Reappropriating Ashby's Ultrastability for the Modelling of Neural Assemblies

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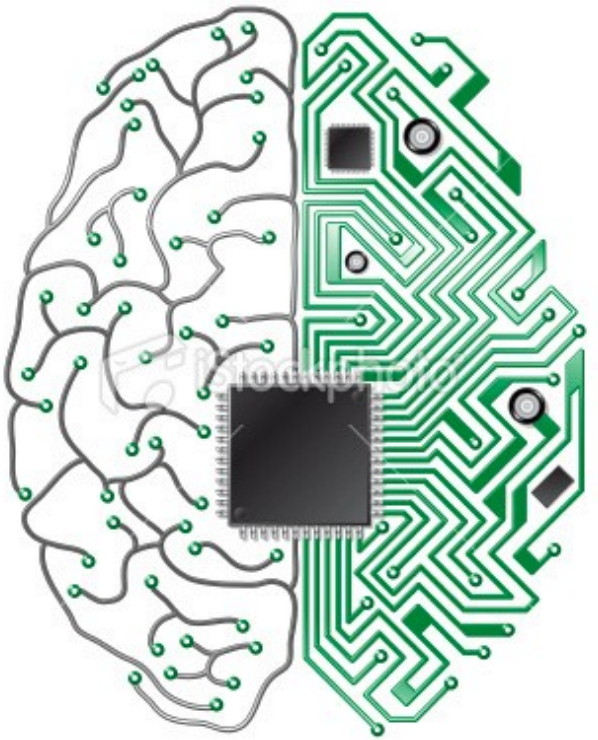
Miguel Aguilera

Introduction

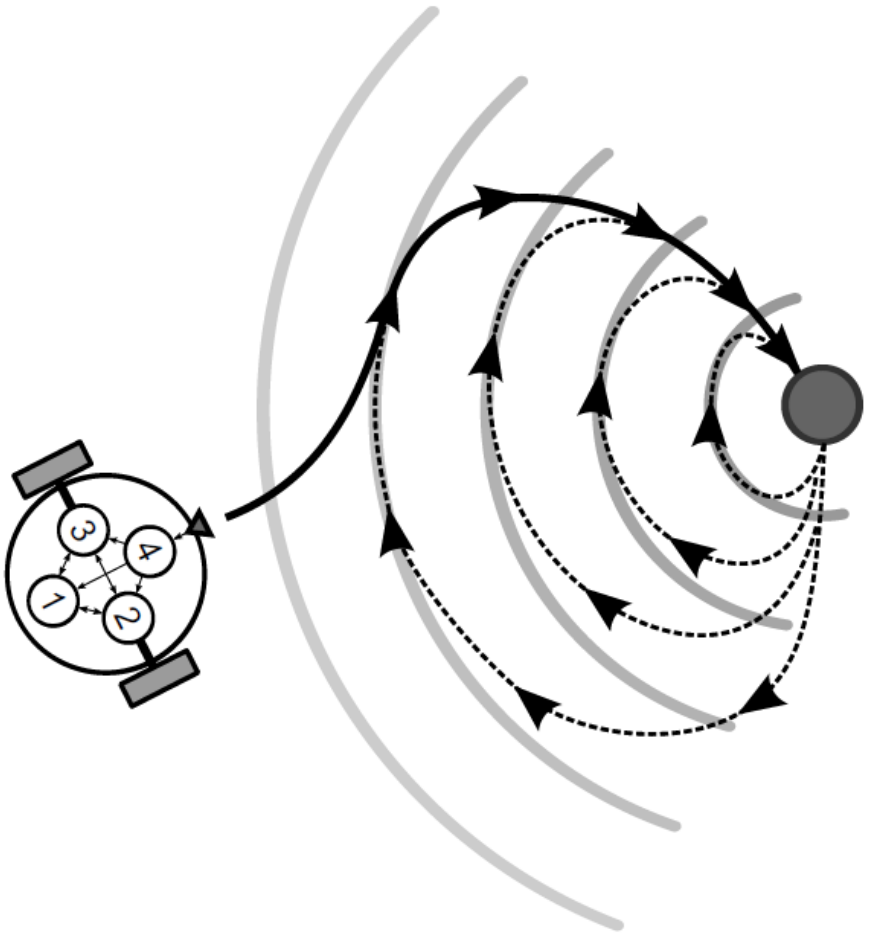
- When we want to model intelligent agents, properties such as intentions, meaning, or purposeful behaviour are elusive

- Cognitivist approaches solve this problem by assuming the *a priori* existence of representations and a world of meaning



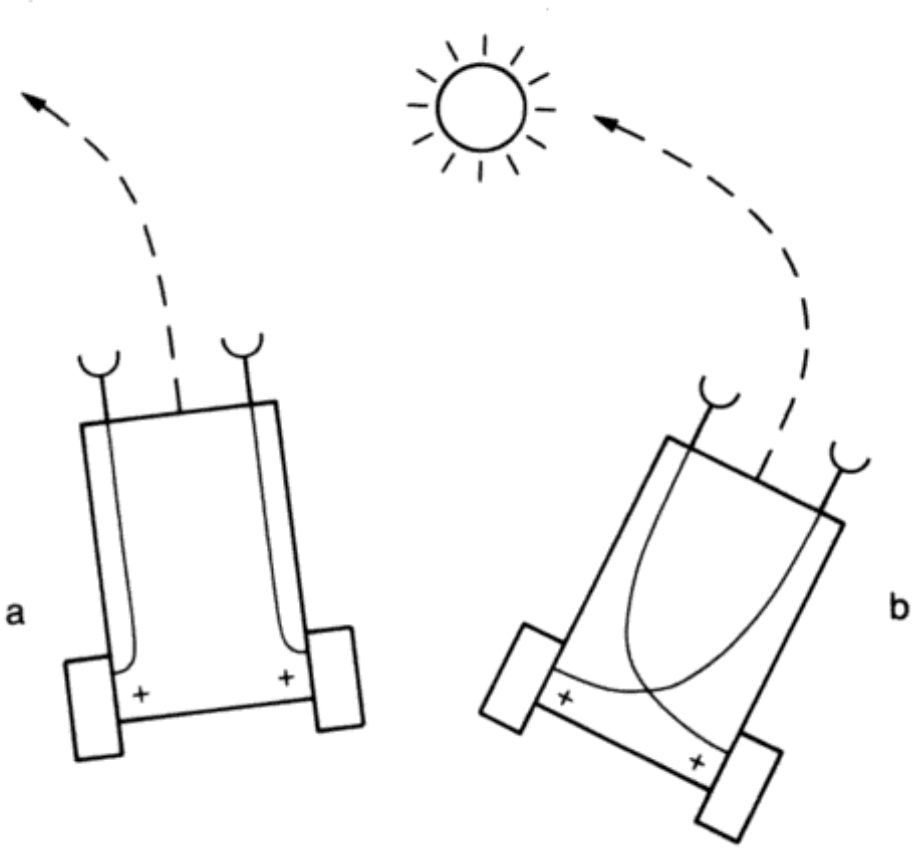
Situated/embodied cognition

- Dynamicist approaches try to solve this problem without assuming the existence of symbolic representations
- Behaviour emerges from a closed sensorimotor loop (interactions in the agent-body-envirnoment system)



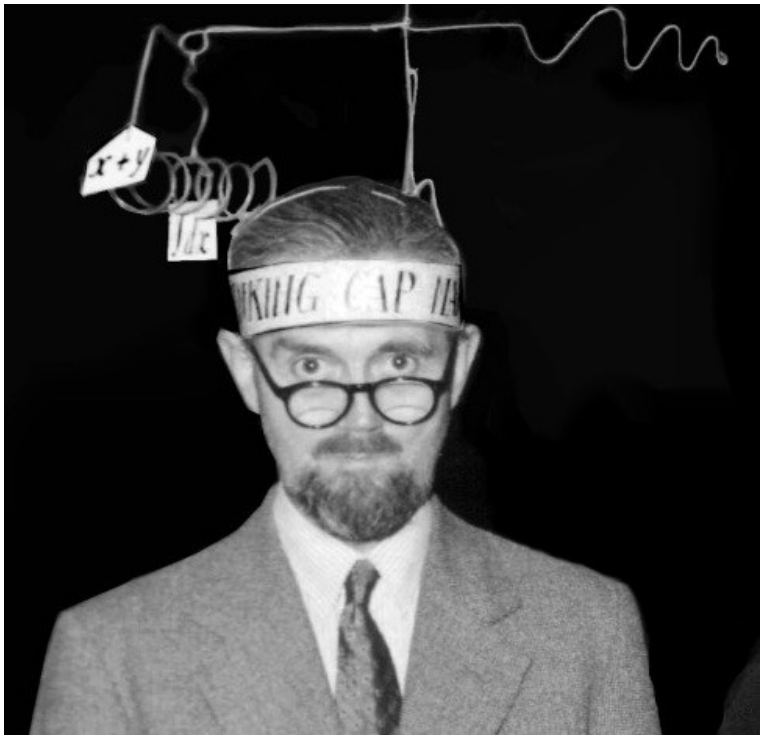
Meaningful activity?

- A robot failing in its performance does not show any signs of concern
- Is it just a complexity problem?
- Is it enough a closed sensorimotor loop to perform meaningful behaviour?



