On the Emergent Nature of Behaviour and Cognition

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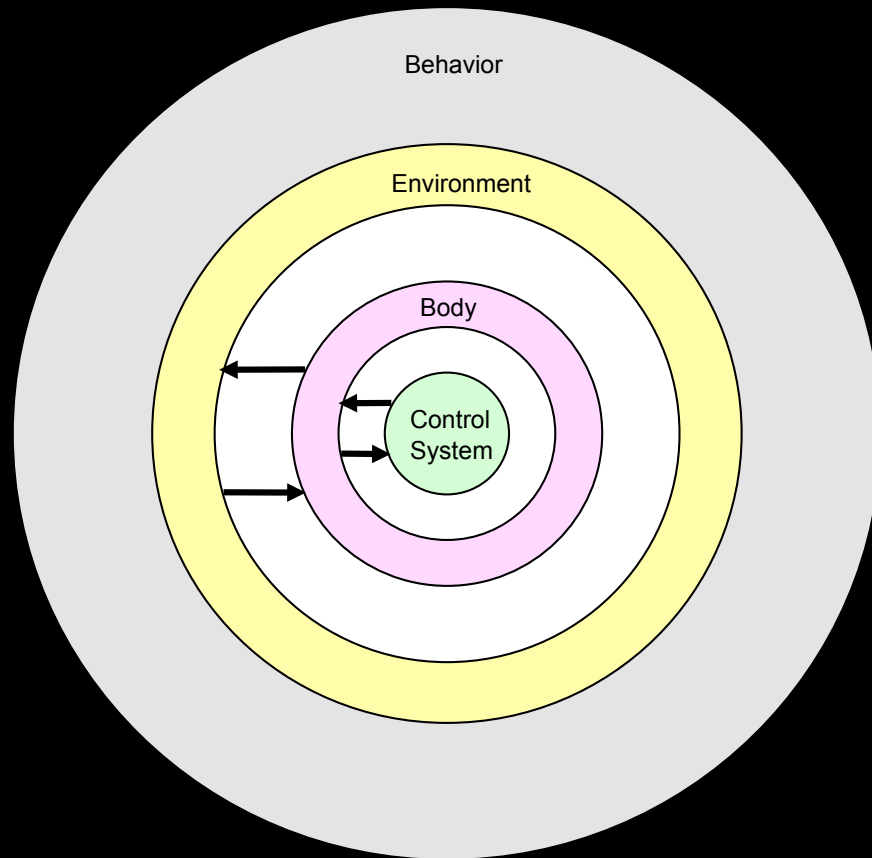
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# Behavior and cognition as emergent dynamical properties

The environment and the robot/environmental relation co-determine the body and the motor reaction of the robot that, in turn, co-determines how the environment and/or the agent/environmental relation changes

Sequences of interactions (occurring at a fast time rate) lead to dynamical processes – behaviors – that extend over a significant longer time scale

Behaviors and behavioral properties cannot be traced back to any of the three elements taken in isolation

How bipedal walking can emerge from the interaction between a passive body and an inclined terrain
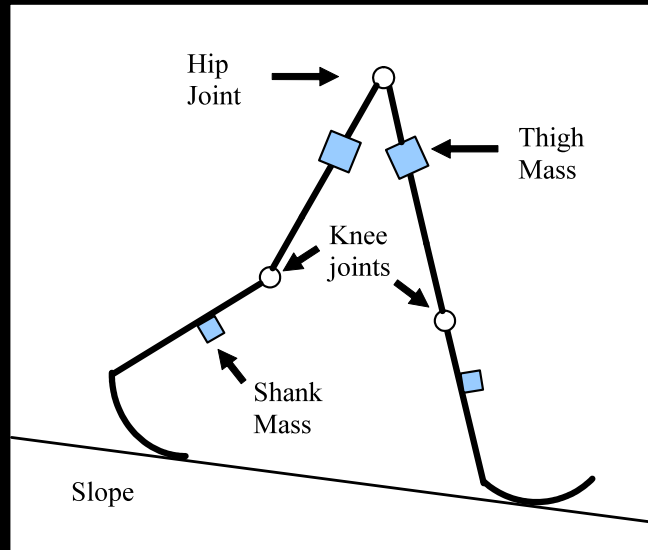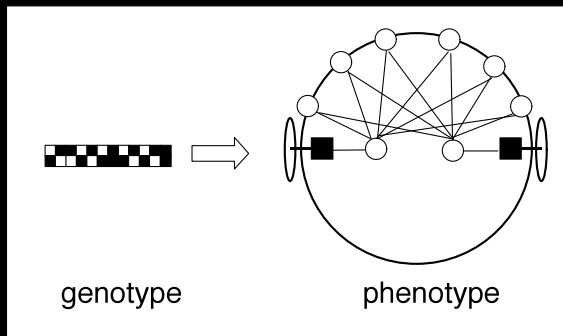

