Mona: Hierarchical Context-learning in a Goal-seeking Artificial Neural Network

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Approach

- A functional model of animal behavior:
  - Goal-seeking for survival in an environment.
  - Environment modeled by hierarchies of context.
- Biology inspires, but the “clay” to make machines is different from that of living systems.
- Convergence of artificial and biological neural networks to discover essential mechanisms.

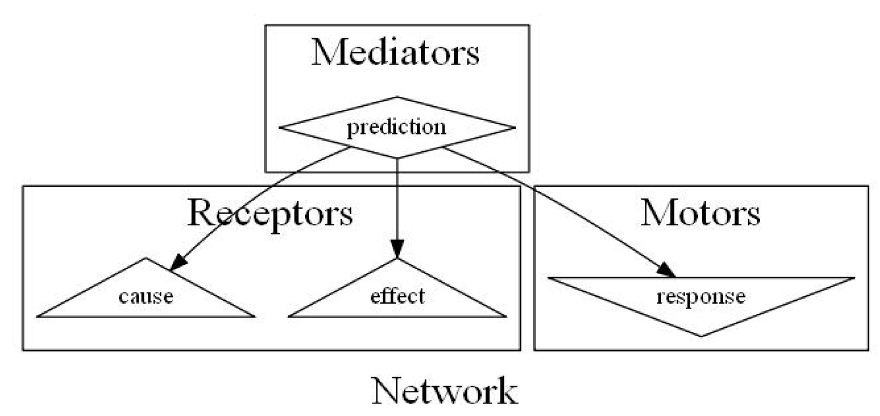
Overview

- Learn hierarchies of cause and effect environmental contexts to predict and manipulate future events.
- Long-term memory models the structure of the environment; working memory models the state of the environment.
- Goal-seeking uses contexts to produce responses to navigate the environment toward stimuli that satisfy needs.

Biological functionality

- Problems that ANNs tend to struggle with, yet biological neural networks have solved to a large extent:
  - Stability: how well is previous learning retained while new learning occurs?
  - Plasticity: how quickly can new learning be done, especially in the presence of previous learning?
  - Modularity: can independently learned things naturally integrate?

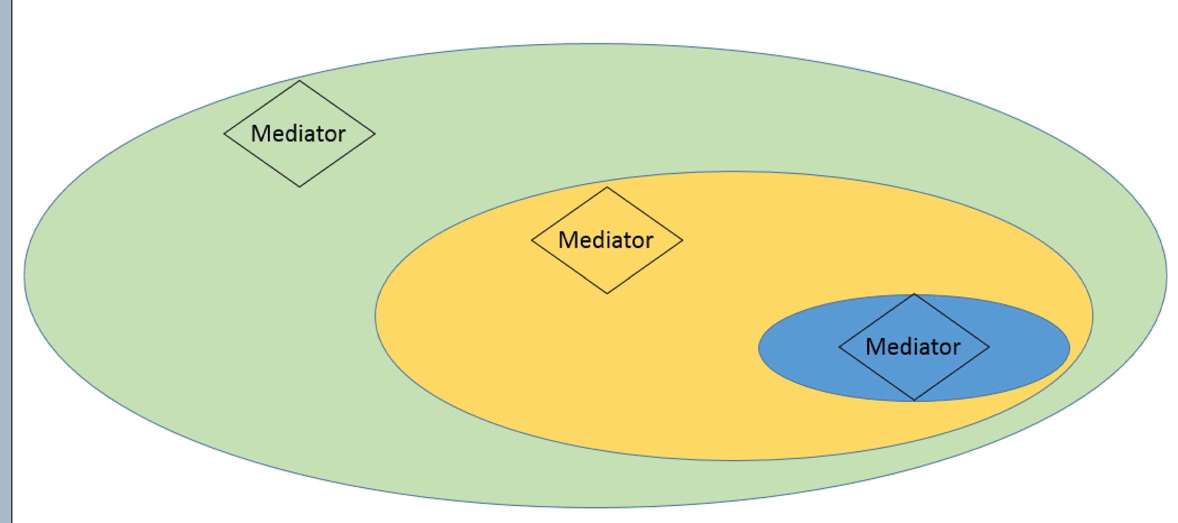
A simple Mona network



Network components

- Three types of neurons: receptors, motors, and mediators:
- Receptor neurons are associated with input sensors.
  - Sensors can also be grouped into modalities, e.g. vision, hearing.
- Motor neurons are associated with output responses.
- Mediator neurons capture the long-term memory notion of a causal relationship between environmental events signified by neuron firings:
  - The enablement of a mediator represents the cause and effect reliability of the mediator.
  - Working memory is implemented by the enabling state of a mediator.
- Higher level over-arching mediators represent hierarchical enabling contexts.

