MODULAR NETWORKS WITH RANDOM PROJECTIONS FOR HIGH-CAPACITY ASSOCIATIVE PATTERN AND SEQUENCE MEMORY

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ABSTRACT

How does the hippocampus, vastly outnumbered by the number of potential patterns in cortical neurons, store memories of experiences encoded by cortex? It is assumed to act as an associative memory, but classical models such as the Hopfield network store and robustly recall only up to N arbitrary patterns in a network of size N. Recently proposed associative memory architectures enable robust reconstruction of an exponential number of patterns (Hillar & Tran, 2018; Chaudhuri & Fiete, 2019; Krotov & Hopfield, 2016); however, these networks involve biologically implausible assumptions about synapses (Krotov & Hopfield, 2016) or the amount of information recalled per pattern is small because they are highly structured (Hillar & Tran, 2018; Chaudhuri & Fiete, 2019).

We construct an entorhinal-hippocampal (EC-HC) attractor network (Figure 1a) using the theme of modular input structures with random feedforward EC-HC projections and associatively learned return weights that exhibits exponentially many robust (large-basin) fixed points (Figure 1b). Training the HC to EC weights over only a small subset of contiguous grid cell states results in the formation of a large number of additional HC fixed points with large basins that can be reconstructed robustly from unseen grid cell states. In other words, these untrained hippocampal patterns can be robustly reconstructed in the presence of large amounts of noise from grid inputs. Further, the addition of hetero-associative recurrent synapses within HC leads to learning of the grid state transition matrix and the potential for high-capacity sequence memory.

Because place cells construct conjunctions between sensory experience and abstract spatial coordinates (Manns & Eichenbaum, 2006), we add a sensory input stream to HC. The combination of structured and unstructured inputs enables storage and robust recollection of a large number of arbitrary sensory patterns from partial cues. Thus, randomly mixed modular networks may support high-capacity associative memory, essential for interference-free episodic memory and spatial learning across time.

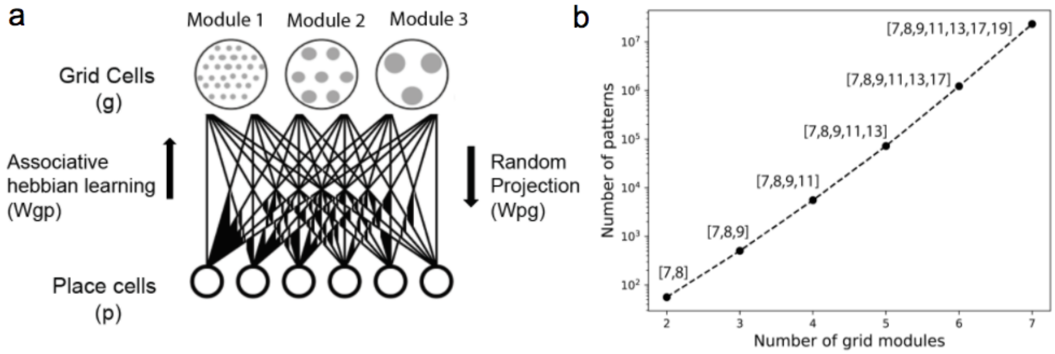

Figure 1: (a) Network architecture. (b) Plot showing that capacity is exponential in the number of grid cell modules. Labels beside data points show corresponding module periods. Y-axis: log scale.

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