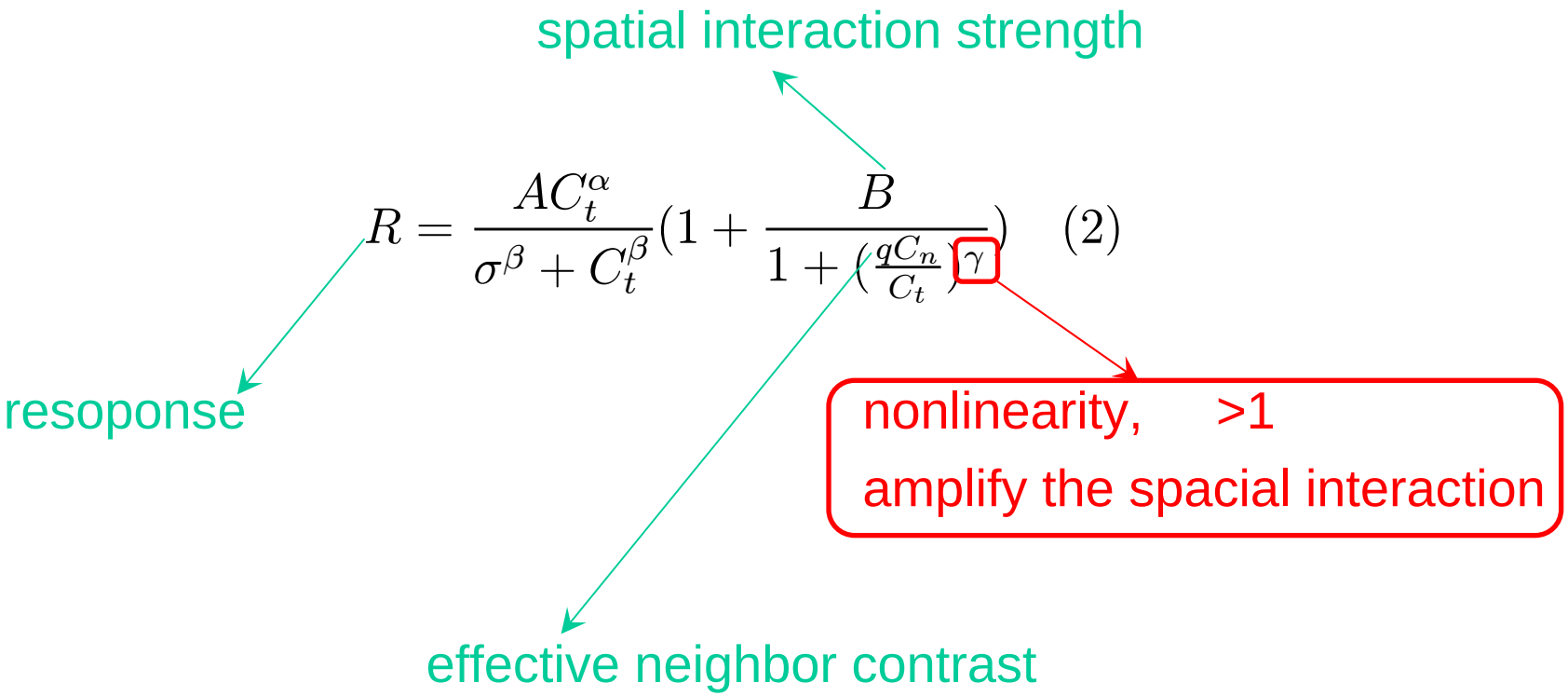
Normalization Model

- Nonlinearity of contrast response function
- Inhibition from neighbor stimulus
- Mathematical simplicity
- Code more efficiently

High neighbor contrast & low center contrast

Asymptotic inhibition, Ejima & Takahashi (1985)