[McGeer, 1996]

[Collins, 2000']

The designer has carefully selected the length, the mass, and the size of the leg segments and of the foot in order to obtain the desired behavior.

As object categorization emerges from robot/ environmental interaction mediated by simple rules


genotype   phenotype

Fitness = time spent close to cylinders

6 infrared sensors, 2 motorized wheels

distances in mm

wall

cyli

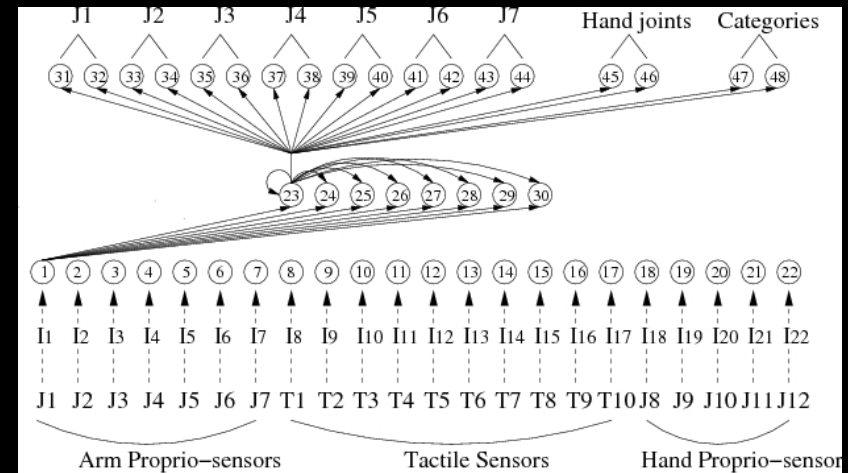relative orientations in degrees
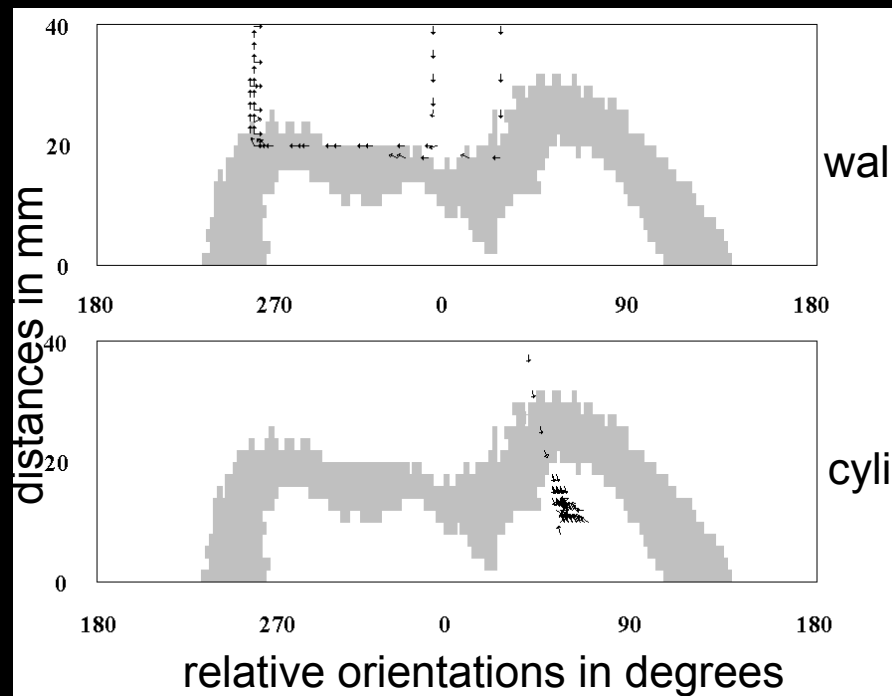
By tuning how much the robot turns left/right and forward/ backward depending on how the infrared sensors are activated lead to a behavioral attractor close to cylindrical but not close to wall objects.
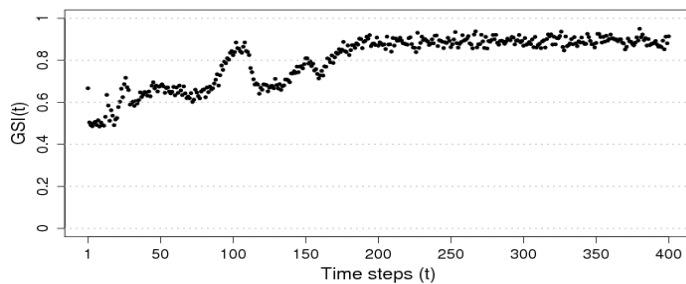
[Nolfi, 1996]

