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NERVOUS SYSTEMS

Concept Neural Microcircuits with Novelty Search

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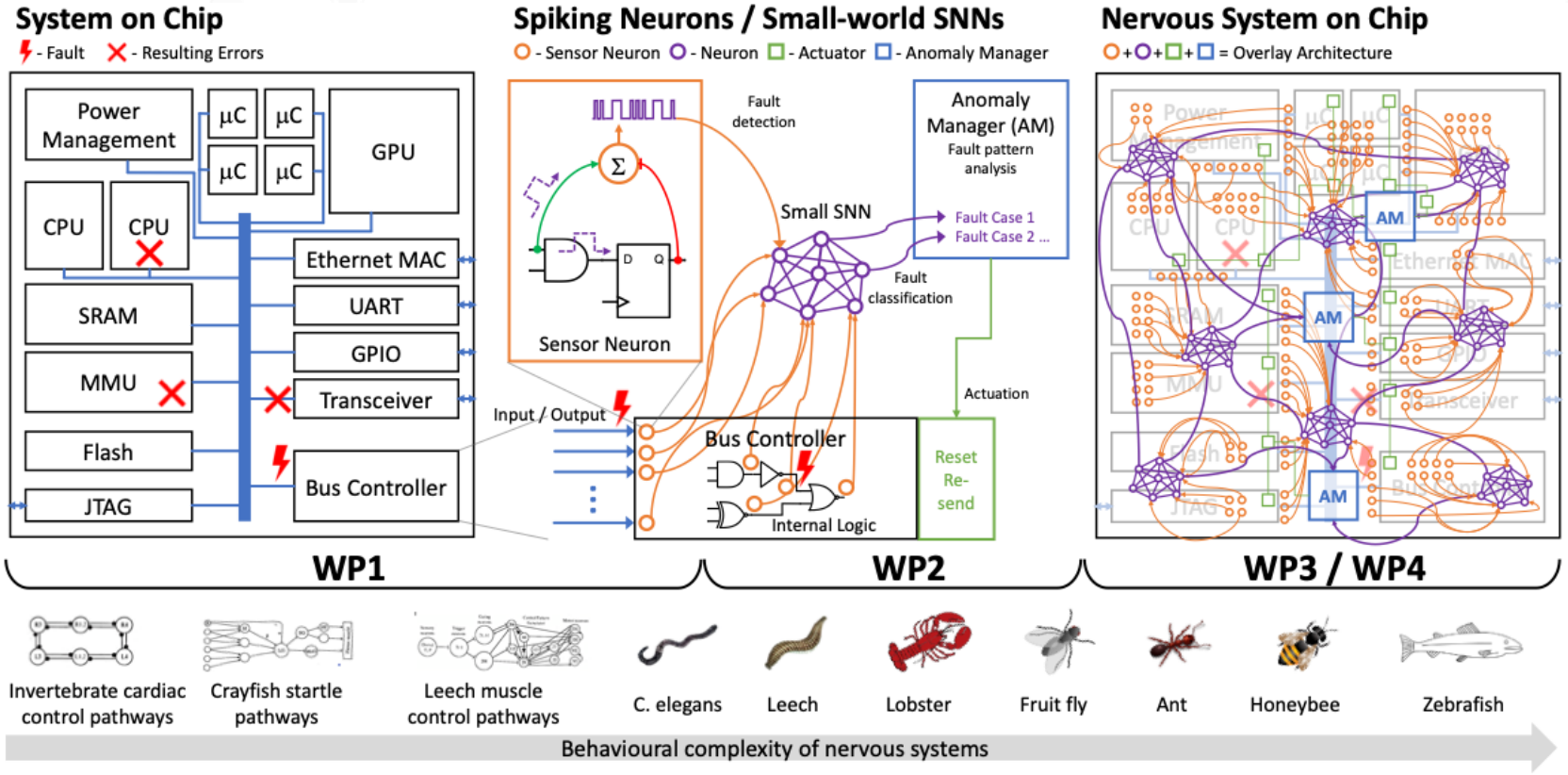
The Nervous Project Methodology