Multiplicative Model



Multiplicative Model

$$R = \frac{AC_t^{\alpha}}{\sigma^{\beta} + C_t^{\beta}}\left(1 + \frac{B}{1 + \left(\frac{qC_n}{C_t}\right)^{\gamma}}\right) \quad (2)$$

physical target stimulus contrast

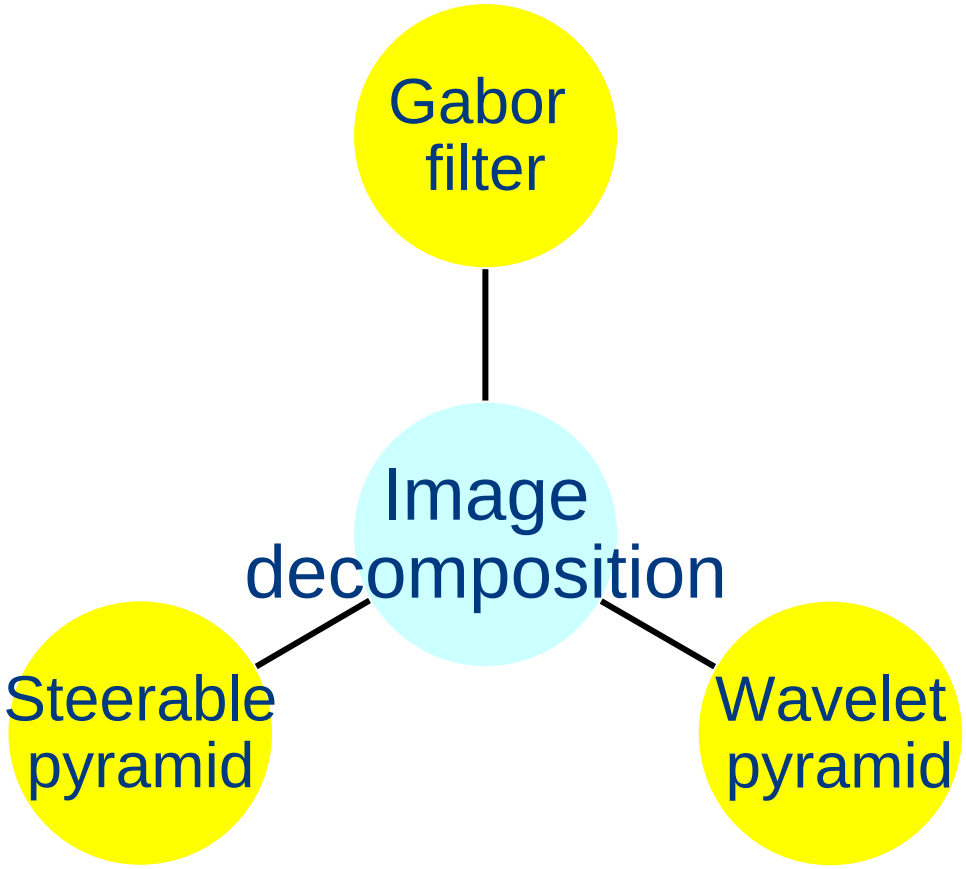
spatial interaction

Multiplicative Model

- Nonlinearity of contrast response function
- Amplify the spatial interaction
- The saturation of spatial interaction

- Two more parameters

Image Decomposition

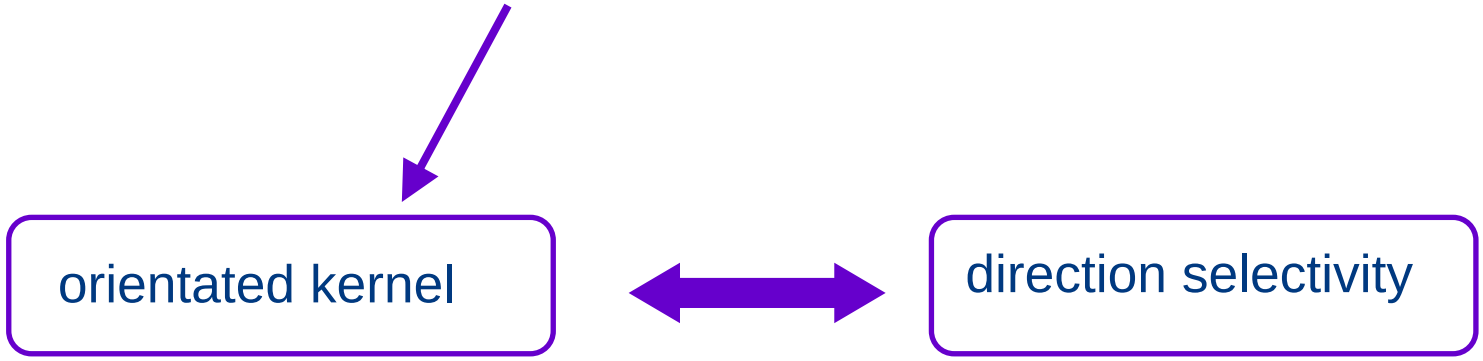


Gabor Filter

$$g(x, y, \lambda, \theta, \phi, \sigma, \nu) = \exp(-\frac{x'^2 + \nu y'^2}{2\sigma^2}) \cos(2\pi \frac{x'}{\lambda} + \phi) \quad (3)$$

