Challenges for A-Life Approach to Artificial Cognition: in Search for Hierarchy of Cognitive Systems

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Building artificial cognitive systems is a multidisciplinary endeavor, but the diversity of backgrounds and motivations make it difficult to formulate common objectives and challenges.

Three sets of motivations can be identified:

(i) engineering systems which have capabilities equivalent to biological systems, but which are based on different principles, (

(ii) engineering systems that use solutions that are close to biological materials and/or are bio-compatible,

(iii) building biologically-inspired systems in order to inform biology, to understand-by-construction, or to test biological hypotheses.

Not all features of biological systems may be relevant for cognition per se (e.g.,, (self-)construction, regeneration, reproduction, and evolution)

Cognition can be cast as sensorimotor coordination and requires embodiment.

Our objective here is to create a list of landmarks on the road towards artificial cognition that can be phrased in terms of incremental improvements, that would be welcoming evolutionary and developmental approaches, and that would allow, on one hand, mapping existing A-Life approaches, and on the other hand, well-known biological systems.

Relating the landmarks to biology can allow benchmarking and provide an intuition for implementation

Our first attempt for the list of challenges for cognitive systems (which specify the classes of systems that can meet them) is as follows:

1. *Sensing with feedback(s) to reach optima of environmental gradients.* Example: search/avoidance of objects that are sources of diffusive substances, agent placed at random position in the environment with random position of sources.

2. *Taking advantage of spatial/temporal structure of the environment*. This challenge requires an internal representation of the environment. Example: an agent able to learn the position of the objects in the environment or regularities of the neighborhood relations between objects and able to navigate on the map regardless of their initial position.

3. *Manipulating the external physical environment*. Example: an agent which stores objects belonging to different categories at different locations (biological motivation: internal storage limitations).

4. *Taking advantage of the regularities in the behavior of other agents.* Example: agent of type A which takes advantage of the fact that another agent in its environment, B, in certain situations is able to find objects of interest to A; A can follow B should such a situation arise.

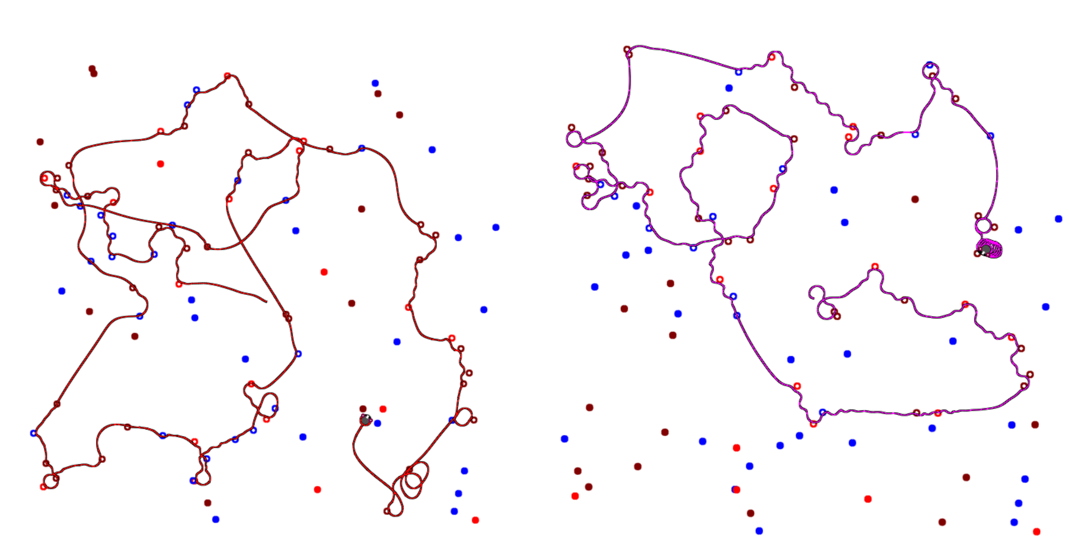
5. *Taking advantage of the knowledge about the cognitive abilities and limitations of other agents* in order to influence their behavior. For example, A would make B collect objects of interest to A. This challenge can be framed in an egoistic fashion or in a framework of cooperation (reciprocal altruism).

