

Artificial Life

(+ swarm robotics
& embodied evolution)

solving problems by looking at nature

Iñaki Fernández Pérez
Postdoctoral Researcher Univ. Toulouse
fernandezperez.inaki@gmail.com
[@InakiFdezPerez](https://twitter.com/lnakiFdezPerez)

Iñaki Fernández Pérez

Me

- B.Sc. CS Valladolid, ES (06-10)
- Erasmus Nancy, FR (10)
 - Semantic Web, ...
- Research Engineer (10-11)
- M.Sc. Artificial Int. (11-13)
- Ph.D. Collective Rob. (13-17)

My circumstance

- Postdoc. researcher
 - Univ. Toulouse 3
- Bioinsp. optimization and more
 - Depl. intervention teams
 - Collective robot behavior
 - Comunic. in bact. colonies
- Vice chair ISALStud. group
 - Intern. Soc. for Artif. Life
- Teaching, outreach, pedagogy



Structure of this talk

- What is nature? Examples
- What is Artificial Life? Examples
- Swarm Robotics + Embodied Evolution
- My global view on Artificial Life

In nature, we look for....

- 1) Patterns 2) Self-organization

Let's see some examples....





Hopetoun Falls, Victoria, Australia (Wikimedia Commons)





Cañón del Río Lobos, Soria, Spain (Wikimedia Commons)





Rice Terraces, Bali, Indonesia (Wikimedia Commons)





Rinjani Volcano Eruption (1994), Lombok, Indonesia (Wikimedia Commons)



Metal casting (Wikimedia Commons)





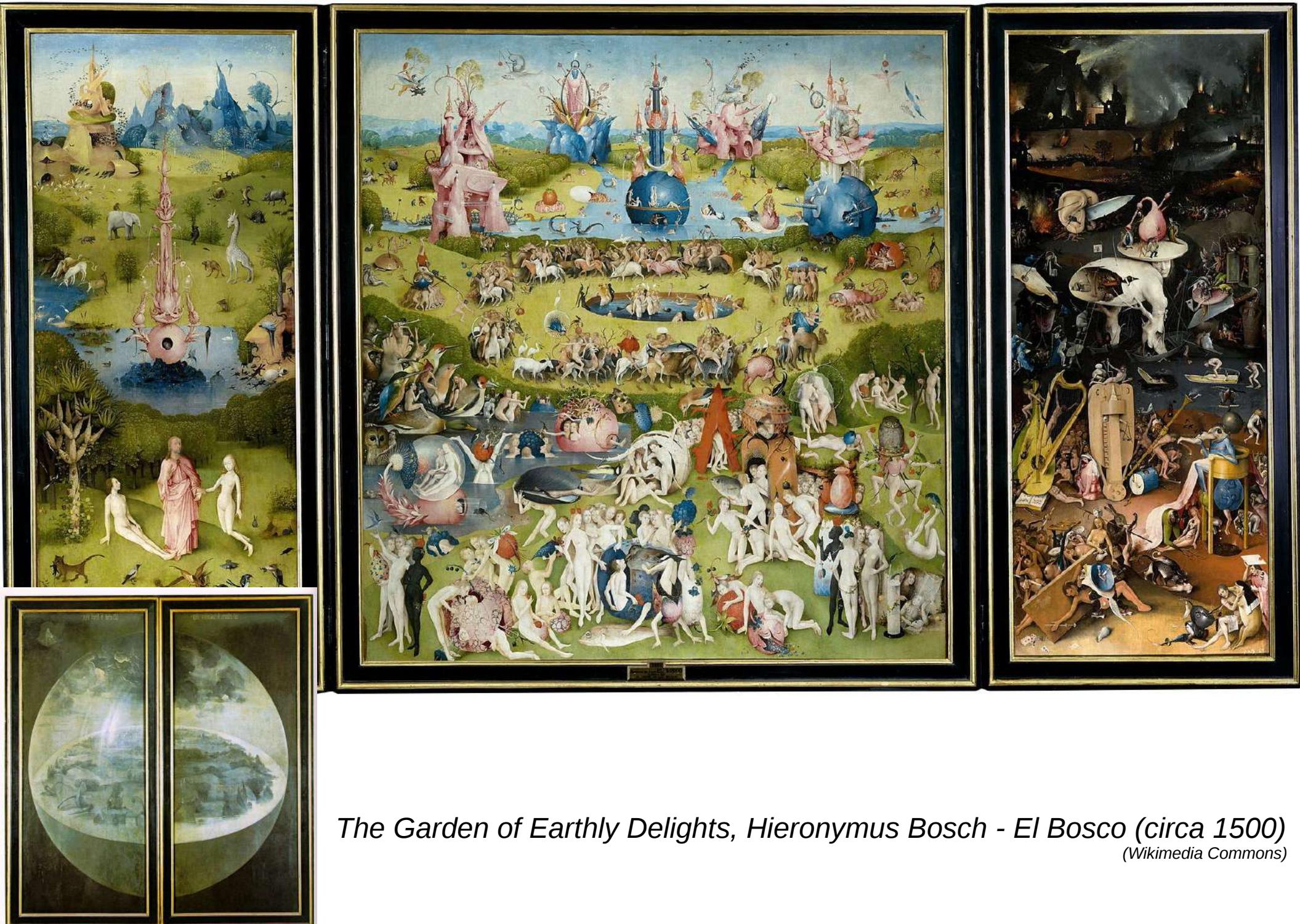
La Cistérniga (winter 2009), Valladolid, Spain (Wikimedia Commons)



27 sept. 2018

Artificial Life, Swarm Robotics, Embodied Evolution

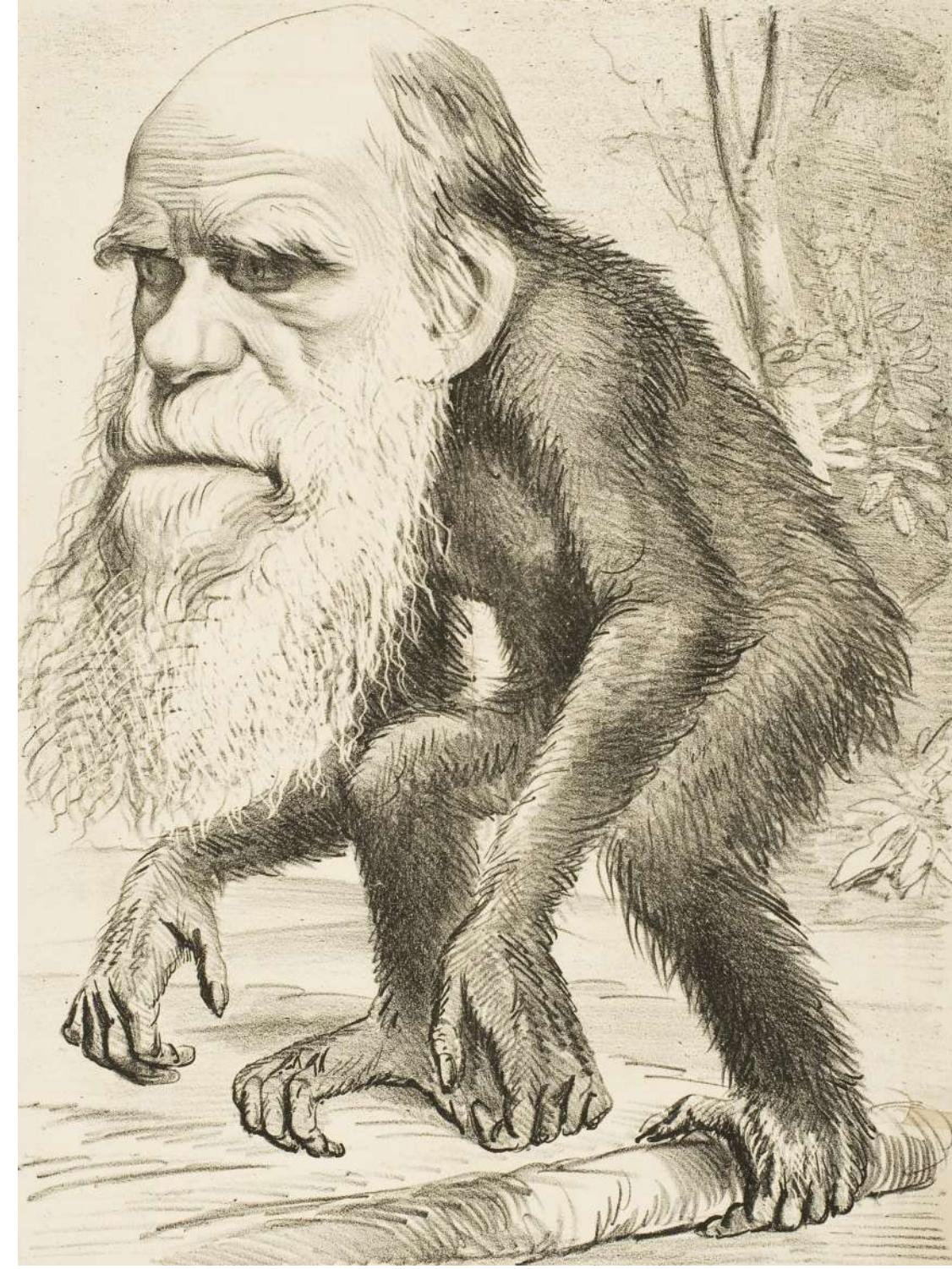
18/74



The Garden of Earthly Delights, Hieronymus Bosch - El Bosco (circa 1500)
(Wikimedia Commons)



Reconciling Science [and Religion], Harishbabu Laguduva, 2013 (Wikimedia Commons)



ON
THE ORIGIN OF SPECIES

BY MEANS OF NATURAL SELECTION,

OR THE

PRESERVATION OF FAVOURED RACES IN THE STRUGGLE
FOR LIFE.

By CHARLES DARWIN, M.A.,

FELLOW OF THE ROYAL, GEOLOGICAL, LINNÆAN, ETC., SOCIETIES;
AUTHOR OF 'JOURNAL OF RESEARCHES DURING H. M. S. BEAGLE'S VOYAGE
ROUND THE WORLD.'

LONDON:
JOHN MURRAY, ALBEMARLE STREET.
1859.

The right of Translation is reserved.