Active Categorical Perception
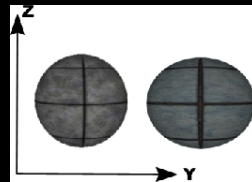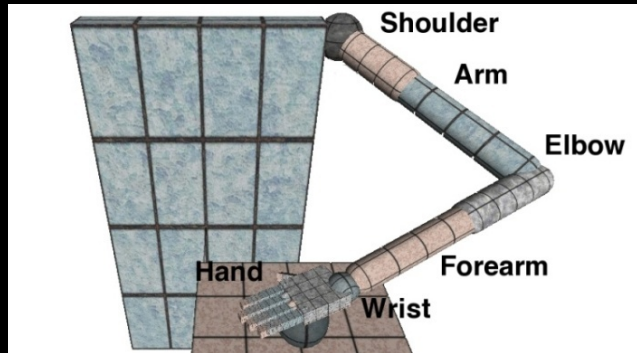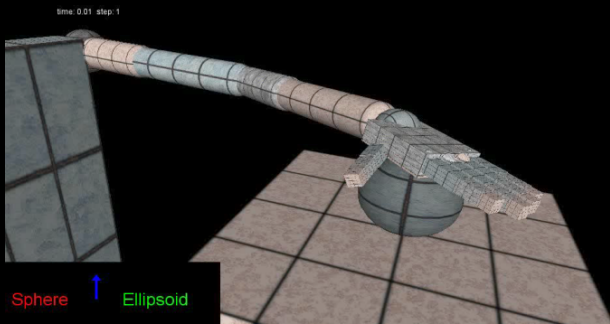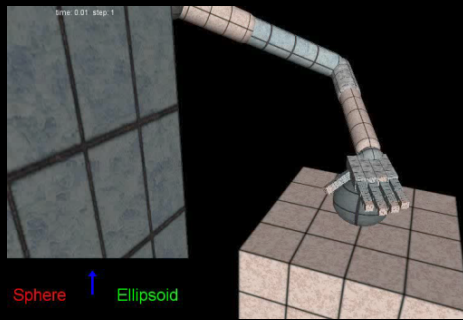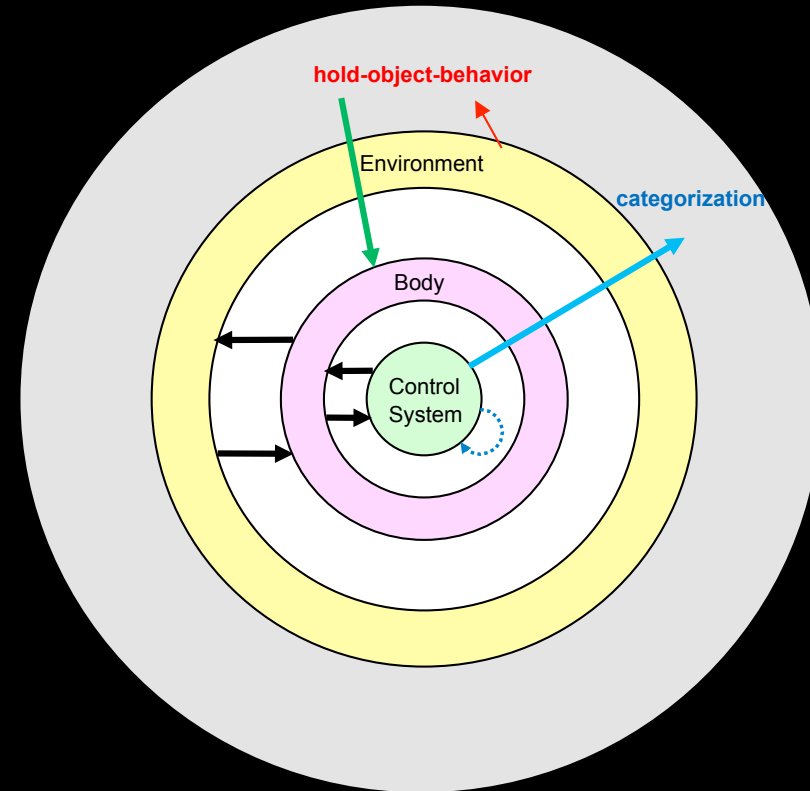

