Grid cell realignment based on idiothetic head direction cues

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Autonomous mobile robots need to incorporate a significant number of sensors to reliably plan and securely follow trajectories in partially unknown or dynamically changing environments. Rodents, in contrast, navigate remarkably well with a limited number of sensors, outperforming state-of-the-art engineered systems in terms of adaptability and employed computing resources. Consequently, the recent discovery of grid cells in the Entorhinal Cortex, assumed to perform path integration (Hafting et al. 2005), and of the pre-play of future Place Cells (Pfeiffer 2013) raise the question if understanding these mechanisms helps to improve navigation for autonomous robots.

A basic mechanism that is still not properly understood is grid realignment. The periodic spatial response of grid cells changes when place cells undergo remapping, which itself indicates a significant change in the animal’s environment. As the grid cells are one synapse upstream, they are assumed to be one source of inputs to place cells, and thus the cause for such remapping (Monaco 2011).

On the one hand, we assume that imposing a grid orientation based on visual cues is a key source of realignment. On the other hand, we assume that realignment itself is crucial to translate idiothetic motion information into a reliable allothetic path. In this work we demonstrate a model which is able to compensate for different idiothetic head direction estimates and compute an allothetic path integral. We adapted a recently published model (Couey et al. 2013) to incorporate various such idiothetic signals and validated the performance using simulations of virtual rats, closely resembling the movement statistics of real rodents.

The required connectivity from head direction cells to grid cells can be acquired using Hebbian Learning. The integration of different velocity inputs in the grid cell network may help to understand the parallel conduction of sensory integration and alignment for robotic real-world systems.

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References