Flock of starlings (murmuration) (Wikimedia Commons)



Fire ant raft ([Wikimedia Commons](#))



Bait ball (Wikimedia Commons)



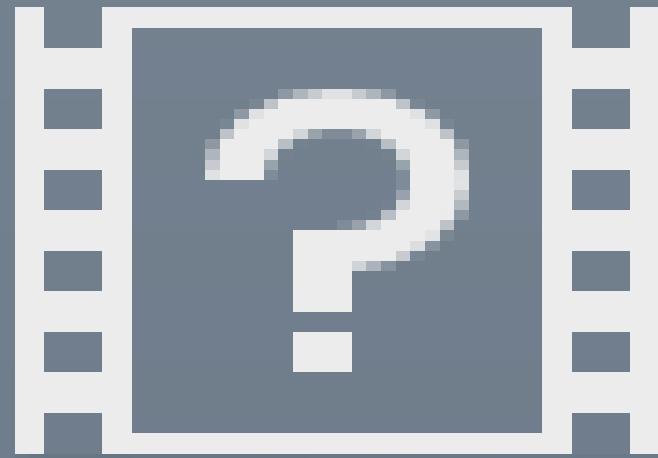
Bee hive (Wikimedia Commons)



Ant bridge (Wikimedia Commons)



Shibuya crossing, Tokyo, Japan, 2018



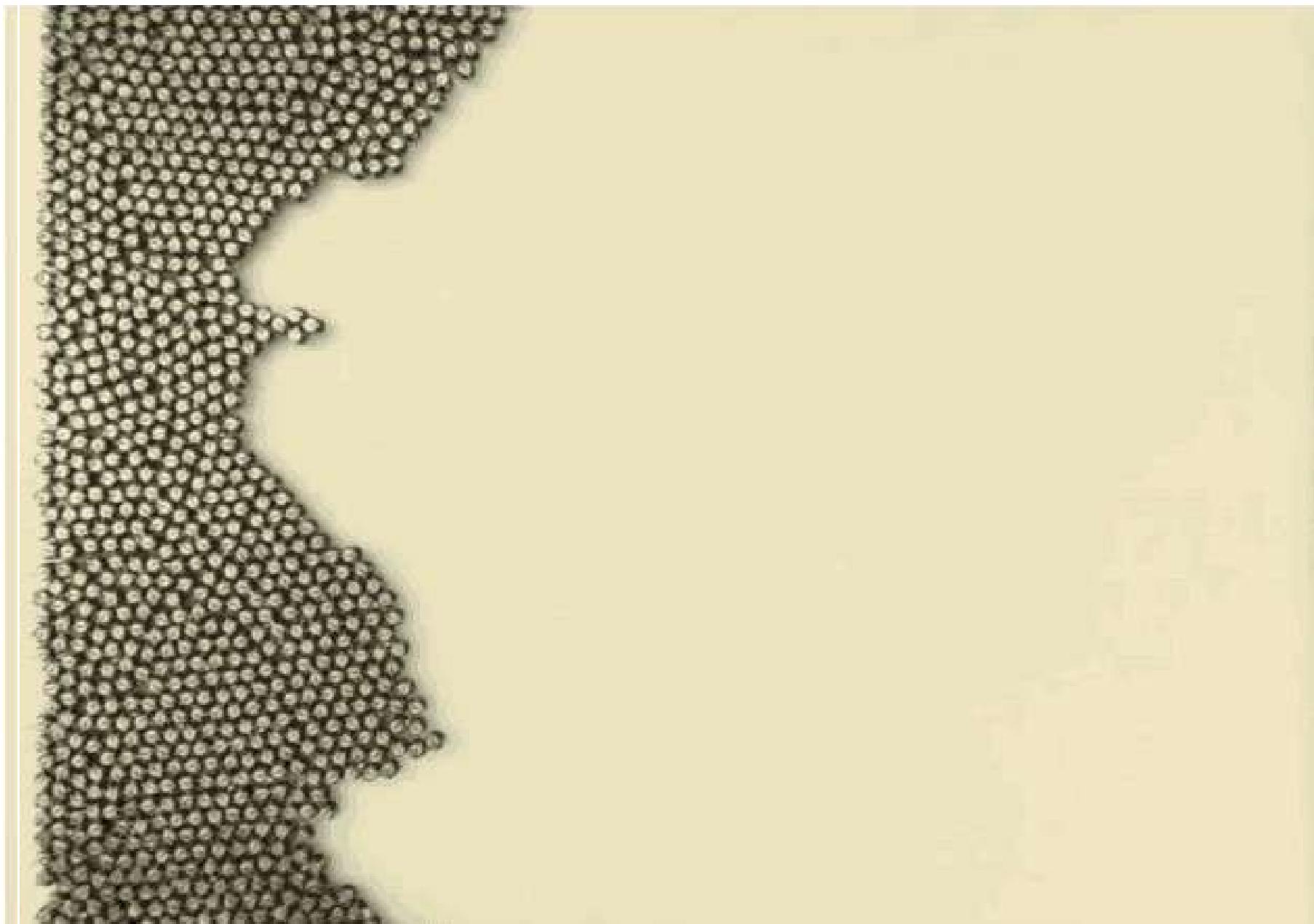
Posted on Twitter by Francisco Boni (@boni_bo)



Kilobots, Radhika Nagpal Self-organizing Systems group, Harvard



Me, playing with the toys during my Ph.D. at LORIA/Inria lab



Self-organizing kilobots forming a star shape, Nagpal lab



Semi bug (cicada), Chiyoda, Tokyo, Japan, 2018



Dung beetles fighting (Wikimedia Commons)

So....

What is Artificial Life?

Some videos....



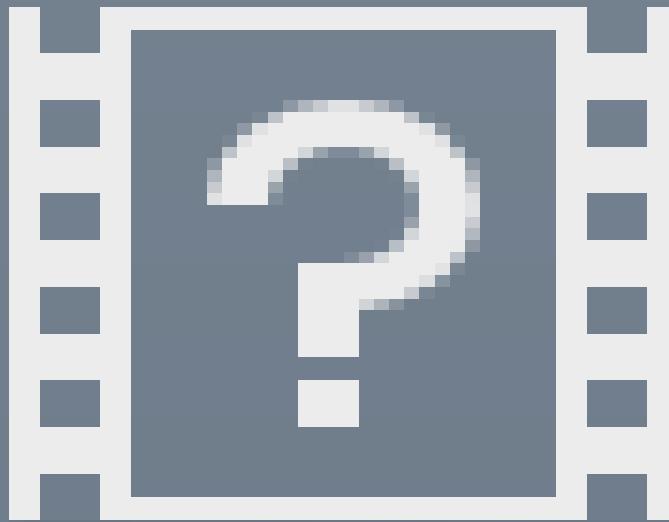
ALIFE 2018 @alifelab . 27 juil.

ALIFE 2018 has just finished!

We appreciate your support and cooperation!!!

#alife #ALife2018

2018.alife.org



(not really Alife per se) Spot Robot, Boston Dynamics
<https://www.youtube.com/watch?v=M8YjvHYbZ9w>



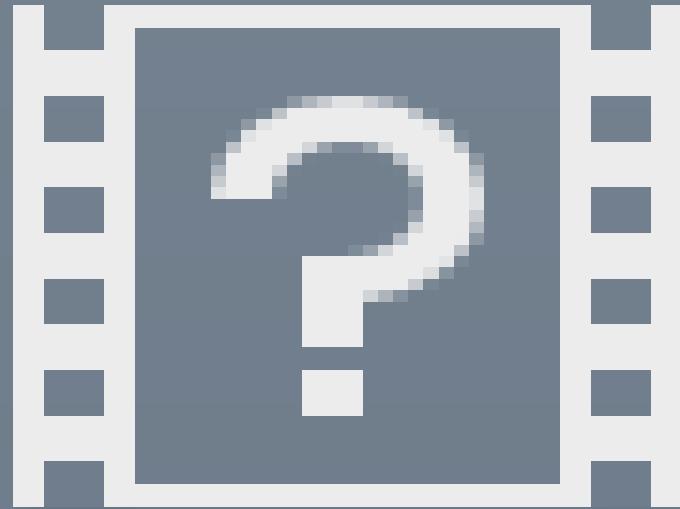
Maruyama, N., Hashimoto, Y., Mototake, Y., Saito, D., & Ikegami, T. (2017). Revisiting Classification of Large Scale Flocking. In SWARM 2017 (pp. 307–310)

Thanks to Lana Sinapayen for providing the support

W. Noguchi, H. Iizuka, and M. Yamamoto, Adaptive Behavior 25.3 (2017): 129-146
Cognitive map self-organization from subjective visuomotor experiences in a hierarchical recurrent neural network

Thanks to Wataru Noguchi for providing the support

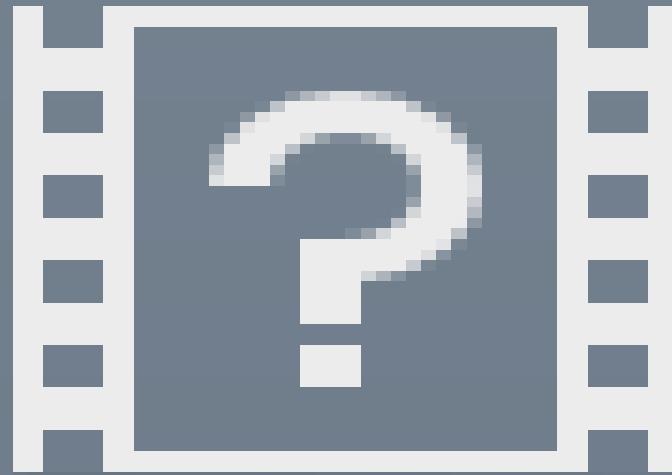
Artificial Life, Swarm Robotics, Embodied Evolution



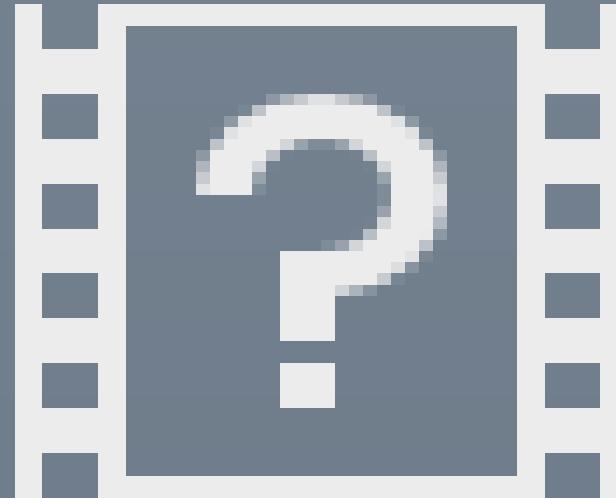
Hiroki Sayama, 2018 Conference on Artificial Life, Tokyo, Japan
Seeking Open-Ended Evolution in Swarm Chemistry II: Analyzing Long-Term Dynamics via Automated Object Harvesting
Thanks to Penny Faulkner Rainford for providing the support



Autonomously Shaping Natural Climbing Plants: A Bio-hybrid Approach
M. Wahby, M. K. Heinrich, D. N. Hofstadler, E. Neufeld, I. Kuksin, P. Zahadat, T. Schmickl, P. Ayres, H. Hamann
Royal Society Open Science 2018
Thanks to Payam Zahadat for providing the support