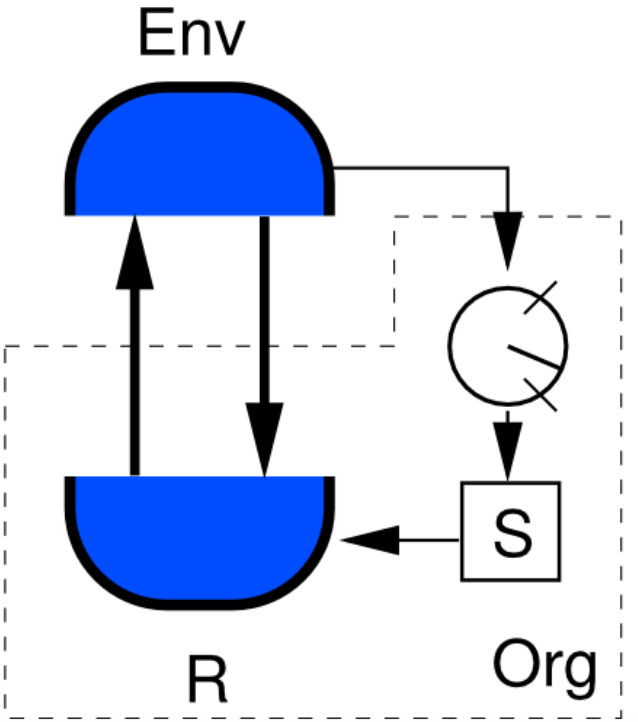
Recalling Cybernetics

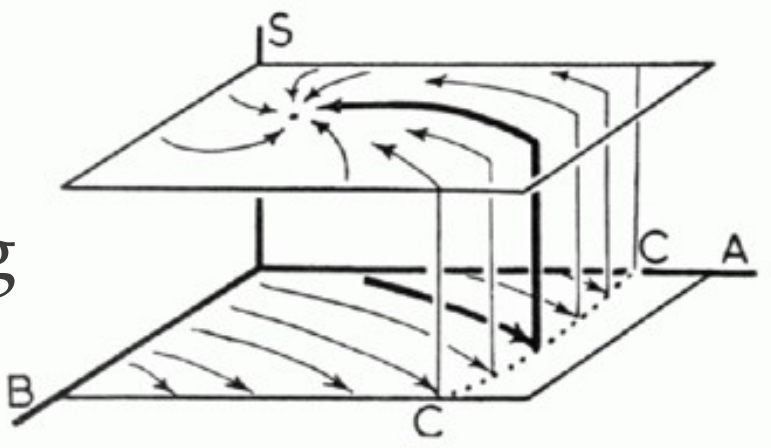
- The work of Ross Ashby showed how apparently intelligent behaviour can accounted for by a simple homeostatic system driven by random step functions (Ashby, 1960)
- Adaptation consists in the conservation of the *identity* of an organism



Ultrastability

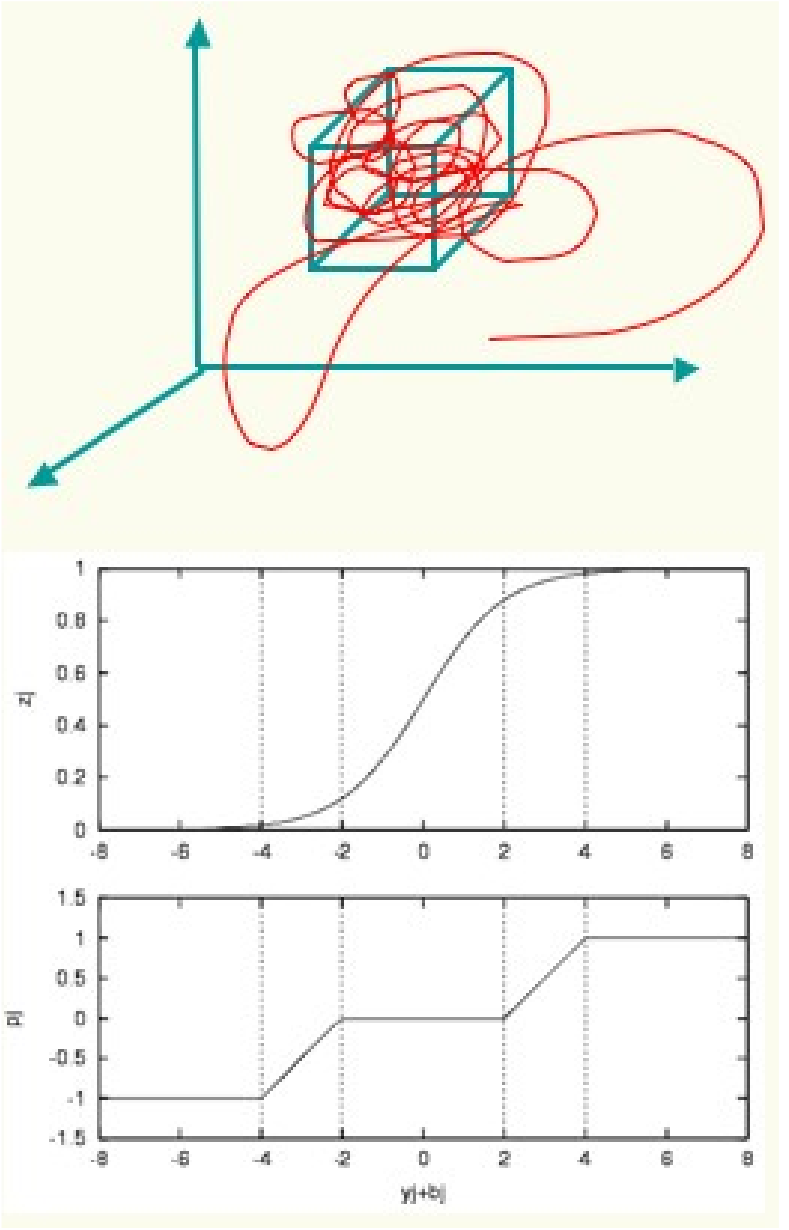
- The survival of an organism (R) could be described in terms of maintaining some essential variables (S) under homeostatic control
- When these variables go outside their bounds, the organism must undergo parametrical changes returning them to their viability zone





CTRNN implementation

- Ashby's model has been successfully implemented in a homeostatic CTRNN controller (Di Paolo, 2000)
- Weight connexions were changed when neuron's state was to low or too high
- An robotic agent was able to re-adapt to a condition of inversion of the visual field

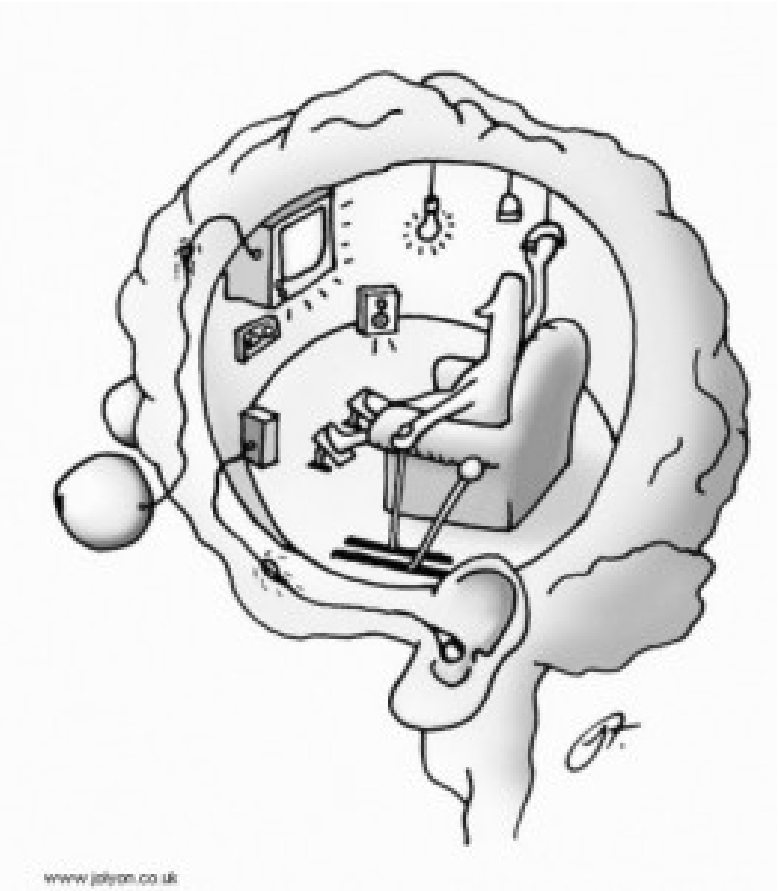


Limitations

- Can really intelligent life-like behaviour be reduced to this?
- There is no representations or intentions. Just purposeless mechanisms creating an apparently purposeful behaviour.
- Is there something more than physical processes creating an ilusion “as-if” the subject was acting for authentic reason?