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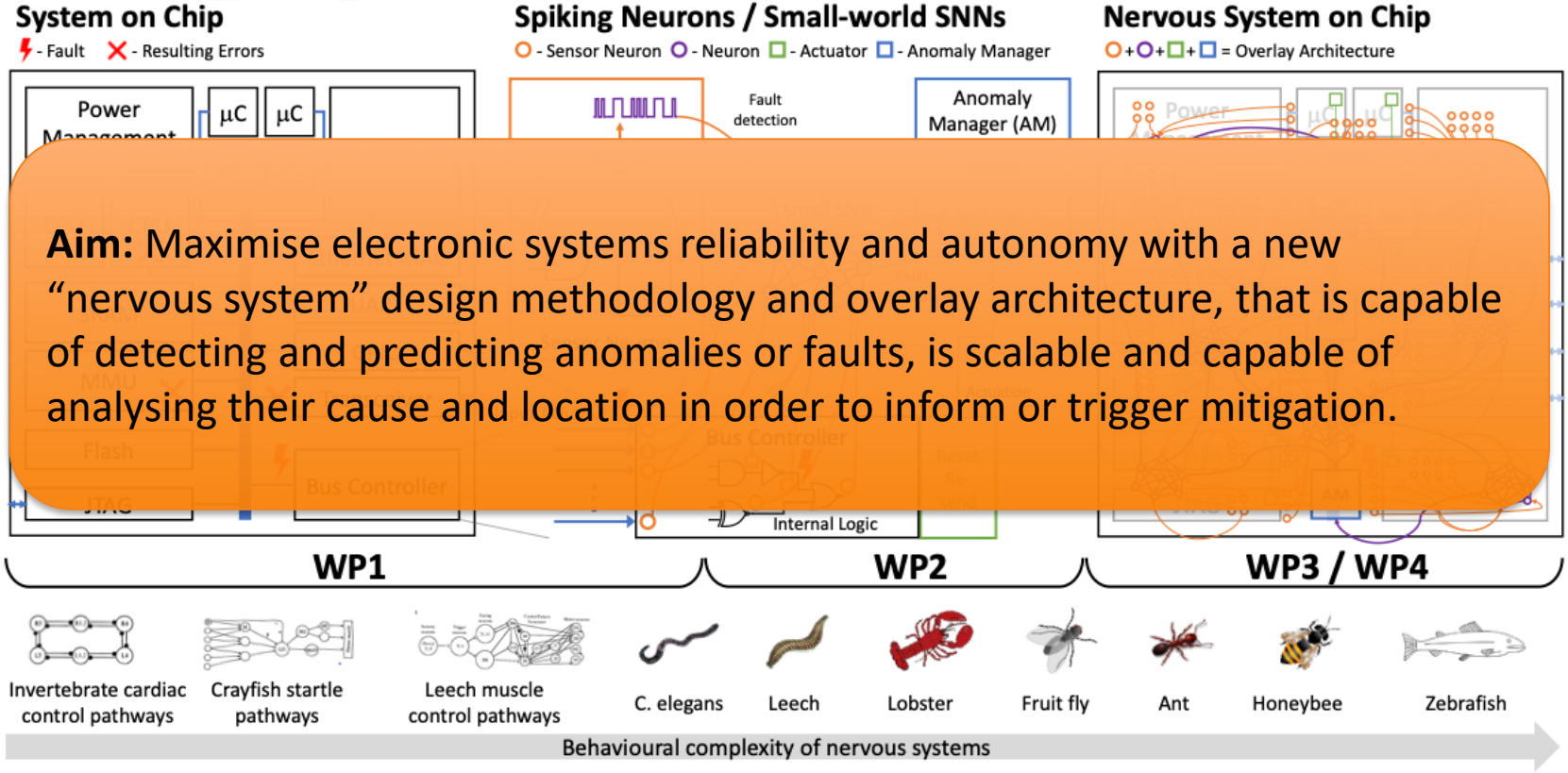
The Nervous Project Proposition



Aim: Maximise electronic systems reliability and autonomy with a new "nervous system" design methodology and overlay architecture, that is capable of detecting and predicting anomalies or faults, is scalable and capable of analysing their cause and location in order to inform or trigger mitigation.

