Hippocampal Spatial Mapping As Fast Graph Learning

Paper available on Arxiv: https://arxiv.org/abs/2107.00567

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Summary

Question

Is spatial mapping a fundamental algorithm of the hippocampal formation? Or is spatial mapping just one application of a more general fundamental algorithm?

This model's answer

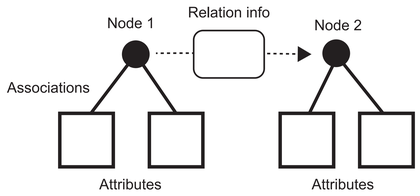
- The hippocampal formation quickly learns graphs, associating information with nodes and relation information with edges.
- Such a model could learn environments as arrangements of parts.

Implications

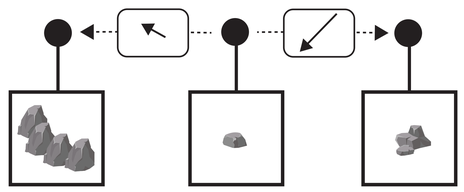
- Unique grid cell location codes are not needed.
- Learned maps consist of external parts and their relations. They don't consist of learning what is sensed at every self-location.
- Fast Graph Learning may be a useful abstraction for artificial neural networks / AI.

Fast-learned graphs as a general data structure

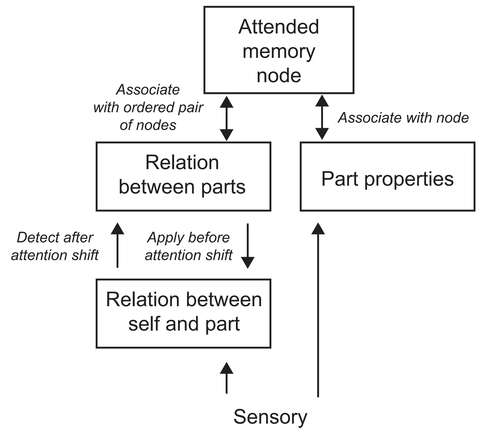
Fast-learned graphs: The core pieces



Example fast-learned graph: A spatial map



Spatial mapping: High-level mechanism

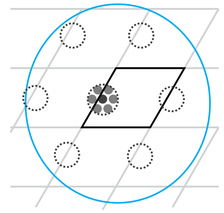


Grid cells' ambiguity complements the ambiguity of relations

Complementary location types

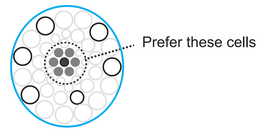
	"Vector" cells: Flexible, long range Coarse	Grids: Fixed resolution Ambiguous over long ranges
Relation between self and other (transient)	Spatial relation between parts	Location of part on grid
Relation between other and other (good to store in memory)	Object-vector cells	Grid cells

Object-vector cells cannot be uniquely inferred from the two grid cell populations

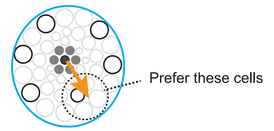


Combining spatial relation information with the current active cells solves this ambiguity

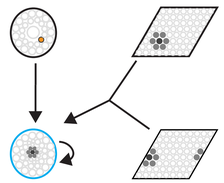
Path integration: No sudden displacement



Switching between nodes: Use learned relation to disambiguate.



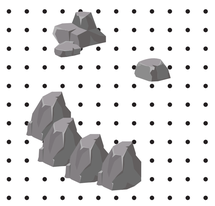
The connections involved



Efficient mapping

Agent in environment

Inefficient mapping, Cartesian

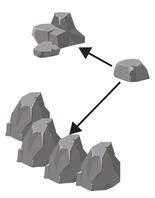


Store sensory information at many points

Efficient mapping, Cartesian

Store the parts and their locations

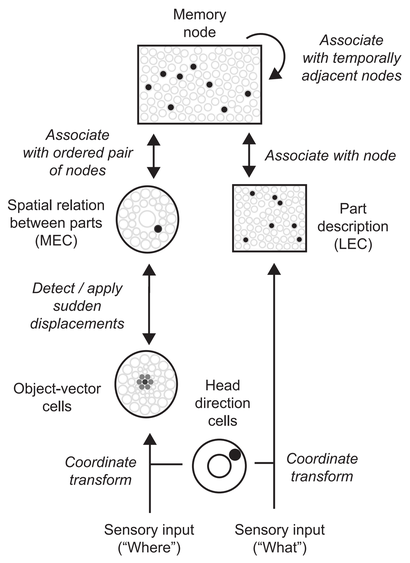
Efficient mapping, Relation-based



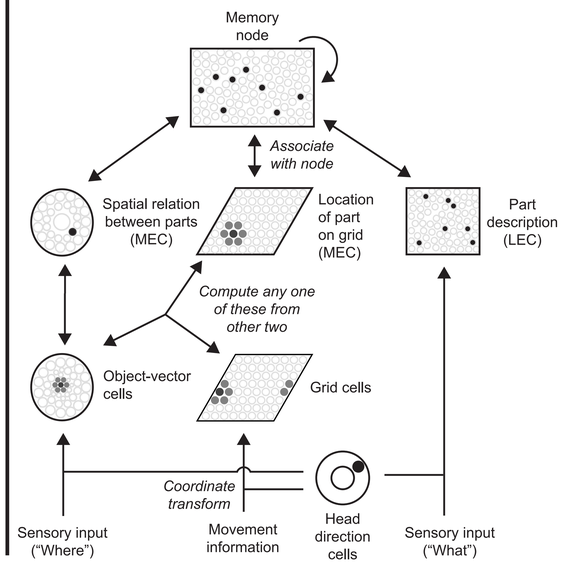
Store the parts and a set of relations

Neural mechanism for quickly building memory graphs

Coarse spatial mapping

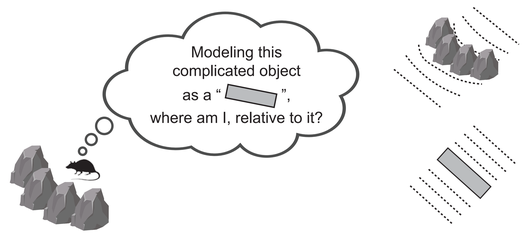


Adding grid cells provides path integration and precise spatial mapping

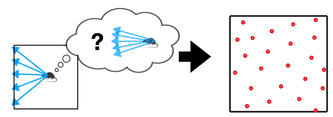


Decoding arrangements-of-parts from grid distortions

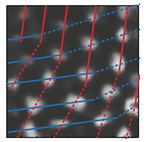
Describing environments using idealized parts can lead to distortions



Can we infer idealized maps from distorted grids?

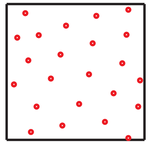


Empirical

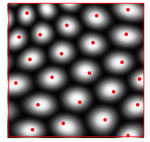


Stensola, T., Stensola, H., Moser, M.B., and Moser, E. I. (2015)

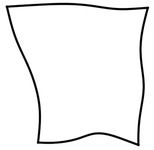
Empirical (simplified)

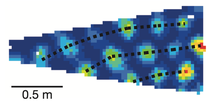


Simulated grid

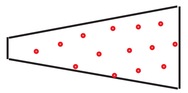


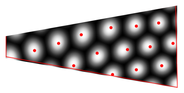
Decoded map

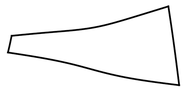




Krupic, J., Bauza, M., Burton, S., Barry, C., and O'Keefe, J. (2015)







Paper / references: https://arxiv.org/abs/2107.00567