Open Problems: the Lurking Homunculi

- The Ultrastability theory reduces the problem of live and meaning to the maintenance of state of the system components
- The problem is to attribute to particular components what otherwise are systemic properties of an organism (e.g., organismic, mental, phichological)



Ashbyan Crisis

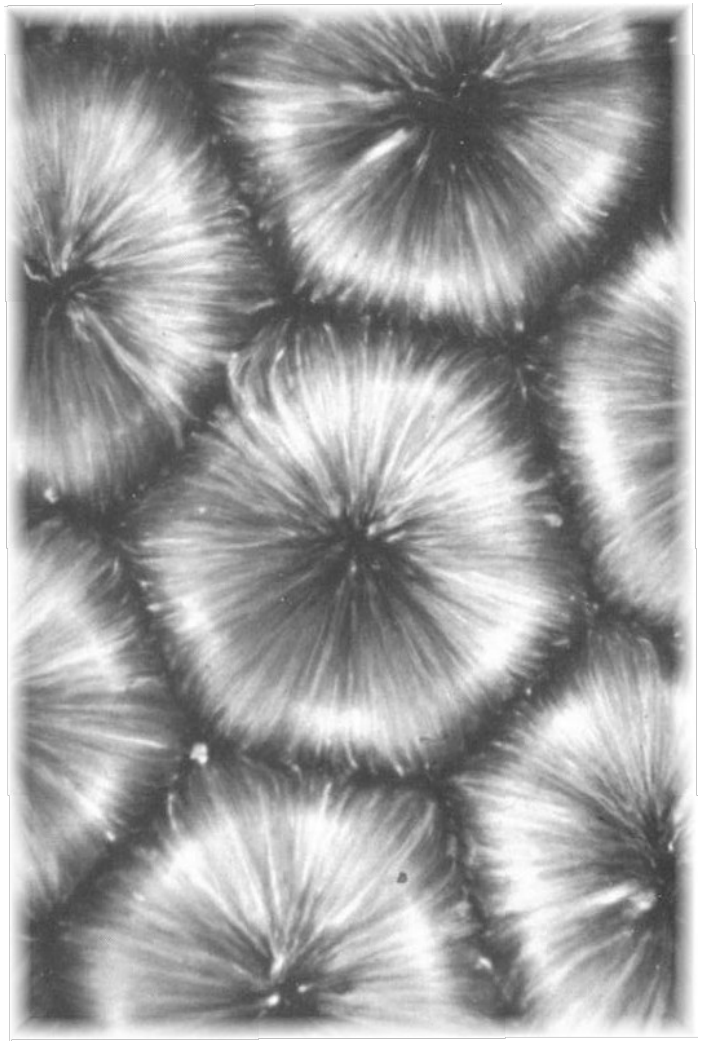
- Ashby's work exposed the limitations of the cybernetic program and the contradictions of the as-if assumption, leading to divisions in the field
- The cybernetic framework leaves no place for self-organization. Ashby himself rejected the term as a confusing and inconsistent idea of self-reference within a system

Ashbyan Crisis

- Computationalism will arise as a fresh start where these problems are conveniently forgotten
- However, it was also an opportunity to take seriously the limitations exposed by Ashby's work, explorging uncharted territory into the world of complex systems

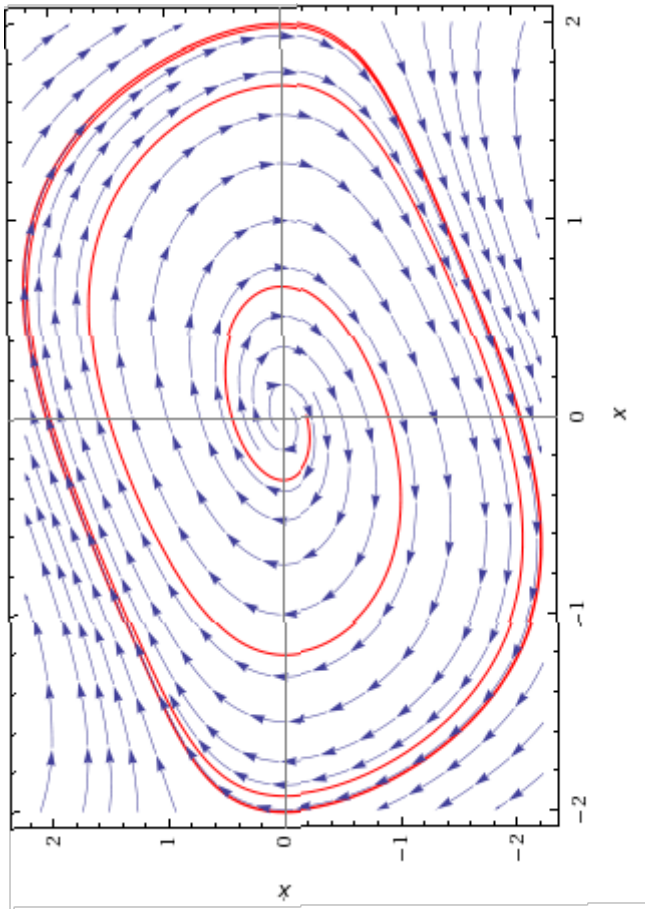
Homeokinetics

- Developed by A. Iberall in the 1950s, it aspired to explain self-organizing living beings through non-equilibrium thermodynamics
- In contrast with a static homeostasis, it captures the dynamic regulations and interactions that constitute and preserve life



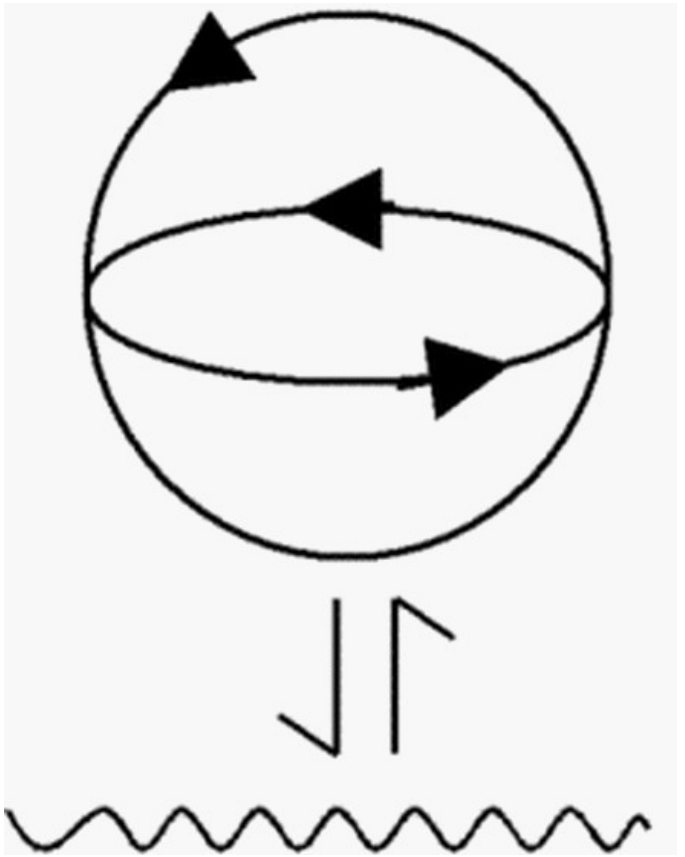
Homeokinetics

- The objective was to describe life in terms of limit-cycle oscillators coordinated into *constellations* defining patterns of behaviour (Iberall & McCulloch, 1969)
- It inspired the framework of modern Coordination Dynamics (Kugler, Kelso & Turvey, 1980)



Autopoiesis

- Maturana & Varela (1973) concept of Autopoiesis tries to characterize the organization of the living
- It defines living organization as an homeostatic system with its own organization as the fundamental variable it maintain constant



MODEL

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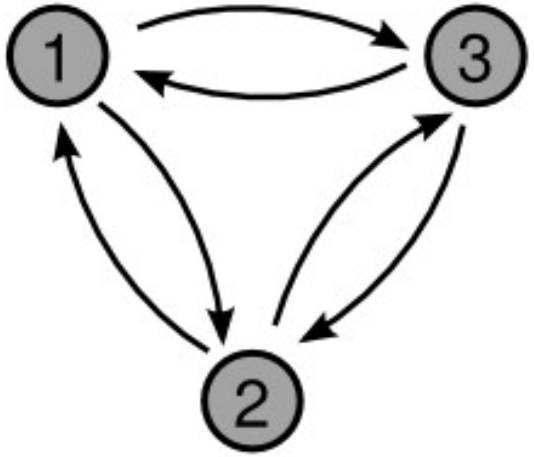
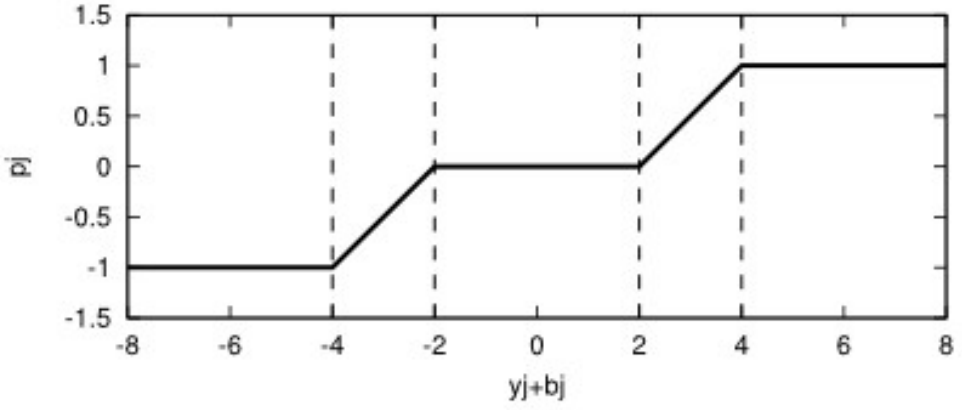
Homeokinetic Neural Assemblies