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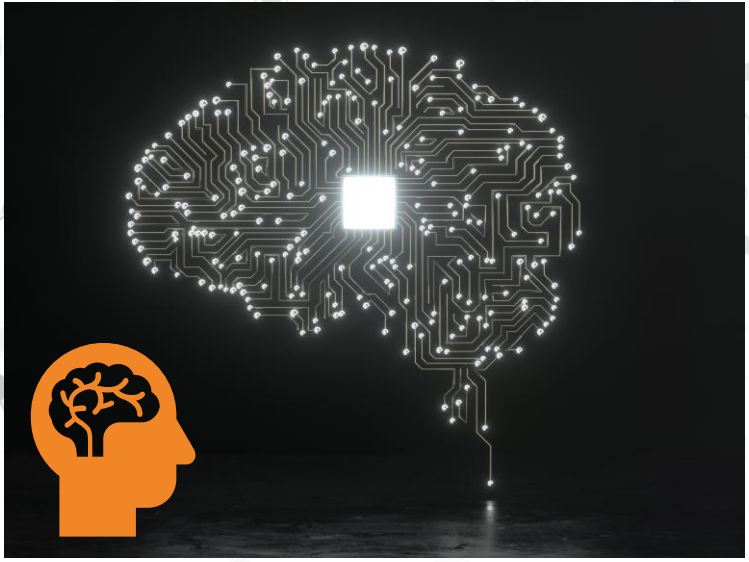
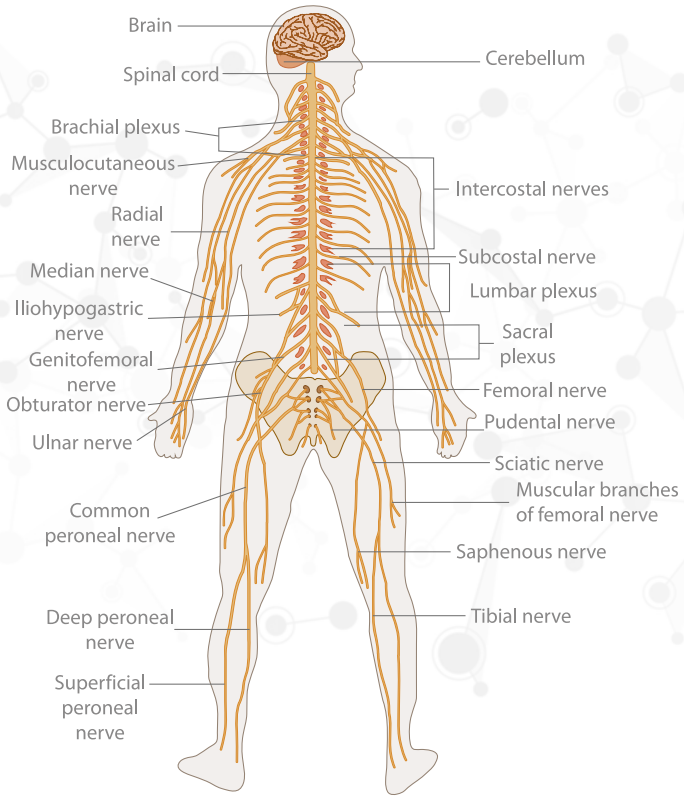
Rethinking Neuromorphic HW Systems

TAKING INSPIRATION FROM THE NERVOUS SYSTEM ARCHITECTURE





Figures from https://en.wikipedia.org/wiki/Nervous_system and Microsoft PowerPoint

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Rethinking Neuromorphic HW Systems

TAKING INSPIRATION FROM THE NERVOUS SYSTEM ARCHITECTURE

Key:
- = Structure
- = Function

Central Nervous System (CNS)
- Brain and spinal cord
- Integrative and control centers

Peripheral Nervous System (PNS)
- Cranial nerves and spinal nerves
- Communication lines between the CNS and the rest of the body

Sensory (afferent) division
- Somatic and visceral sensory nerve fibers
- Conducts impulses from receptors to the CNS

