Modeling pre-attentive stereo grouping by intracortical interactions in early visual cortex.

Zhaoping Li, University College London
www.gatsby.ucl.ac.uk/~zhaoping

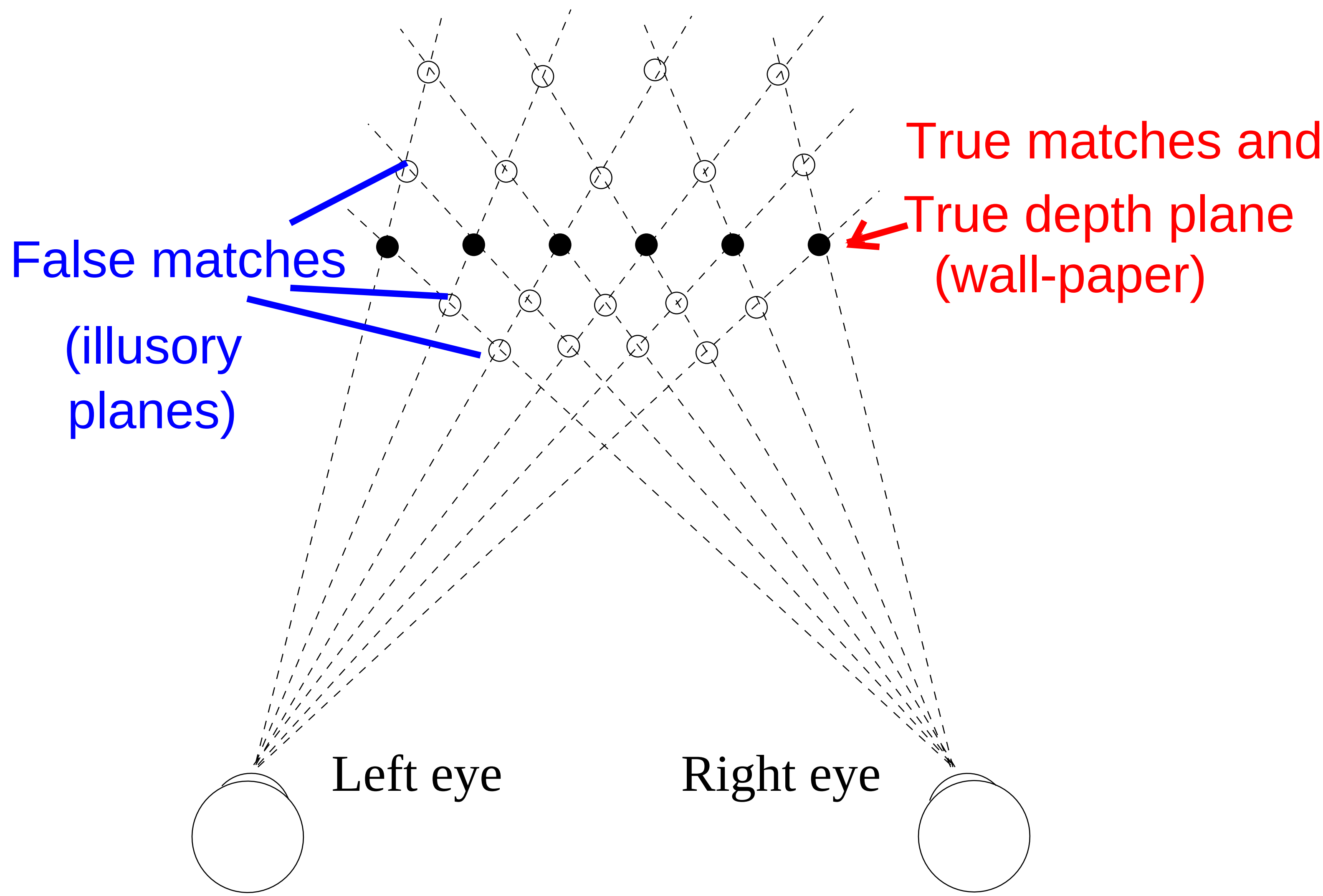
urpose: to see if intracortical interactions can account for some ereo grouping phenomana in physiology and psychophysics

tereo Grouping Phenomena modelled here:

- Enhanced V2 responses to stereo edges. (von der Heydt et al, 2000).
- Disparity capture (wall-paper effects) manifested by V2 responses (Bakin et al, 2000).
- Pop-out of a target of a unique depth from distractors of a different depth.
- Transparency.

The stereo matching problem

Example: the wall-paper effect



he visual input samples both the true and he false matches

1 neurons respond to both the true and false matches. umming and Parker, 2000)

ut the cortex has to compute the true atches only

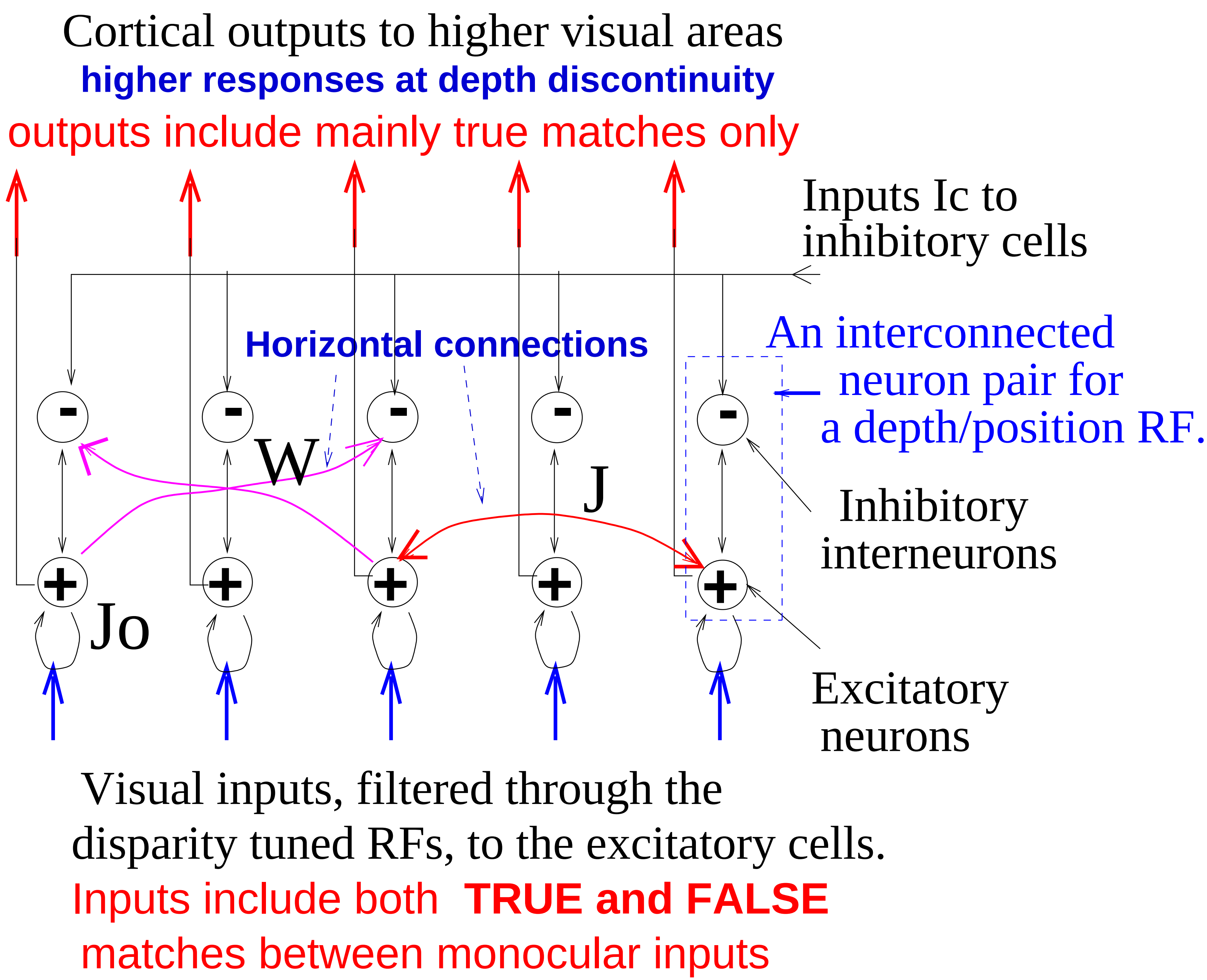
2 neurons respond to only the true matches in the wall-paper fect (Bakin, Nakayama, and Gilbert, 2000 observed that a V2 uron's response is tuned to the disparity value outside its receptive ld, at the boundary of the depth plane (of the wall-paper-like ating.).

he stereo segmentation (grouping) problem

etecting or highlighting discontinuities in depth, or depth ges, can serve segmentation, e.g., to segment two nearby planes of fferent depth, or to detect a target of a different depth — **pop-out**.
n der Heydt, Zhou, and Friedman, (2000) observed that **V2 cells spond more vigorously when their receptive fields are near a pth edge**.

ansparency: perceptually segregating two superimposed depth anes.

he model



Cortical outputs to higher visual areas
higher responses at depth discontinuity
outputs include mainly true matches only
Inputs Ic to inhibitory cells
Horizontal connections
An interconnected neuron pair for a depth/position RF.
W
J
Jo
Inhibitory interneurons
Excitatory neurons
Visual inputs, filtered through the disparity tuned RFs, to the excitatory cells.
Inputs include both TRUE and FALSE matches between monocular inputs

odel features and elements

- The model aims to emulate intracortical computations in **V2**.