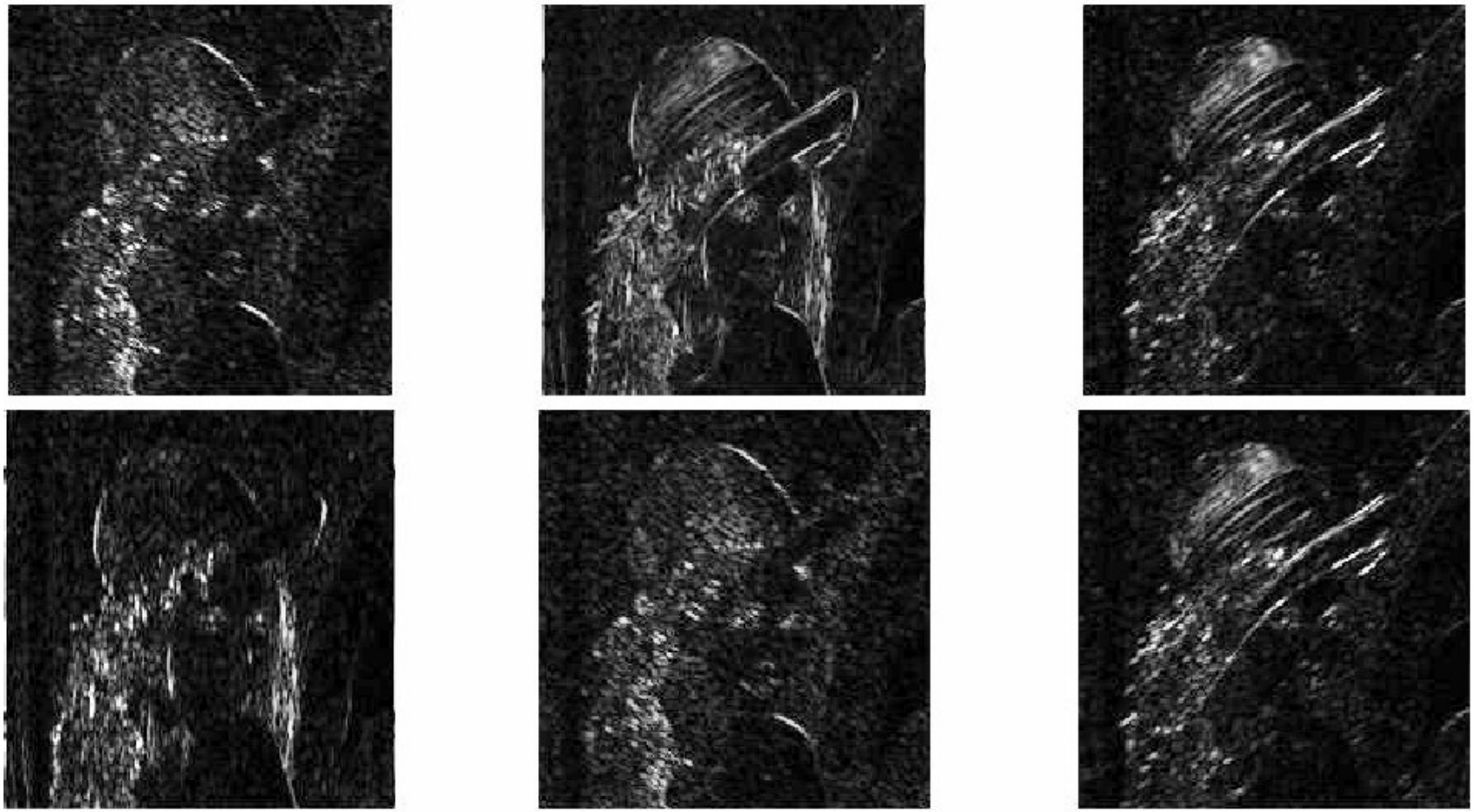
$$x' = x\cos(\theta) + y\sin(\theta), \quad y' = -x\sin(\theta) + y\cos(\theta)$$

