Bio-inspired SLAM

Exploring the Tolman-Eichenbaum Machine for Modeling Spatial Understanding in Robots

Abstract

Spatial understanding is a crucial cognitive component in all agents acting in 3D physical space, including people and robots. We investigate the Tolman-Eichenbaum Machine for use in biologically inspired Simultaneous Localization and Mapping (SLAM) in robots.

SLAM as a problem

SLAM or Simultaneous Localization and Mapping is a more than 2 decade old problem in mobile robotics. The core of the issue lies in determining the location of the robot in an unknown environment.[1]

The robot generally uses its sensors to construct a representation of its environment called a map, while at the same time, trying to determine its location in this constructed map.

Motivation

Traditional SLAM solutions consist of two parts, mainly localization and mapping, which can be separate, deeply interconnected or run in parallel. Various modelling techniques have been used in traditional SLAM solutions to improve stability of the algorithms, but some aspects of the problem remain challenging. [1]

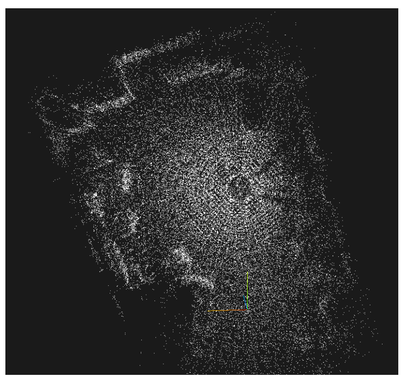


Figure 1. A 3-D map generated by a traditional SLAM method.

Ability of humans and animals to map and navigate physical and abstract spaces depends largely on the hippocampus, which has been well studied. [2] Therefore, we aim to take inspiration from it and build our SLAM solution from an already established working system.

Previous Bio-inspired methods

Of course, we are not the first to take inspiration from biological systems.

- Milford and Wyeth (2004) have developed RatSLAM, a SLAM system using competitive attractor networks which has successfully navigated office but lacks variety in its celluar representations which do not transfer across environments. [3]
- Tang and Michmizos' (2018) Gridbot is based on Spiking Neural Network (SNN) architectures. In particular, Gridbot is hard-wired similarly to the hippocampus, but has not been extensively tested on SLAM tasks. [4]

The Tolman-Eichenbaum machine

The Tolman-Eichenbaum Machine (TEM) is a relational memory system adopting which can generalize structural knowledge not only in spatial tasks, but also non-spatial tasks. [5]

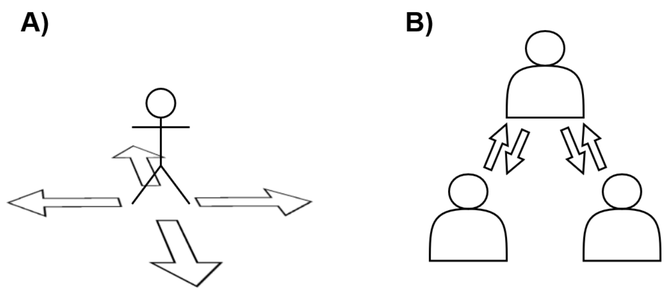


Figure 2. Example of relations **A)** spatial: {*Forward*, *Backward*, *Left*, *Right*} **B)** non-spatial: {*Parent*, *Child*}

When trained on a sequence of sensory observations, TEM is able to learn the structural regularities of the underlying graph. This graph is given by the task it is trained on, where nodes are random data and edges are as described in Fig 2.

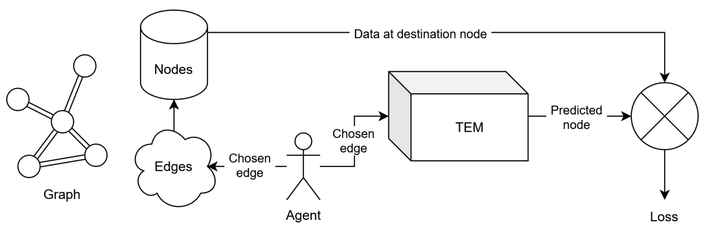


Figure 3. TEM training architecture

Grid cells and place cells

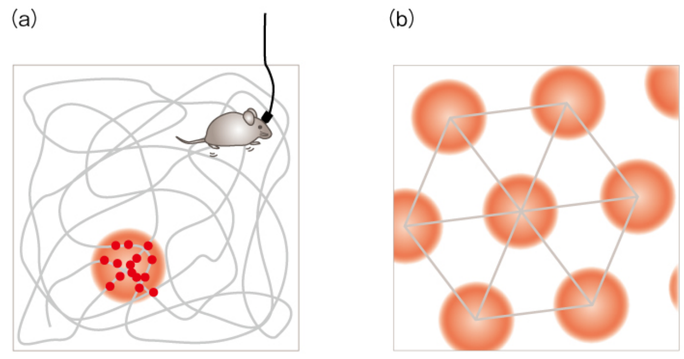


Figure 4. (a) Place cell. (b) Grid cell. [6]

Other types of cells

While grid cells and place cells were naturally found within TEM's hippocampal cells, other types of cells such as border cells, object vector cells and landmark cells, all of which have been observed in rodent hippocampus.

Future work

Now that we've established TEM as a candidate model for SLAM and understood it's working principles, our future work will be focused on adapting the TEM architecture from its original task space defined by graphs into the sensorimotor space of robotics. Given TEM's general sensory and action encodings, we will look into possible encoder architectures to link TEM with robotic sensors and perhaps do it in real time.

References

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