- **Each model unit is binocular and disparity tuned**. The excitatory cells model cortical pyramidal cells. Each excitatory cell couples with a local interneuron to form a disparity tuned unit with a finite (small) size receptive field. **Other input dimensions (e.g., orientation, color, motion) are omitted**.

- Different cells are tuned to different depths, the receptive fields (RFs) of all model cells **sample 3D visual space** (2D frontol-parallel and 1D depth).

- **Both true and false matches provide input to the model** (pyramidal) cells.

- **Long but finite range horizontal connections** mediate monosynaptic excitation and disynaptic inhibtion between nearby pyramidal cells. Horizontal connections tend to link cells tuned to similar depth.

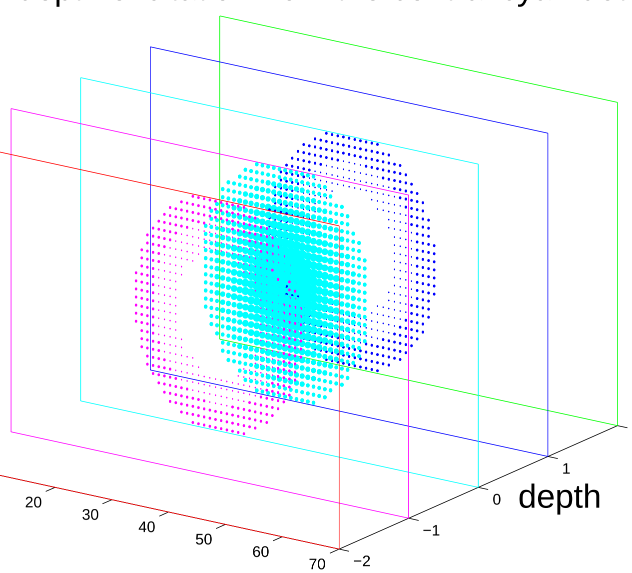
- **Cells responding to the same monocular location but different depths inhibit each other**.

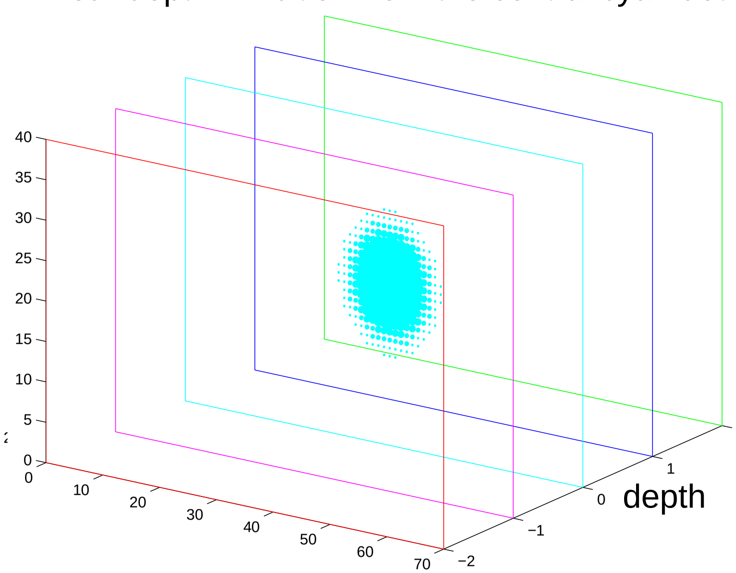
- Horizontal connections mediate contextual influences such that, after initial transients, **(1) the model cells respond significantly only to the true matches, and, (2) responses to depth discontinuities (depth edges or pop-out targets) are relatively higher.**

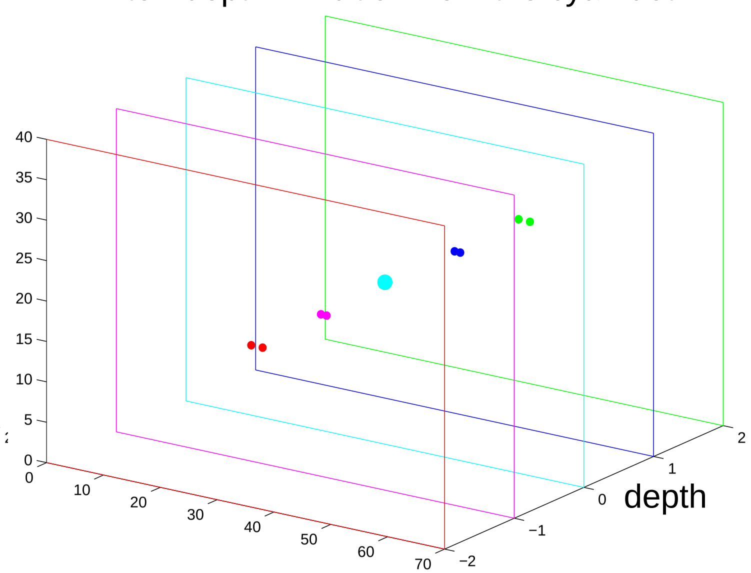
The model horizontal connection pattern

There are 3 components in the connections

ear depth excitation　　**Near depth inhibition**　　**Inter-depth suppression**







del cells sample the visual space of 5 depth planes (5x70x40 3-d locations).
ferent depth planes are color coded
ch dot on a depth plane represents an RF center.
t size codes interaction (or response) strength

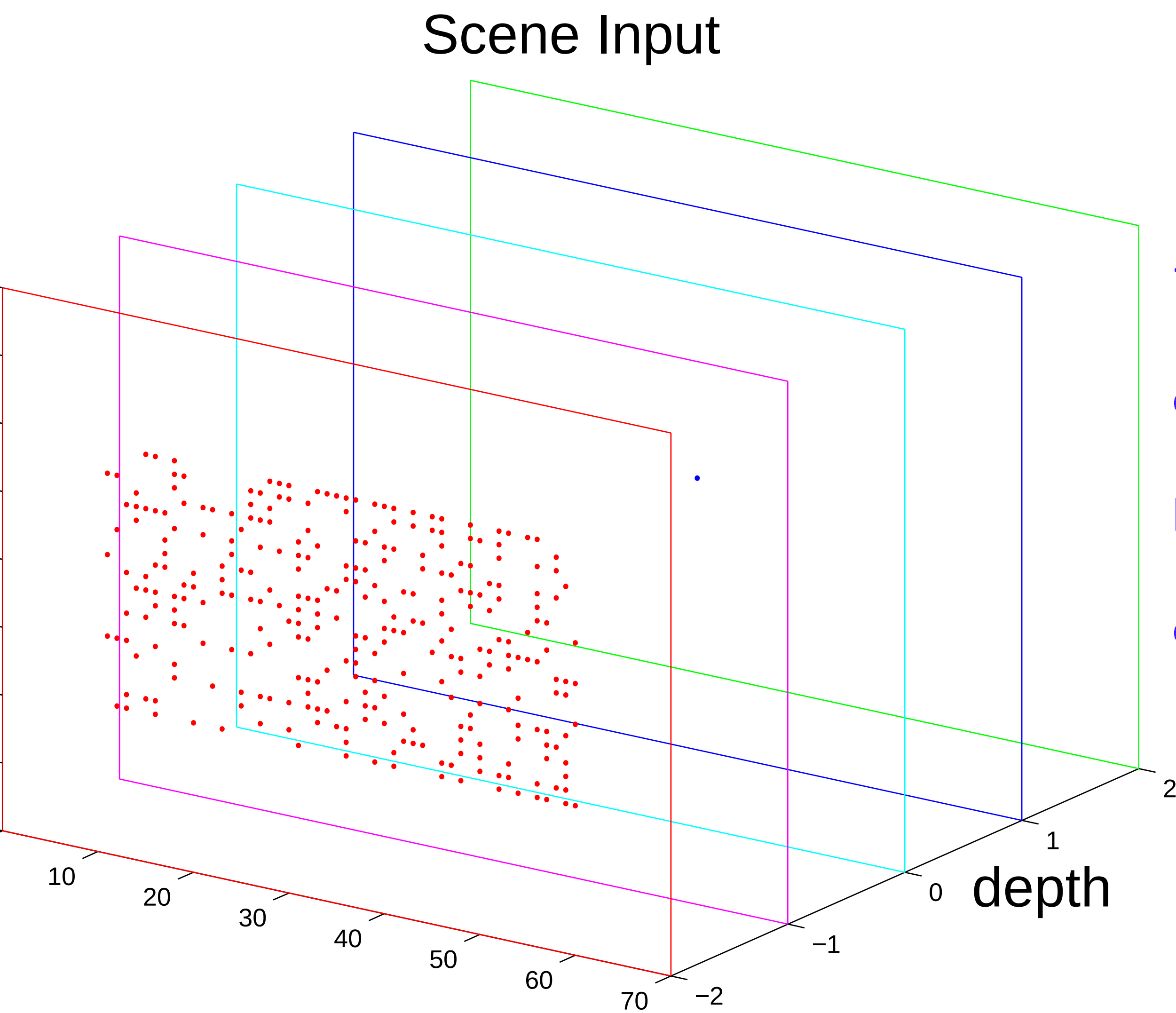
he equations of motion:

