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A discrete operator model of episodic memory

Artificial recurrent neural networks (ANN) are treated as functional operators which map points in their n -dim. discrete and finite state spaces (n being the number of constituent neurons). An orbital graph, attached to such an operator, is studied and its properties used to model biological neuronal networks (BNN). Cortical sub-networks, able to contain episodic memory, represent an interesting object for such a model, since within such a concept nodes of orbital graphs represent network states, graph branches represent operator actions, while linear sub-graphs of orbital graphs correspond to episodic memory contents. Namely, as orbital graphs of constant operators consist of one or more connected components, each of them further consisting of a circular attractor or a fixed point (obligatory) and non-cyclic sub-graphs (tree-like structures, optional), we propose that an episode may be stored in the «tree trunk», while the corresponding association states form a «tree crown».

Storing and recalling information (learning and remembering). While holding (or recalling) the stored information, BNNs are close to constant operators. When receiving new information, however, they must be modeled as changing, variable operators: $O_2 = S * O_1$, where O_1 stands for the BNN operator before, O_2 after the storing process, while S marks the «storing operator». Without any analytical apparatus introduced, only operator composition and its effects on graph properties could be studied. The operator power operation, as a special case of composition, and its impact on orbital graph structure is described. Idempotents, as operators of particular interest, are introduced and their graph properties described. First order idempotents are pointed as elementary inducers of operator modifications. A «local singularity transfer» (LST) rule is described, imposing mathematical limitations on O_1 in case that operator modification by composition (OMC) is the storing model. If BNNs actually do store information by OMC, (it is interesting to explore whether hippocampo-cortical interaction could be modeled by operator composition), the hypothesis that the storing network increases its «degree of singularity», as the learning process advances, is introduced. «General operator modifications» (GOM) are also discussed. They impose no limitations on O_1 , but lack an analytical tool (such as composition). In case of OMC, the storing operator, S , could be modeled as being composed of a number of first-order idempotents. An example of storing a simple 3-state episode by OMC is presented and the corresponding S operator calculated.

Losing or modifying the stored information (forgetting). The process of losing (or modifying) the stored information (of potential interest for clinical practice) is described as a set of random modifications of an existing constant BNN operator graph by elementary GOMs. An interesting problem is to explore how many different topological (structural) graph modifications exist. The seven different modifications, found so far, are presented and illustrated with appropriate graphs. In actual BNNs, the real forgetting process may be a combination of some of these seven different types.

Bibliography

Kalauzi A., Spasić S. (2000). Neural networks as functional operators (in Serbian). XLIV ETRAN Conference, Proceedings, Book I, 151-154.