λ:wavelength, θ:orientation, ϕ:phase offset, σ:Gaussian envelope



Gabor Filter

Gabor Filter



The Steerable Pyramid

→ *Linear*

→ *Multi-scale*

→ *Multi-orientation*

→ *Directional derivative operator*

order → *orientations*

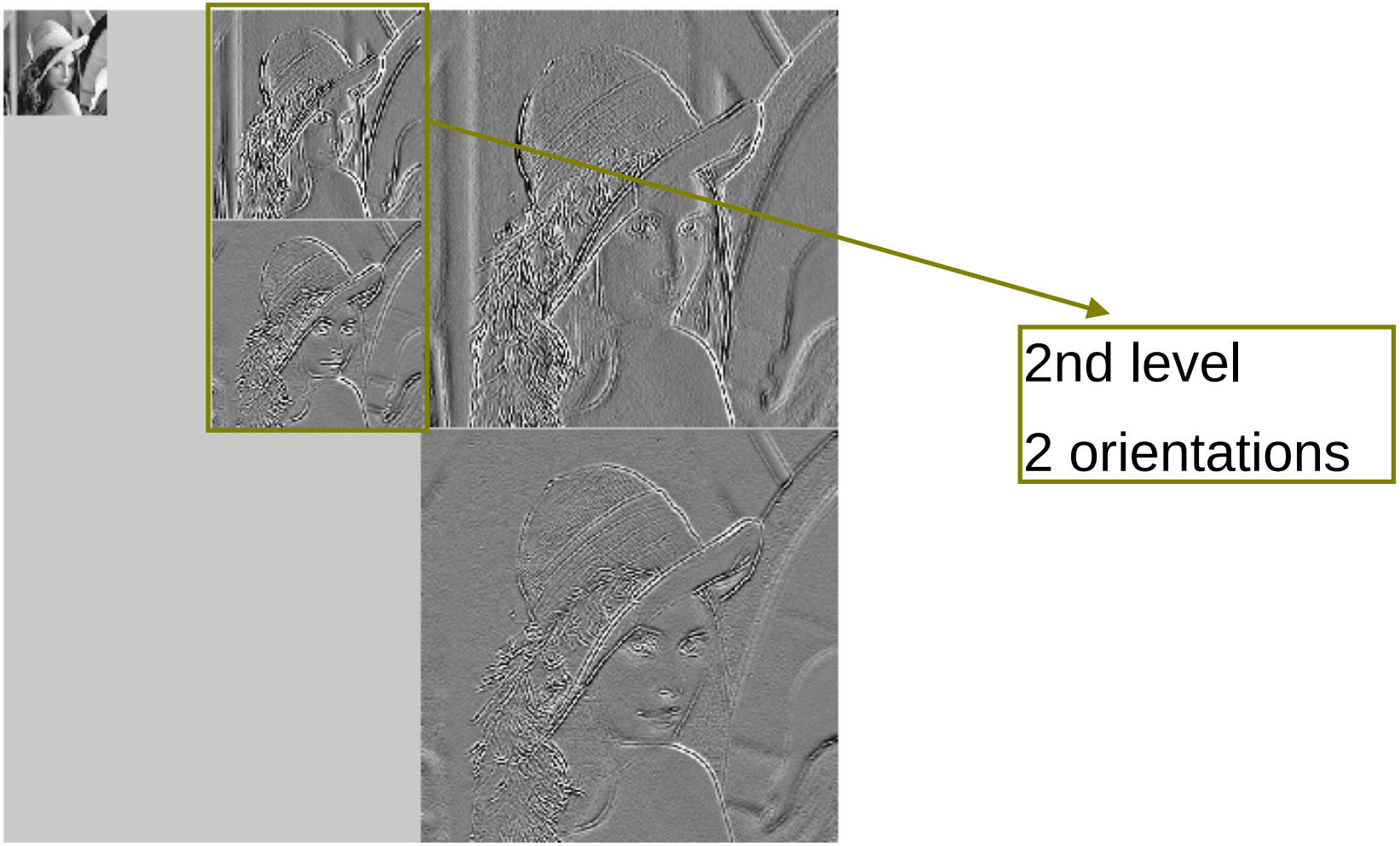
The Steerable Pyramid

- No orthogonality
- Rotation invariant ⟷ Orientation
- Translation invariant ⟷ Position
- Independent scale
- Independent orientation