$$\dot{x}_{id} = -\alpha_x x_{id} - g_y(y_{id}) + J_o g_x(x_{id}) + \sum_{j,d' \neq i,d} J_{id,jd'} g_x(x_{jd'}) + I_{id} + I_o$$

$$\dot{y}_{id} = -\alpha_y y_{id} + g_x(x_{id}) + \sum_{j,d' \neq i,d} W_{id,jd'} g_x(x_{jd'}) + I_c$$

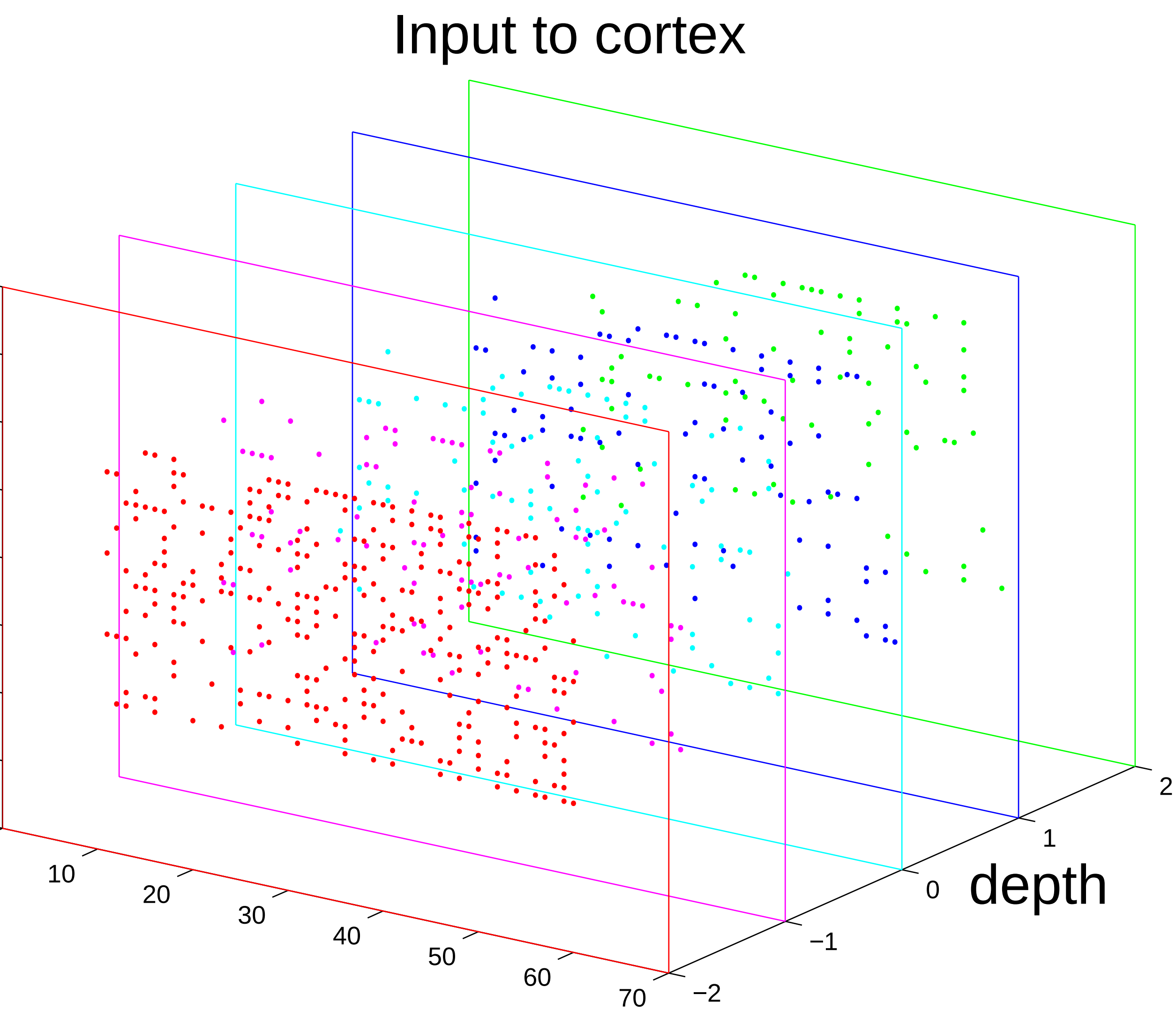
or y: membrane potential for excitatory or inhibitory cells, i, d index r frontal parallel location i and depth d, J, W, horizontal connection atrix, g sigmoid-like activation functions, I_{id} visual inputs, etc.

Model computation illustrated by Popout



The scene consists of one depth plane and a single lone target dot at a different (blue) depth