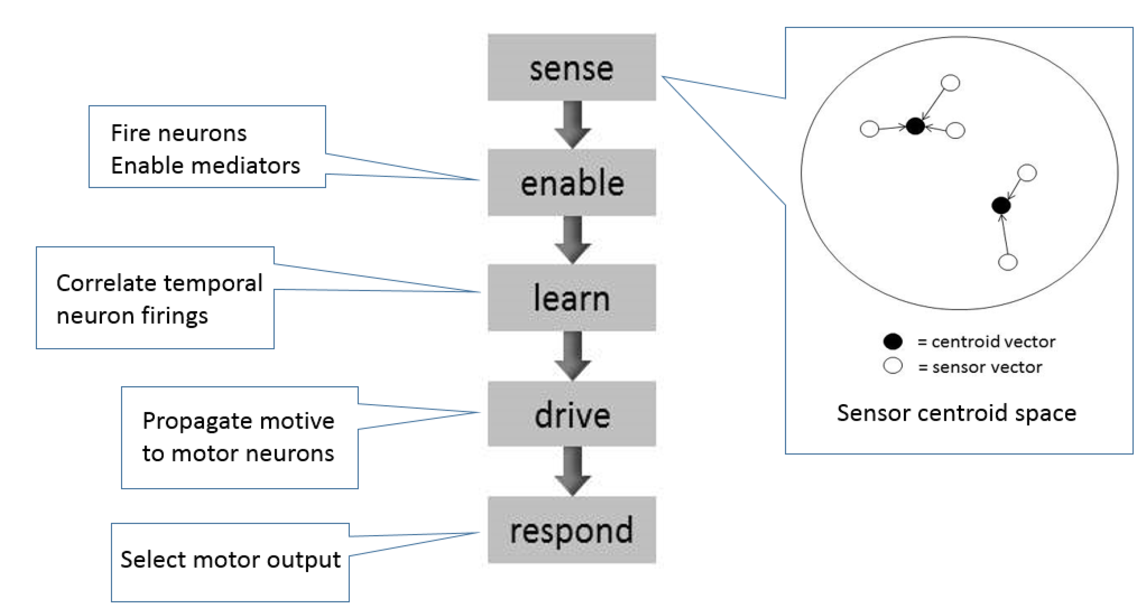
Mediator context hierarchy



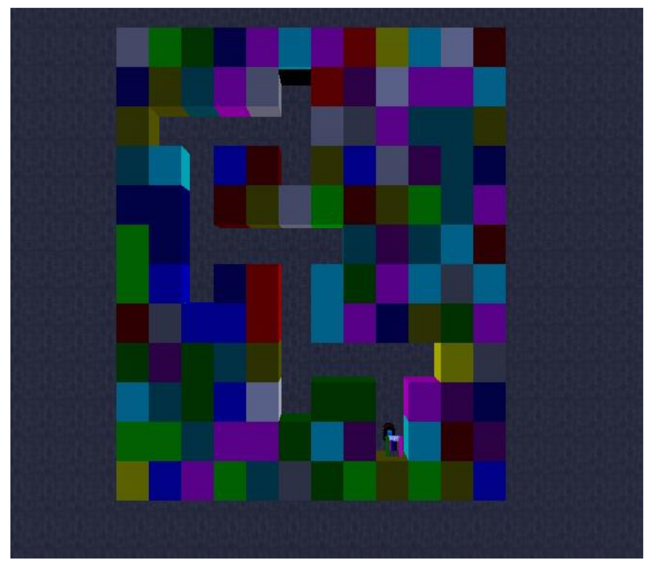
Needs, goals, and motive

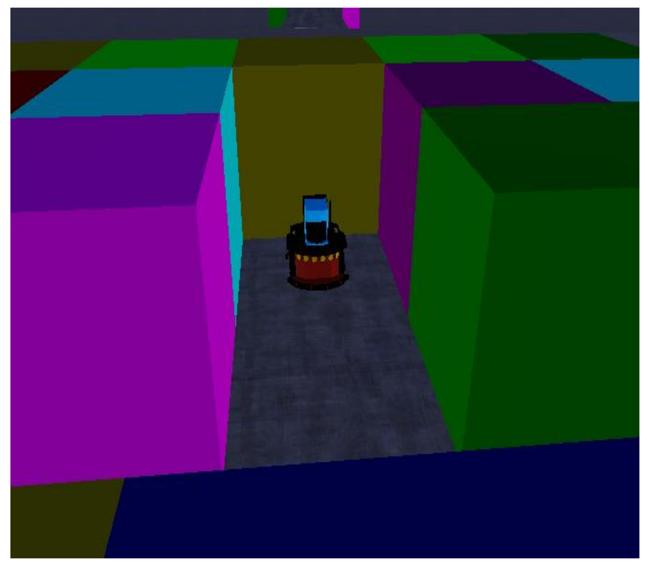
- Needs can represent homeostatic quantities such as hunger or thirst. A need is associated with one or more goal neurons.
- Needs drive motive backward through the gating network formed by the enabling state of the mediators to produce a sequence of motor responses that navigate from the current state toward the firing of goal neurons.
- Needs and goals constitute a separate control of the network. The same network can be used for different tasks, such as seeking food and water.