Over-completeness 4/3K

The steerable pyramid

The Steerable Pyramid



Implementation Results

Schwartz and Simoncelli (1999):

Model:

$$R = C^2 / [\sum_k \omega_k P_k^2 + \sigma^2]$$

interaction

adjacent coefficient

center coefficient

Objective function:

$$\{\hat{\omega}, \hat{\sigma}\} = \arg\min \mathbf{E}[C^2 - \sum \omega_k P_k^2 - \sigma^2]^2$$

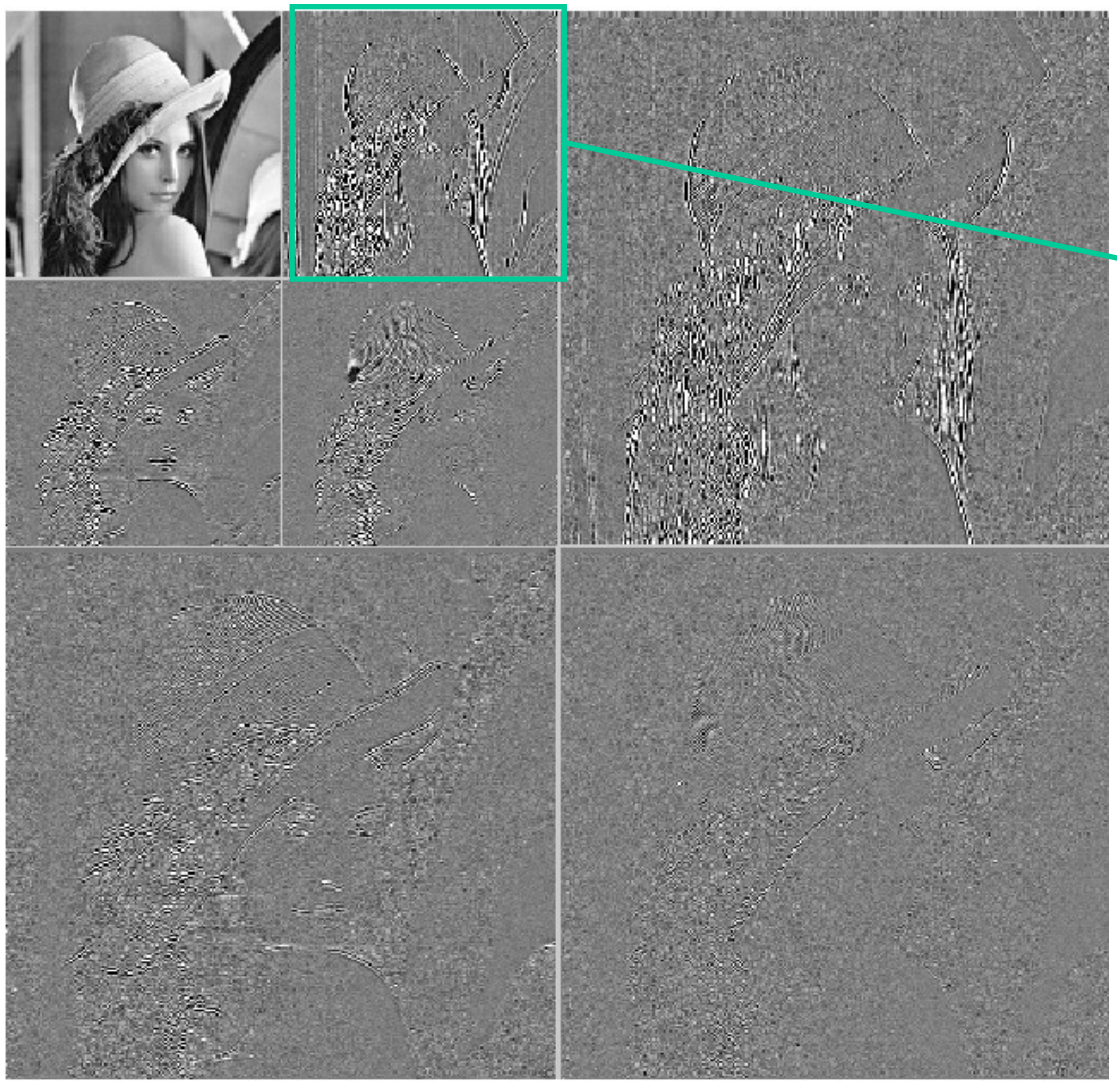
expected mean value

Objective function

$$\{\hat{\omega}, \hat{\sigma}\} = \arg\min \mathbf{E}[C^2 - \sum \omega_k P_k^2 - \sigma^2]^2$$