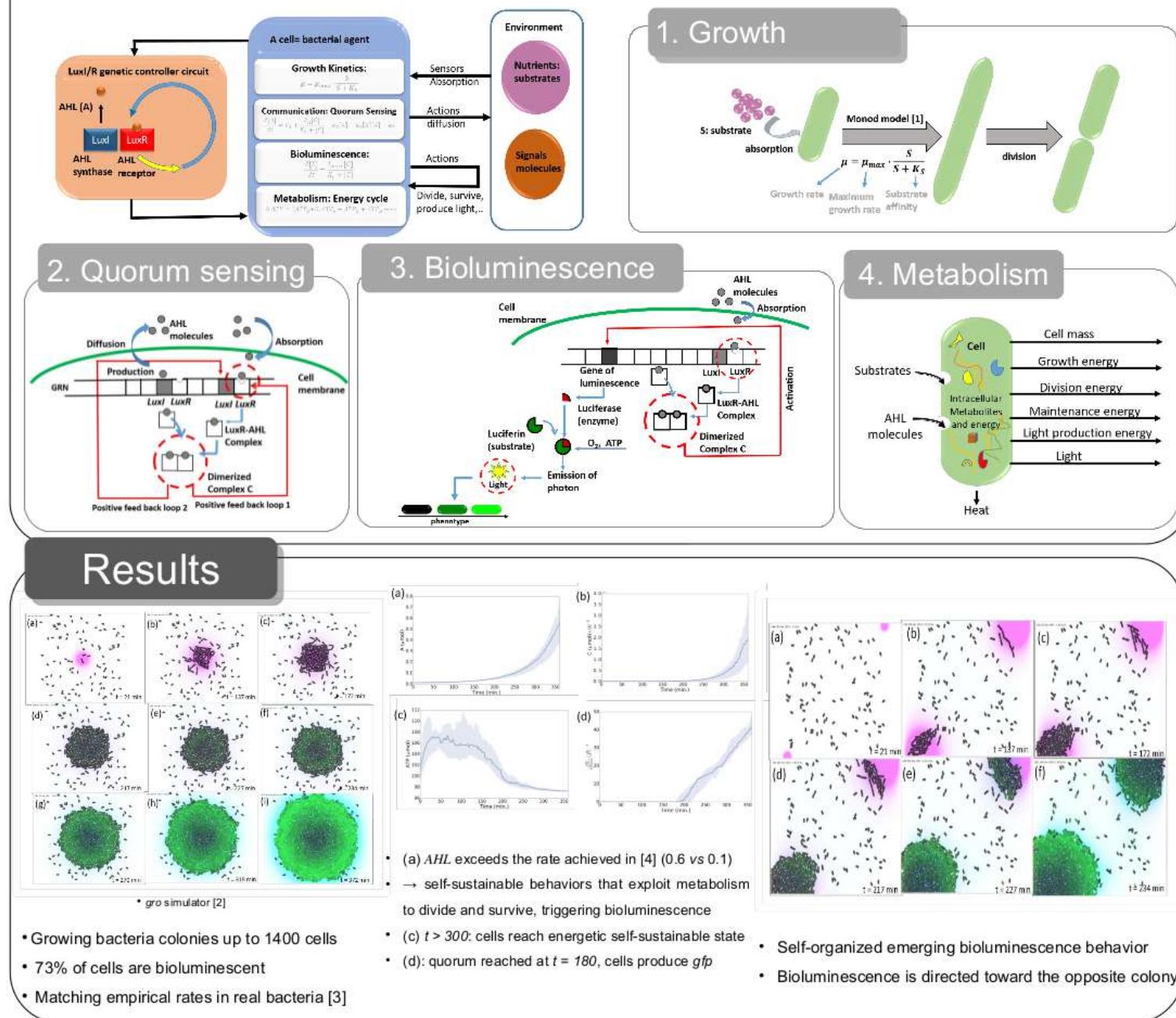


*subCULTron project - Cultural Development as a Tool in Underwater Robotics, T. Schmickl et al.
<http://www.subcultron.eu/>*
Thanks to Payam Zahadat for providing the support



*H. Haraldsen Roen, B. Bocquillon, S. Hoebeke, S. Nichele, K. Bergaust, H. Dahlsveen, H. Lieng
Emergence of Collective Intelligence: an Artificial Pheromone-Based Swarm Robotic System
The 3rd Open Fields Conference, RIXC Art Science Festival 2018 (IN PRESS)
Thanks to Stefano Nichele for providing the support*

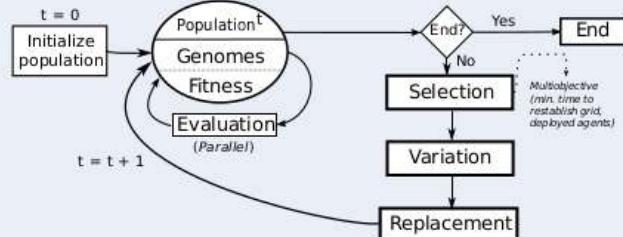
Computational agent-based model



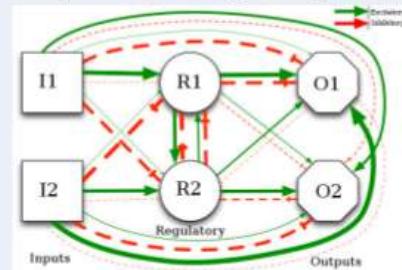
Simulation of Bioluminescent Bacteria Colonies Tweeting via Quorum-Sensing Molecules,
Djezzar, Fernández Pérez et al., late-breaking poster at Alife 2018



EA: blind variations + selection pressure



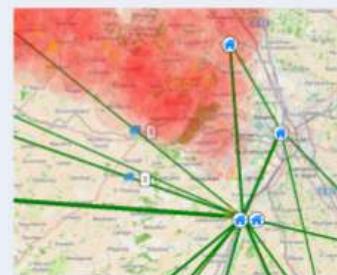
Example of Gene Regulatory Network



An storm approaches from the west
generating failures over the grid



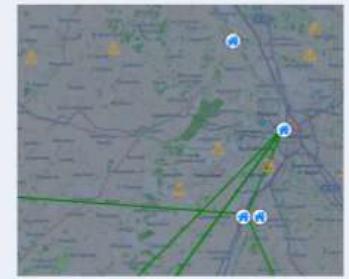
An evolved GRN controller reads the state of the system and decides the teams to allocate to the bases



Teams are deployed and progressively repair the failures on the grid



The teams return to the bases at night,
with nearly every failure repaired



Evolved GRN controllers are able to repair failures and restore power faster while deploying slightly fewer teams than the standard policy typically used



Dynamic Resource Allocation using Evolving Gene Regulatory Networks, Fernández Pérez et al., late-breaking poster at Alife 2018

Learning Collaborative Foraging in a Swarm of Robots using Embodied Evolution

Iñaki Fernández Pérez, Amine Boumaza, François Charpillet

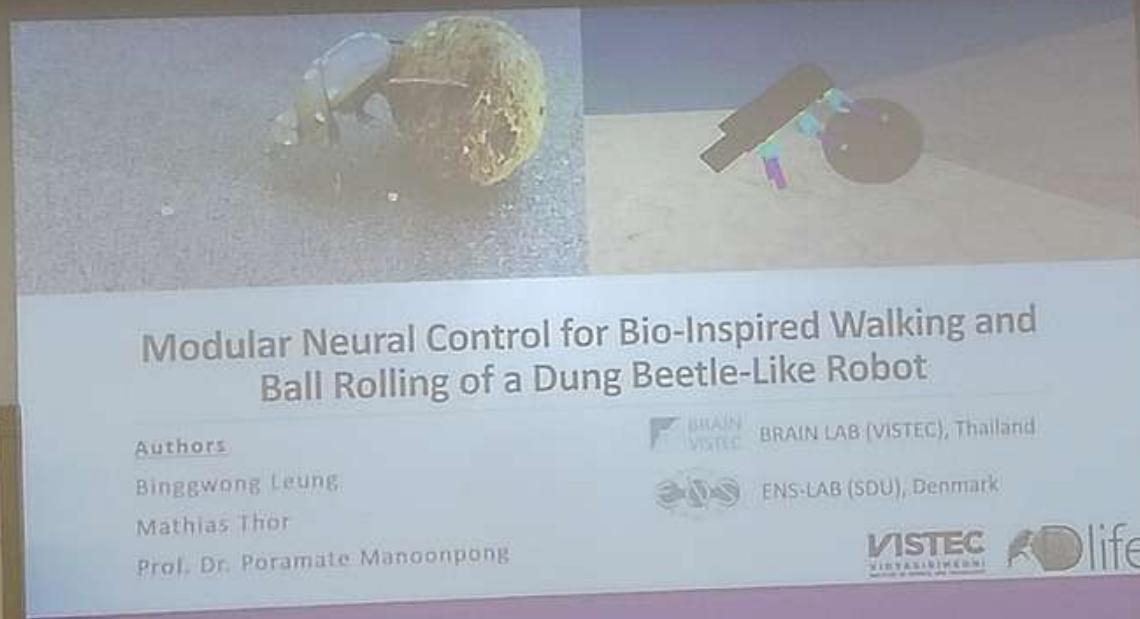
Université de Lorraine, Inria Nancy Grand-Est

Nancy (France)

Paper at ECAL 2017, Lyon (France)



*Learning Collaborative Foraging in a Swarm of Robots using Embodied Evolution
I. Fernández Pérez et al. ECAL 2017, Lyon
Nominated to best paper award at ECAL17 Lyon (4 nominees among 100+ papers)*

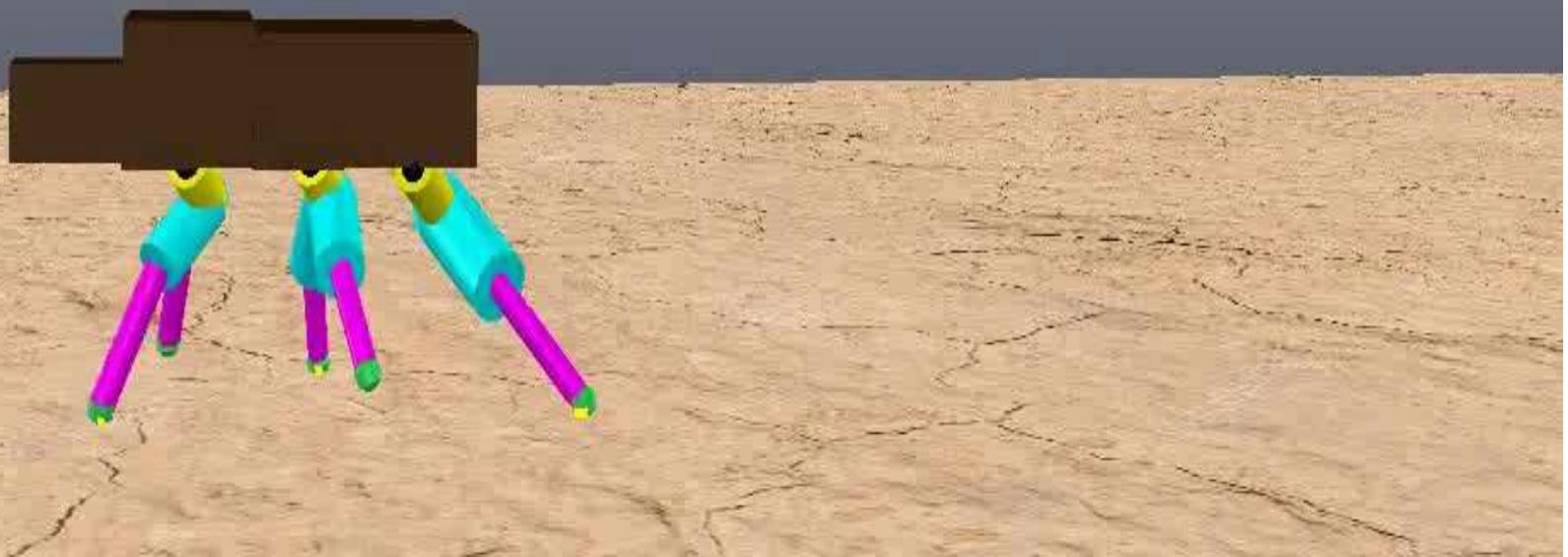


Iñaki Fernández Pérez @InakiFdezPerez · 26 jul.

