Memory in DFT

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What is memory?

- The influence of past experience on present perception, action, or thought
Time scale and types of memory

- working memory
- short term memory
- long term memory
- semantic memory/skill learning
Working memory

- perceptual, mental, or motor states that are immediately available to ongoing neural processes…

- arise on the time scale of perceiving, thinking, and acting…

- have strong capacity limits… 4 to 7 “items”

- are part of processing
Working memory

standard neural interpretation: activation induced by stimulation (a detection decision) is sustained once that input is removed
Sustained activation

- monkey in a delayed response task
- neural recording from pre-frontal cortex

[Fuster 1971]
Working memory

- a huge behavioral and neural literature
- with ongoing debates: resource allocation, re-activation of working memory etc
DFT: Working memory emerges from the memory instability

- **Self-excited peak**
  - Input: $h$
  - Dimension: $0$
  - Sub-threshold attractor: $h$

- **Self-sustained peak**
  - Input: $h$
  - Dimension: $0$
  - Self-sustained peak: $h$
Time scale and types of memory

- working memory
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STM/LTM

- defined by the need/capacity to “recall” the memory...
  - cued recall
  - free recall
- its neural foundation is still actively researched
  - Hippocampus plays a role
postulate that peaks of activation lay down a memory trace

that conversely pre-activates the field
Mathematics of the memory trace

\[ \tau \dot{u}(x, t) = -u(x, t) + h + S(x, t) + u_{\text{mem}}(x, t) \]

\[ + \int dx' \ w(x - x') \sigma(u(x')) \]

\[ \tau_{\text{mem}} \dot{u}_{\text{mem}}(x, t) = -u_{\text{mem}}(x, t) \]

\[ + \int dx' \ w_{\text{mem}}(x - x') \sigma(u(x', t)) \]

- memory trace only evolves while activation is excited
- potentially different growth and decay rates
The memory trace reflects the history of decisions.
The memory trace suffers from interference.
Cued recall: boost + localized input

Re-creates a peak at the location at which the memory trace pre-activates = preshapes the field.
Stable memory in DFT: Hebbian learning

- Hebbian learning of projections
  - among fields
  - forward from sensory input to fields
- interaction leads to localized rather than distributed representations (SOM)

\[ \tau \dot{W}(x, y, t) = \epsilon(t) \left( -W(x, y, t) + f(u_1(x, t)) \times f(u_2(y, t)) \right) \]

[Sandamirskaya, Frontiers Neurosci 2014]
Hebbian learning

- Learning reciprocal connections between zero-dimensional nodes and fields
- => Grounded concepts
- Analogous to the output layer of DNN
- => Ensembles of such nodes coupled inhibitorily form the basis for conceptual thinking…
Cued recall

- with ridge/slice input in joint representations of different feature dimensions

=> module on higher-dimensional fields and binding
Memory trace ~ first-order Hebbian learning

- Increases local resting level at activated locations
- ~ the bias input in NN
- Boost-driven detection instability amplifies small bias => important role in DFT