Simulating Grid Cells using ROOT

Jochen Kerdels

University of Hagen - Chair of Human-Computer Interaction
Prof. Dr. Gabriele Peters

Jochen.Kerdels@FernUni-Hagen.de,
http://mci.fernuni-hagen.de
Universitätsstrasse 1, 58097 Hagen - Germany

ROOT Users' Workshop 2015

Outline

Introduction

A new GNG-based Model

Simulation and Analysis using ROOT

References

Introduction (1/2)

- Jochen Kerdels
  - Computer Scientist
  - Current position:

    Doctoral candidate of Prof. Gabriele Peters
    Chair of Human-Computer Interaction
    University of Hagen
- Research Interests
  - Current focus: modeling of grid cells
  - Machine Learning $\leftrightarrow$ Neuroscience
  - Robotics
  - Philosophy of Mind

Introduction (2/2)

Grid Cells

- Discovered by the Moser group in 2004/2005 [4, 5].
- Initially found in the rat MEC, and later in the pre- and parasubiculum [1].
- Stensola et al. showed that the population of grid cells in the EC has a modular structure along a dorsoventral gradient [11].
- Besides rats, grid cells were found in bats [12], mice [2, 10], primates [7], and humans [6].

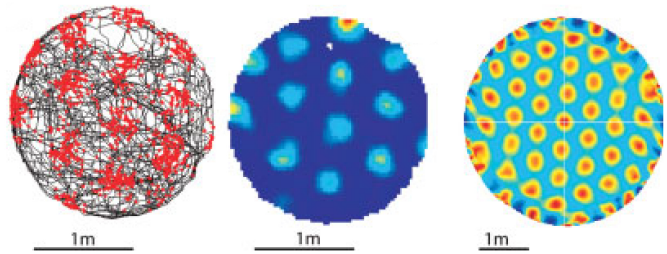


Figure from Moser et al. [8].

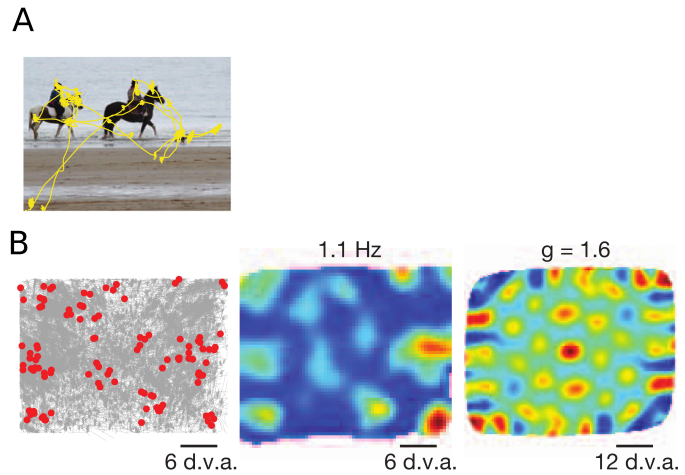


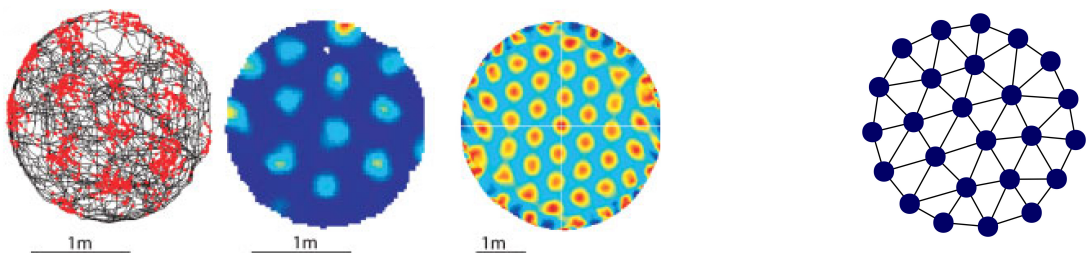
Figure from Killian et al. [7].

A new GNG-based Model

Grid cells may provide a rare view on the general principles by which neurons in the higher-order parts of the cortex process information [9].