The wavelet pyramid

Extracting channels



Second level, vertical

Optimization algorithm

$$\{\hat{\omega}, \hat{\sigma}\} = \arg\min \mathbf{E}[C^2 - \sum \omega_k P_k^2 - \sigma^2]^2$$

Extract the corresponding coefficients matrix, 128×128

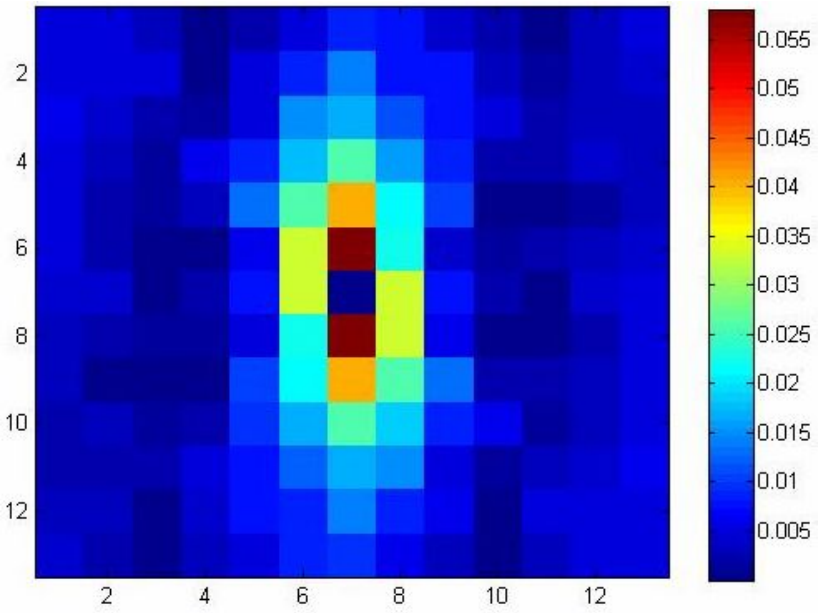
Choose a 13×13 window with the center pixel modeling the center neuron

Link $\{\omega_k\}$ to each pixel inthis window

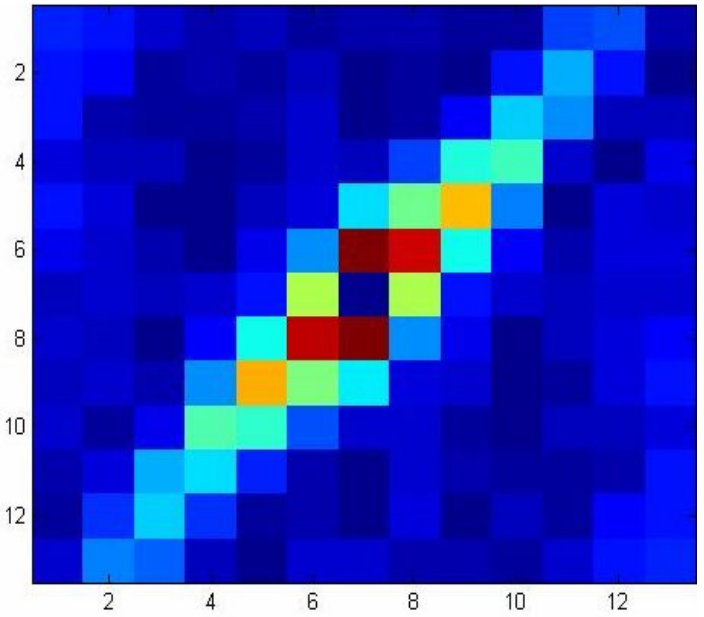
Move the window over the whole extracted area to establish the objective function

Apply optimization algorithm to find the weights $\{\omega_k\}$ by minimizing the objective function