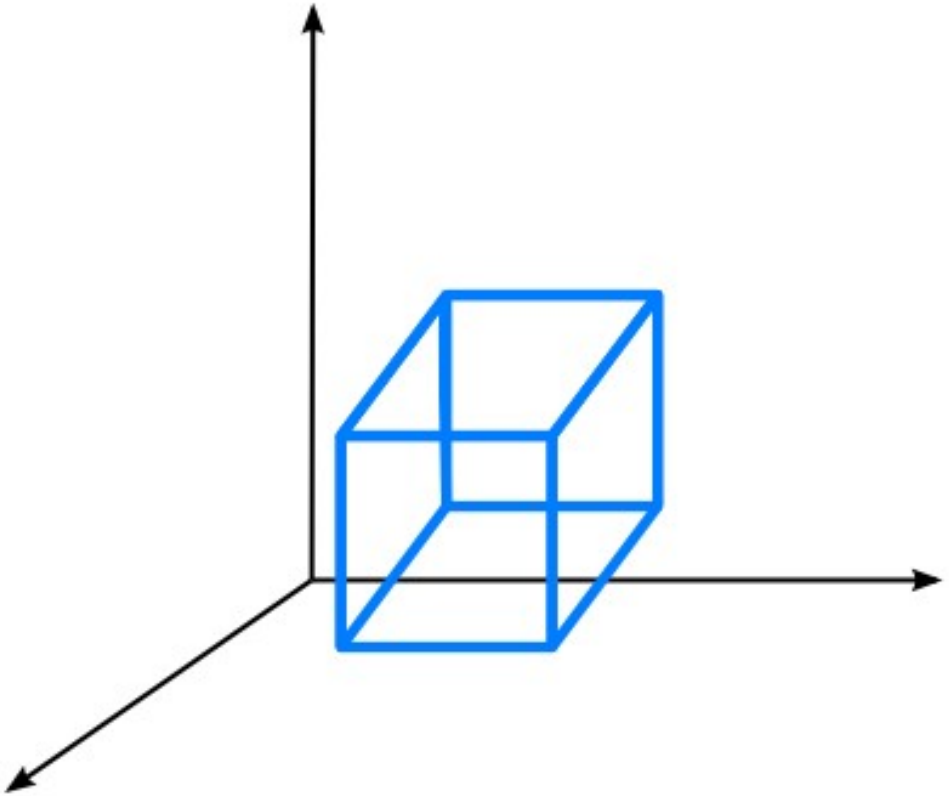
Model

- With our model we tried to capture a system where:
  - A global level of description emerges from the coordination of local oscillatory processes
  - The configuration of this global level is maintained in a viability zone by homeostatic (homeokinetic) mechanisms in the local level

Previous model



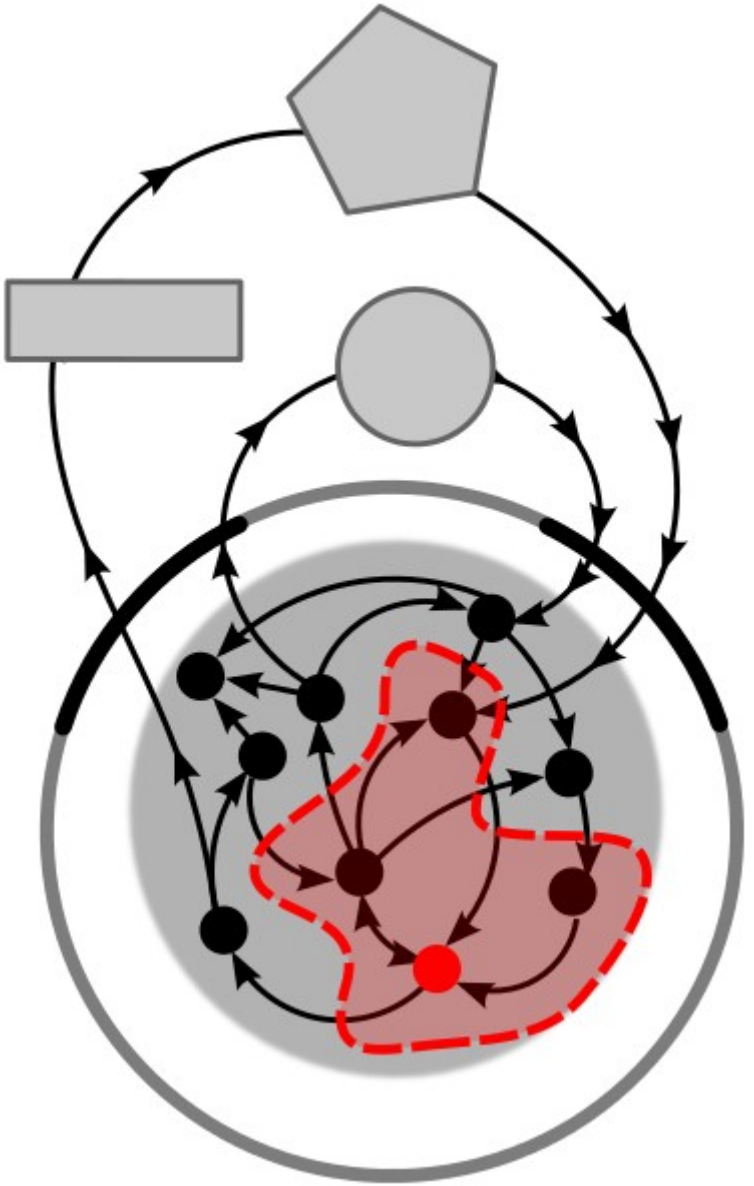




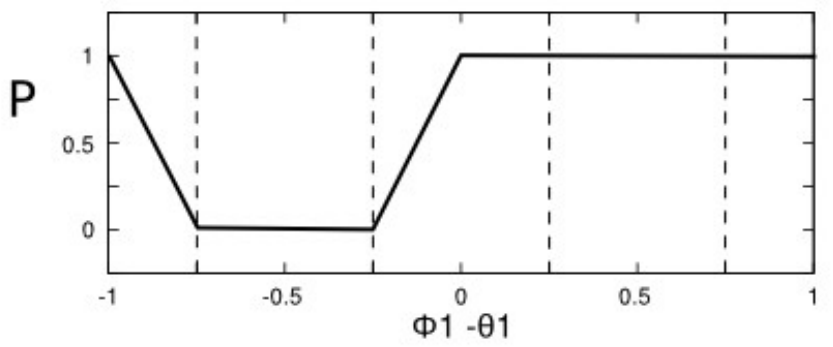
The components' state is maintained constant