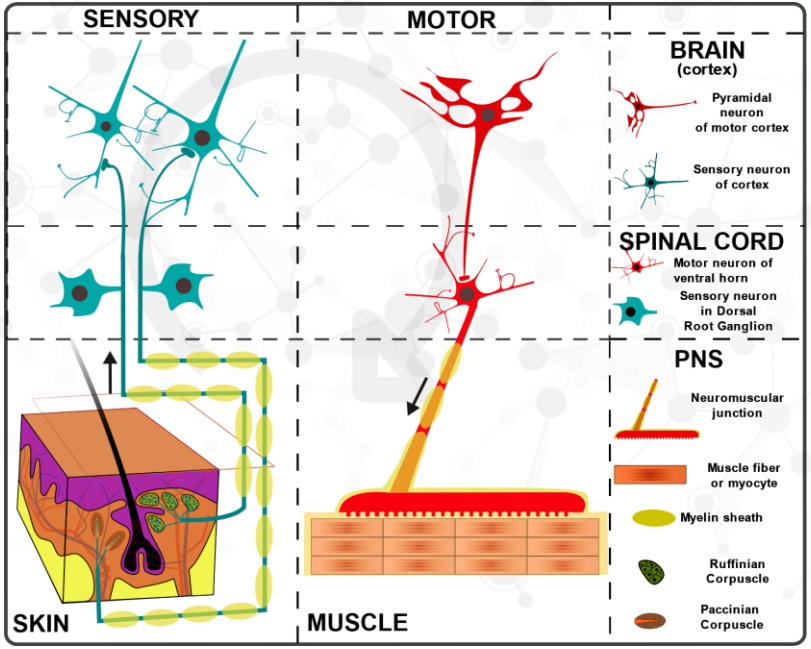
Motor (efferent) division
- Motor nerve fibers
- Conducts impulses from the CNS to effectors (muscles and glands)

Sympathetic division
- Mobilizes body systems during activity ("fight or flight")

Parasympathetic division
- Conserves energy
- Promotes "housekeeping" functions during rest

Autonomic nervous system (ANS)
- Visceral motor (involuntary)
- Conducts impulses from the CNS to cardiac muscles, smooth muscles, and glands

Somatic nervous system
- Somatic motor (voluntary)
- Conducts impulses from the CNS to skeletal muscles



Figures from https://en.wikipedia.org/wiki/Nervous_system

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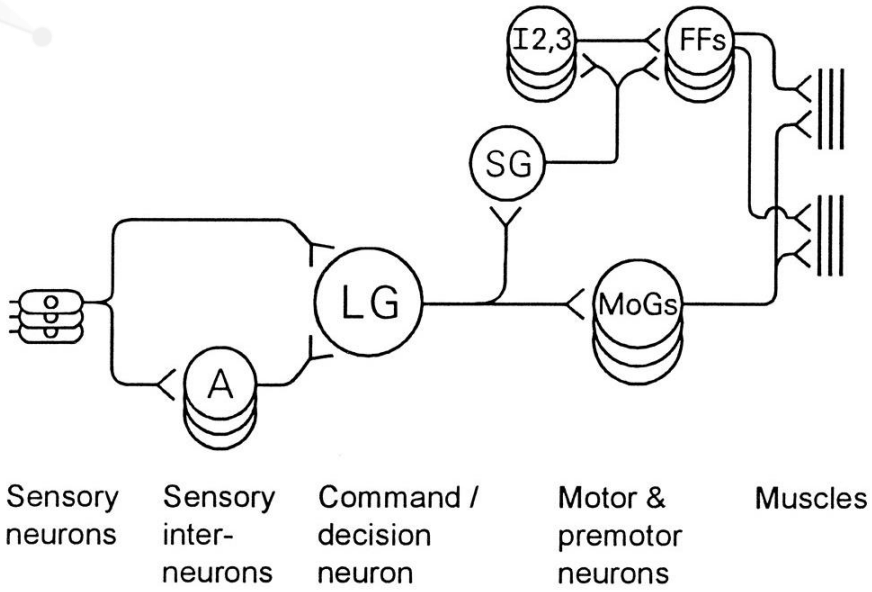
Biological Neural Microcircuits



- "Elementary processing units" within the nervous system.
- Crayfish Startle Reflex -> fault tolerance?
- Sophisticated behaviours.
- Temporal correlation of multiple environmental stimuli.
- Translate microcircuits to electronic systems?

Postexcitatory Inhibition of the Crayfish Lateral Giant Neuron: A Mechanism for Sensory Temporal Filtering; Journal of Neuroscience 15 November 1997, 17 (22) 8867-8879; DOI: https://doi.org/10.1523/JNEUROSCI.17-22-08867.1997