Evaluation criterion: (1) producing non-overlapping categorization outputs for object with different shapes, and (2) touching the object.

On the dynamics of the categorization process

Sphere   Ellipsoid

Sphere   Ellipsoid

hold-object-behavior

Environment

categorization

Body

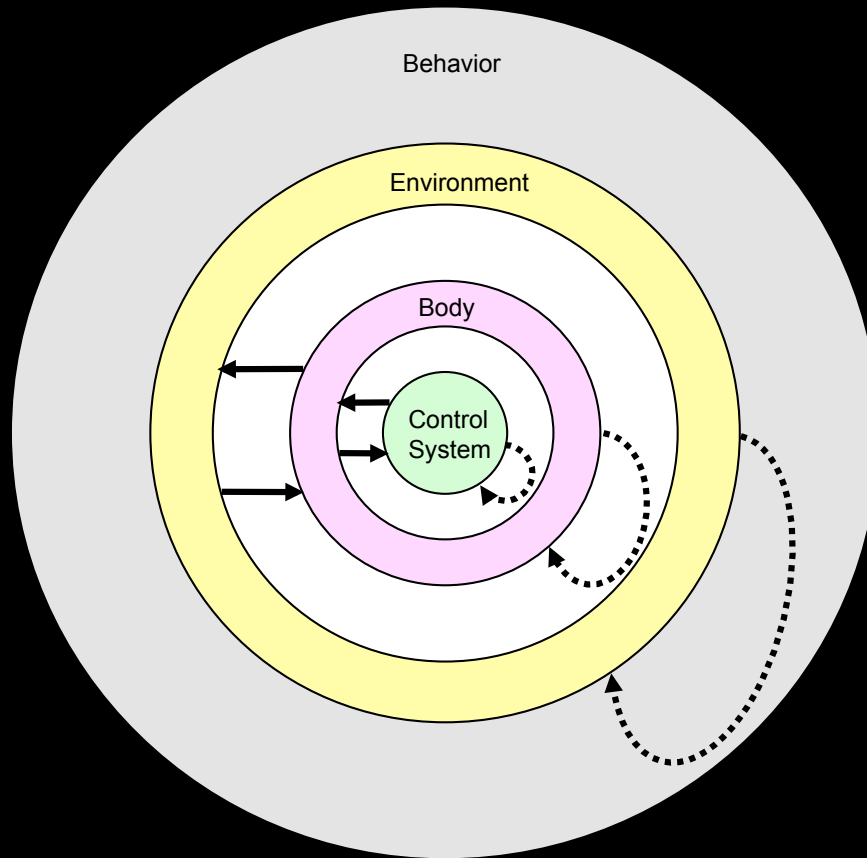Control System

separation of stimuli in sensory space

1) Robot/environmental interactions mediated by simple control rules give rise an hold-object behavior

