Vida Artificial

(+ robótica en enjambre & evolución encarnada)

resolver problemas mirando la naturaleza

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Iñaki Fernández Pérez

Yo

- Infor. Sistemas UVa (06-10)
- Erasmus Nancy, FR (10)
  - Web semántica, …
- Ing. de investigación (10-11)
- Máster Inform. Int. Art. (11-13)
- Doct. Rob. Colectiva (13-17)

Mi circunstancia

- Investigador postdoc
  - Univ. Toulouse 3
- Optimización bioinsp., y más
  - Despl. eq. intervención
  - Comport. robot colectivo
  - Comunic. en col. de bact.
- Vicepres. grupo ISALStud.
  - Intern. Soc. for Artif. Life
- Enseñanza, divulg., pedagogía


distributed
Automata
flocking
boid
birds
space
nature
swarms
One
artificial
behaviour
boids
evolution
computer
model
growth
natural
swarm
physical
animals
flock
simulation
system
also
rules
life
Models
systems
group
way
robots
avoid
current
robotics
human
Intelligence
applications
individual
towards

Estructura de esta charla

- ¿Qué es la naturaleza? Ejemplos
- ¿Qué es la Vida Artificial? Ejemplos
- Robótica en enjambre + Evolución encarnada
- Mi visión global sobre la Vida Artificial

En la naturaleza, buscamos….

1) Patrones 2) Autoorganización

Veamos unos ejemplos….

Hopetoun Falls, Victoria, Australia *(Wikimedia Commons)*

Cañón del Rio Lobos, Soria, Spain *(Wikimedia Commons)*

Rice Terraces, Bali, Indonesia *(Wikimedia Commons)*

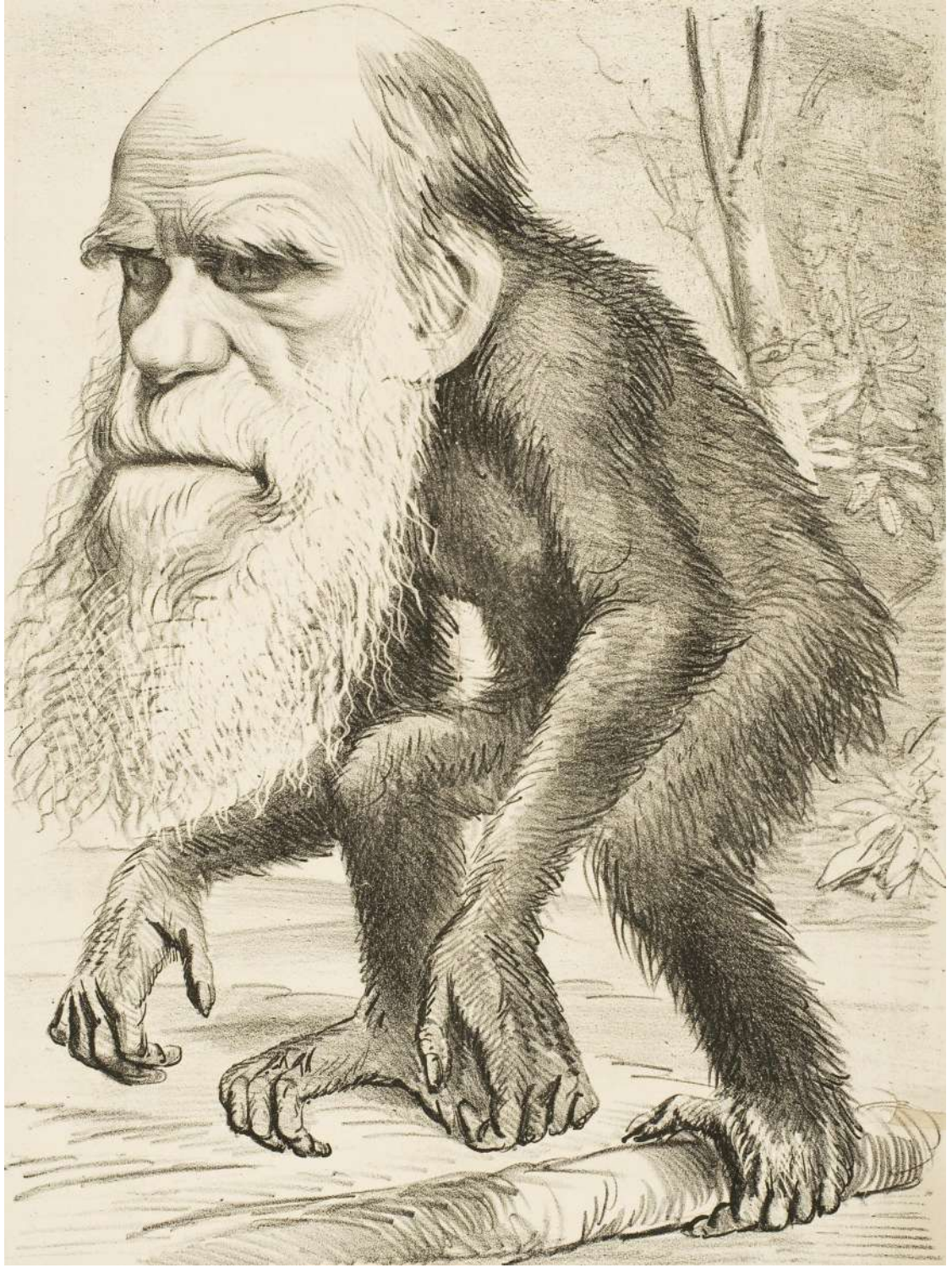
Rinjani Volcano Eruption (1994), Lombok, Indonesia *(Wikimedia Commons)*

Metal casting *(Wikimedia Commons)*

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

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.

