



# RatSLAM: A Bio-inspired Approach to Robot Navigation

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**Technical Aspects of Multimodal Systems**

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# Outline

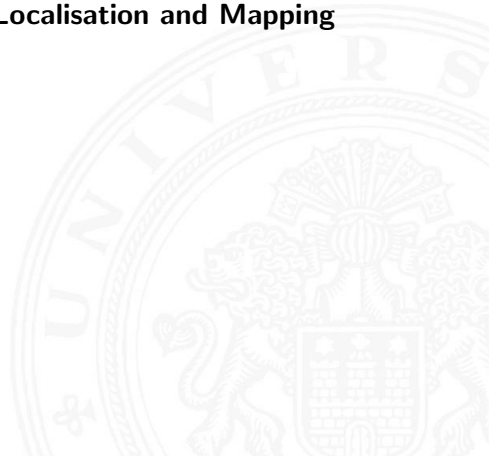
1. The SLAM Problem
2. SLAM in Biological Systems
3. RatSLAM
4. Results
5. Further Developments
6. Conclusion





# The SLAM Problem

**SLAM = Simultaneous Localisation and Mapping**





# The SLAM Problem

## SLAM = Simultaneous Localisation and Mapping

How can a mobile robot, dropped into a completely unknown environment:

- ▶ create an internal **map** of its environment...
- ▶ ...and identify its **location** within the map...
- ▶ ...**at the same time?**

Also known as the Kidnapped Robot Problem



# The SLAM Problem - Typical Approaches

OpenSLAM.org



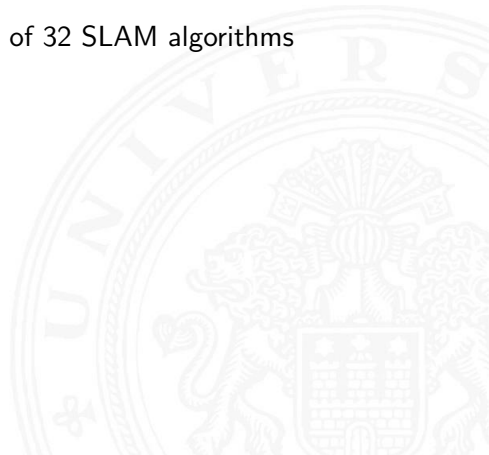


# The SLAM Problem - Typical Approaches

OpenSLAM.org

- ▶ Open source implementations of 32 SLAM algorithms

Main categories:





# The SLAM Problem - Typical Approaches

OpenSLAM.org

- ▶ Open source implementations of 32 SLAM algorithms

Main categories:

- ▶ (Extended) Kalman filter
- ▶ Particle filter
- ▶ Graph-based

Some good solutions in there... but none are perfect



# SLAM in Biological Systems

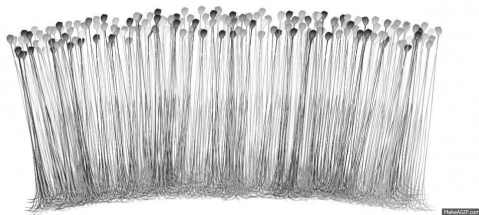
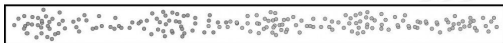






## SLAM in Biological Systems - Place Cells

- ▶ Located in the hippocampus
- ▶ Activate when the rat is at a specific location (“place field”)

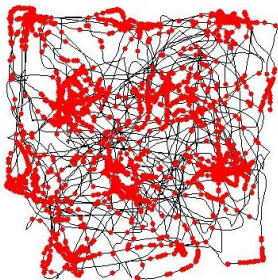


*Place cells in the hippocampus [1]*

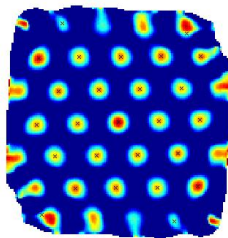


## SLAM in Biological Systems - Grid Cells

- ▶ Located in the endorhinal cortex
- ▶ Activate in a grid-like pattern



(a) Trajectory of a rat through a square environment [5]

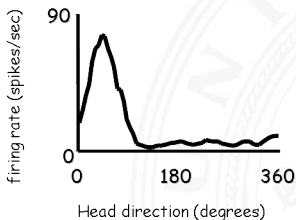
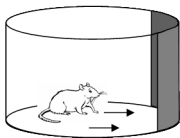


(b) Spatial autocorrelogram of the neuronal activity of the grid cell [4]

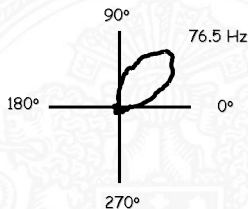


## SLAM in Biological Systems - Head Direction Cells

- ▶ Located in various brain areas, including the thalamus
- ▶ Fire based on the direction the rat is facing
- ▶ Direction is absolute, not relative to the rat's body

