Working title: Rats and their maps

Brief background

The ability to navigate is critical to animals. Mammals like rats, bats and humans possess brain cells which seem to encode locations with high accuracy, and in a world-based reference frame. Such an 'allocentric representation' of space has been likened to a map, and recent modelling shows that having a map is absolutely essential to: a) determine one's location, and b) account for the in vivo activity of rat hippocampal place cells in darkness [1].

However, the neural computational processes used to build a map are largely unknown. Furthermore, it is unknown even in principle what combinations of sensory cues and arena designs allow the formation of useful maps in the presence of biologically realistic noise. This project seeks to address the problem by developing a computational tool which can build maps using a near-optimal fusion of available sensory information, and using biologically realistic levels of noise.

Proposed modelling and analysis

Inputs

1) Biologically realistic sensory inputs and noise, based on published rodent data

2) User-configurable arena designs and trajectory algorithms

Map building

MATLAB implementation of FastSLAM 2.0 – a type of Rao-Blackwellized recursive Bayesian filter designed for Simultaneous Localization and Mapping (SLAM) [2]. The use of a particle filter reduces the need to make simplifications about the pose uncertainty which is analytically intractable. The use of occupancy grid maps will enable SLAM without the need to explicitly identify corresponding features in the environment or 'closing the loop'. The latter may not be available in rat experimental arenas with rotational symmetry or in circumstances with reduced sensory information (e.g., total darkness).

Outputs

1) Arena map and current pose (position and orientation) estimate.

2) Performance measures of FastSLAM 2.0, including similarity of estimated map to true map, and error of estimated pose from true pose.

3) Model place and grid cell activity using the map and pose estimates of FastSLAM 2.0, and analysed using time-averaged metrics (e.g., spatial and directional information content, spatial coherence).

1) A user-friendly tool which can be used by both experimentalists and theoreticians to test hypotheses and make predictions about spatial navigation performance which can be achieved given a set of input assumptions.

2) Gain an in-depth understanding of FastSLAM 2.0, which will inform future investigations into the possibility of approximating the particle filter by a neural network model.

References

1. Cheung A, Ball D, Milford M, Wyeth G, Wiles J (2012) Maintaining a cognitive map in darkness: the need to fuse boundary knowledge with path integration. PLoS Comput Biol 8: e1002651.
2. Montemerlo M, Thrun S (2007) FastSLAM: A Scalable Method for the Simultaneous Localization and mapping Problem in Robotics. Berlin: Springer.

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