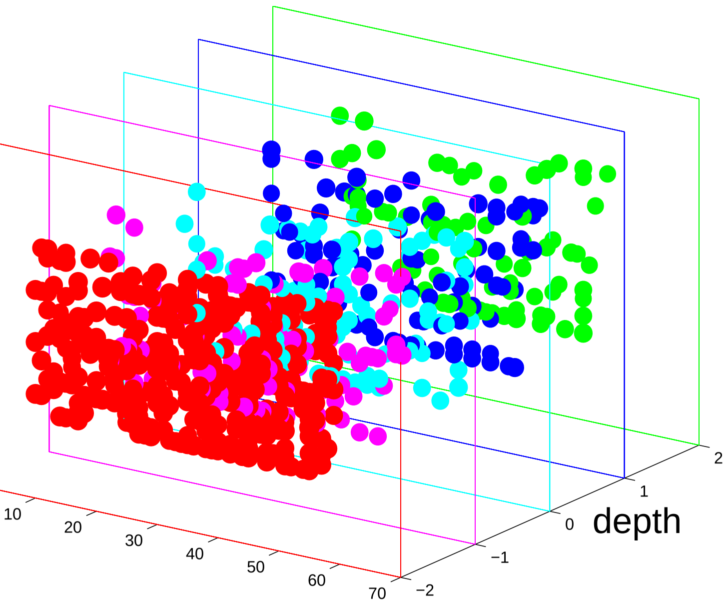
nput to the model



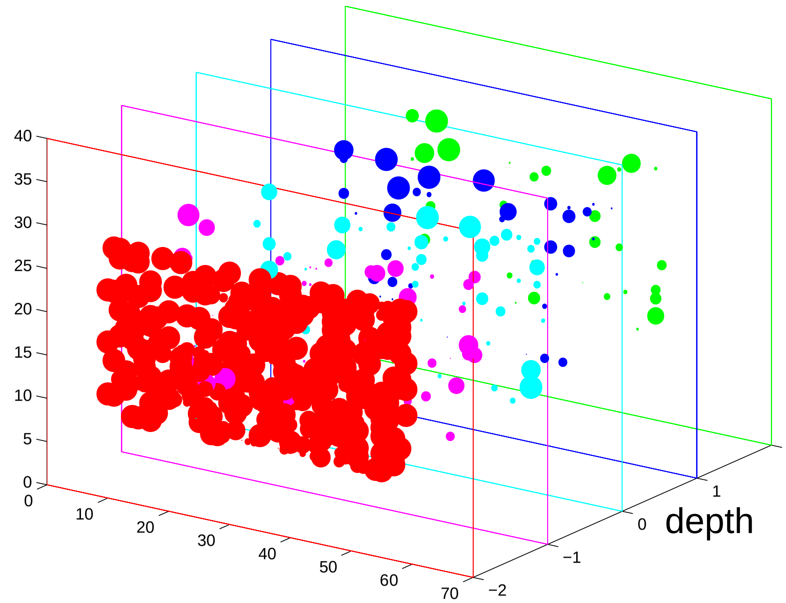
contains true and false matches

Evolution of activity with time

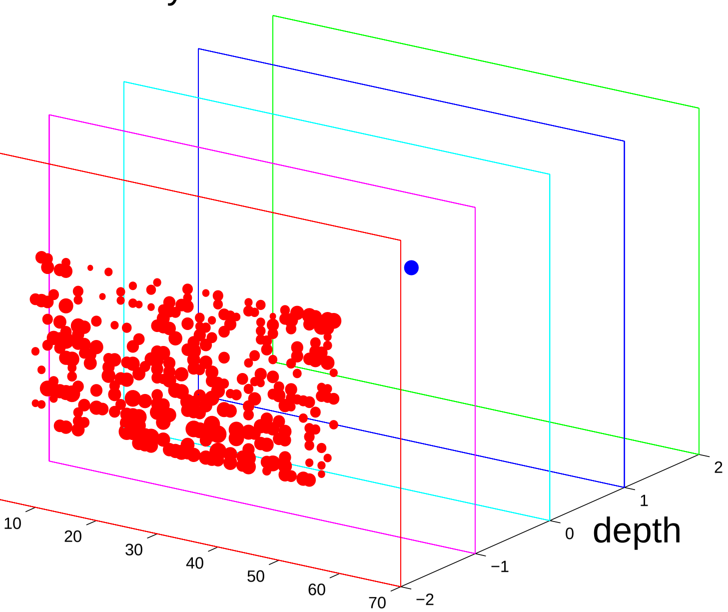
rtical activity at 0.60 membrane time constants



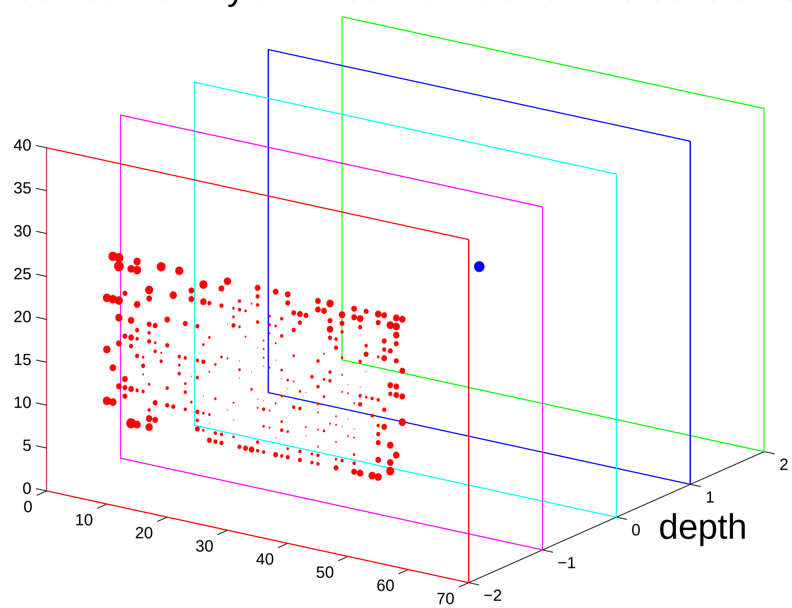
cortical activity at 1.40 membrane time constants



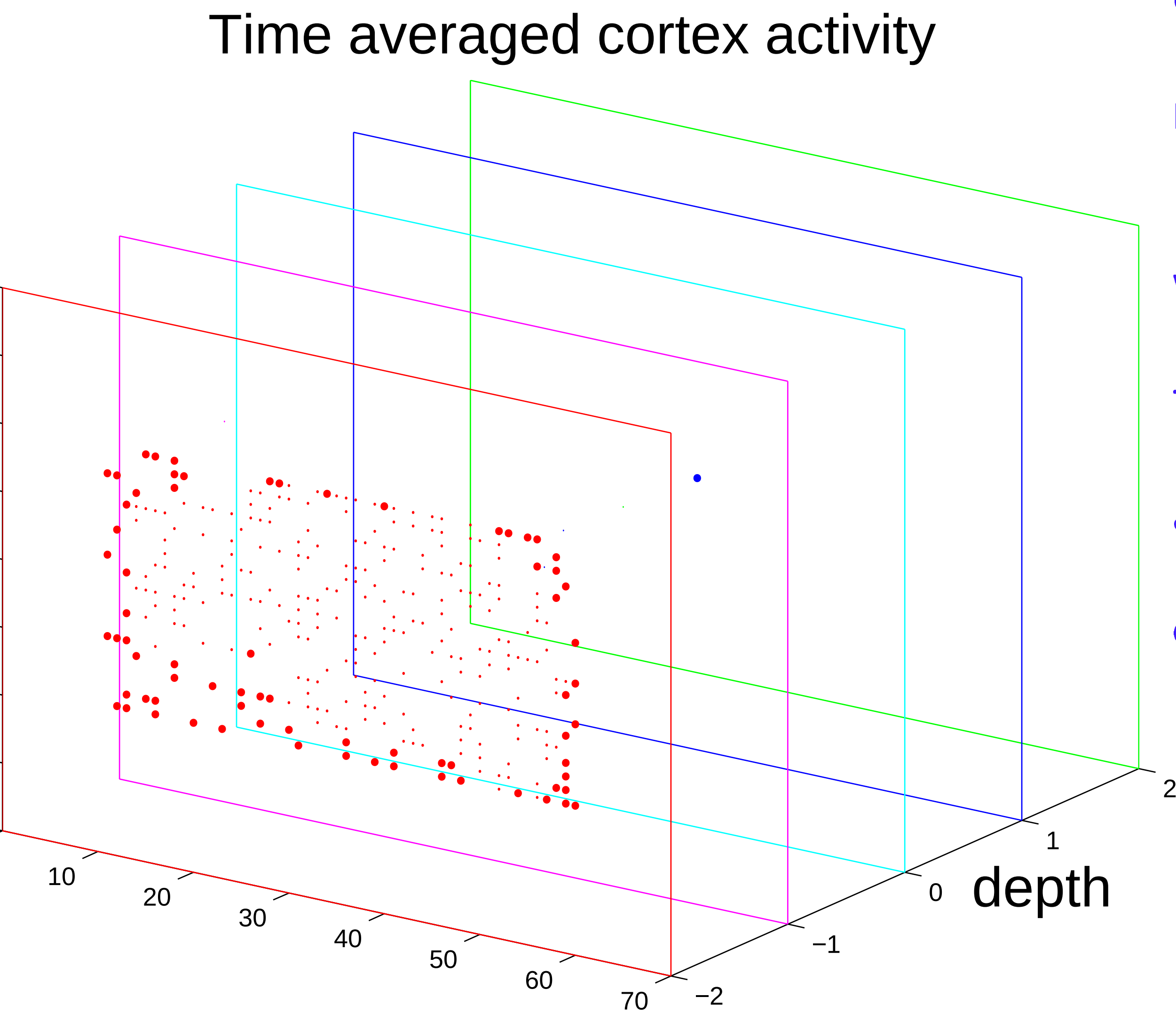
rtical activity at 6.00 membrane time constants