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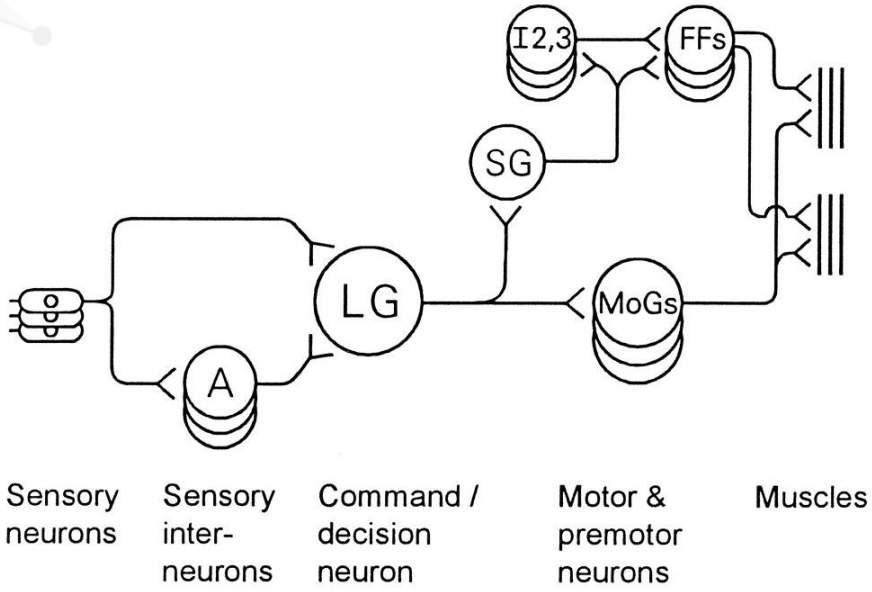
Crayfish Tail Startling Reflex



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Making Artificial Microcircuits

- Building blocks (Neural Motifs)
- Components

- Design Language (Matrices)

- Design Methodology (Genetic Algorithm)
- Neuromorphic Design Automation (Novelty Search)

- Physical representation (Netlist for Brian2, NEST)
- FPGA prototyping (VHDL Model)

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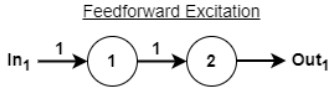
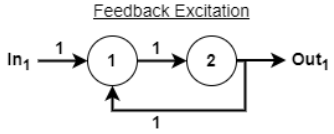
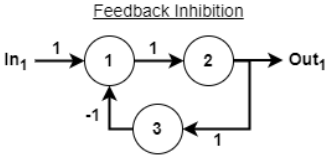
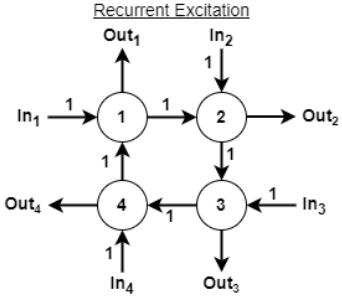
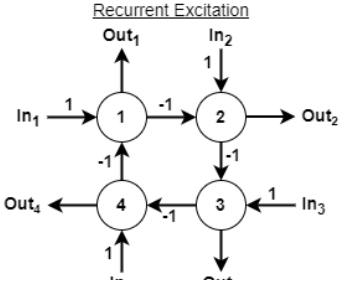
Neural Motifs as Components

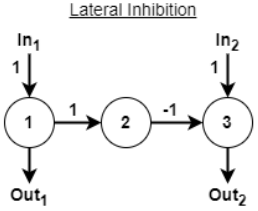


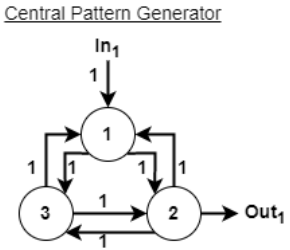












Recurring patterns (motifs) in biological nervous systems:

- FeedForward Excitation (FFE)
- FeedBack Excitation (FBE)
- FeedBack Inhibition (FBI)
- ReCurrent Excitation (RCE)
- ReCurrent Inhibition (RCI)
- LaTeral Inhibition (LTI)
- Central Pattern Generator (CPG)