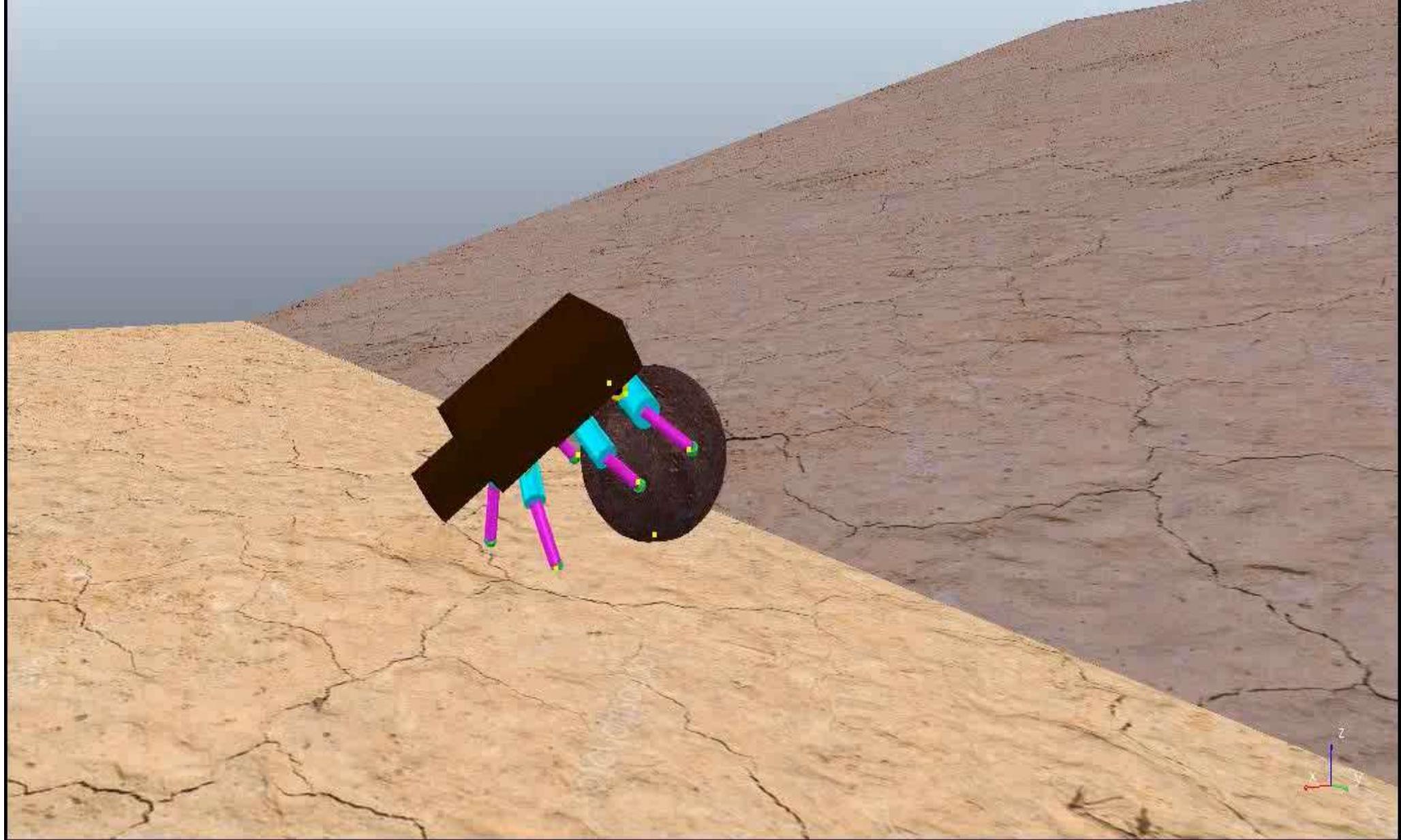
Binggwong Leung creating robots inspired by dung beetles: impressively innovating idea, and he managed to get several useful behaviors, such as roll a ball... And "a dung is a shit" ^^ #alife2018



Leung, B., Thor, M., & Manoonpong, P. (2018).
Modular Neural Control for Bio-Inspired Walking and Ball Rolling of a Dung Beetle-Like Robot.
2018 Conference on Artificial Life, Tokyo, Japan (pp. 335–342)



Leung, B., Thor, M., & Manoonpong, P. (2018).
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Modular Neural Control for Bio-Inspired Walking and Ball Rolling of a Dung Beetle-Like Robot.
2018 Conference on Artificial Life, Tokyo, Japan (pp. 335–342)
Thanks to Binggwong Leung for providing the support

Computational Understanding of Mental Development

From Behavioral Learning to Language Acquisition



- A human child acquires many physical skills, concepts, and knowledge, including language, through physical and social interaction with his/her environment.
- How do we become able to communicate via symbols?
- We'd like to obtain an understanding of the **computational process** of mental development and language acquisition.

Constructive approach

Develop robotic and computational models to better understand the original

Symbol Emergence in Robotics



Iñaki Fernández Pérez @InakiFdezPerez . 25 juil.

"I've never installed any computer library in their head" Tadahiro Taniguchi about his children's language acquisition process  #alife2018

Tadahiro Taniguchi about Symbol Emergence at EVOSLACE workshop, Alife 2018

Examples of applied ALife

- Neural nets (~1955-...), deep learning (~2005-...)
 - Classification, identification, decision, regulation,....



- Design *via* genetic algorithm (e.g. antenna Hornby et. al.)

- Deployed in 3 NASA satellites (2006)



- Other metaheuristic optimization algorithms

- *Ant Colony Optimization, Artificial Immune Systems, Particle Swarm Optimization*

- Annual *HUMIES* competition at *GECCO* conference

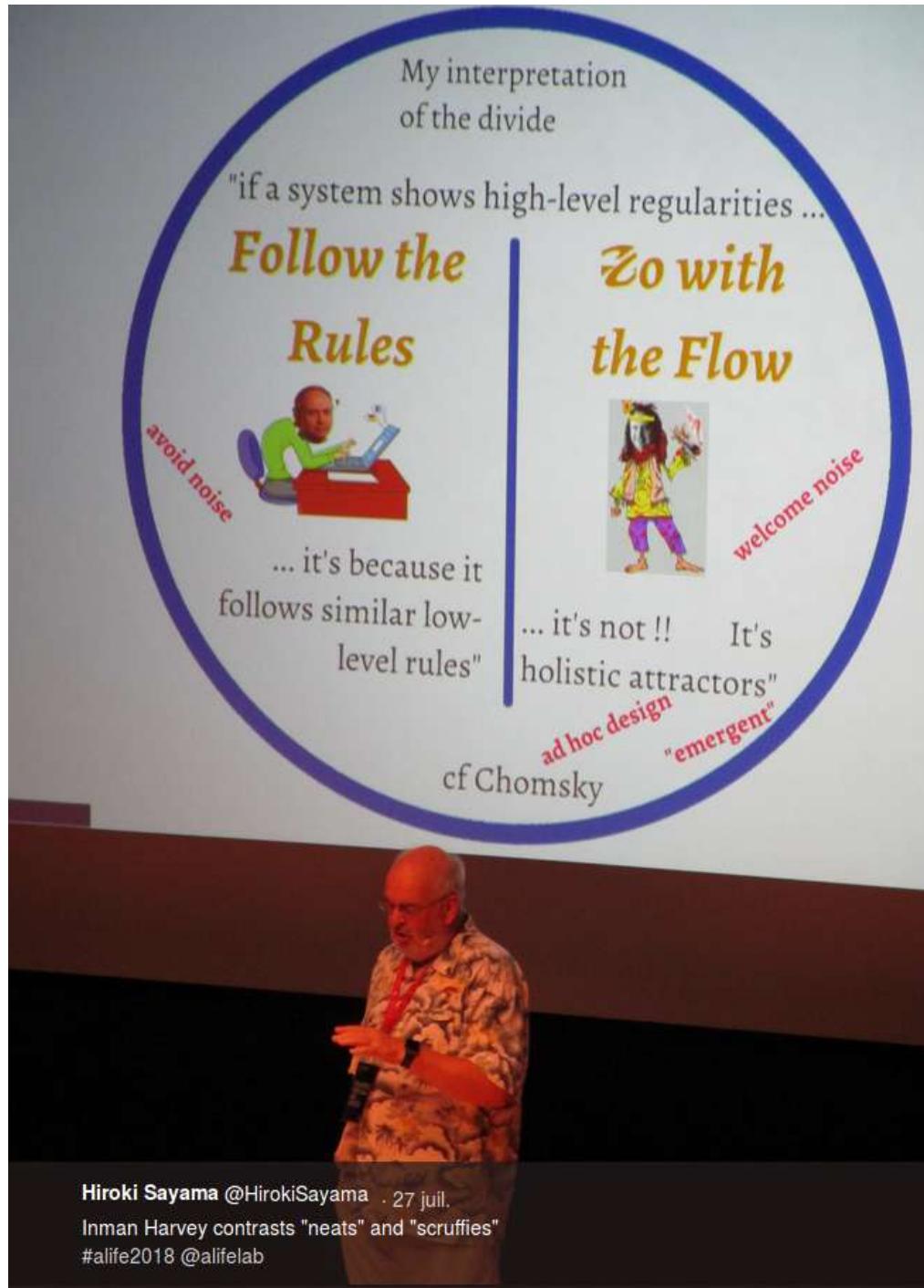
- Applications of genetic alg. with human-level performance

- Virtual scene generation, social modelling, bioinformatics,...



EXHIBITION VIEW AT THE MIRAIKAN, TOKYO - DIMENSIONS OF THE SET 135 x 70 x 12 cm

Art competition winner at Alife 2018, Tokyo, Japan: Thamesiology by Olivia Guigue



Inman Harvey's keynote at Alife2018: scruffy and neat approaches to Alife research
Tweet by @HirokiSayama

Swarm Robotics



NO FLIPARSE

Don't go overboard



Lea detenidamente las noticias sobre inteligencia artificial

Read carefully the news on A.I.