cortical activity at 12.80 membrane time constants



fter initial transients,
me averaged model response



contains mainly true

matches

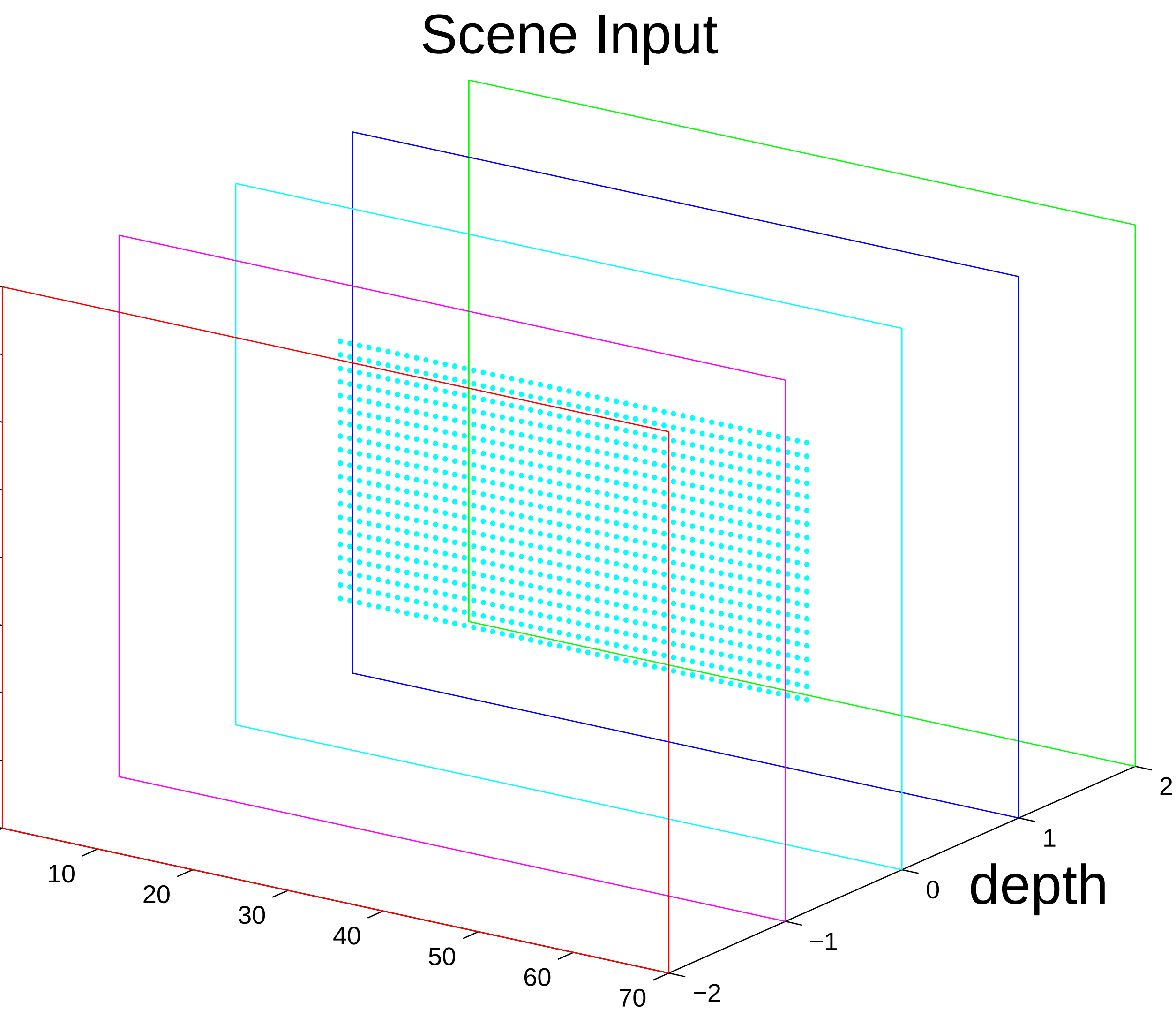
with higher responses to

the lone target — popout

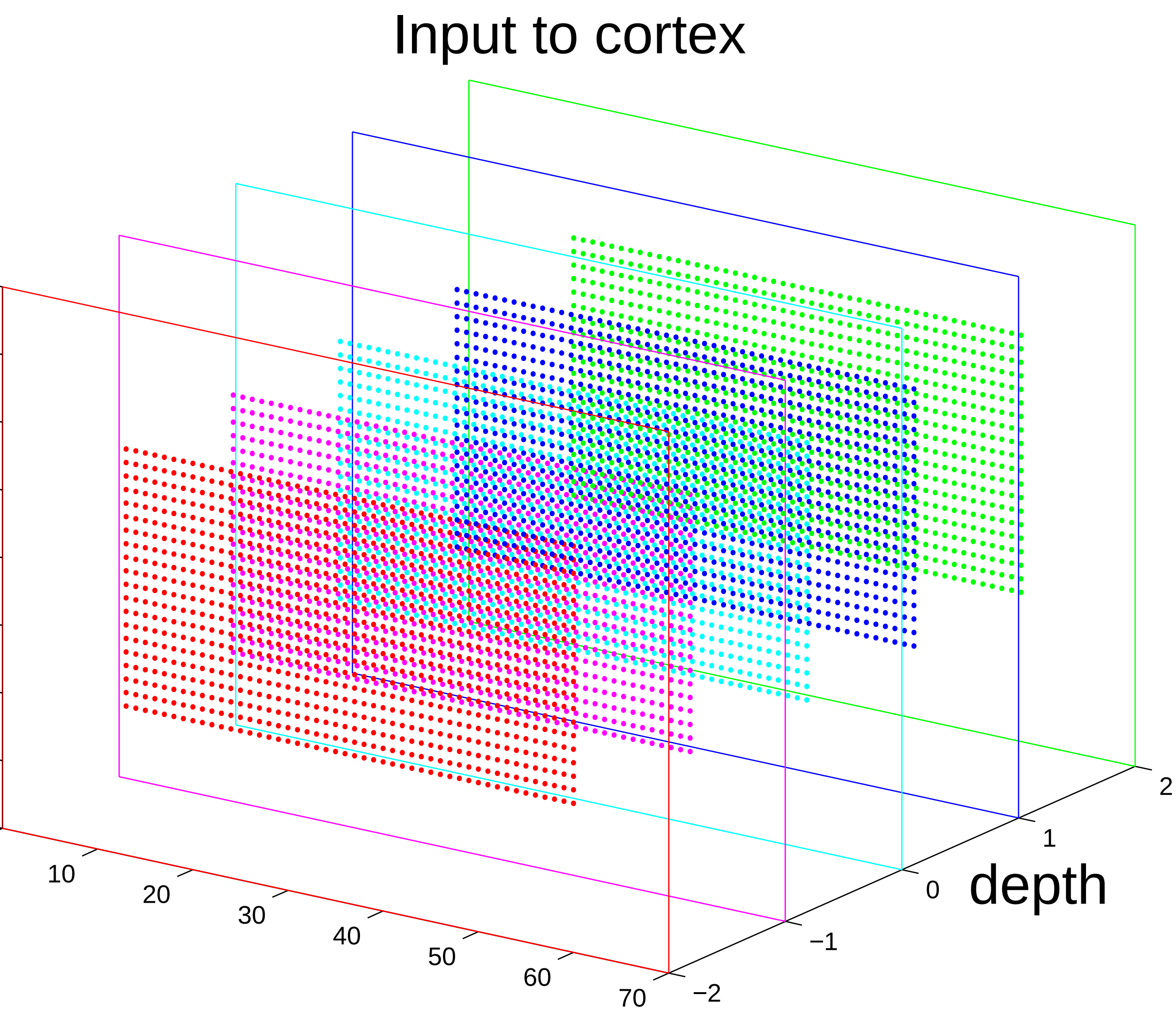
and to the borders

of the depth plane

lodel computation for Disparity Capture