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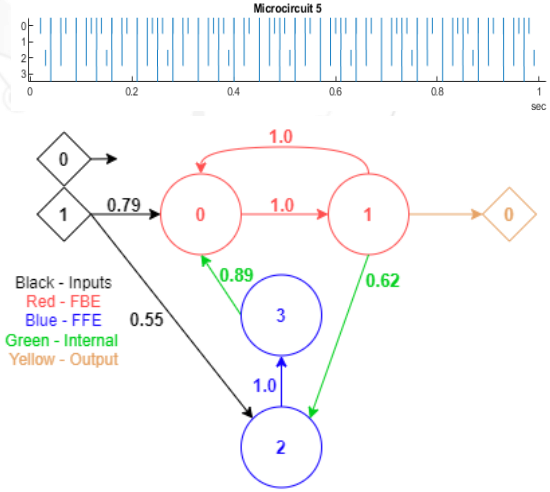
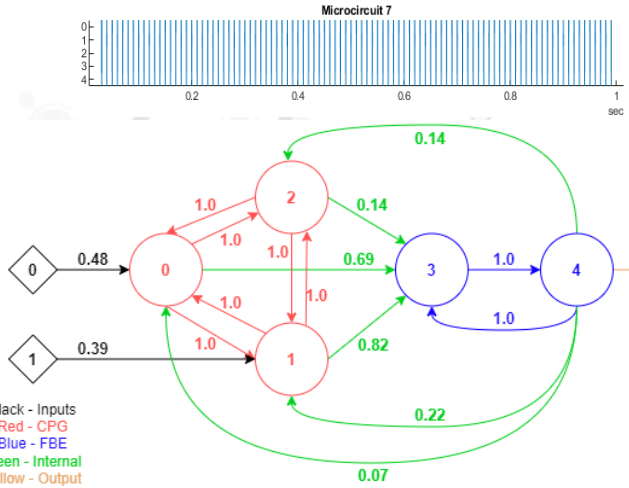
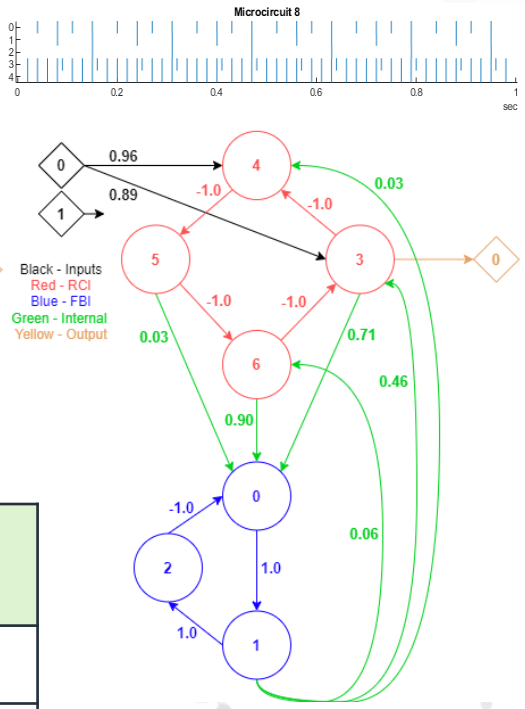
Microcircuit Evaluation – Diverse Behaviours







Spike Train Distance	FBE/FFE	CPG/FBE	RCI/FBI
FBE/FFE		0.2282	0.1520
CPG/FBE	0.2282		0.2360
RCI/FBI	0.1520	0.2360	

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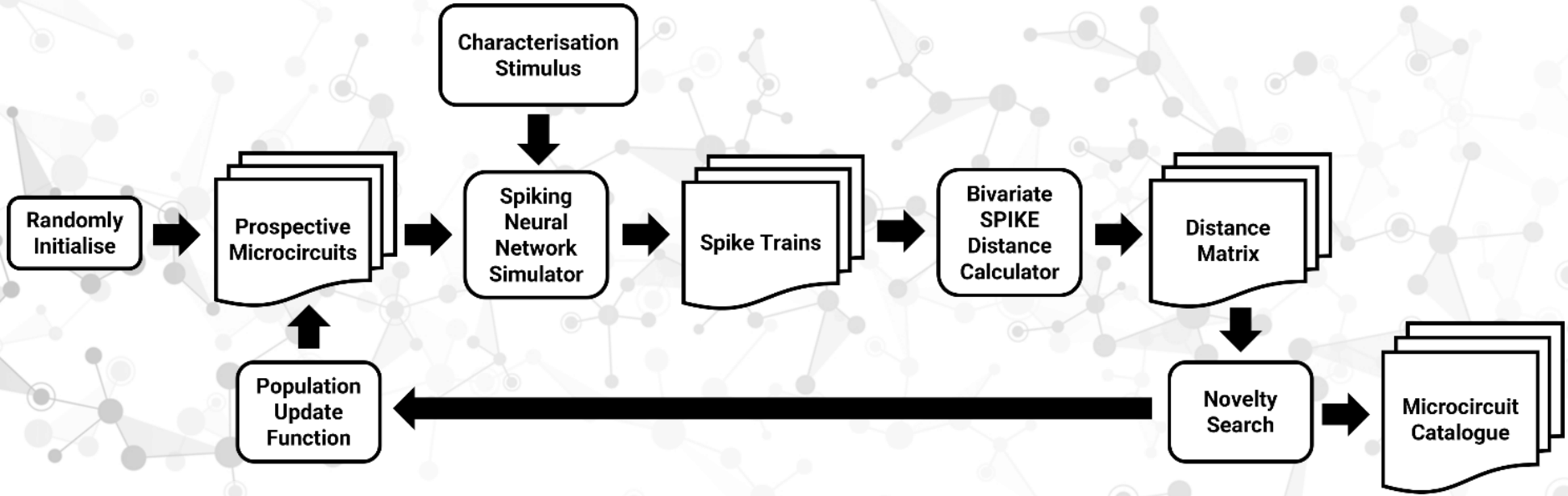
Microcircuit Design using Novelty Search