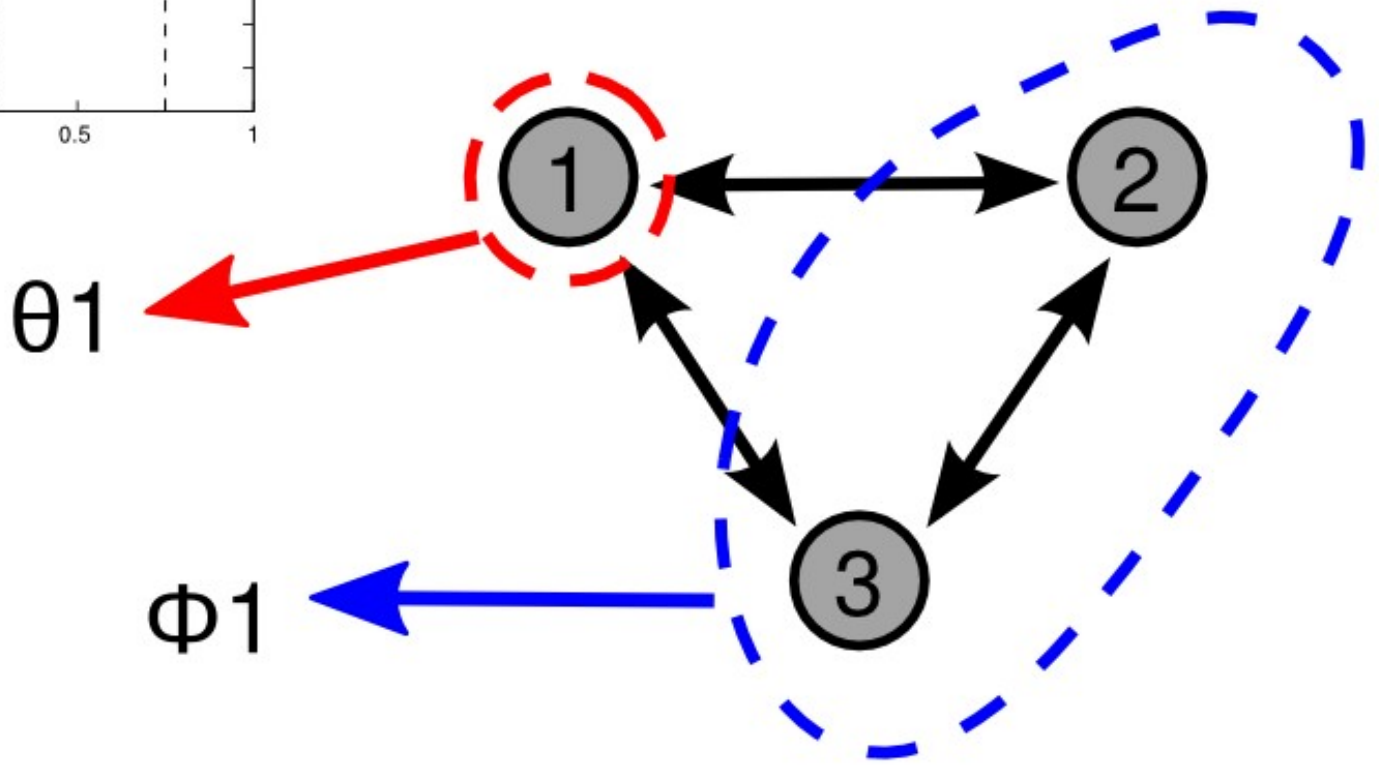
Model

- Our model consists in a homeostatic network of oscillators
- The fundamental variable is defined as the phase relation between an individual oscillator and the synchronized cluster in which it is embedded



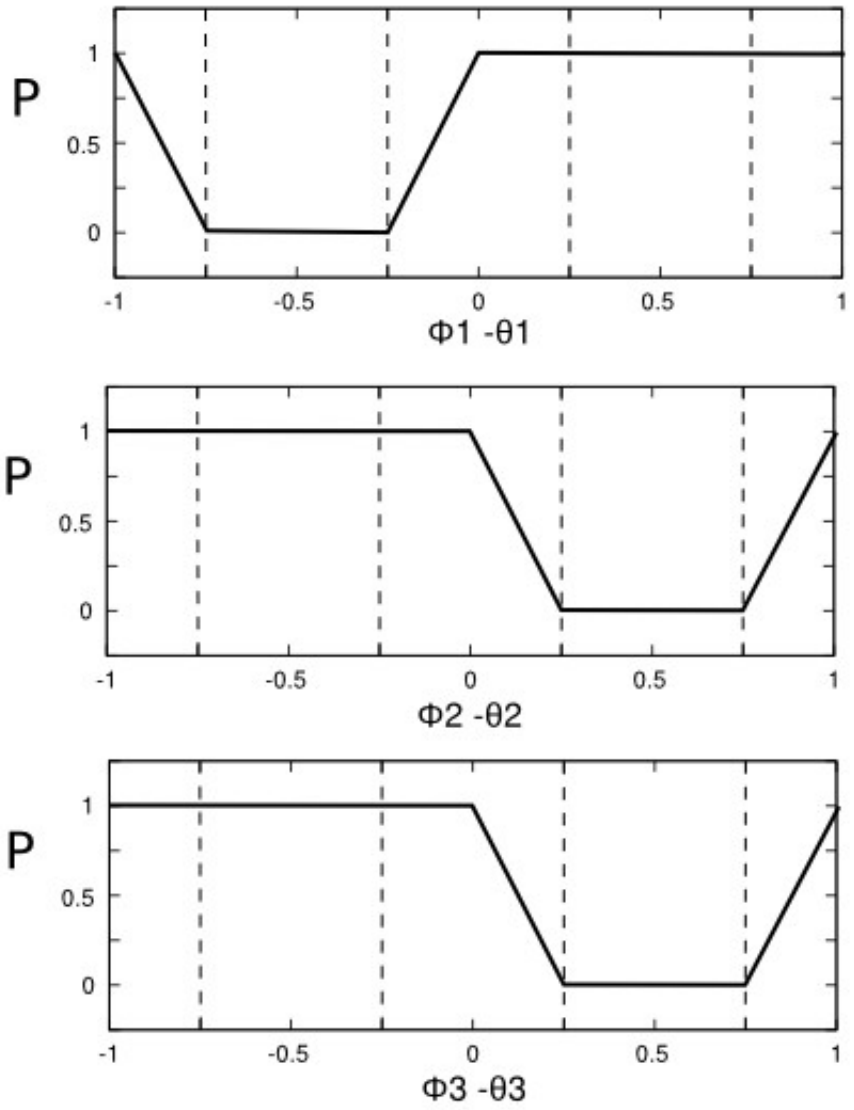
Example

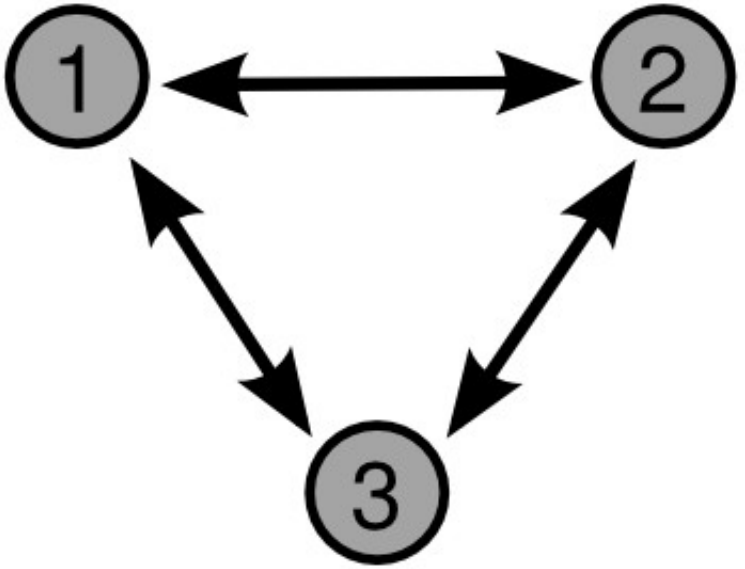




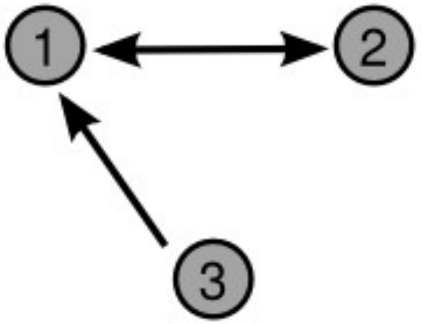
The components' relations are maintained constant