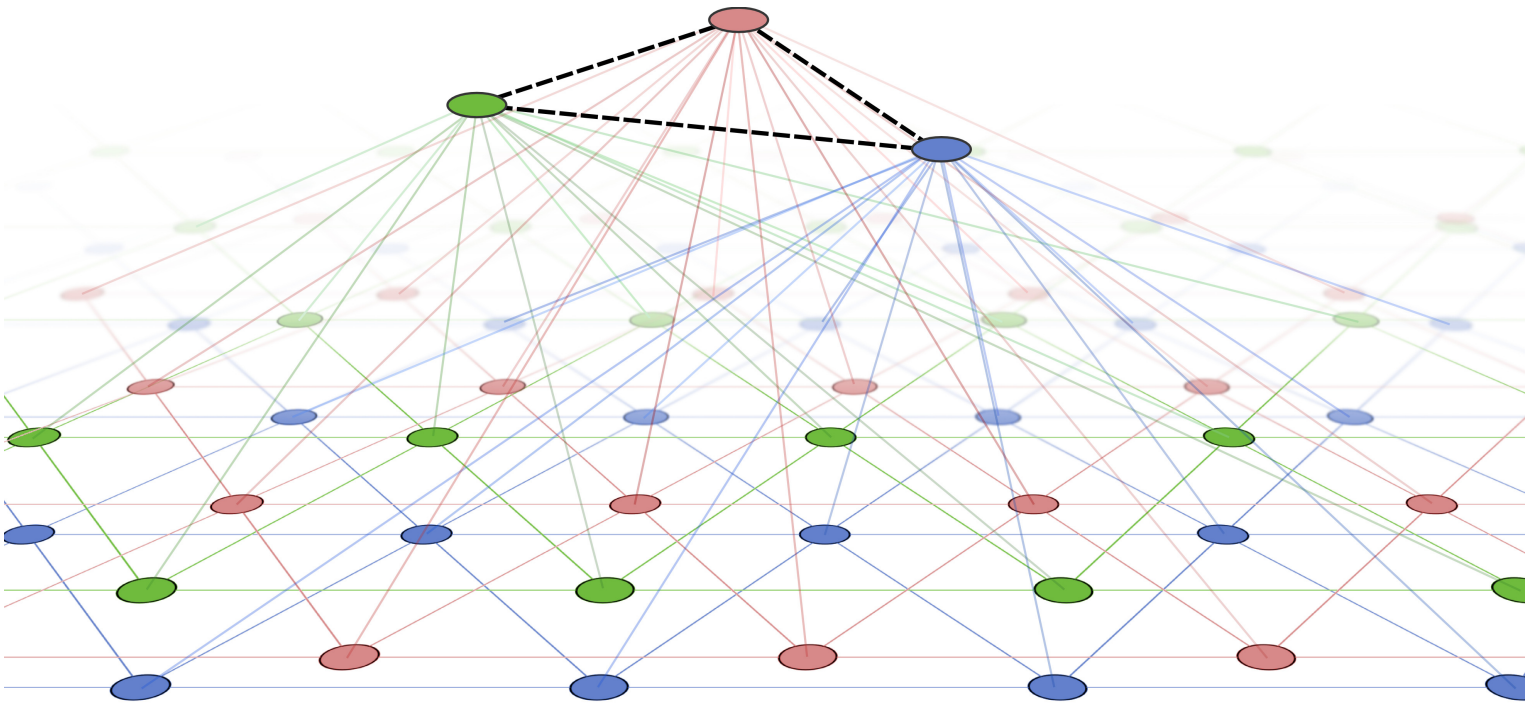
The triangular structure of the grid cell's firing fields resembles the outcome of processes that perform some form of error minimization.

One possible implementation: A two layer growing neural gas (GNG) [3], where the prototypes of the top layer are GNGs themselves.

