PIB Ch. 18
Sequence Memory for Prediction, Inference, and Behavior

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Quiz

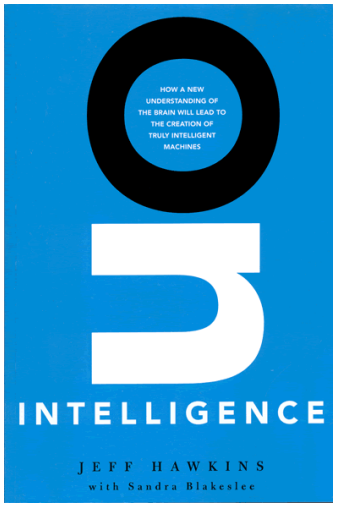
- Briefly describe the neural activities of minicolumn in the neocortex and why this is useful for sequence memory.

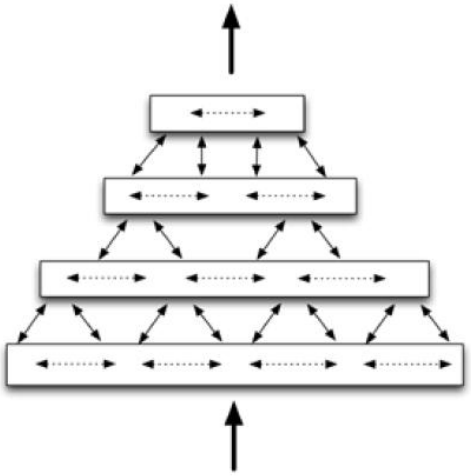
Prediction and Sequence Memory

- Prediction is ubiquitous
- Prediction makes our brain easy to handle complex spatiotemporal data

Hierarchical Temporal Memory

- HTM was suggested mainly by Jeff Hawkins
- Its philosophy was presented in his well known book *On Intelligence*





HTM in comparison with other algorithms

- Hierarchical models like HMAX or Convolutional Neural Network are suitable for recognizing spatial pattern but not for temporal pattern.
- HHMM (Hierarchical HMM) is strictly temporal and not suitable for spatial patterns
- HTM combines best of above two. It can handle both spatial and temporal patterns.

How HTM learns?

- Basic idea is Hebbian rule: patterns that frequently occur together in time share a common cause and can be grouped together
- Because of the hierarchical structure, fast changing sensory inputs result in slower changing patterns as you ascend the hierarchy

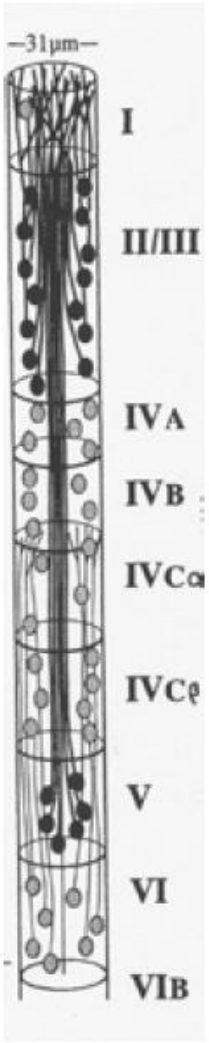
Constraints on Sequence Memory

- Probabilistic Prediction
  - Data is noisy so it uses probability distribution to predict rather than deterministic
- Simultaneous Learning and Recall
  - There's no distinct border between them
  - It learns by recalling (predicting) and comparing
- Auto-Associative Recall
  - Must be able to recognize sequences even if it is partially given

Constraints on Sequence Memory

- Variable-Order Memory
  - If there are patterns 'ABCDE' and 'YBCDZ', then it should be able to predict the 5th character from the sequence already observed.
  - Variable-order memory can deal with this problem (not distinguishable if it only considers order of 3)
- Biological Constraints
  - The structure should be shared by all the regions in the neocortex

What is going on in Minicolumn?



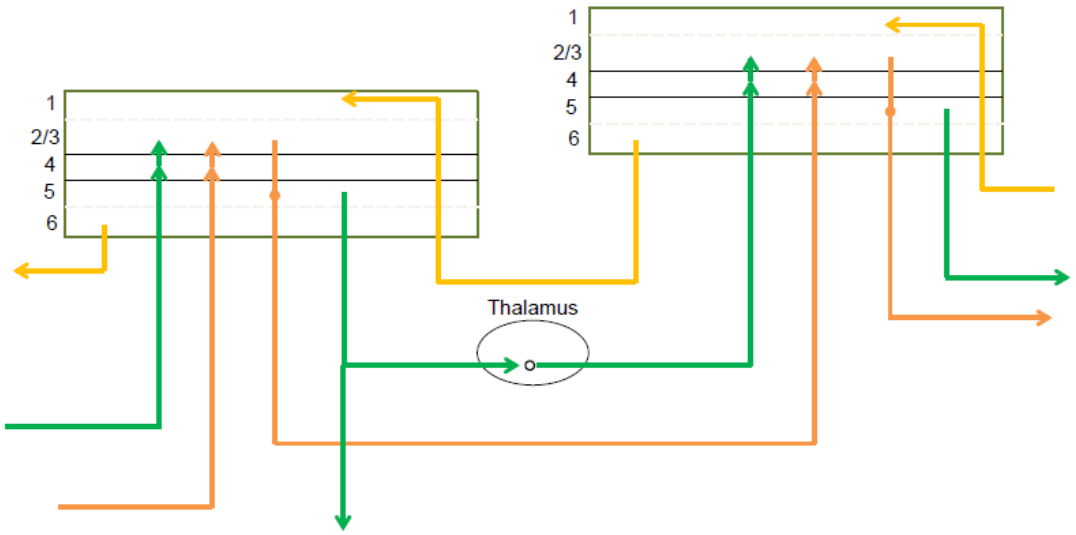
- Minicolumn passes through the 6 layers of neocortex in vertical direction
- Cells in minicolumn exhibit identical response to feedforward input (when there is no context)
- Cells in minicolumn inhibit each other, which leads to the phenomenon that the most active cell rules out all the responses of other cells (winner takes all)
- From this structure, each neuron in minicolumn represents the same pattern but different context

