Path Planning Using Spike Propagation
Shashikant Koul and Timothy K Horiuchi

INTRODUCTION
The development of mixed-mode VLSI circuits to mimic the computational behavior of neural circuits ("neuromorphic VLSI") has a long history within ISR. Originally, the focus was purely on the brainstem sensory circuits of echolocating bats, but has since expanded to focus on questions of neural representations of space and memory-assisted decision making. Long-time collaborators include P. S. Krishnaprasad, Cynthia Moss, Shihab Shamma, and Pamela Abshire.

The hippocampus is a mammalian brain area associated with the storage and retrieval of declarative memory (rodents, humans). Studied extensively in rats on spatial navigation tasks, hippocampal "place" cells activate at specific locations in a given environment, providing a glimpse into how mammals represent space in world-centered (allocentric) coordinates. In this work, we explore how place cells could be linked to form a map and how this "active" map could be used for path planning.

BACKGROUND
As depicted in the figure above (left) from O'Keefe and Nadel (1978), the recorded neuron fires spikes when the rat is in a particular region on the far end of the arena, independent of the orientation of the animal. These regions of activity vary from neuron to neuron in both size and shape.

Whenever the rat's motion is interrupted by pauses (or during slow-wave sleep), an intermittent bursting activity is observed, which is characterized by high frequency oscillations in the local field potential (100-150Hz) called "sharp waves". Sharp wave events correspond to place cell activation sequences, that sometimes represent paths just taken in forward or reverse order. A recent study by Pfeiffer and Foster (2013) above right), reported goal-directed planning activity in the hippocampus of an rodent in the future.

We use a spiking neural network to implement this graph, if we simulate a node (i.e., cell) in the graph that represents a desired destination, bidirectional synaptic links spread the activity in all directions on the graph eventually arriving at the cell representing the animal's current location. By monitoring the direction (at the current location's place cell) of the first arriving spike using a temporal winner-take-all network, the next place field on the "shortest" path (i.e., the next waypoint) is revealed.

Similar models such as the one proposed by Filip Ponulak (2013) after the synaptic weights of the network during the planning process to store the desired path. Although desirable for many reasons, storing and accessing the full plan is not necessary to execute the path. In our simulations, the planning process is repeated after each waypoint is reached to provide instructions for the next action until the goal is reached. This architecture can choose the shortest path even with multiple choices of destinations. Current information about the environment (e.g., knowing the location of a hazard or blockage) can be injected into the path planning process by changing the propagation speed of spikes (through synaptic or neuronal modulation).

The hippocampus is also implicated in episodic memory and humans, a form of high-level memory that links many different contextual and sensory inputs. A mechanism that can explore these memories may provide a substrate for problem-solving through the recall of similar situations.

REFERENCES

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