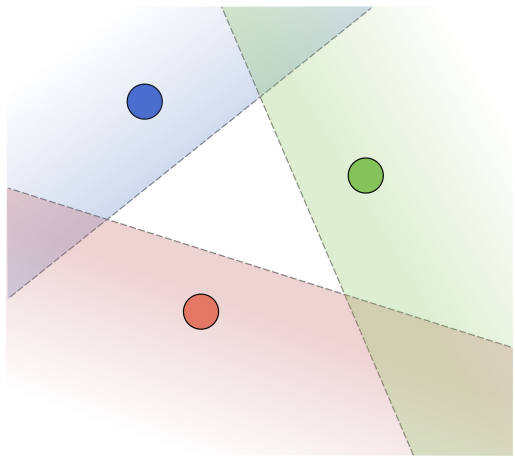


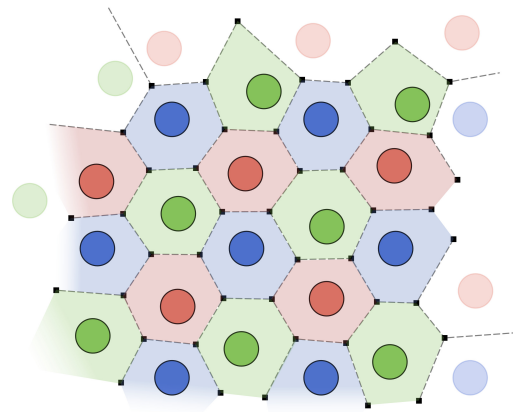
Left figure from Moser et al. [8].

Basic Structure

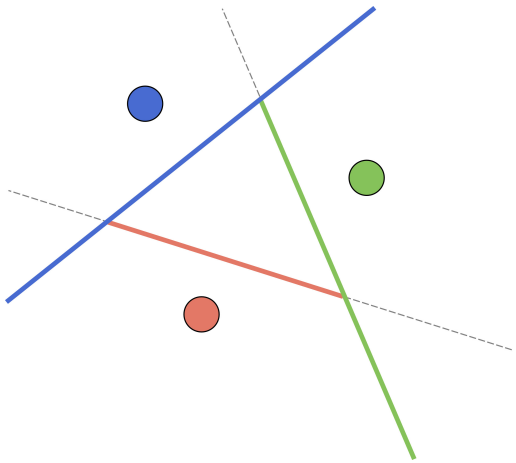


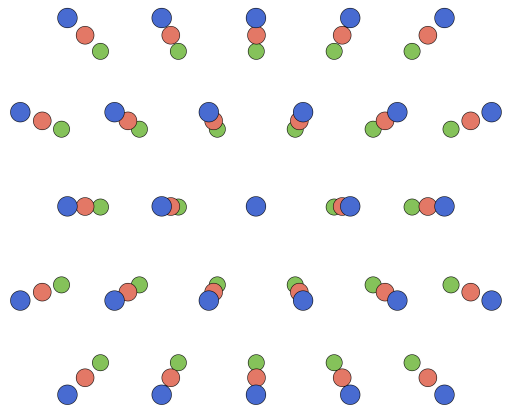
Comparison with Perceptrons (1/2)





Comparison with Perceptrons (2/2)





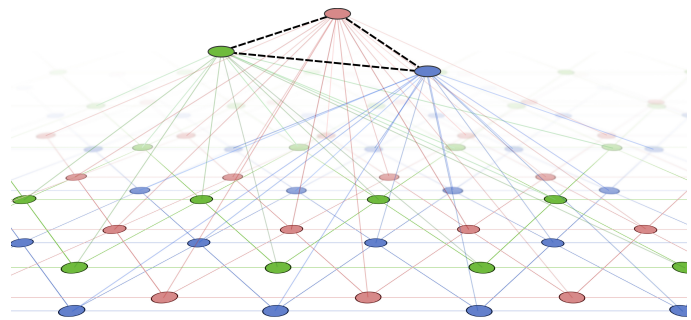
Simulation and Analysis using ROOT

ROOT is a vital part of our grid cell simulations:

- Implementation, setup, and execution of simulations.
- Continuous logging and storage of the simulation state.
- Analysis of logged data.
- Visualization of analysis results.

Implementation

OO-Design of the simulation components using C++ Classes derived from TObject.



The state of a simulation is represented by a dynamic set of objects that refer to each other.

Most important tradeoff: flexibility vs. performance

Most important aspects: introspection and reproducability

Download: http://www.fernuni-hagen.de/mci/resources/Software/tgng

Logging

Ideally, the simulation should be "recorded" by writing the whole simulation state at every time step, but serialization of such complex object structures is costly.

Currently:
Writing the most important data points at every time step into multiple trees. Storing the whole state every N time steps.

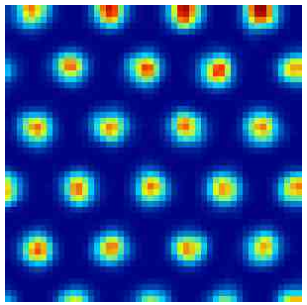
Challenges:

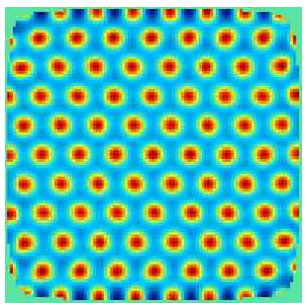
- In many cases the "entry" index of TTree cannot be directly used as "timestamp".
- The automagic splitting into multiple files triggered by TTree can cause problems.
- Multithreading capabilities are unclear.