Novelty

Standard

Lehman & Stanley's Novelty Search: instead of driving a problem towards a specific goal, the population is searched for individuals which exhibit new behaviours.

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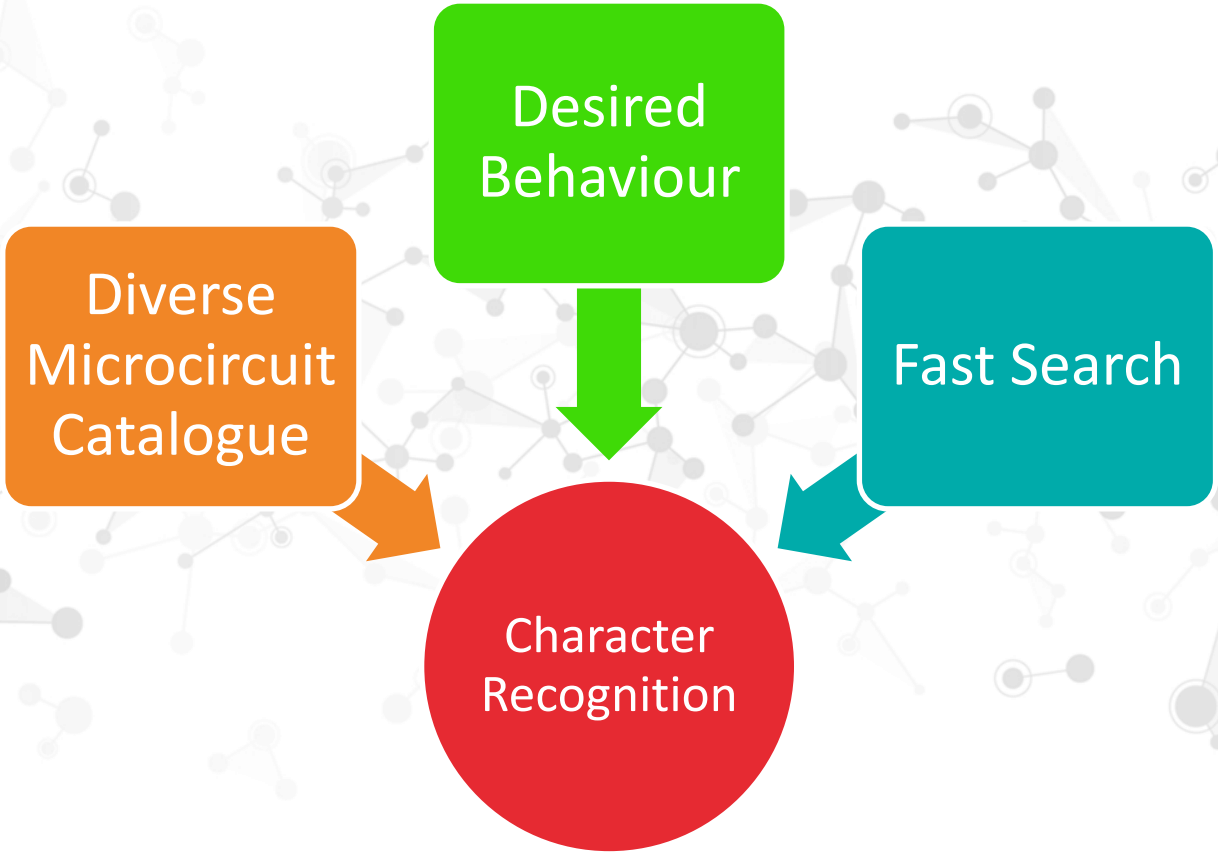
Solving Problems with Artificial Microcircuits