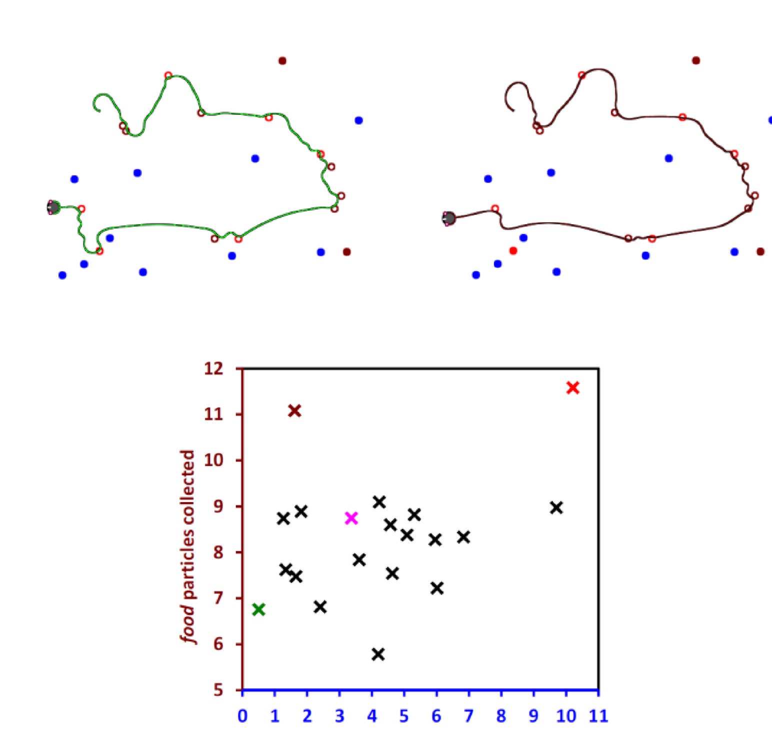
Increased computational abilities and memory capacity can allow for increased precision, for dealing with larger-scale problems, and for dealing with more uncertainty/noise/distractors.

Another dimension to a particular challenge can be added by considering the rate of change of the physical world relative to the temporal scale relevant to an individual agent (requiring higher abilities for learning /adaptation/plasticity

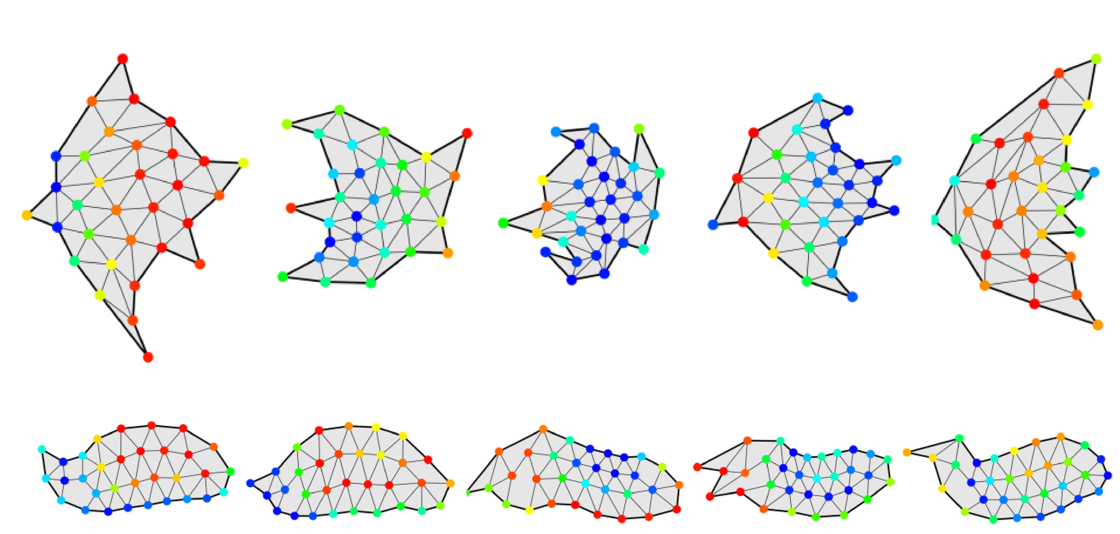
In our work, we use an Artificial Life platform, GReaNs (which stands for Gene Regulatory evolving artificial Networks) to investigate the evolution of simple behaviour of modelled unicellular and multicellular organisms controlled by gene regulatory networks (we are now working to include cell differentiaton to artificial neurons).

Please refer to our webpage (www.evosys.org) for details, here are some figures from recent papers:





Multiple foraging strategies for two resources (*food* and water) of unicellular 2-dimenional animats whose behaviouris controlled by evolved artificial gene regulatory network.



Two examples of morphologies of multicellular 2-dimenional animats whose locomotion is controlled by an artificial gene regulatory network.