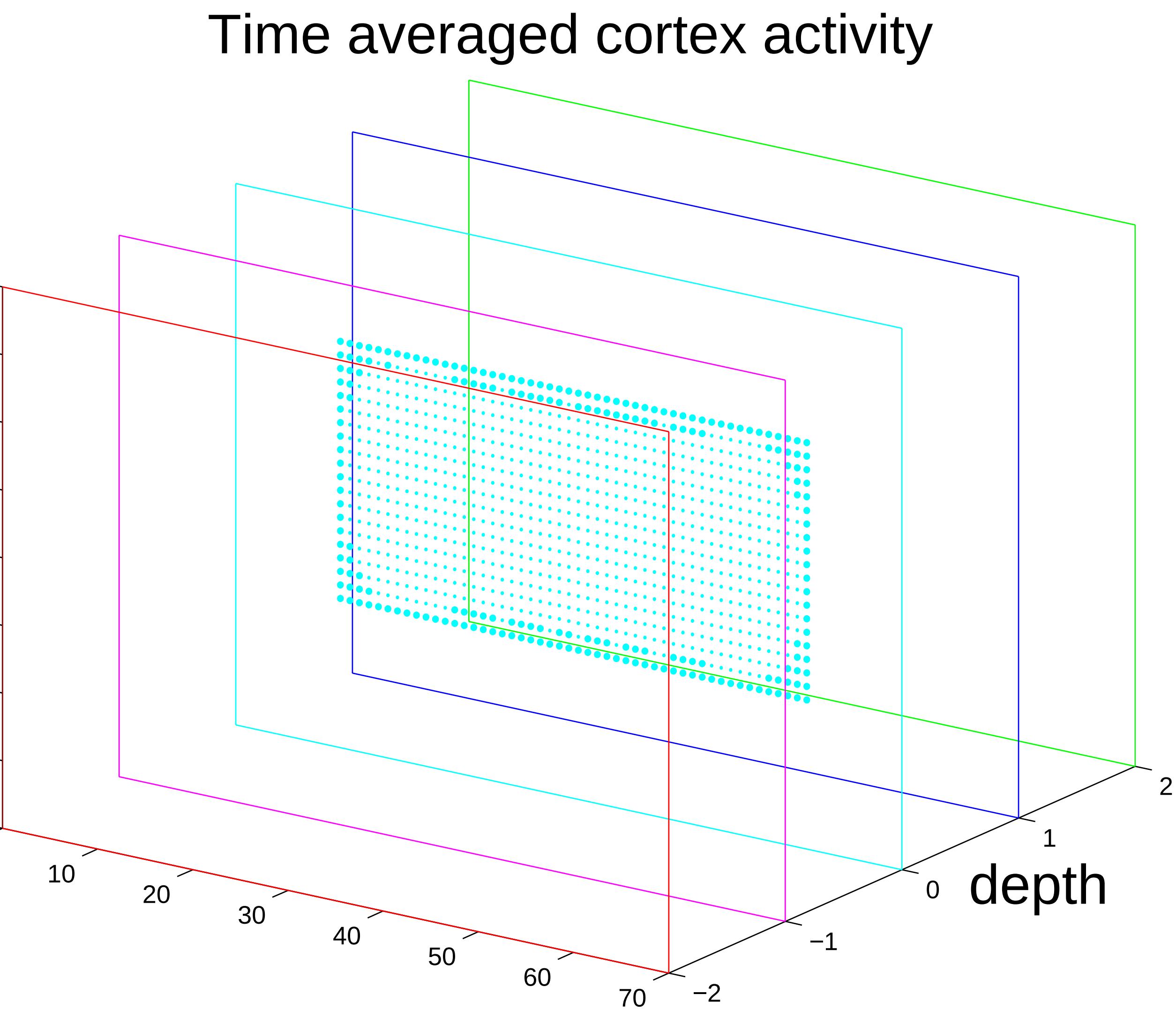


nput to the model



contains true and
illusory depth planes
from true and
false matches

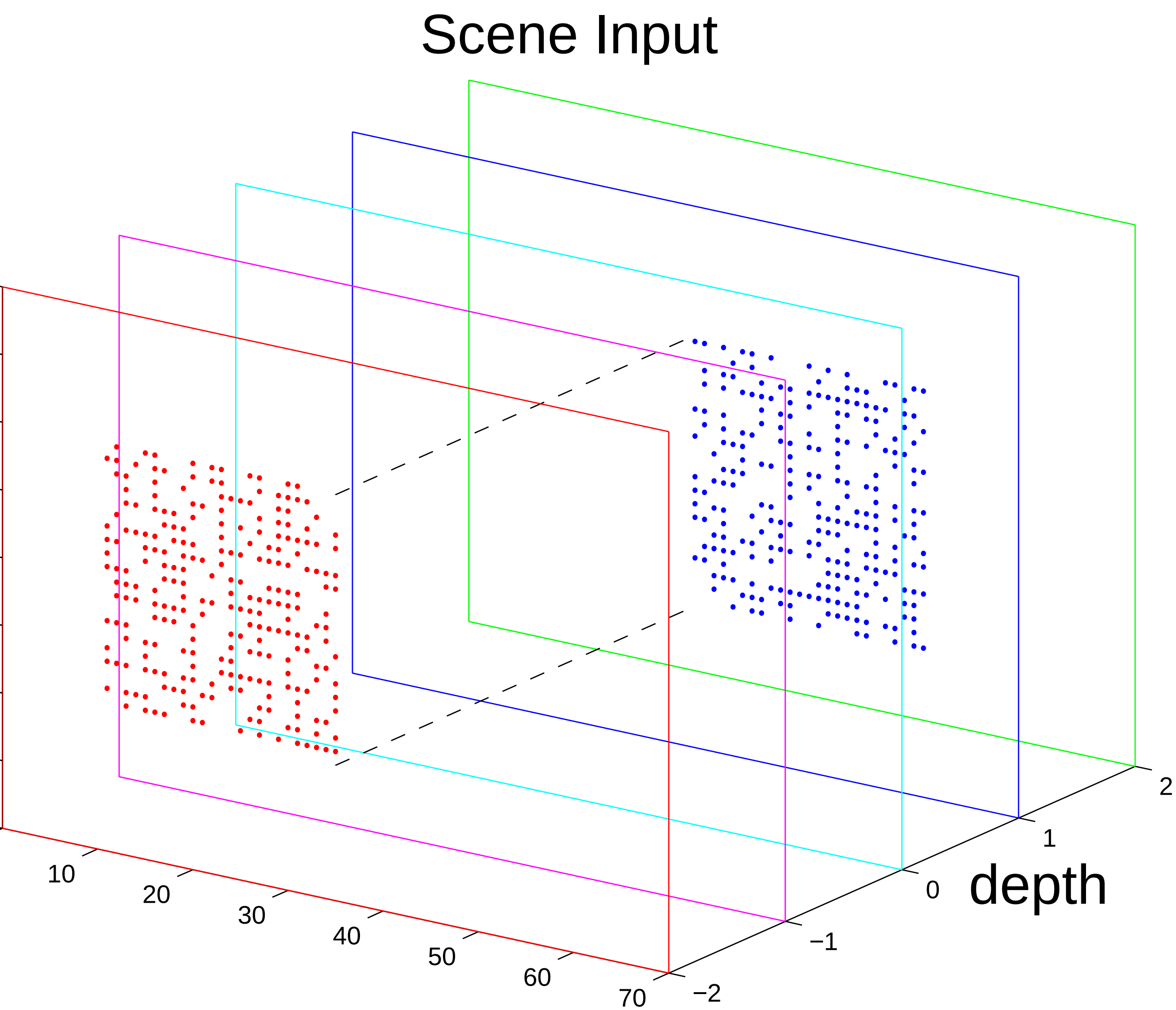
fter initial transients, me averaged model response



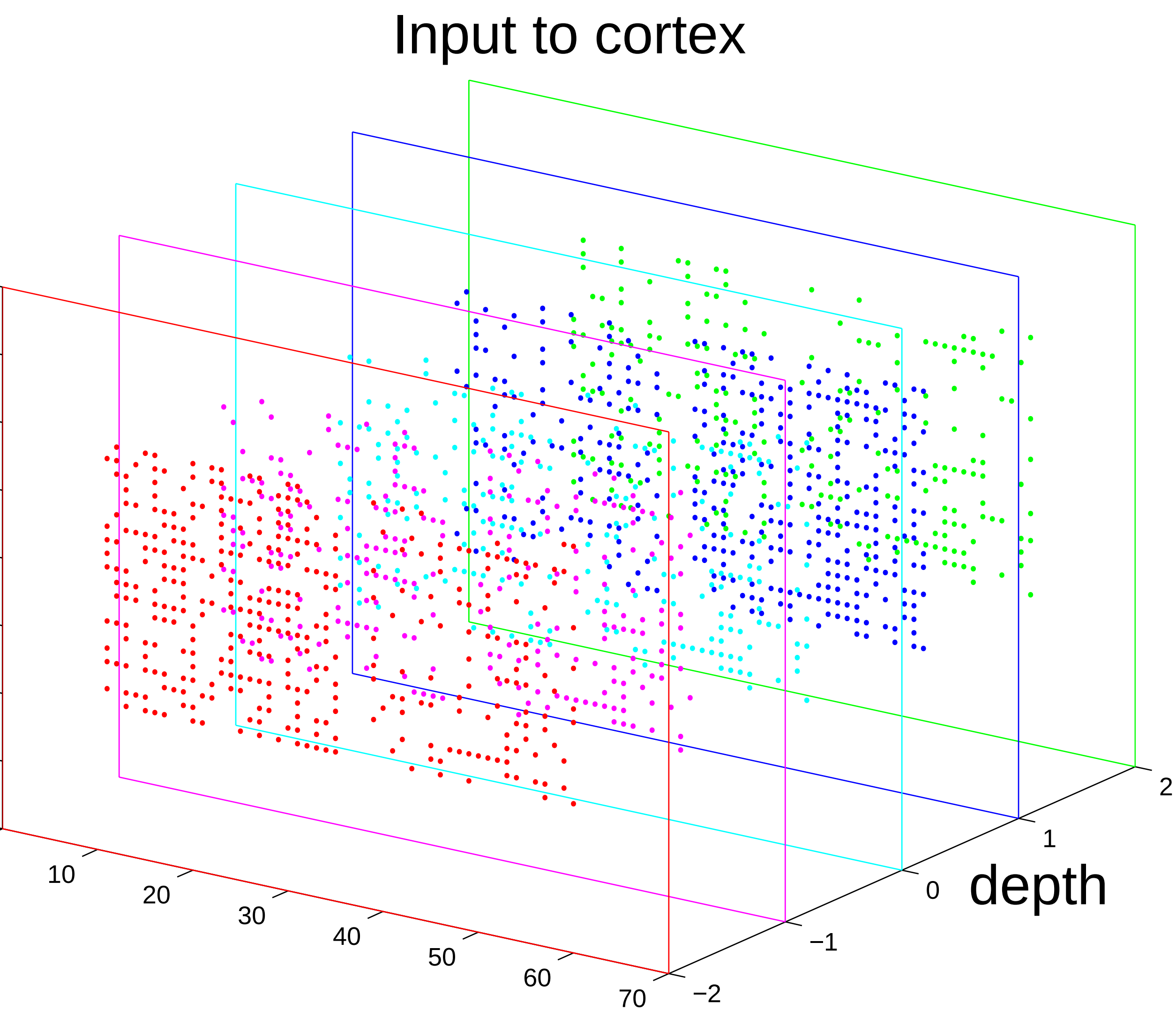
Higher responses to the borders of the plane