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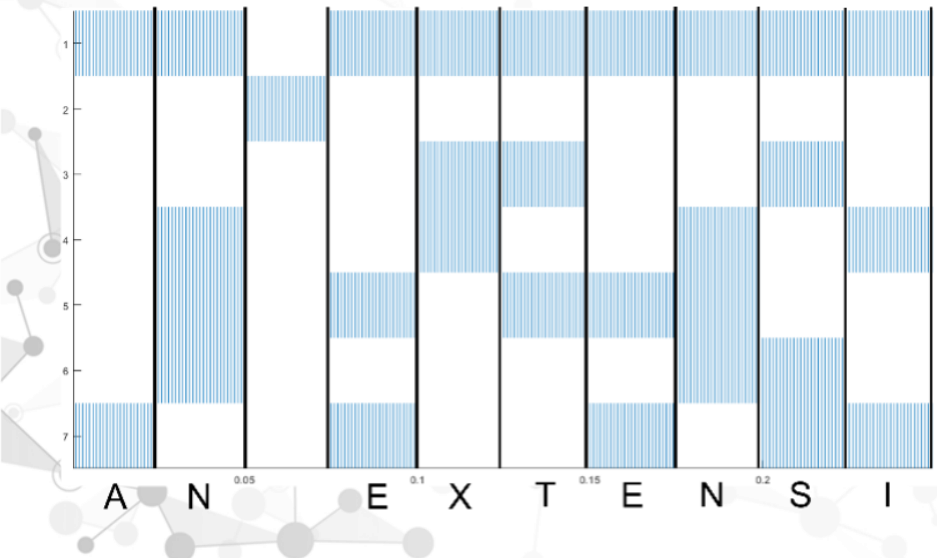
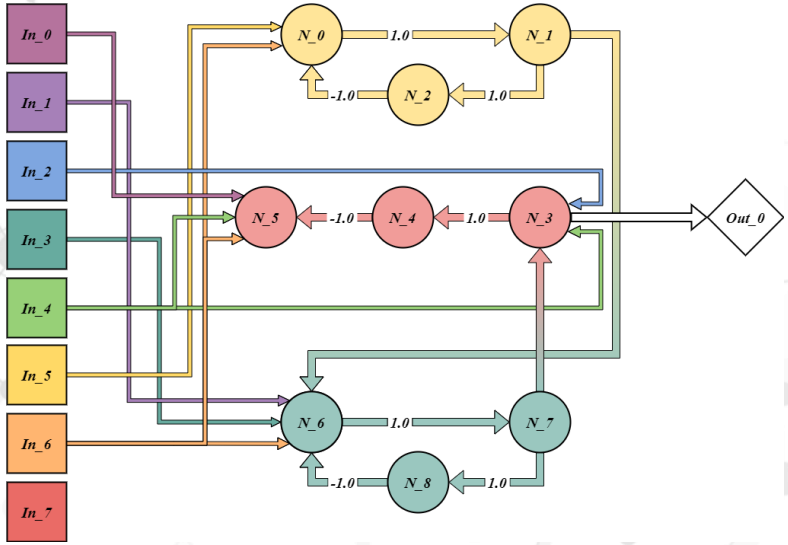
Punctuation Detector with 9 Neurons





- Many different behaviours in the catalogue.
- Examples in the subsequent hands-on session.
- Hands-on session https://www-users.york.ac.uk/~mt540/nervous-systems/index.html#resources

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Thanks

TO THE LAB TEAM AND COLLEAGUES:

SIMON BALE, LINAN CAO, LIAM MCDAID, TIAN GAN, JIM HARKIN, SIMON O'KEEFE, ALEX MCDONNELL, MALACHI MCELHOLM, MOHAMMAD MUSAMEH, AMRUTHA R K, RINKU SEBASTIAN, SUSAN STEPNEY, NIDHIN THANDASSERY, ANDY TYRRELL, ARUNKUMAR VENKATESHAIAH, RIVERSDALE WALDEGRAVE, ZIWEI WANG, ANDREW WALTER, ISAAC WATSON, CHESTER WRINGE, SHIMENG WU, GUANGSHA XU.

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