Las obras de ciencia ficción son obras de FICCIÓN

SciFi is FICTION



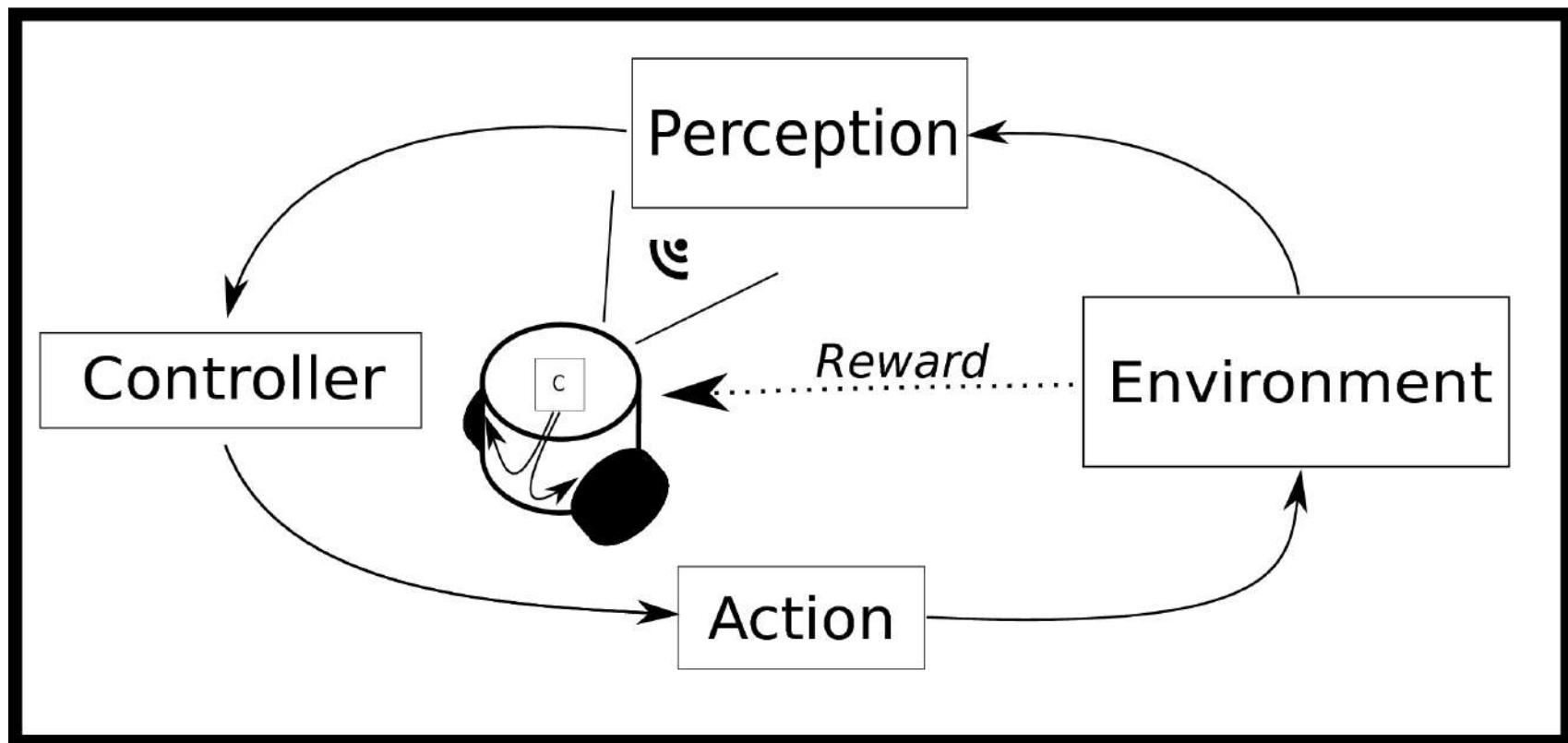
En caso de duda, consulte con su investigador de confianza

*In case of doubt, check with your
trusted researcher*

Swarm Robotics

- Collective and adaptive robot systems
- Self-organized and distributed behavior
 - Without central element / bottleneck
- Emergent global properties
 -from simple rules and interactions
- Robust, scalable, flexible,..., systems
- but difficult to design

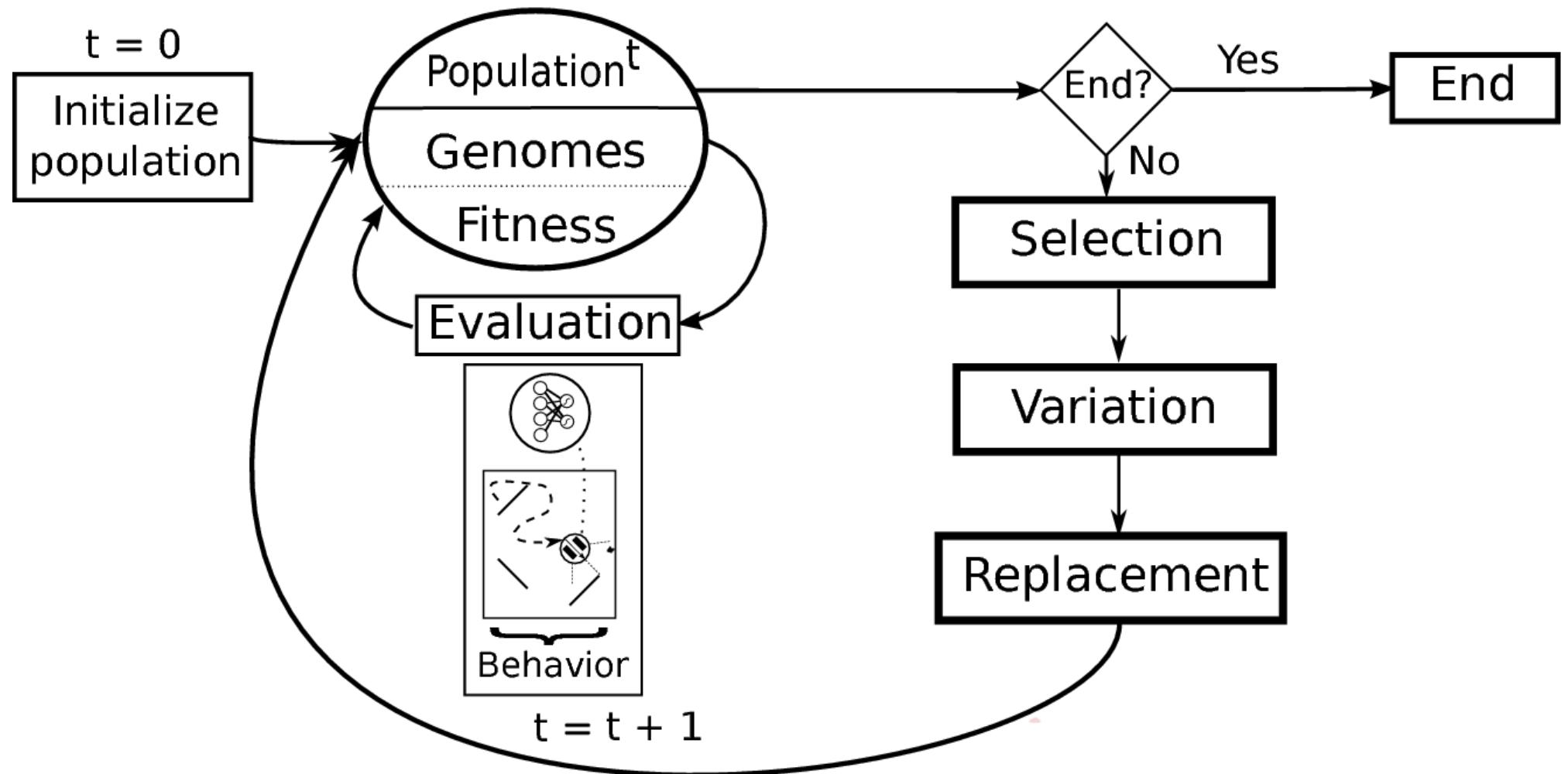
Sensorimotor loop



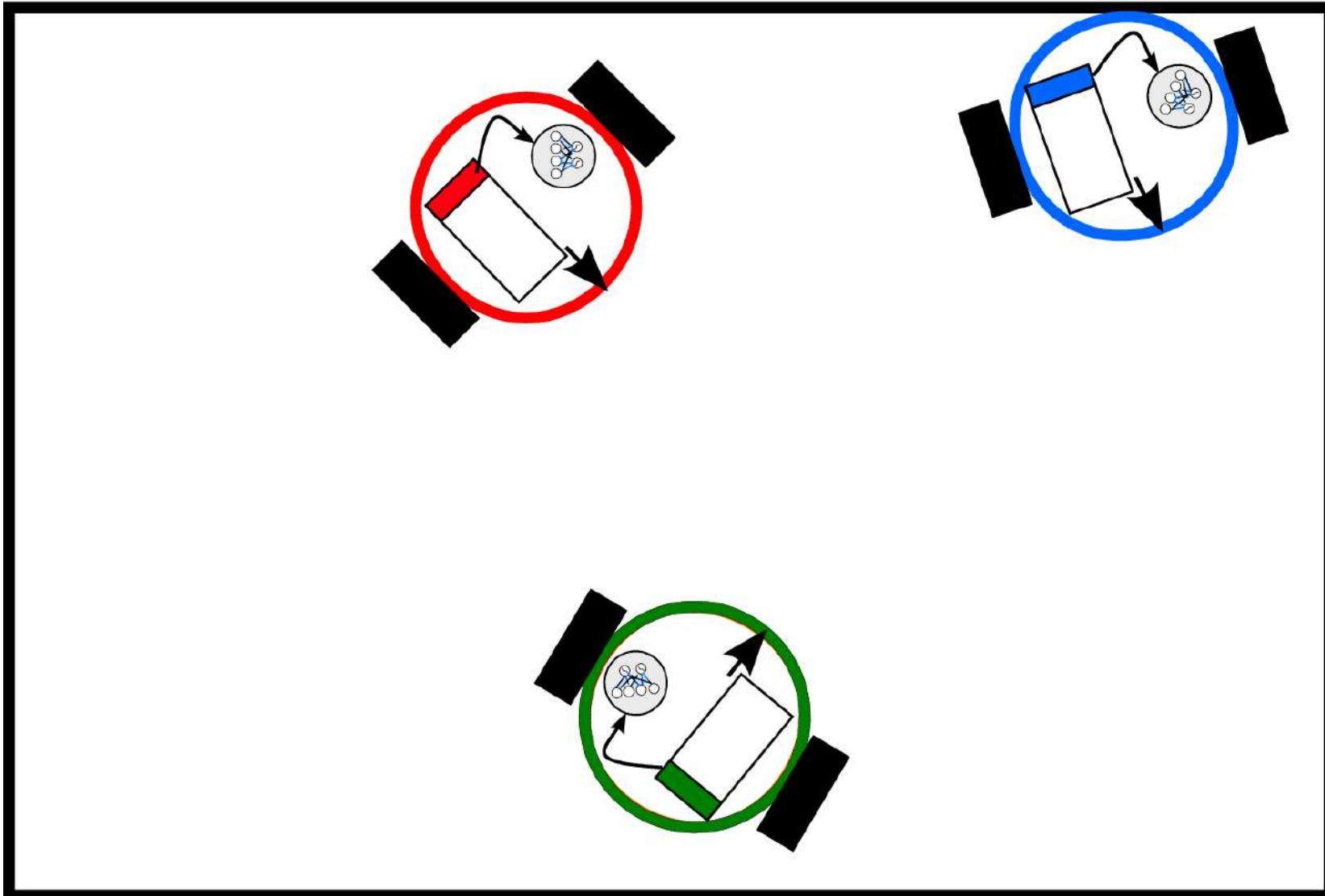
A simple reactive robotic agent and its sensorimotor loop