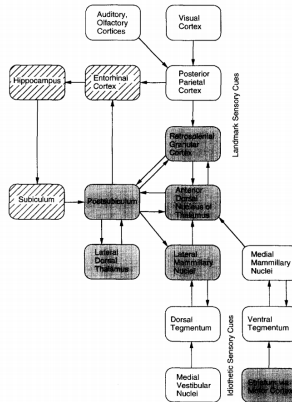


*Head Direction Cells [2]*





# SLAM in Biological Systems -



*Some of the brain areas (probably) involved in navigation [10]*



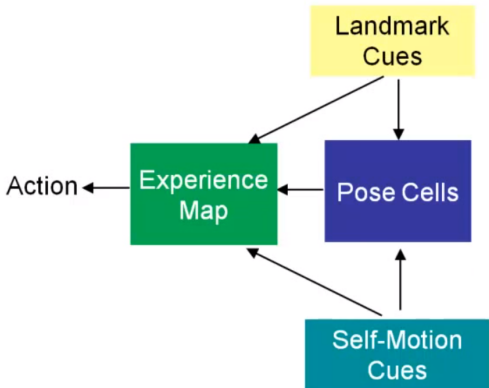
# RatSLAM

Developed at Queensland University of Technology, Australia

- ▶ 2004: Original implementation
- ▶ 2013: OpenRatSLAM
  - ▶ Two versions:
    - ▶ Standalone C++ version
    - ▶ ROS-integrated version
  - ▶ <https://openslam.org/openratslam.html>
  - ▶ <https://github.com/davidmball/ratslam>

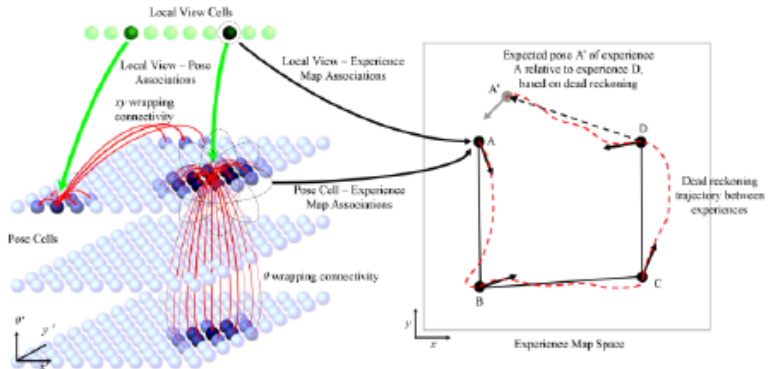


# RatSLAM - Architecture



*High-level architecture of the RatSLAM system [6]*

# RatSLAM - Architecture



*RatSLAM Architecture [3]*



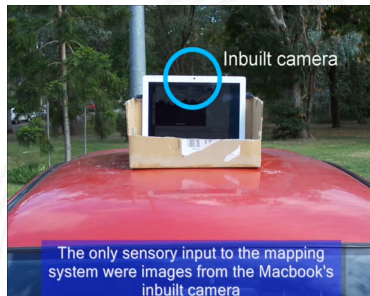
# RatSLAM - Architecture

- ▶ Local view cells
  - ▶ Array of rate-coded cells representing visual scenes
  - ▶ Array varies in size based on the number of landmarks
- ▶ Pose cell network
  - ▶ Pose cells - combination of grid cells and head direction cells
  - ▶ 3D continuous attractor network
  - ▶ Excitatory connections to local neighbourhood
  - ▶ Inhibitory connections to every other cell
- ▶ Experience map
  - ▶ Graphical map of the environment
  - ▶ Combines information from the other two modules



## Results - Suburb Mapping

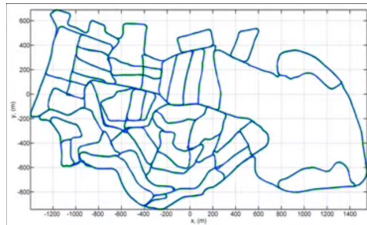
Created map of 66km of roads from a single webcam feed



[7]



# Results - Suburb Mapping



[7]



## Results - Delivery Experiment

- ▶ Camera + odometry (+ IR sensors for collision avoidance)
- ▶ 1,143 “delivery tasks”
- ▶ 11 different locations
- ▶ 2 different buildings
- ▶ 37 hours of active operation
- ▶ 23 autonomous recharges
  
- ▶ Only 1 failed delivery



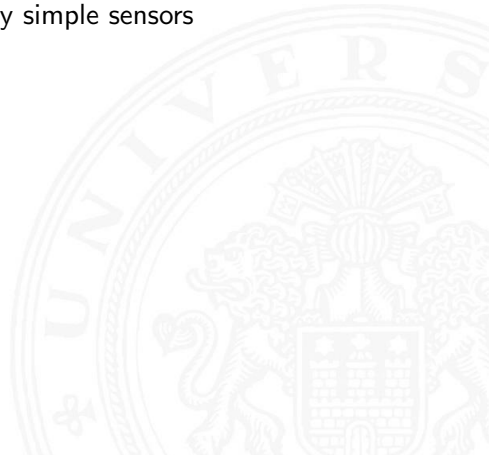
## Further Developments

- ▶ Sünderhauf and Protzel (2010) [9]
  - ▶ Analysed RatSLAM in comparison to Bayesian methods
  - ▶ Developed a novel Bayesian filter based on the analysis
- ▶ Müller, Weber and Wermter (2014) [8]
  - ▶ Adapted RatSLAM to a humanoid robot



## Conclusion - Strengths

- ▶ Reliable results using only very simple sensors
- ▶ Scalable to large spaces
- ▶ Stable over long time periods
- ▶ Neuroscience marches on...





## Conclusion - Weaknesses

- ▶ Large open spaces can be a problem
- ▶ Very simplistic visual odometry
- ▶ Limited by pose cell network architecture
- ▶ Neuroscience marches on...





# Thank you!

## Questions?





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