PhD Thesis

Creating Multi-associative Memory in Cell Assemblies

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Abstract

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Introduction

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Chapter 2

Background

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2.1 Cell Assemblies

(Hebb, 1949) hypothesised that the CA is the neural basis of concepts, and the CA is central to most neural models of memory. The theory proposes that objects, ideas, stimuli and even abstract concepts are represented in the brain by simultaneous activation of large groups of neurons with high mutual synaptic strengths (Wennekers and Palm, 2000). If an external stimulus excites a sufficient number of neurons of an existing CA, it can result in the spreading of activation within the CA, in turn igniting it due to recurrent activity and high mutual synaptic strength. The CA can remain active even after the stimulus is removed. This reverberating behaviour accounts for short term memory.

CAs are learned using the Hebbian learning rule, whereby modifications in the synaptic transmission efficacy are driven by the correlations in the firing activity of pre-synaptic and post-synaptic neurons (Gerstner and Kistler, 2002). When external stimuli are presented to a network, synaptic strength between neurons are adjusted so as to gain more strength if they undergo repeated and persistent activation or firing, gradually assembling them into a group, a CA. This formation of CAs accounts for long term memory. Thus, the CA hypothesis provides a structural and functional account for such cortical processes. A significant amount of evidence exists supporting the fact that CAs are the neural basis of concepts (Huyck and Nadh, 2009).

2.2 Associative memory

Even though CAs account for memory formation, their precise neural dynamics are far from perfectly understood. As explained in the Section **??**, neurons in a network may belong to different CAs, and if they are repeatedly co-activated by different versions of the same stimulus, they tend to become associated Hebb (1949). This is based on the notion that events that occur together repeatedly should somehow belong together. (Wennekers and Palm, 2000) explained that every time these events occur in conjunction, they drive certain subgroups of neurons, their correlated firing should be learned, and, by that, respective groups should become associatively connected.

Repeated co-activation of neurons can lead to the formation of CAs. Similarly, repeated co-activation of multiple CAs result in the formation of multiple and sequential associations, and sometimes new CAs. When an external stimulus activates a CA, it might lead to the activation of neurons that ignites a different CA that is not directly stimulated. This forms the rudimentary, neural level explanation of associative memory. Humans constantly retrieve and form associations with whatever sensory input they receive for the purpose of perception, understanding and reasoning.

2.3 Multi-associative memory

Auto-associative memory is not typically what is meant by associative memory. Instead, associative memory is generally a shortened form (usually implicitly) of multi-associative memory; this has also been called hetero-associative memory. Psychologically, memories are not stored as individual concepts, but large collections of associated concepts that have many to many connections Anderson and Bower (1980). Each memory (CA) is associated with many other memories (CAs) (Huyck and Nadh, 2009).

2.4 CAs and auto-associative memory

The CA is a form of auto-associative memory. In auto-associative memories, an initial state is allowed to settle into a stored memory, allowing subsequent noisy input to retrieve a stored pattern. The Hopfield Model illustrates this property (Hopfield, 1984). A network of units that are well connected with bidirectional weighted connections is used to store a set of binary patterns (typically using a Hebbian calculation). When an initial set of neurons is switched on, in the discrete version of the system, activation spreads through the system based on the weighted connections. In most cases the system will settle into a stable state with no neurons switching between on and off. If the input pattern is close to a stored pattern, it will settle into that pattern's state, thus functioning as a content-addressable memory. Neurons may also belong to multiple CAs. Hopfield patterns that share on-bits are models of CAs that share neurons.

While CAs are critical for the model of multi-associative memory described in this paper, they are not the solution. The question is how different CAs are associated with each other.

2.5 Related work

2.5.1 Nullam facilisis

2.5.2 In consequat

Models are described in detail in Chapter 3

Chapter 3

Work so far

3.0.3 Section 1

3.0.4 Section 2

Chapter 4

Conclusion

4.1 Future work

4.2 Timeline

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