2) Such behavior ensure that the robot later experience mostly discriminative stimuli (but also conflicting evidences)

3) The integration over time of the partially conflicting cue provide by these stimuli produce the categorization process

Tuci, Massera, Nolfi (2008, 2010)

Behavior and cognition as phenomena originating from the interaction between coupled dynamical processes

The external dynamic originates from the interaction between the control system, the body, and the environment

The internal dynamics originates from the interaction occurring within the control system, the body, and the environment

The interaction between dynamical processes which have been co-adapted might lead to coupled dynamics (i.e. to dynamical properties that are co-shaped so to produce adaptive properties as a result of their interaction)

A robot capable of self-localizing in a maze-like environment
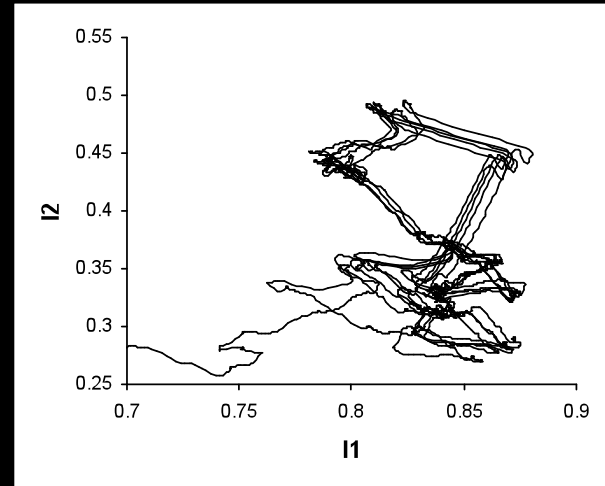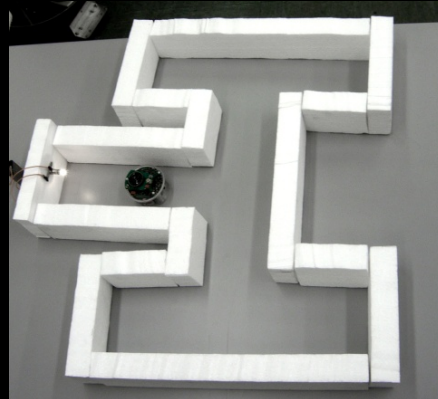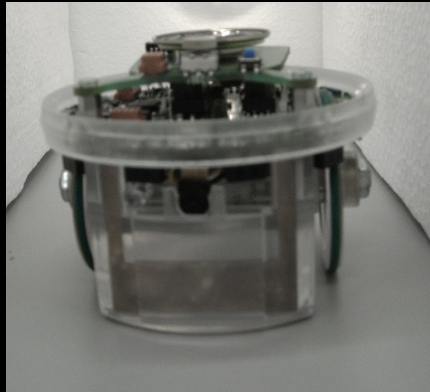
8 Infrared, 8 light sensors, 2 motors

Fitness = recognize previously visited locations

The internal dynamics consists of the inertial dynamic of robots' internal neurons

The agent/environmental dynamics consists in the alternation of few relatively stable sensory states lasting for different time duration

The coupling between the two dynamical processes originates from the fact that the free parameters that regulate the two dynamics and their interaction are co-adapted and co-shaped during the evolutionary process

[Gigliotta & Nolfi, 2007]