Contextual influences enable disparity information at the boundaries to propagate into the center of the plane

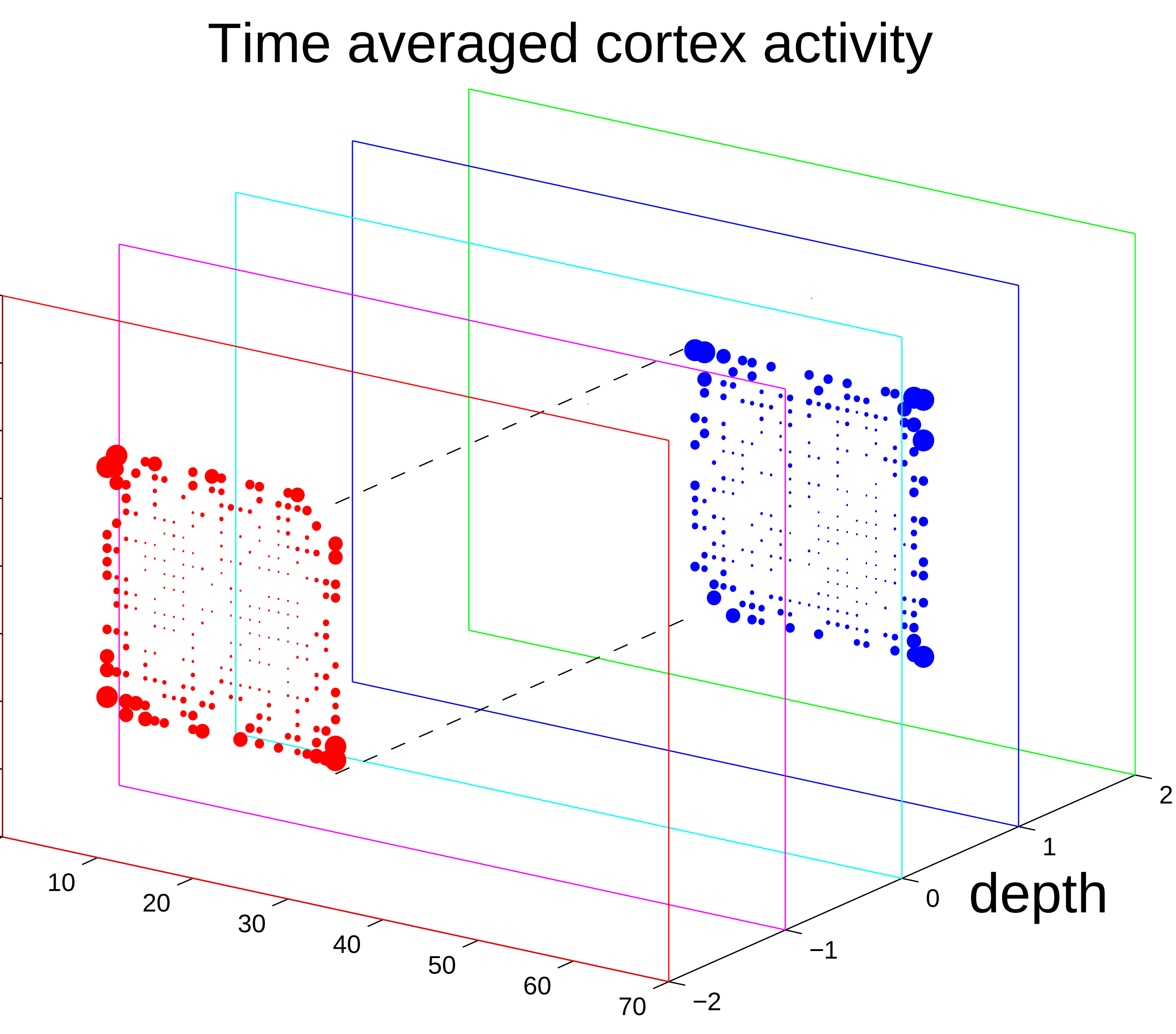
lodel computation for Depth Discontinuity