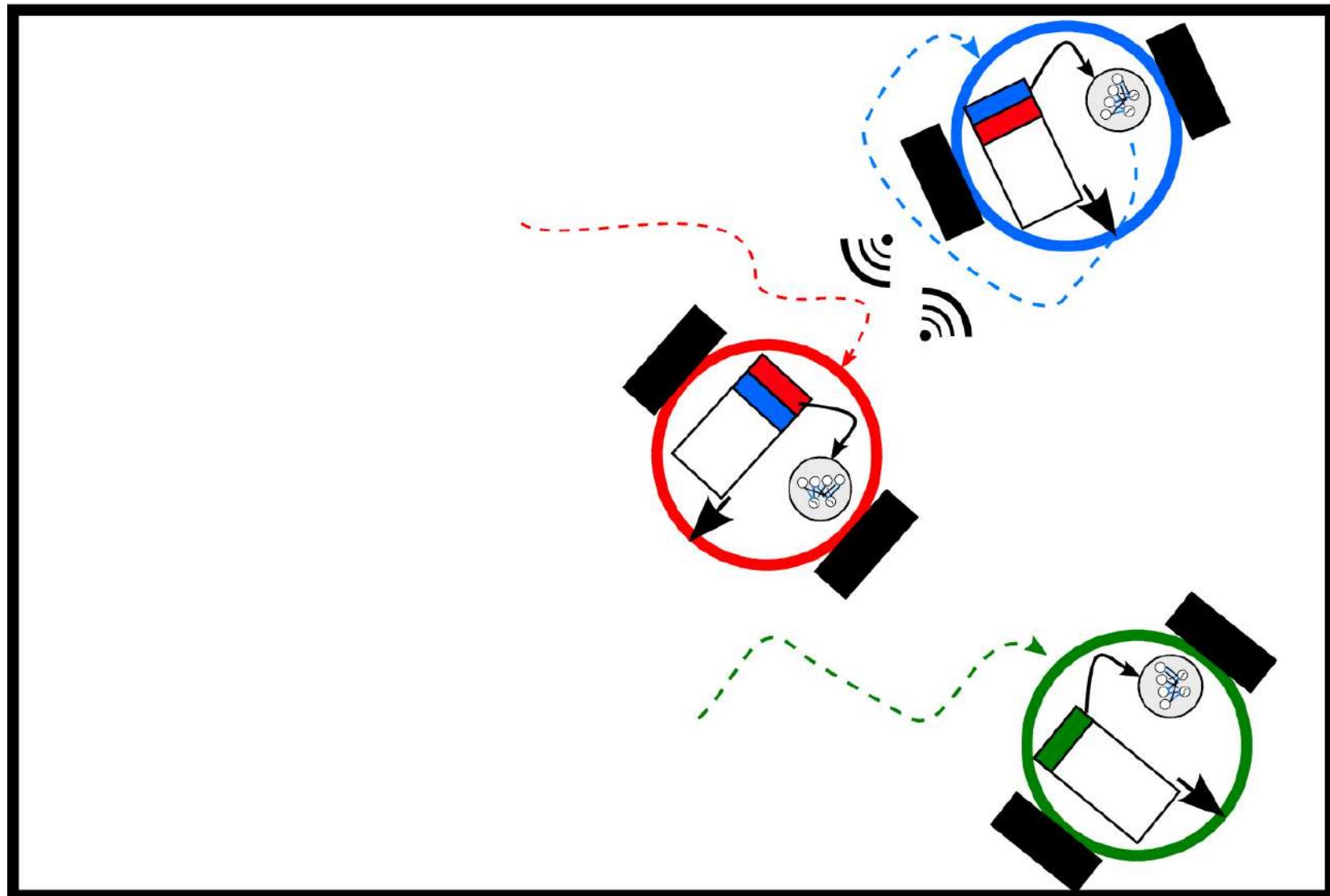
Evolutionary Algorithms



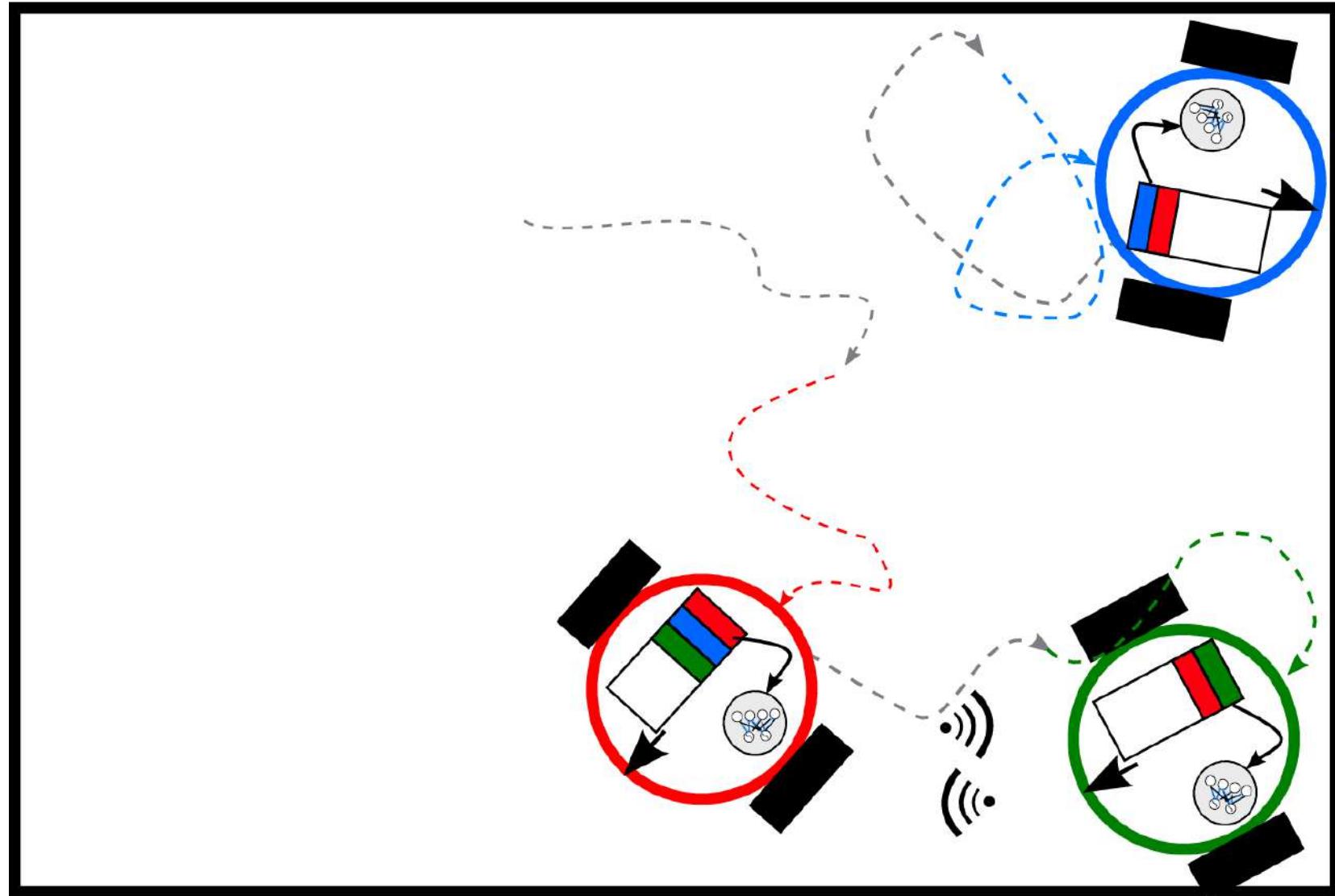
(Distributed) Embodied Evolution



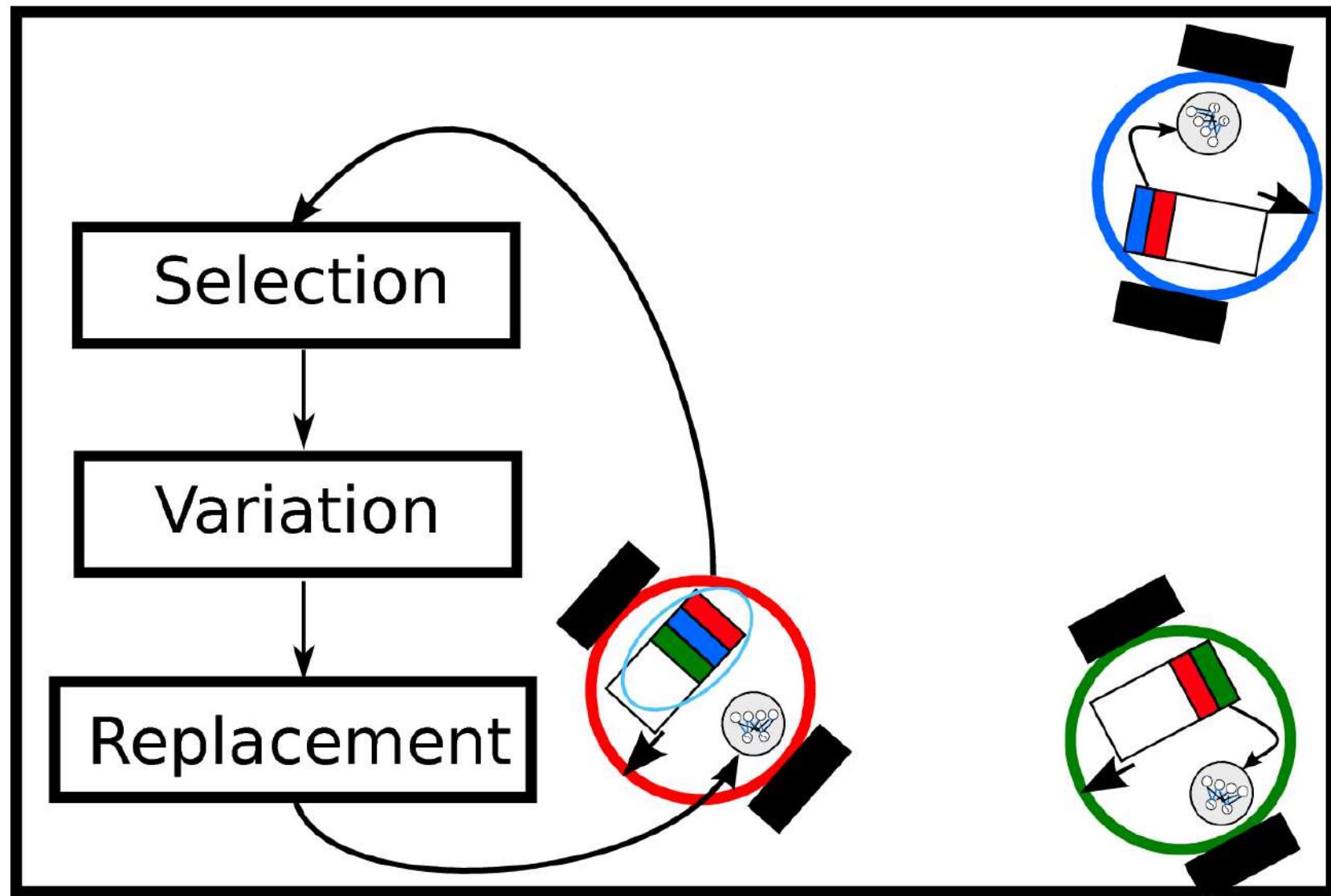
(Distributed) Embodied Evolution



(Distributed) Embodied Evolution



(Distributed) Embodied Evolution



Evolution of Collaboration

Learning Collaborative Foraging in a Swarm of Robots using Embodied Evolution

Iñaki Fernández Pérez, Amine Boumaza, François Charpillet

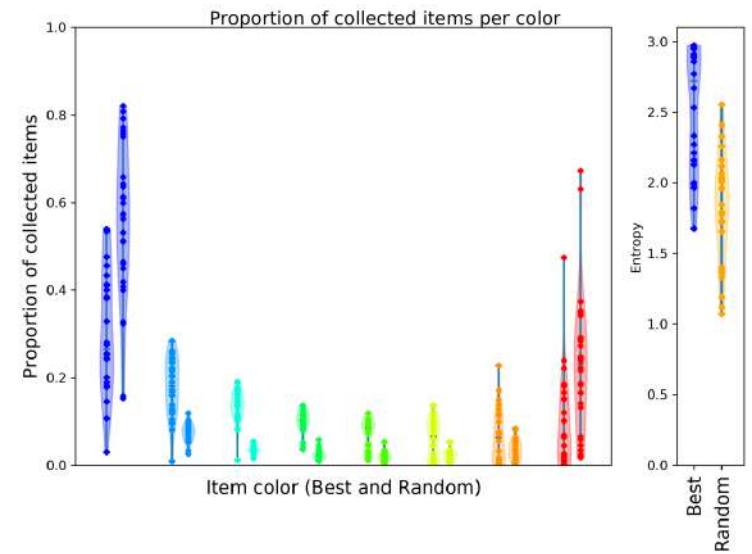
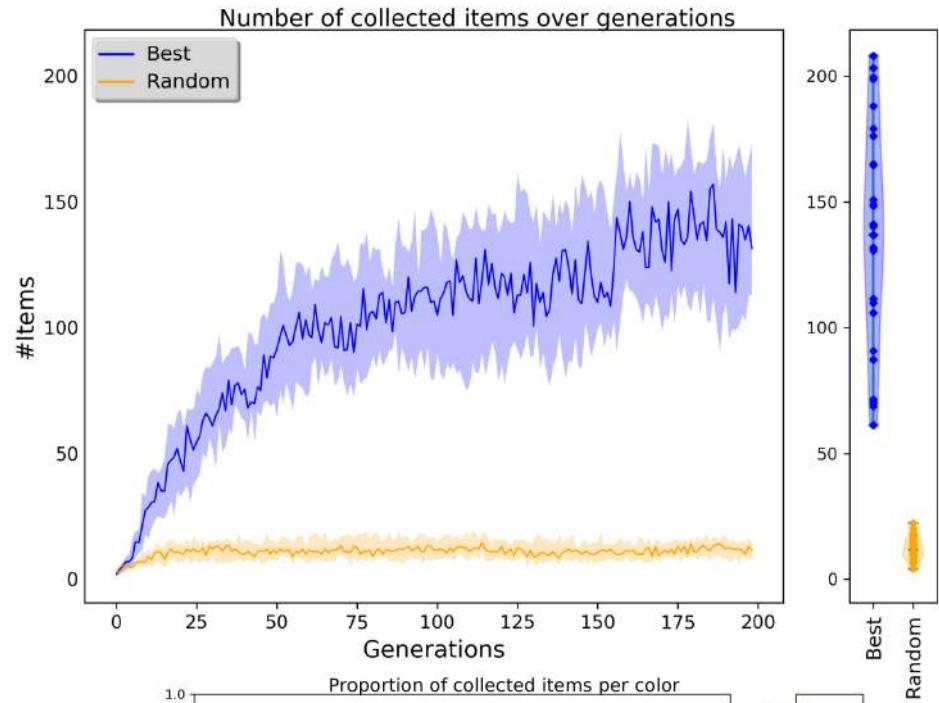
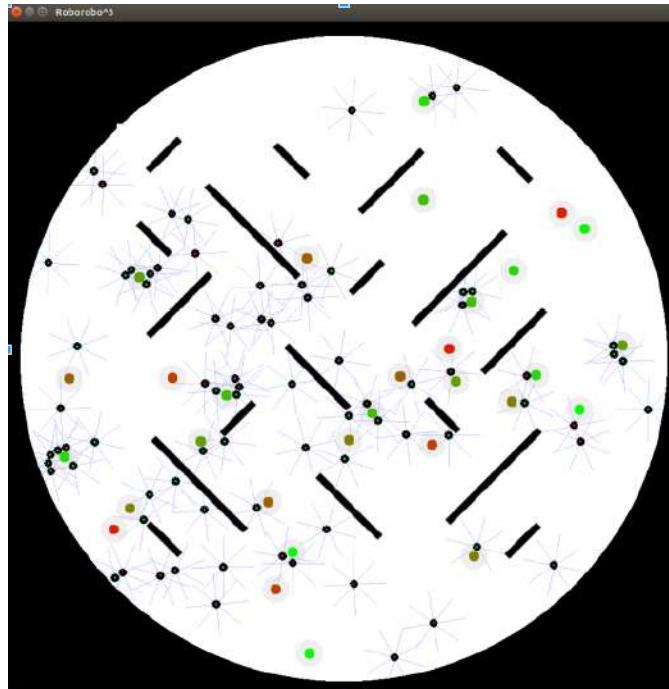
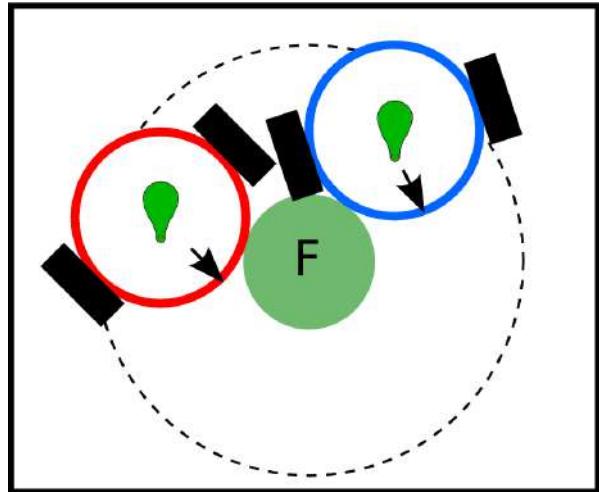
Université de Lorraine, Inria Nancy Grand-Est
Nancy (France)

Paper at ECAL 2017, Lyon (France)



Learning Collaborative Foraging in a Swarm of Robots using Embodied Evolution
I. Fernández Pérez et al. ECAL 2017, Lyon
Nominated to best paper award at ECAL17 Lyon (4 nominees among 100+ papers)