How a representation skill can emerge from the interaction between robot's internal and external dynamics
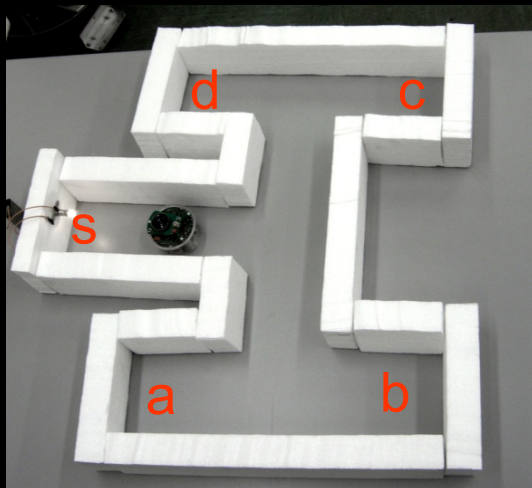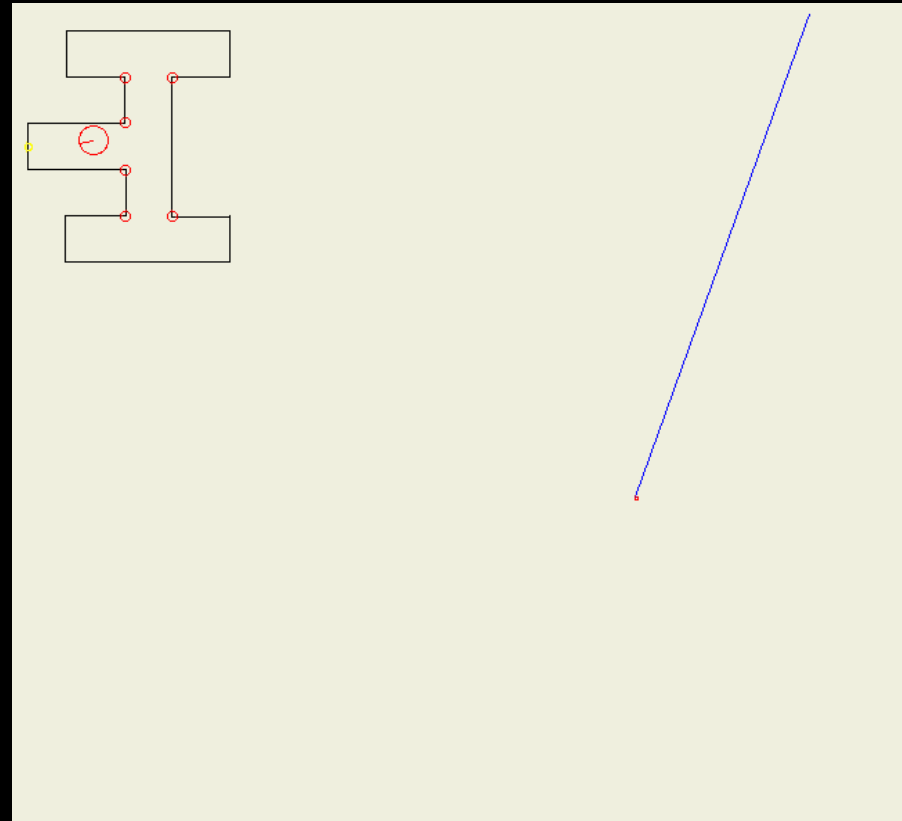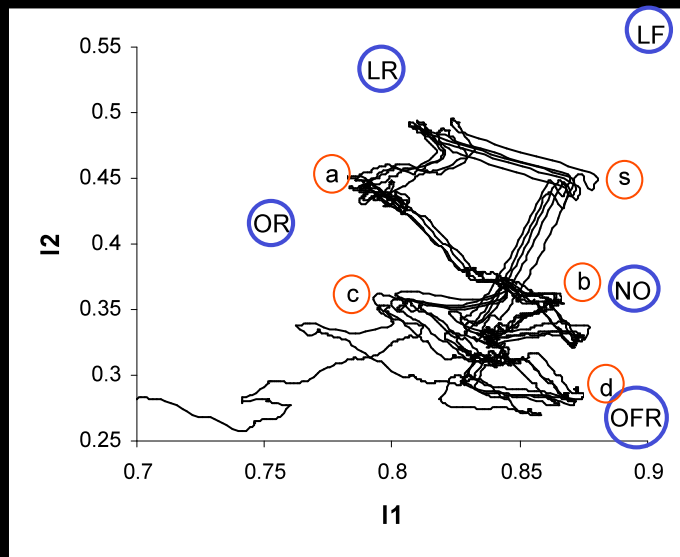
The limit cycle originates from the slow movement of the internal state toward the transient attractors that alternates while the robot move in the env.

[Gigliotta & Nolfi, 2007]