Is addressable memory required for spatial cognition?

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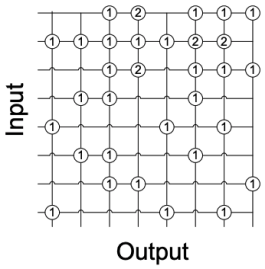
Food caching and retrieval in scrub jays

Animals are able to employ complex behaviours to retrieve food efficiently: this implies conserving energy by searching in the right place. Western scrub jays (*Aphelocoma coerulescens*) hide and retrieve thousands of caches in the wild.

When allowed to make caches in distinctive trays in the lab, jays are able to consider several trays and selectively dig up the right ones. They are also able to avoid food which, after caching it, they learnt was perishable - showing their ability to take new information into account.

A Western scrub jay retrieving a food cache



A correlation matrix memory (CMM) (Kohonen 1972)

Gallistel and King's Memory and the Computational Brain (MCB)

The central claim of Memory and the Computational Brain (2011) is that human and animal cognition is supported by a read-write memory which is **addressable** and symbolic. It is read-write in that storage is decoupled from processing and stored information is read back unaltered. It is addressable in that information is stored in an isolated manner under an address; such a system is not content-addressable.

We argue that, while these are the characteristics of a computer memory using the von Neumann architecture, there is little evidence that natural cognitive systems use a read-write addressable symbolic memory.

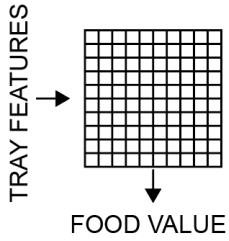
Gallistel and King further argue that connectionist systems are not flexible enough to implement such a memory, claiming that reverberative loops are limited to short lifetimes. We argue that this view underestimates the demonstrated capabilities of connectionist systems [5].

Connectionist networks can do similar tasks

Q-learning is a reinforcement learning algorithm which improves a policy (a mapping from percepts to best actions). Although modern implementations of Q-learning use experience replay, traditional Q-learning does not, and is able to find effective behaviours using a connectionist network without episodic memory.

The correlation matrix memory (CMM) is an associative memory which links input and output patterns, both binary. The memory is **trained** by placing an input and output on the edges of the network, then incrementing any cell which has a 1 to the left and a 1 below. The memory is **queried** by placing a pattern on the input, adding up the activation on the output, and using an adaptive threshold to generate a bit pattern. The CMM stores and retrieves orthogonal patterns perfectly, but non-orthogonal patterns blend into each other, which is useful for pattern-matching. The CMM is thus content-addressable and has a natural application for search and recall, especially on fuzzy imprecise data.

We modelled the birds' cache retrieval behaviour using a CMM to store, in a distributed manner, a mapping between tray features and food value. The model is able to make appropriate cache selections using a purely connectionist approach.



We are currently extending this model to simulate the more complex case in which jays update their beliefs after cache burial.

Embodiment is central to understanding abstracted computation

Embodied cognition tells us that the organism is a part of its environment; embodied computation tells us that the computation is part of the substrate. We argue that the memory can form a part of the computation (and thus the substrate) rather than a separate component.

Memory does useful computations

We know that memories are malleable: priming and misremembering have evolutionary value. We argue that an addressable read-write memory, which must keep its symbols separate without priming or blending, is neither energy-efficient nor useful. Memories which are associative rather than addressable (such as the CMM) allow useful and efficient fuzzy pattern-matching.

We agree with Gallistel and King that useful information has to be "carried forward into the future"; however, we argue that this can be done by a dynamical, fuzzy system rather than necessarily by an addressable, symbolic memory.

References

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