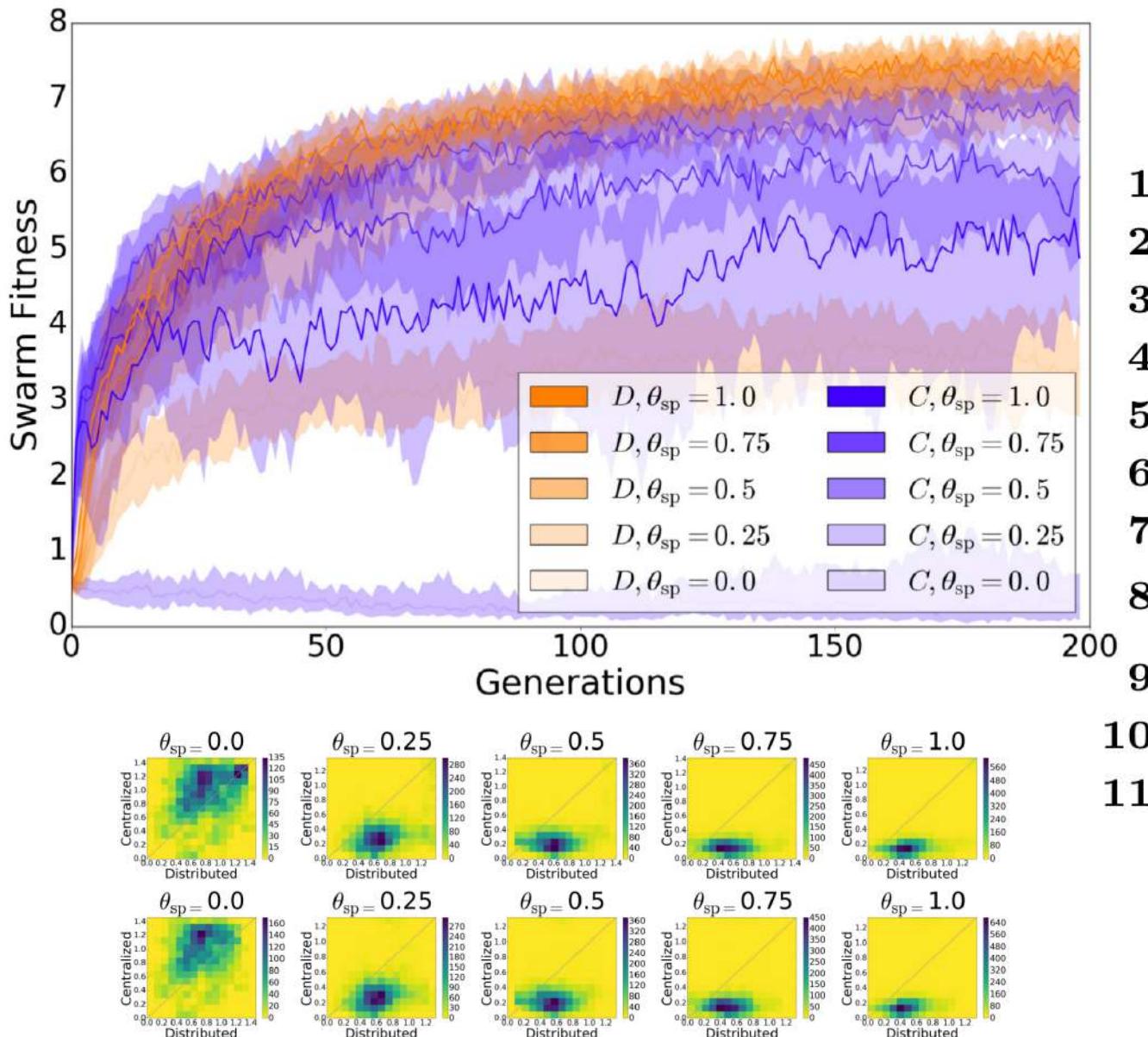
Evolution of Collaboration



Mantaining Diversity over the Swarm

- Diversity → positive for adaptation
 - To unknown environments, changes, diff. tasks,....
- Centralized vs. distributed Evolutionary Algorithm
- Or seen otherwise:
 - 1) global communication
 - 2) long distance
 - 3) medium distance
 - 4) short distance
 - Which one maintains more (useful) diversity,
improving adaptation in the swarm?

Mantaining Diversity over the Swarm



```

1  $g_a \leftarrow \text{random}()$ 
2 while true do
3    $l \leftarrow \emptyset, f \leftarrow 0$ 
4   for  $t \leftarrow 1$  to  $T_e$  do
5      $\text{exec}(g_a)$ 
6      $f \leftarrow \text{evaluate}()$ 
7      $\text{broadcast}(g_a, f)$ 
8      $l \leftarrow l \cup \text{listen}()$ 
9    $l \leftarrow l \cup \{(g_a, f)\}$ 
10   $\text{selected} \leftarrow \text{select}(l)$ 
11   $g_a \leftarrow \text{mutate}(\text{selected})$ 

```

But then....