Conclusion and further discussion



vertical details,second scale



diagonal details,second scale

Optimized weights

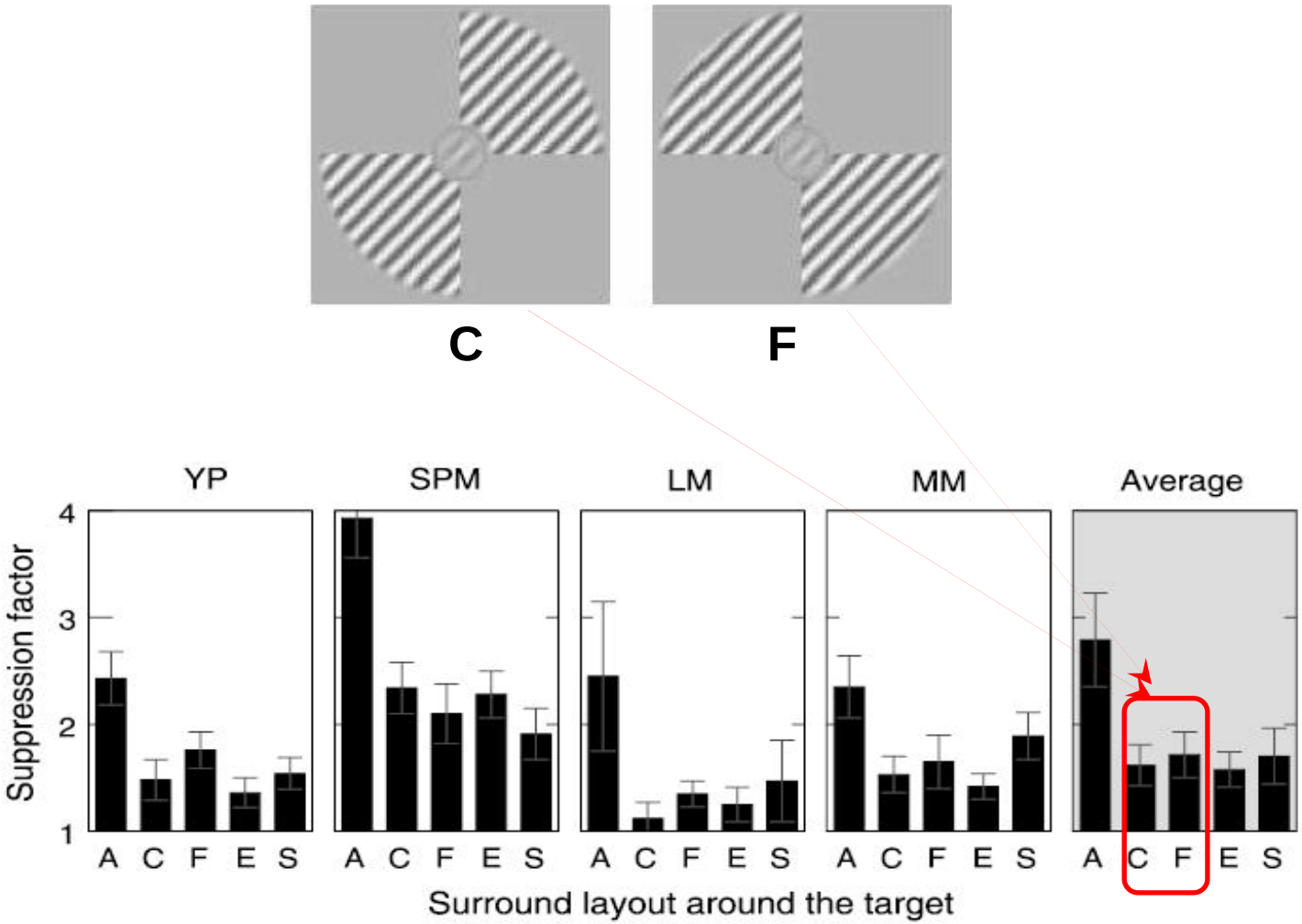
Conclusion and further discussion

- Symmetric
- Declining
- Directional

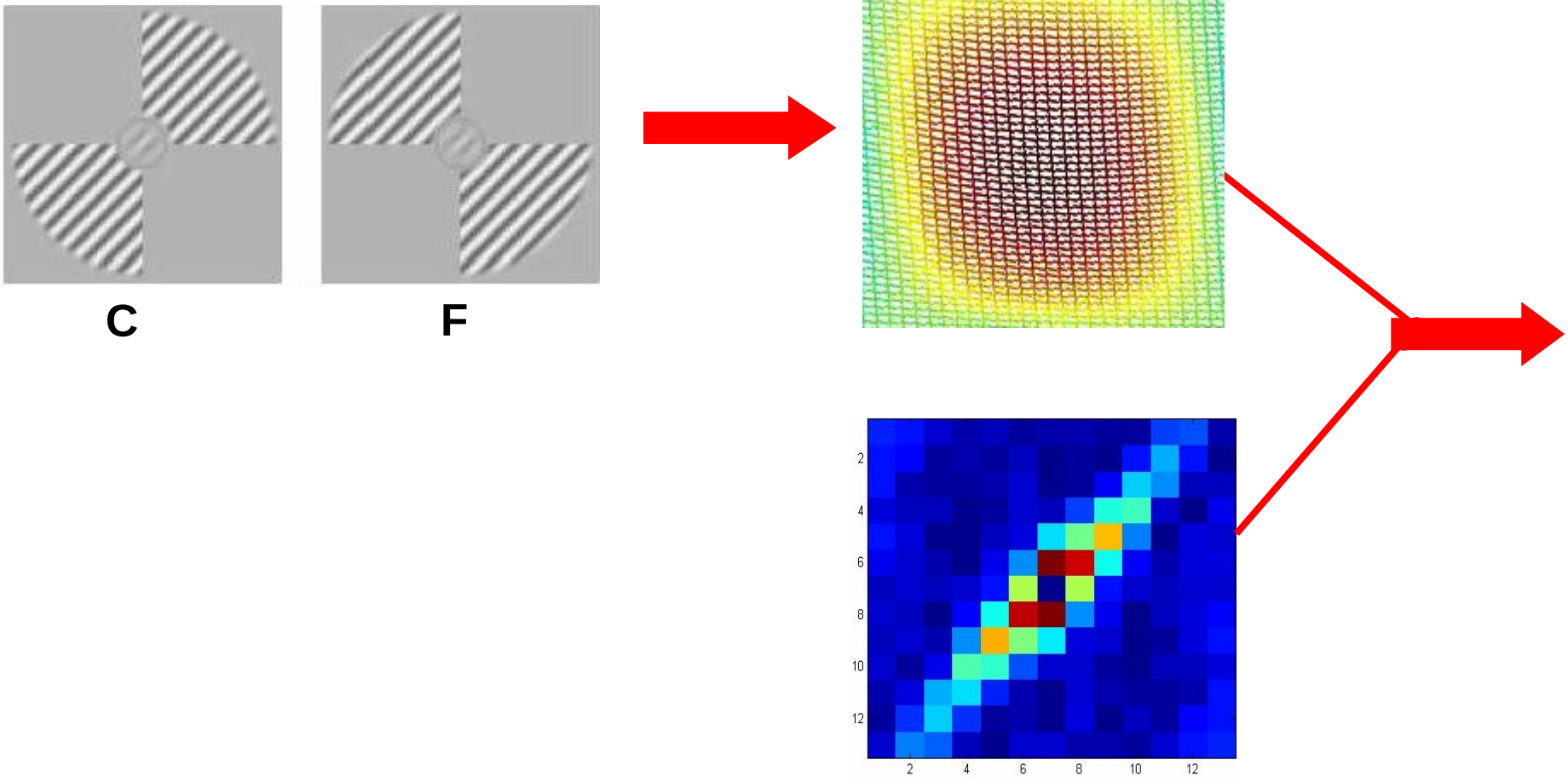
Surround suppression is locally anisotropic
Schwartz & Simoncelli, 2001

Surround suppression should be locally isotropic
Petrov and McKee (2006)

Petrov & McKee (2006)'s experiment



Conclusion and further discussion



Conclusion and further discussion

Surround suppression is locally anisotropic
Schwartz & Simoncelli, 2001

Further:

Across scales, optimization principle…

Acknowledgements

I would like to thank Dr. Pierre Kornprobst and Dr. Neil Bruce for the great help and support during my internship at INRIA Sophia Antipolis Méditerranée.

Thanks are also due to Dr. Chiara SIMEONI and Prof. Victorita Dolean for their organizational help.

Thank you for your attention!