Example

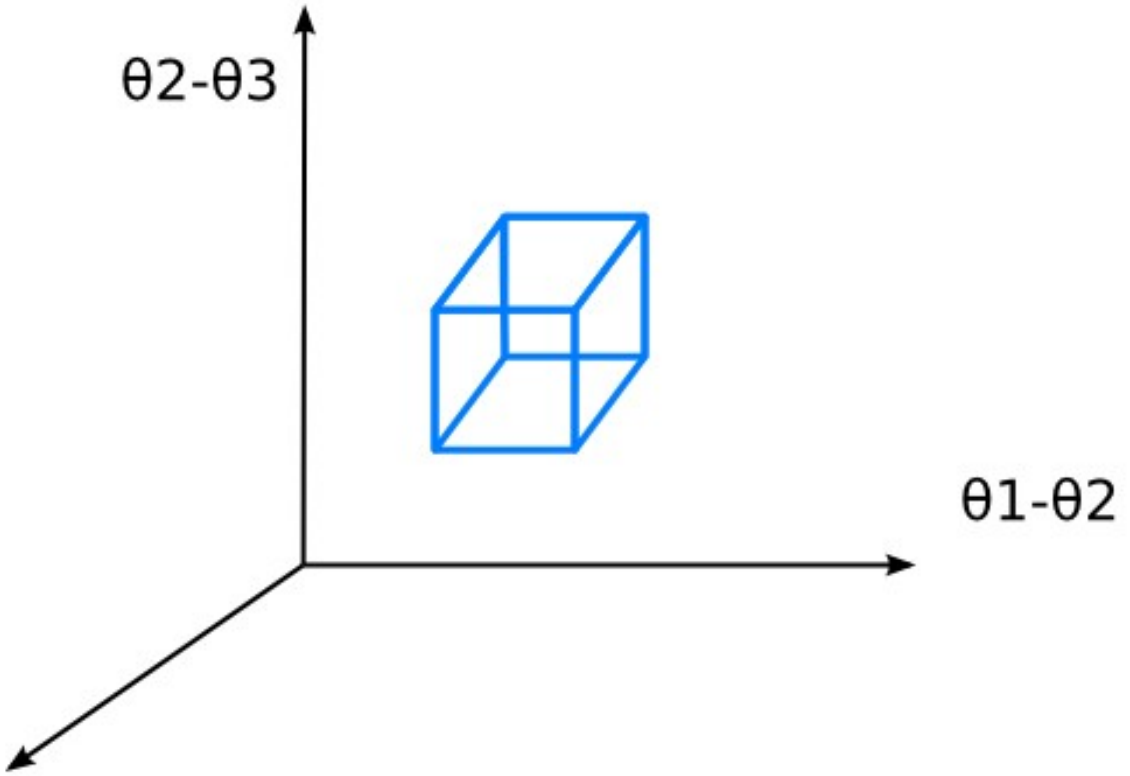




Emergence of Homestatic Regions



θ1-θ2 θ1-θ3 θ2-θ3
1 1 0



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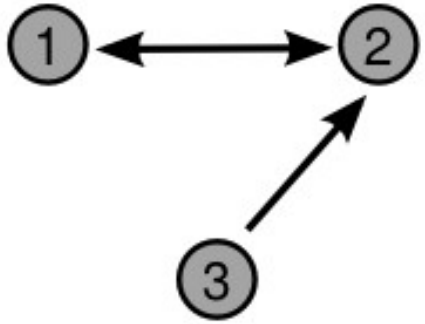
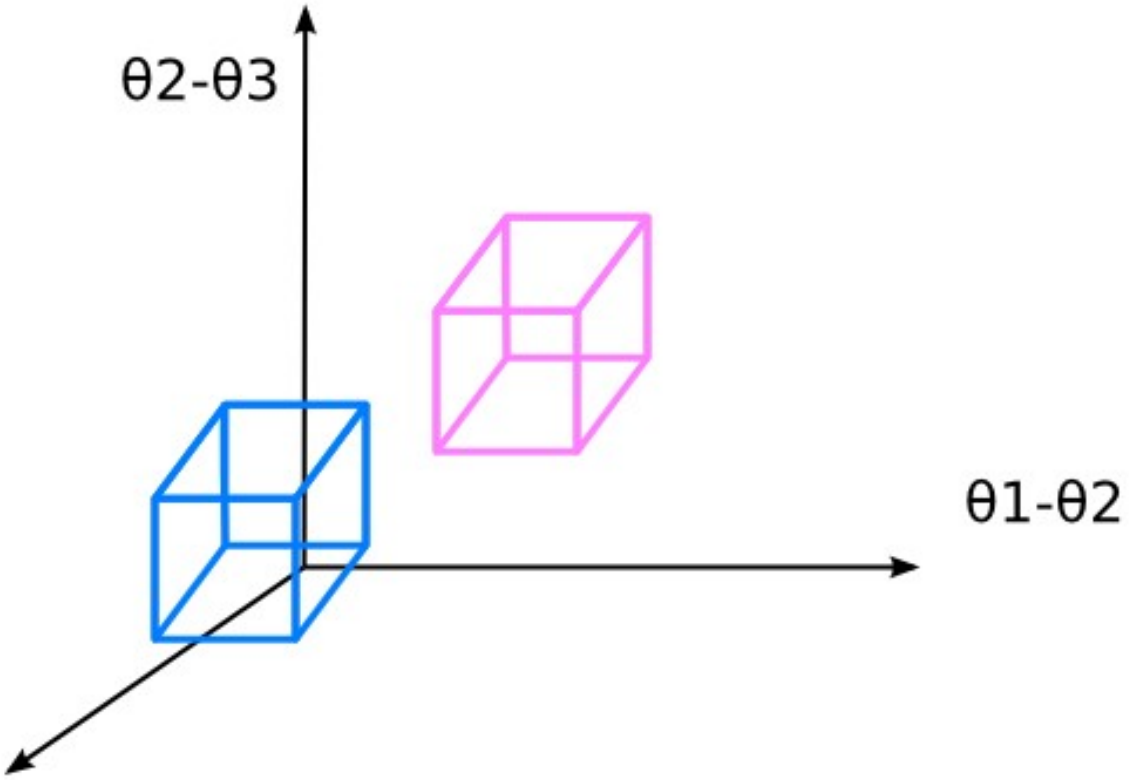


θ1-θ2 θ1-θ3 θ2-θ3
1 2 1



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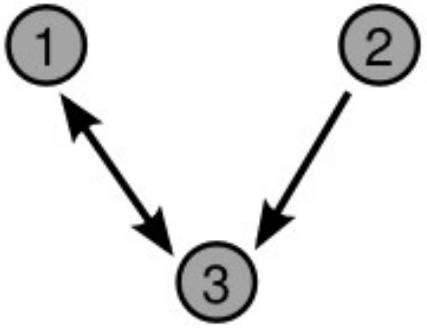
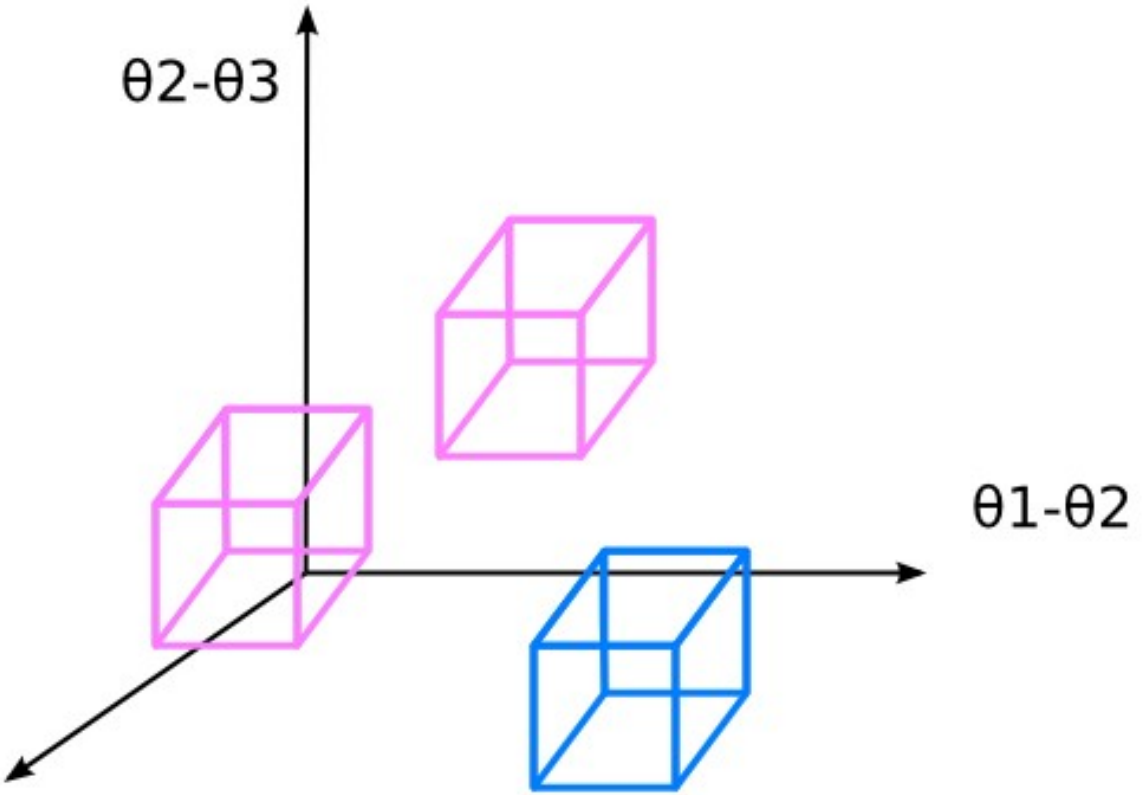


θ1-θ2 θ1-θ3 θ2-θ3
2 1 -1

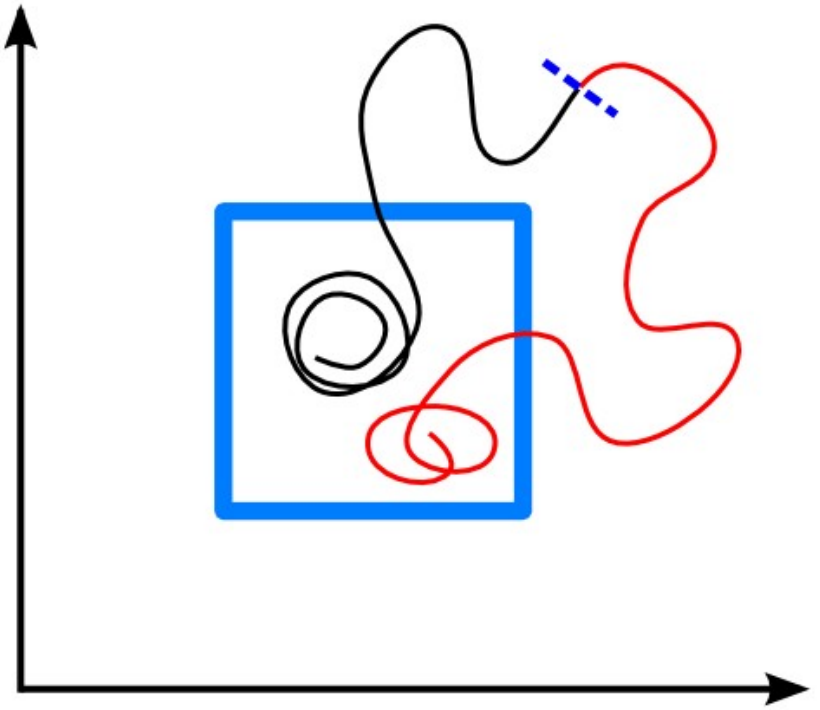


Preliminary Results

- We have replicated an phototactic agent with a homeostatic CTRNN controller with our model
- We are able to offer a solution to two different problems we identified in the original model

