Report from 2015 OHBM Hackathon (HI)

Self-Organization and Brain Function

Project URL: http://brainhack.org/self-organization-and-brain-function

J. P. Pfannmoller[1*], R. Mesquita[2], L.C.T. Herrera[2] and Daniela Dentico[3]

1 Introduction

Self-organization is a fundamental property of complex systems, describing the order spontaneously arising by the local interactions of the system components not mediated by top-down inputs. Though, self-organizing systems typically possess a large number of components and exhibit complex dynamics, their evolution is deterministic and governed by a small number of order parameters. This property was used to model the self-organization of the ocular dominance columns of the striate cortex in patterns of neighboring stripes [1], which respond preferentially to inputs from the left or the right eye. In this model the self-organization across ocular dominance and orientation preference layers was coupled, were both layers were modeled with the Swift-Hohenberg equation [2]. We reduce the model complexity by including only the cortical dominance layer and investigate the parameter dependency of the self-organization with a Matlab implementation.

2 Approach

The Swift-Hohenberg equation [2] was used to model the self-organization of the ocular dominance columns. There are two order parameters in this equation, the first one determines the spatial wavelength (λ) of the stripes and the second one the branchiness (ϵ) of the pattern. Δ is the Laplace operator.

$$\partial_t \psi(x,y,t) = [\epsilon - (\Delta + \frac{4\pi^2}{\lambda^2})^2] \cdot \psi - \psi^3 \qquad (1)$$

The algorithm used to generate the results has been modified from an open source script. The Swift-Hohenberg equation was solved by applying periodic boundary conditions after a Fourier transform to k space, which simplifies the computation of the solution.

3 Results

Figures (a), (b) and (c) show the temporal evolution of the solution to the Swift-Hohenberg equation for random initial conditions (a), constant ϵ and time increasing from (a) to (c). In (c), (d) and (e) three solutions with different ϵ are shown. The branchiness increases with ϵ from (c) to (e). The wavelength (λ) was set to the same value in all figures and the pattern in (d) is similar to the ocular dominance layers found in the visual cortex.

4 Conclusions

A simple model suffices to study basic properties of ocular dominance self-organization. Possibly, a combination of models for self-organization in neighboring cortical layers would allow to investigate even higher organizational principles of the cortex [1], e.g.~the coordination between ocular dominance layers, orientation layers, and cytochrome oxidase.

[*]Correspondence: pfannmoelj@uni-greifswald.de
[1]Functional Imaging Unit, Center for Diagnostic Radiology, Unviersity Medicine Greifswald, Greifswald, University Strasse, 10001, Greifswald, Germany
Full list of author information is available at the end of the article

Availability of Supporting Data
More information about this project can be found at: http://brainhack.org/self-organization-and-brain-function. Further data and files supporting this project are hosted in the *GigaScience* repository doi:10.5524/100235.

Competing interests
None

Author's contributions
JPP, RCM, LCTH, and DD performed the project and wrote the report.

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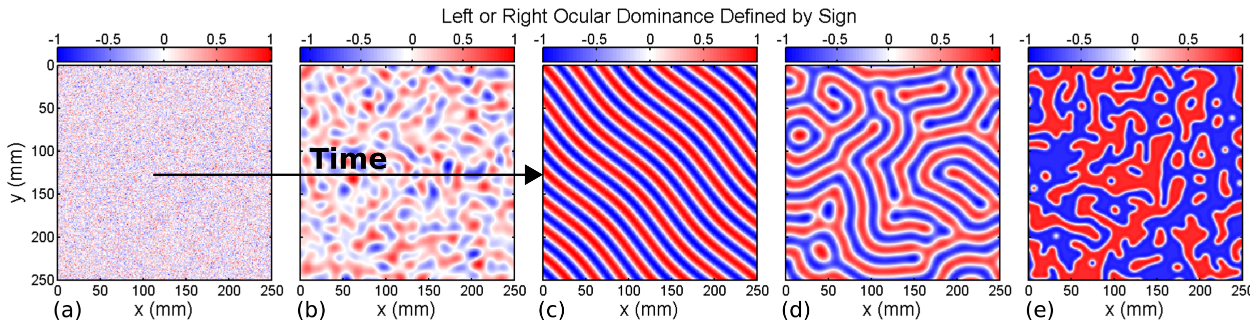

Figure 1 Examples for the temporal evolution of the solution to the Swift-Hohenberg equation for different branchiness parameter ϵ. (a) Random initial conditions for the solution of the equation. (b) Formation of the pattern. (c) Striped pattern for negligible branchiness ϵ. (d) Complex stripes for medium ϵ. (e) No pattern for large ϵ.

Author details

[1]Functional Imaging Unit, Center for Diagnostic Radiology, Unviersity Medicine Greifswald, Greifswald, University Strasse, 10001, Greeifswald, Germany. [2]Institute of Physics, University of Campinas, Campinas, St, 10001, Campinas, Brazil. [3]Waisman Center, University of Wisconsin, Madison, St, 10001, Wisconsin, USA.

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