Dynamic Architectures via Introspection and Neuromodulation

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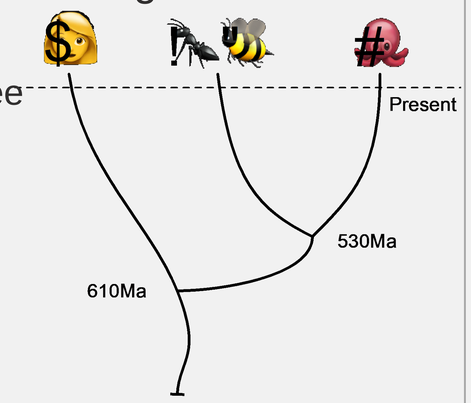
Specialized Functions: Lifelong Learning Machines (L2M)

Overview

Motivation: hardware and architectures capable of learning in real time and adapting to context/tasks and changes in the environment

- Mammals, arthropods, and mollusks provide three "engineering designs" to accomplish L2M tasks
- Despite splitting many years ago, they seem to share some common design principles
- Central nervous systems have vastly different sizes, yet a similar level of cellular and chemical diversity: chemical connectome

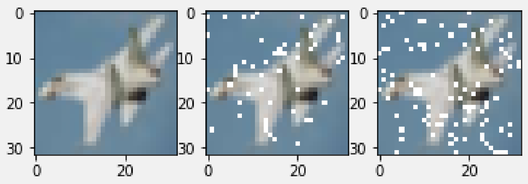


While most neuro-inspired algorithms and architectures have focused on the physical connectome, this project explores the role of chemistry as an inspiration for L2M-capable systems.

Year 1 Accomplishments

Using context to overcome noise and missing data

Context is used to switch a network from 'nominal' mode to 'compromised' mode.

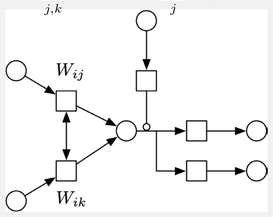


Fusing learning and processing: networks that learn on their own

Networks where weights are first-class citizens.

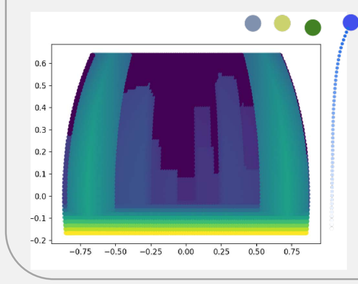
Design via meta-learning optimization

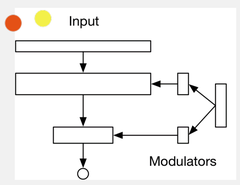
$$\xi_i = \sum_{j,k} w^{(2)}_{ijk} x_j x_k + \sum_j w^{(1)}_{ij} x_j + b_i$$



Context-dependent processing via addressable networks

Agent based systems: learning to track context-dependent targets

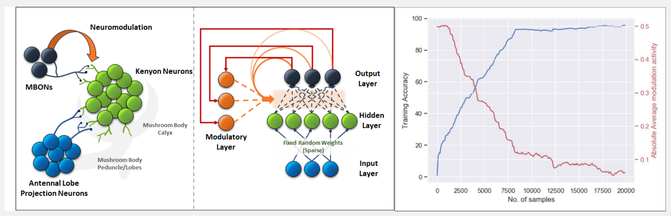




One network, many tasks

On chip L2M: mapping architectures into hardware

Dynamic context-dependent learning in FPGA and neuromorphic chip implementations



Project goals

1. Extend neural networks beyond state of the art to design flexible, continuously learning architectures
2. Determine design principles for L2M-capable hardware
3. Integrate new functionality into L2M-capable systems

Approach

Apply the insect brain as inspiration

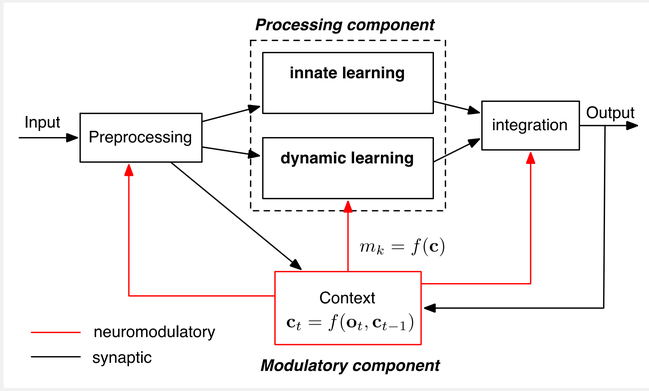
Behavior → Architecture → Kinetics → Abstraction → Hardware

Subjective, internal model of environment

Multisensory integration

Context-selective attention

Persistent internal state



Brain size close to current semiconductor processing capabilities

Focus on chemistry as an enabler of such flexibility

Impact

- Low power computing
- On chip AI and edge processing
- Unmanned vehicles
- Smart sensors and sensor networks
- Extreme, remote environments (space, rad-hard)

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