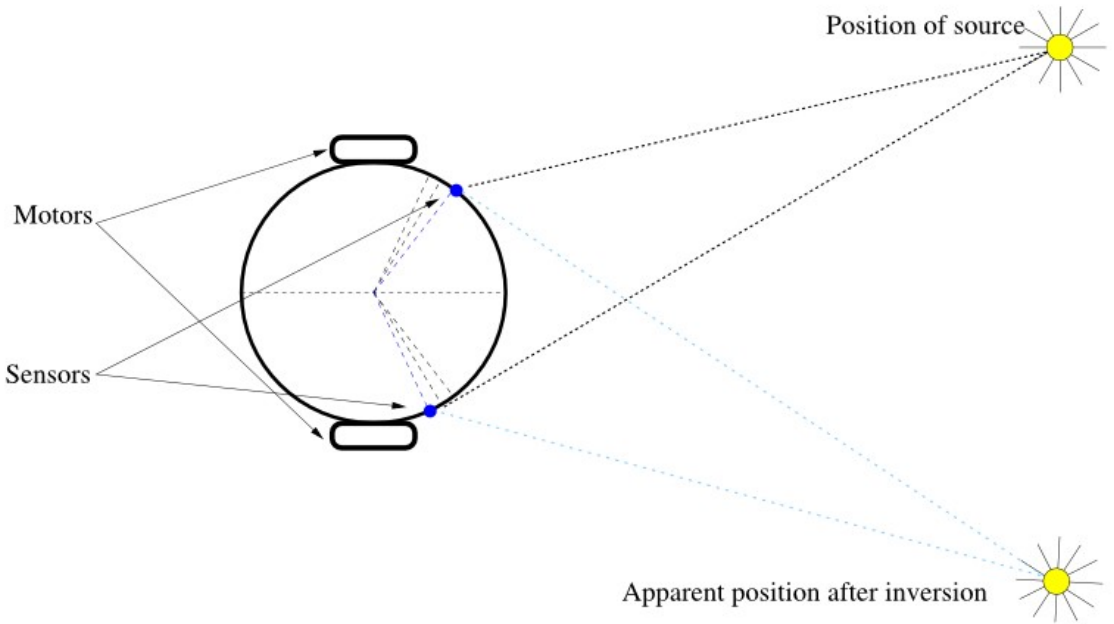
Problem 1

- When the system adapts to a new situation it loses previous adaptations
- Ashby proposed a "gating-mechanism" to channel the effect of essential variables in step mechanisms



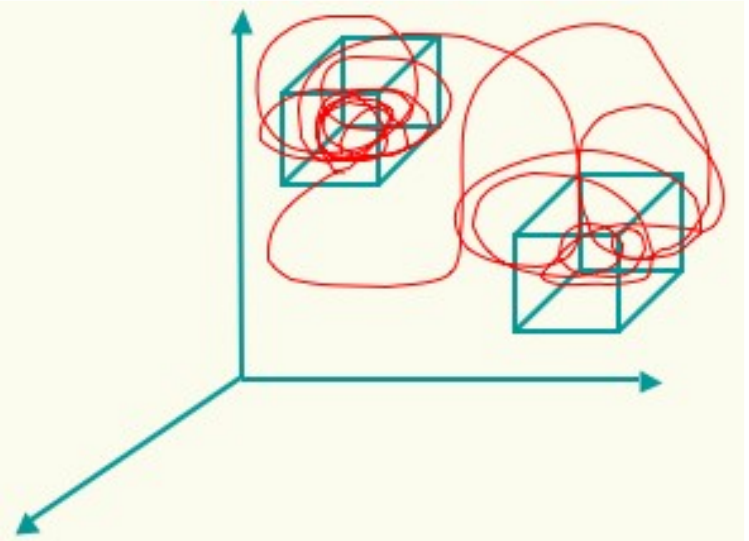
Visual Inversion Experiment

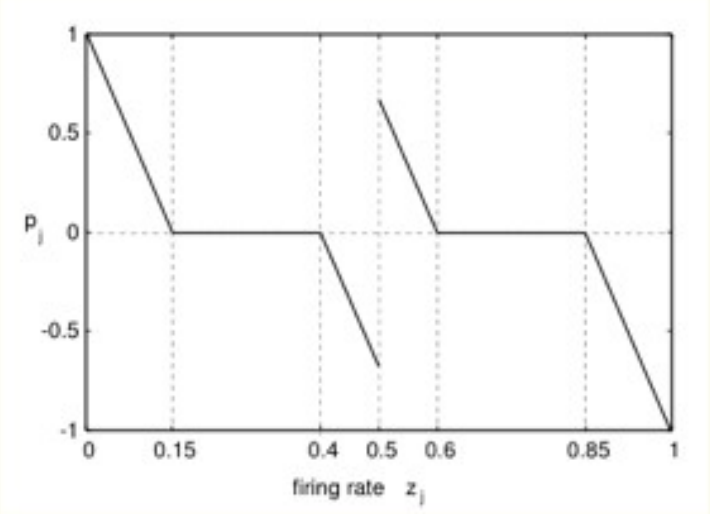
- An agent has to adapt to a situation of visual field inversion
- Our agent adapts much faster, and it is able to immediately recover initial adaptation



Problem 2

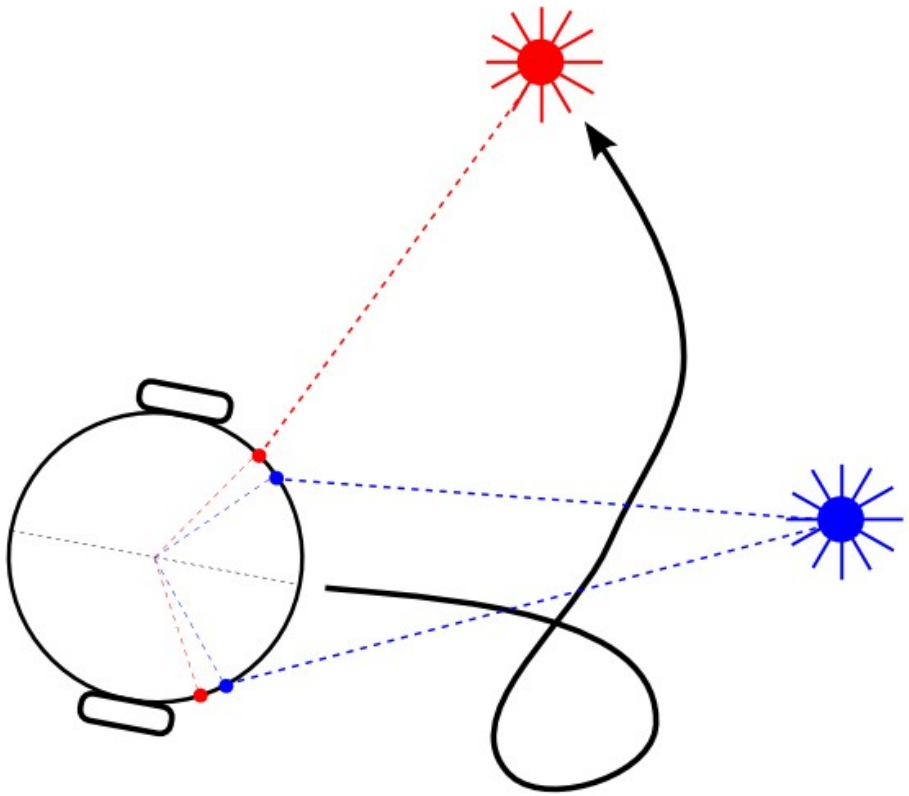
- If we want a system to choose between two different behaviours, we have to predefine the existence of different homeostatic regions (Iizuka & Di Paolo, 2007)