nput to the model

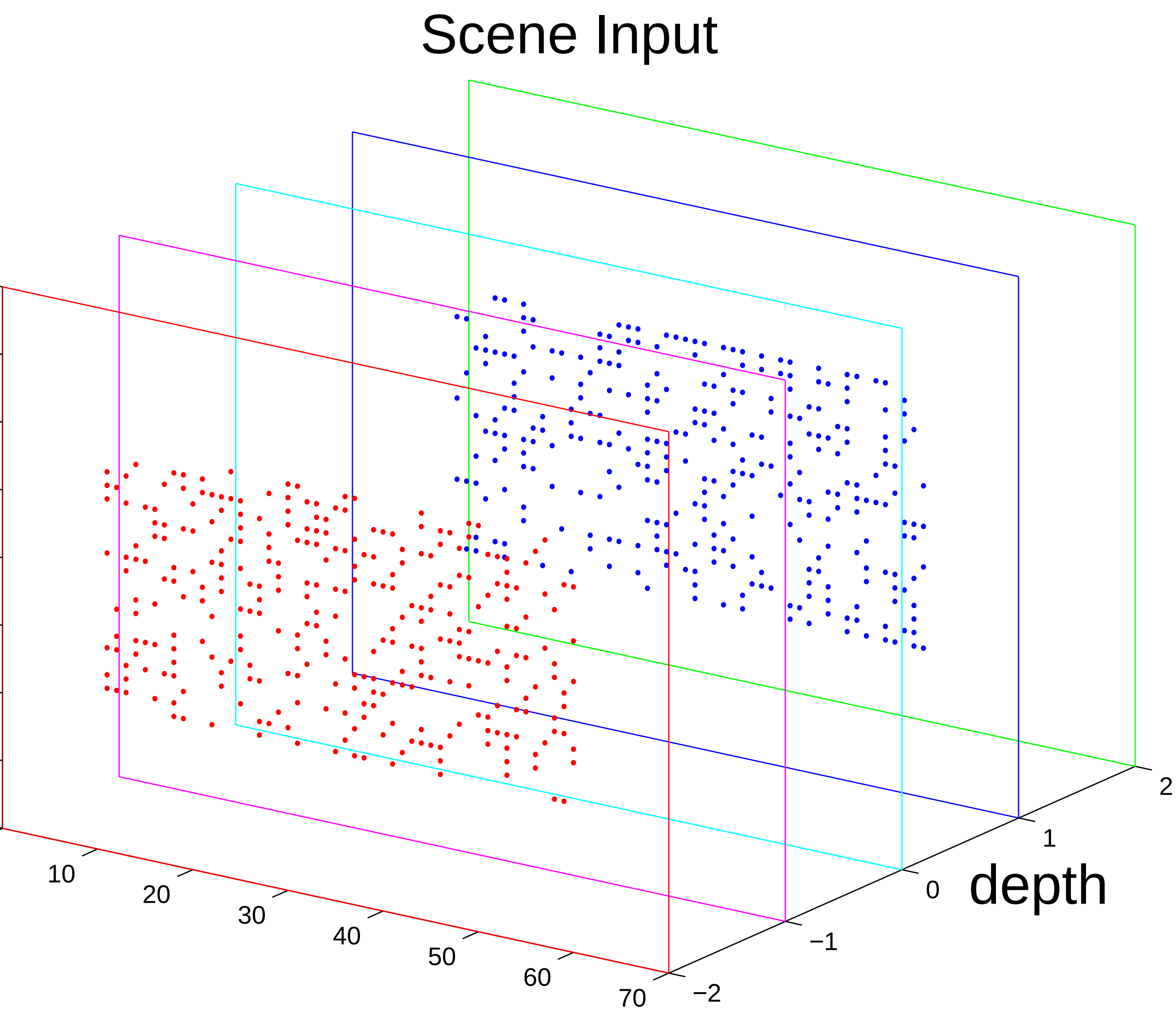


fter initial transients,
me averaged model response

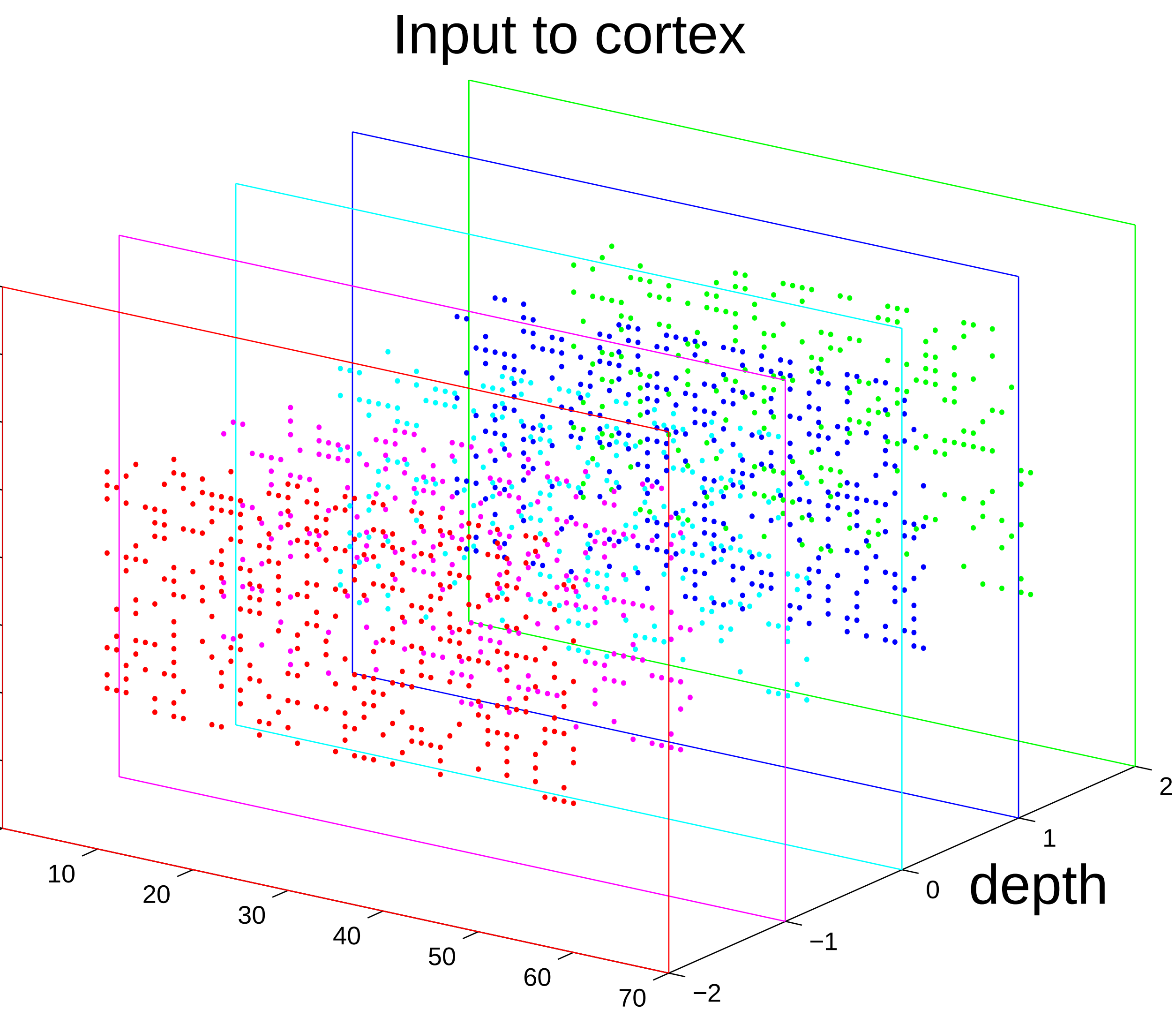


Higher responses to the depth discontunity and boundaries

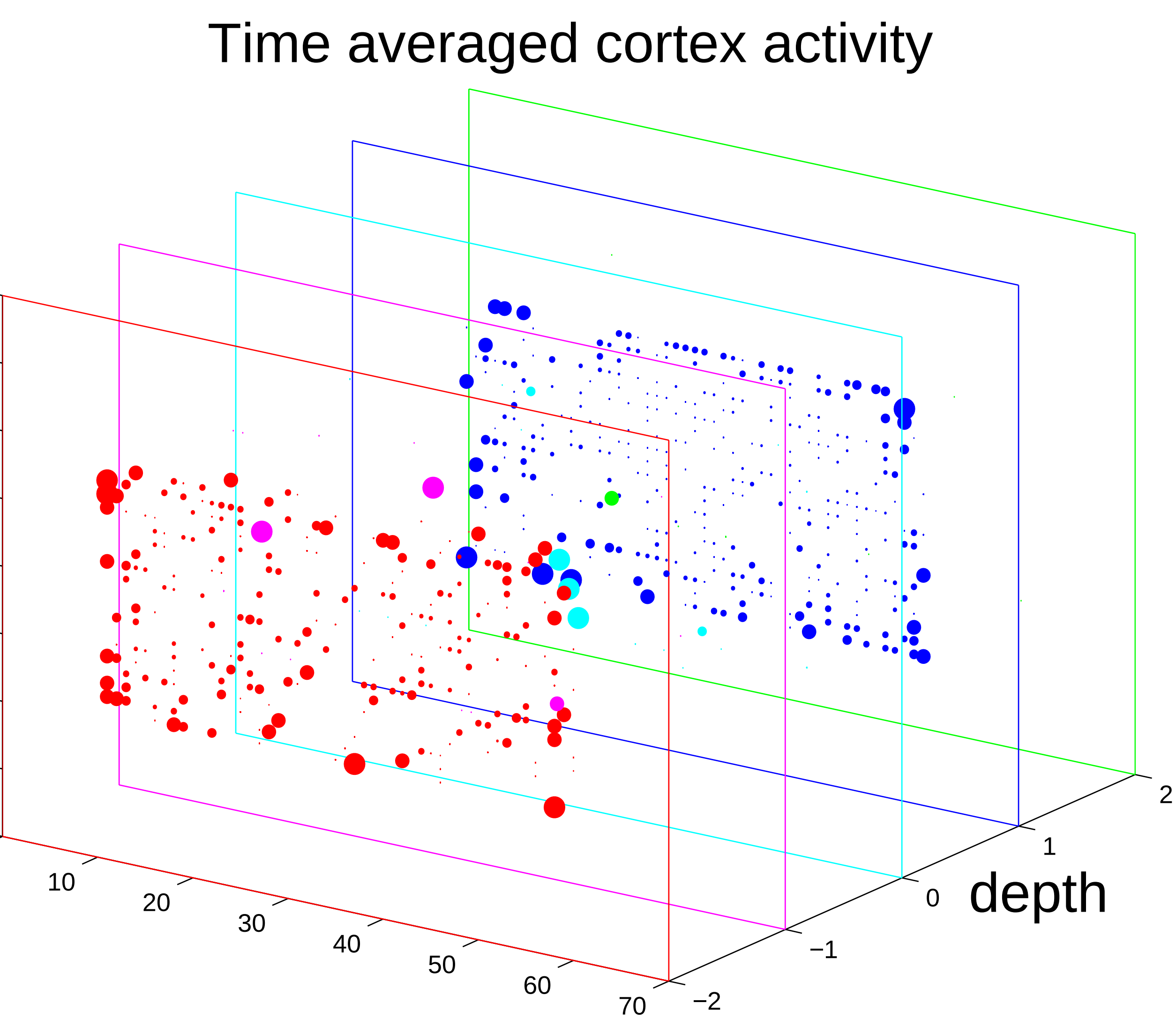
lodel computation on Transparency



nput to the model



fter initial transients,
me averaged model response



Depth segregation

Higher responses to the plane boundaries

plus ghost dots

ummary and Discussion

- Aim to capture both physiology and psychophysics of stereo grouping.

- Suggest contextual influences in early cortex play important roles.

- Relating to previous models: (1) Use cooperative algorithms like previous models (e.g., Marr and Poggio); (2) popout and depth edge highlights modelled for the first time; (3) more physiologically realistic mechanisms for transparency than previous models (e.g., Prazdny, 1985, Pollard et al 1985, Nishihara, 1987, Qian and Sejnowski, 1989, Marshall et al 1996).

hanks to Peter Dayan, Yury Petrov, and Ariella Popple for
scussions and comments, Gatsby Foundation for support.
omments and feedbacks welcome: z.li@ucl.ac.uk
ww.gatsby.ucl.ac.uk/~zhaoping

ue to unexpected difficulties to obtain a U.S. visa for travel,
e author is very sorry not to be able to attend this VSS
eeting. Many thanks to Ariella Popple for her help to present
is poster.