Processing cycle

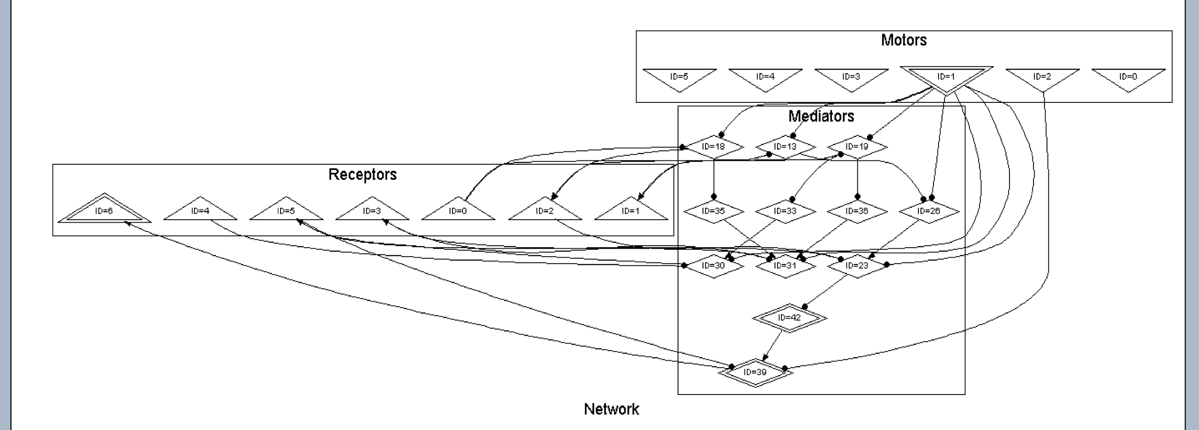


Maze-learning robot

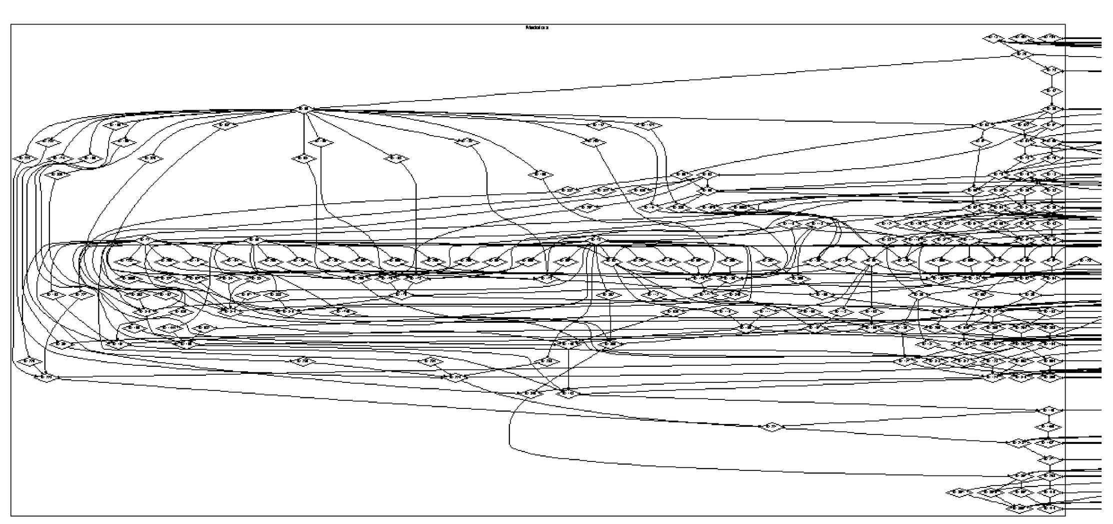




Robot network after a little training



Robot network after more training



Current and future work

- Instinct. Wired-in behavior can serve as a structure for experiential learning to overlay. Instincts are innate generalizations that can be overridden by learned discriminations.
- Internally firing neurons for rehearsal learning, speculation and look-ahead.

References

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