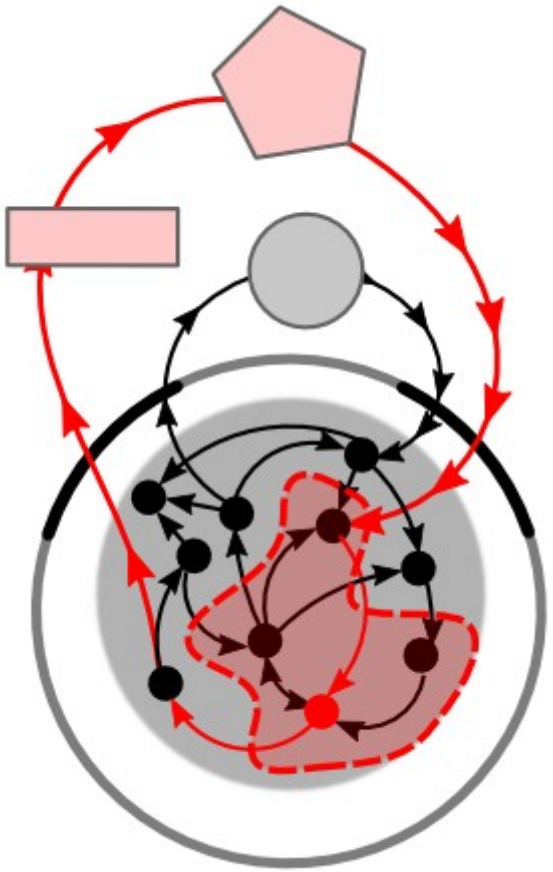


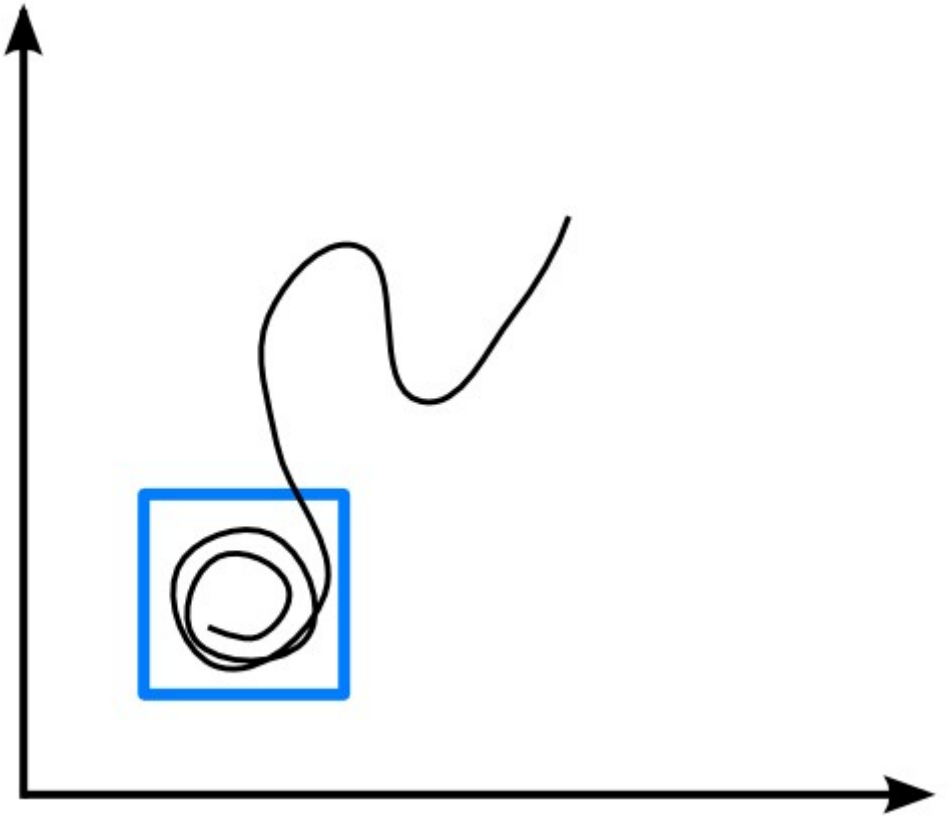
Preference Experiment

- An agent has to be able to develop a durable preference
- Preference is not codified by different homeostatic regions but different temporal configurations of one homeostatic region



Sensorimotor Channelling





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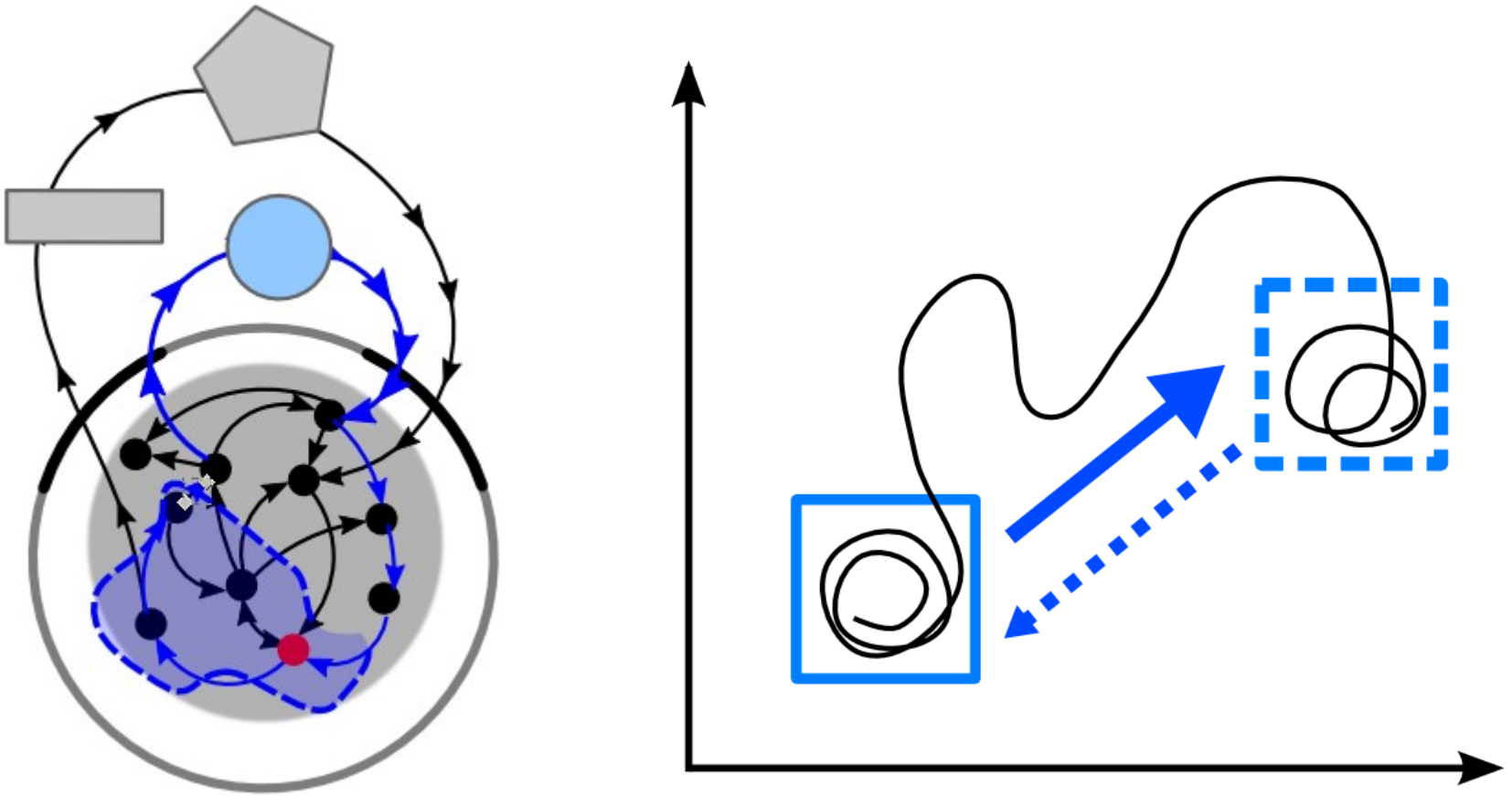
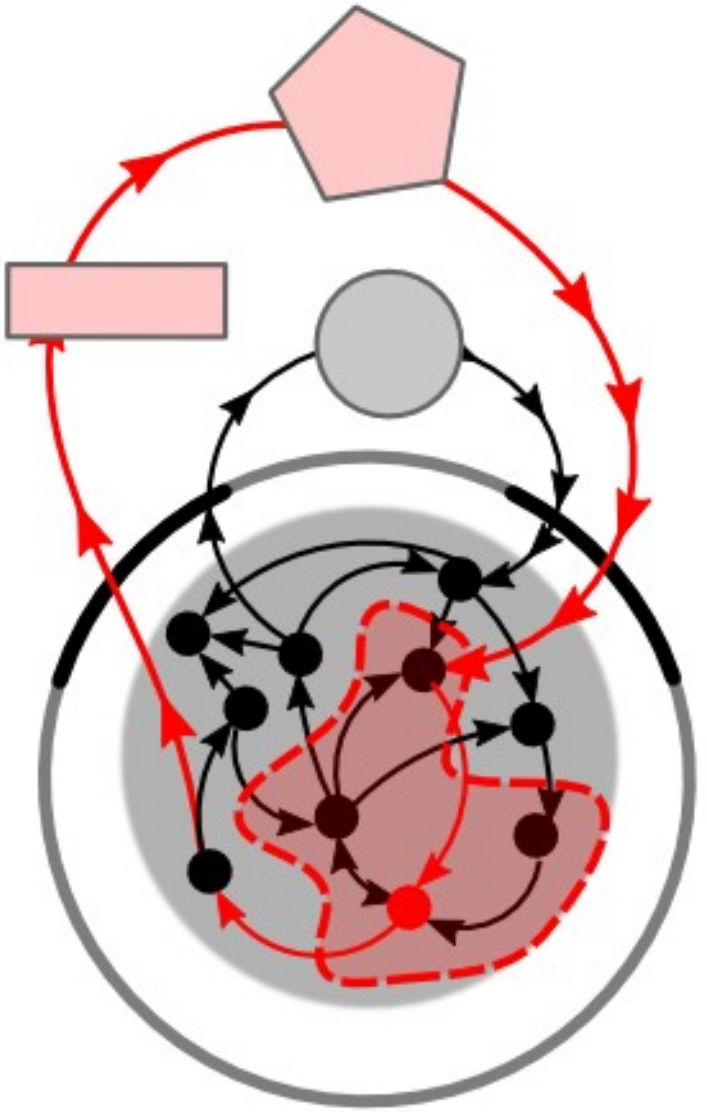


Future Work

- Autonomous Emergence of habits
- Neural assemblies and organization of behaviour
- The binding problem and binding-by-synchrony



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