What is Artificial Life exactly?

A definition of Artificial Life?

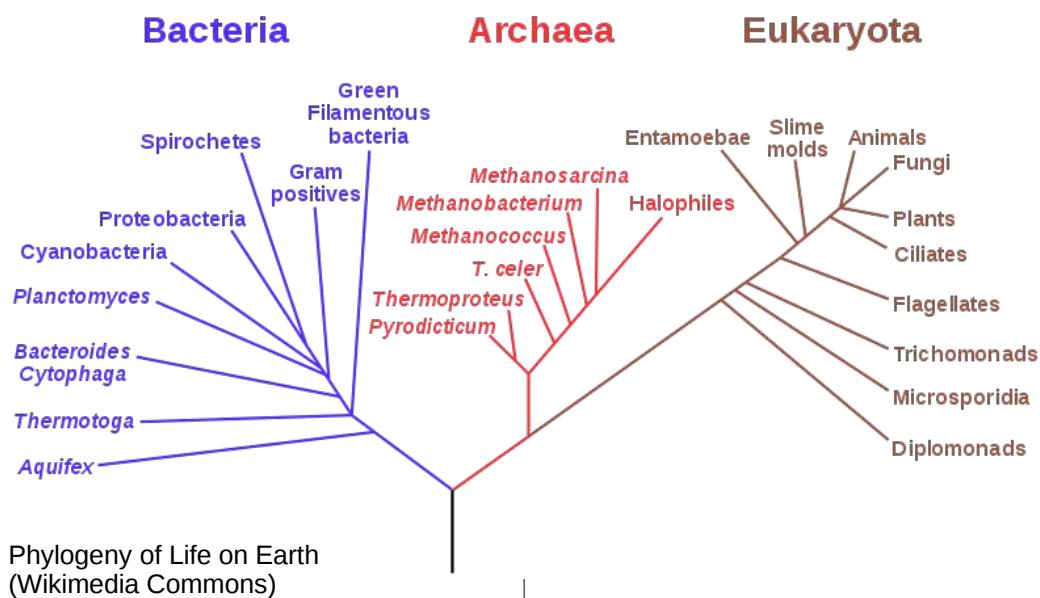
Artificial life is the study of artificial systems that exhibit behavior characteristic of natural living systems. It is the quest to explain life in any of its possible manifestations, without restriction to the particular examples that have evolved on earth. This includes biological and chemical experiments, computer simulations, and purely theoretical endeavors. Processes occurring on molecular, social, and evolutionary scales are subject to investigation.

The ultimate goal is to extract the **logical form of living systems**.

Christopher Langton, Artificial Life, 1989

Biology

Nature

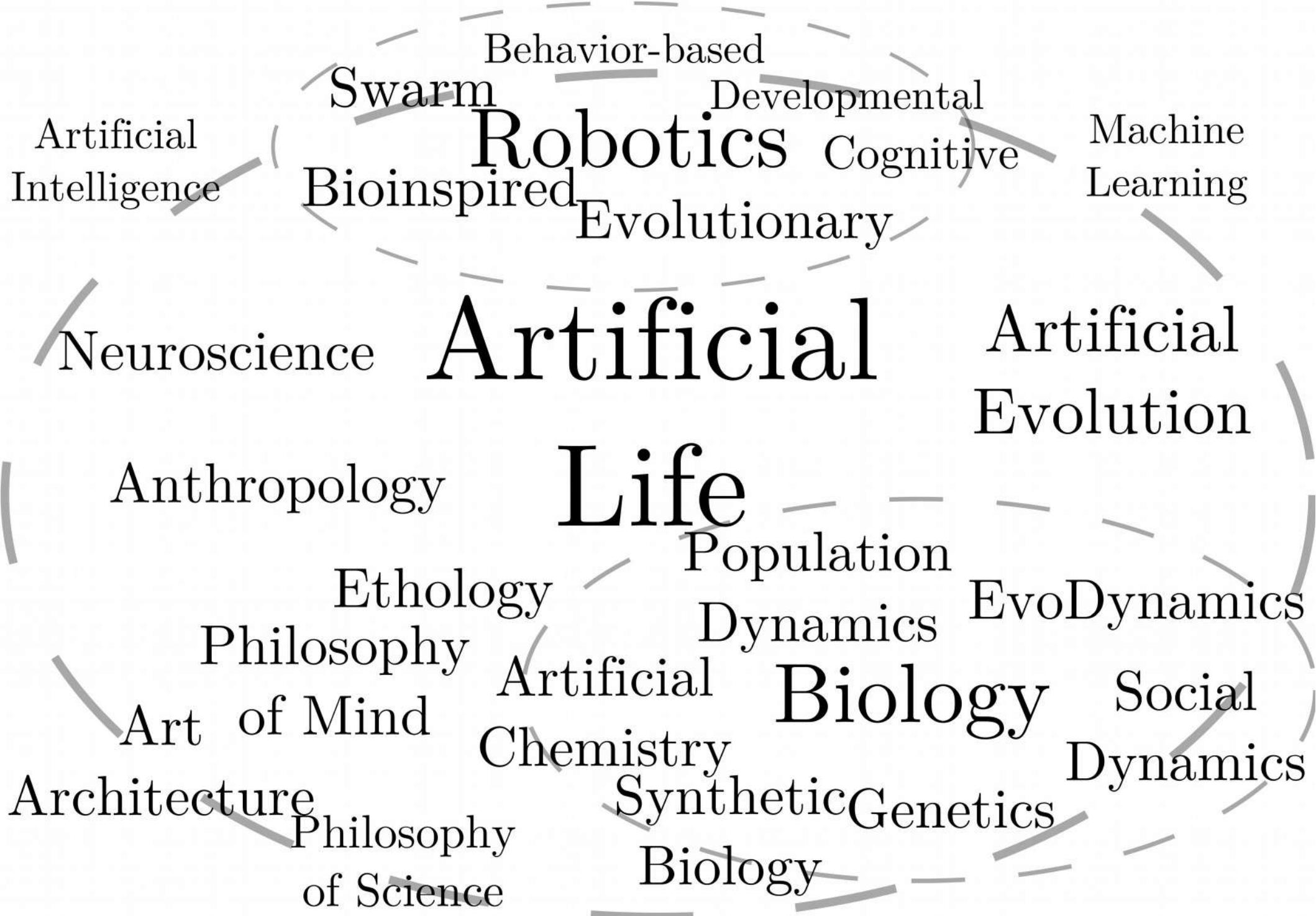


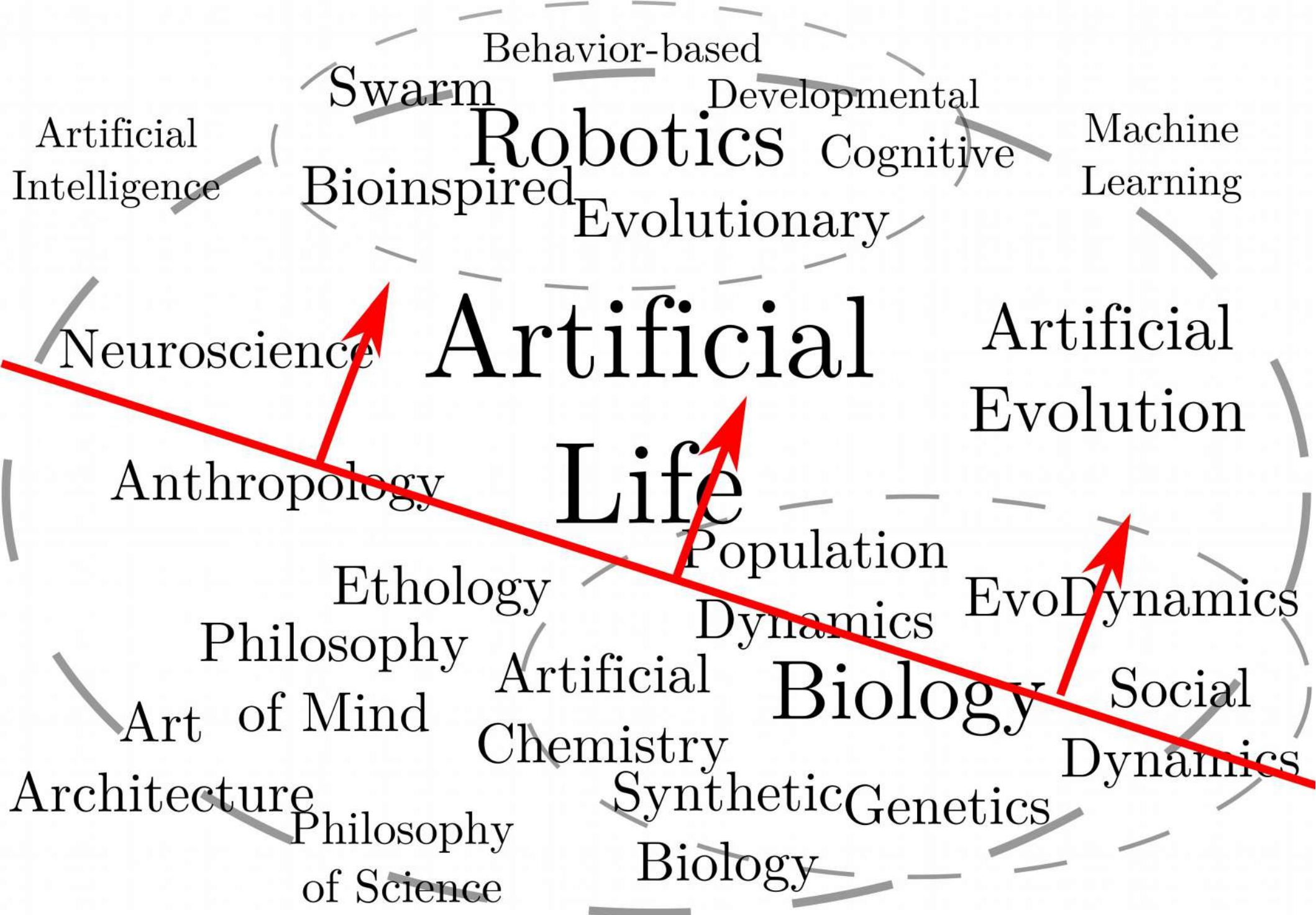
Inspiration (++) → Engineering

Artificial Systems



Postcard, Insil Choi,
Alife 2014





ALife: tools and methods shared (and developed) by the community

- Study of systems (evo/devo, social, cellular,...)
- *Soft, hard and wet Alife* (digital, robotic or biosynthetic)
- Tools: statistical, mathematical, simulation,...
- Experimental and analytic approaches, **scientific method**

Disclaimer: I say this, others may have a different view



Alife references in drawing by staff member at closing ceremony of ECAL 2017, Lyon

Nature is optimized for efficiency

Draw inspiration even
from below rocks

And investigate the
subject of study in a
thorough manner:
scientific method

@ISALStudents and postdoc:

- Diverse activities in Alife: journal club, thematic discussions, collaborations, annual award, events in conferences, ISAL board representative, upcoming *Artificial Life journal* column
- <http://isalstudents.org/>

fernandezperez.inaki@gmail.com [@InakiFdezPerez](https://twitter.com/InakiFdezPerez)
www.irit.fr/~Inaki.Fernandez-Perez