Analysis

Standard grid measures from neurobiology based on "rate maps":

- gridness score
- grid orientation
- grid spacing
- grid phase

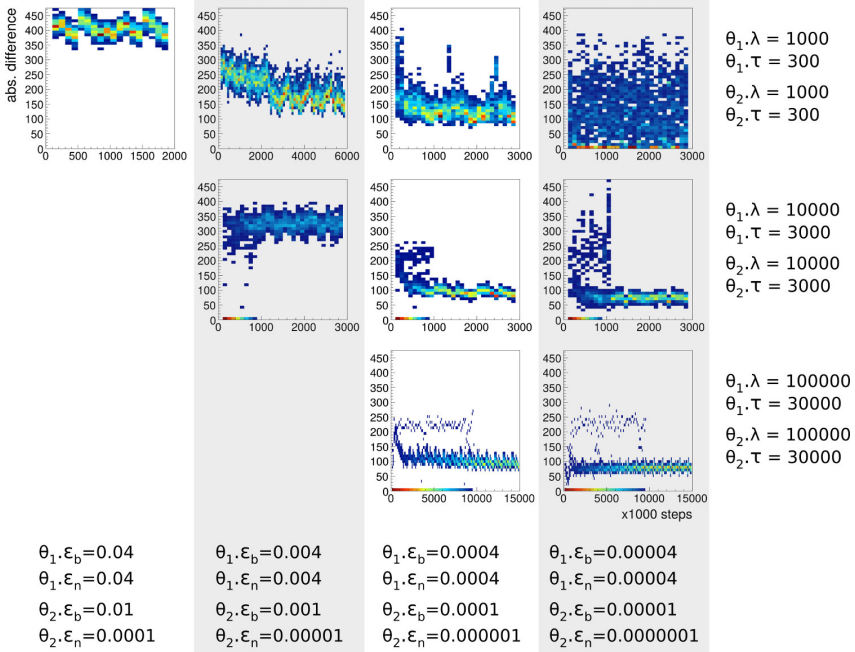


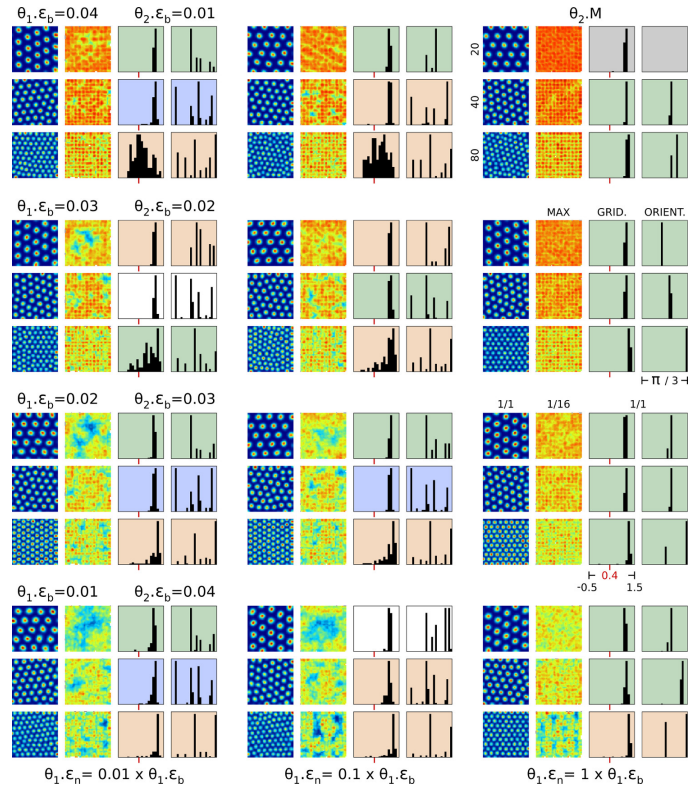


Rate maps are generated by integrating the simulated activity of cells over certain periods of time.

Current analysis uses "hand crafted" code that gathers the required information.