Biological Implications of Sequence Memory Model

- Sparsification of Response
  - Experiments showed that the response from natural images
- Inhibitory Requirements
  - Inhibition in between neurons in minicolumn
- Distributed Representations
  - One pattern should not be represented by a single neuron
- Efficient Computation
  - There are too many states and computationally expensive to calculate the probability distribution of each state. Use Dynamic Programming

Biological Implications of Sequence Memory Model

- Cortical Layers

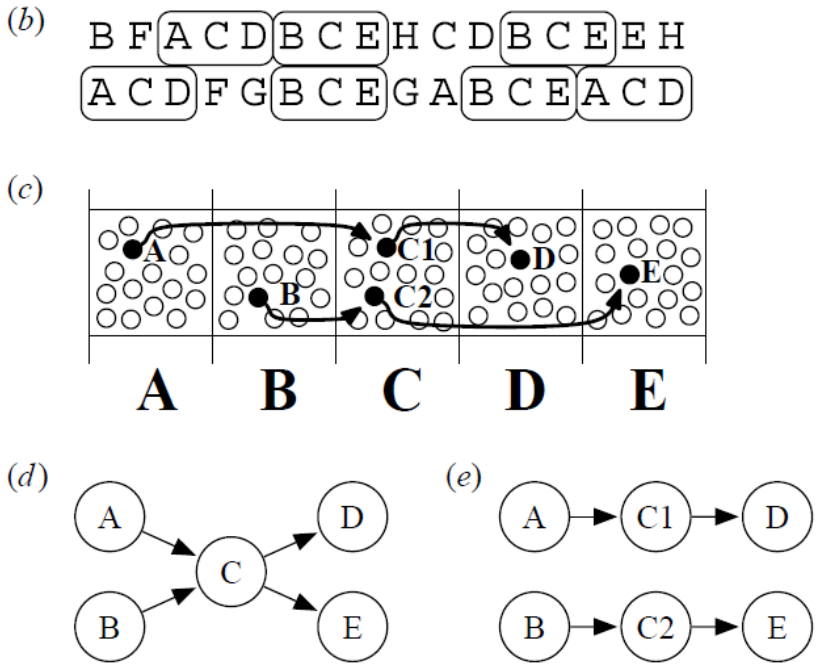


Biological Implications of Sequence Memory Model

- Sequence Timing
  - Human can store the exact duration in sequential pattern even if the recalling rate is different
  - There exists upper limit of duration that the human can remember
- Memory Capacity
  - There is certain capacity limit in memory when the structure (# of columns, # of neurons) is given
  - However this can be resolved by the hierarchical structure in that the same learned sequence can be used again in different combinations of higher layer values

State-Splitting Algorithm

- The only model that the authors found that works same as minicolumn and meets all constraints
- (d)→(e) is state-splitting



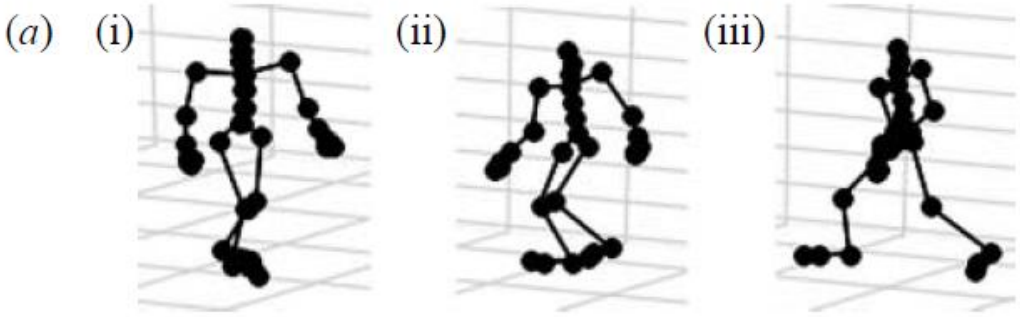
State-Splitting Algorithm

- Unlike minicolumn, state-splitting starts with a single state and then split the state as it learn sequences

- Split occurs when the state is considered to be participating in two or more sequential patterns

Experimental Results

- Data: Motion capture data (from CMU)
- Task: Classify the motion
- Method: The structure is Markov Chain (not HTM) with state-splitting



Experimental Results

- y-axis: ground truth and response of group
- x-axis: distinct groups