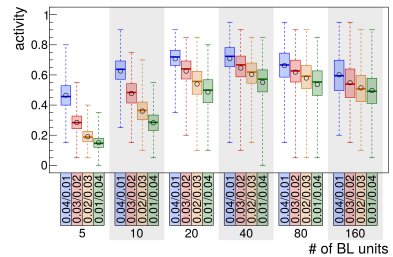
Visualization I



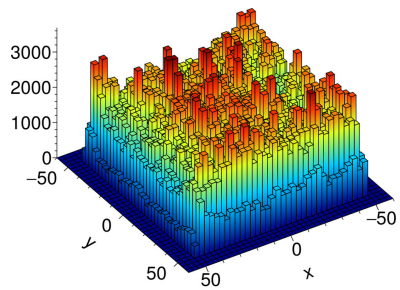


Visualization II

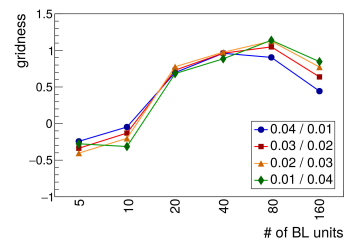
Typical approach: Writing a function for each type of diagram that collects the information from one or more .root-files and creates the drawing.



In some cases the resulting diagrams are finished in inkscape by, e.g., coloring, combining multiple diagrams, or adding additional text.



How can this be done in a more integrated fashion?



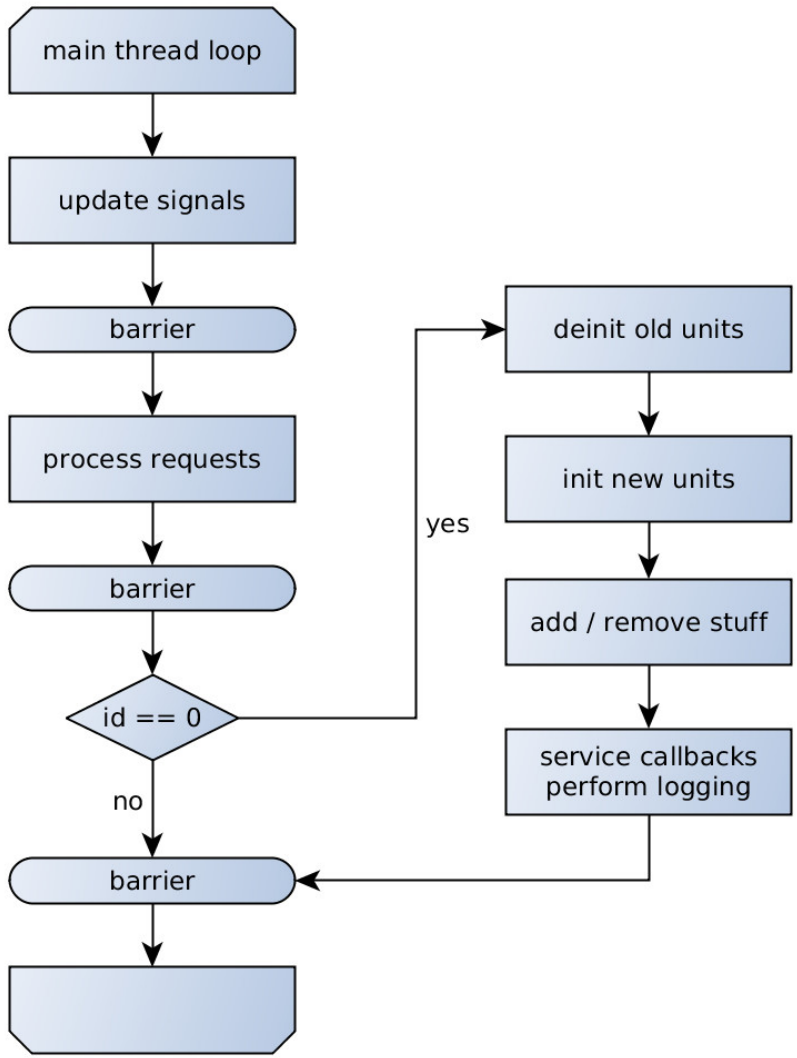
Outlook

Switching to a signal driven simulation model to be able to model more complex networks.

Multithreaded processing with minimal use of locking.

How to minimize single threaded logging of data?

Are there existing facilities in ROOT that perform this kind of processing?



Thank you for your attention.

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