Flock of starlings (murmuration) *(Wikimedia Commons)*

Fire ant raft *(Wikimedia Commons)*

Bait ball *(Wikimedia Commons)*

Bee hive *(Wikimedia Commons)*

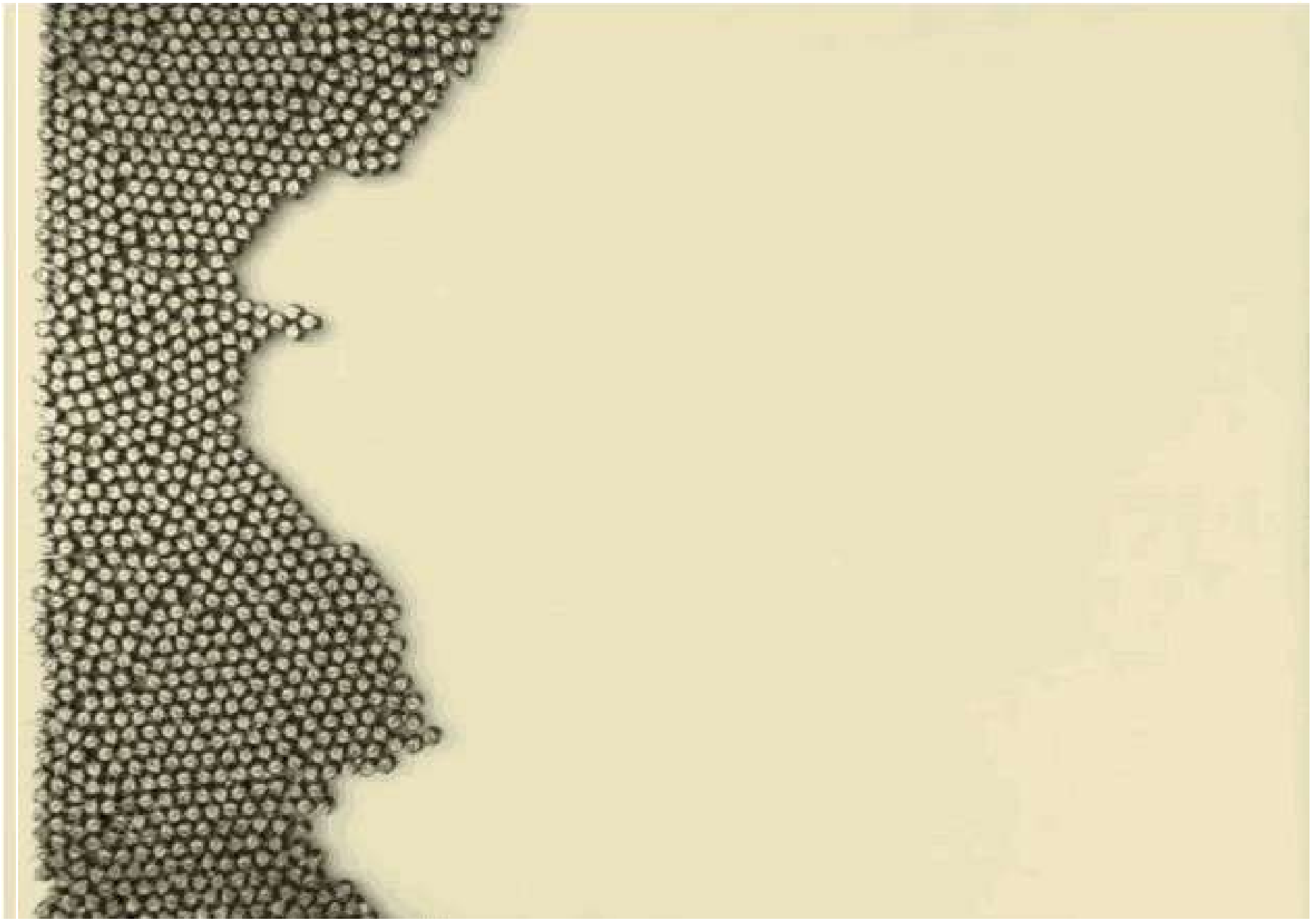
Ant bridge *(Wikimedia Commons)*

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)*

Entonces…

¿qué es la Vida Artificial?

Algunos vídeos...

(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)

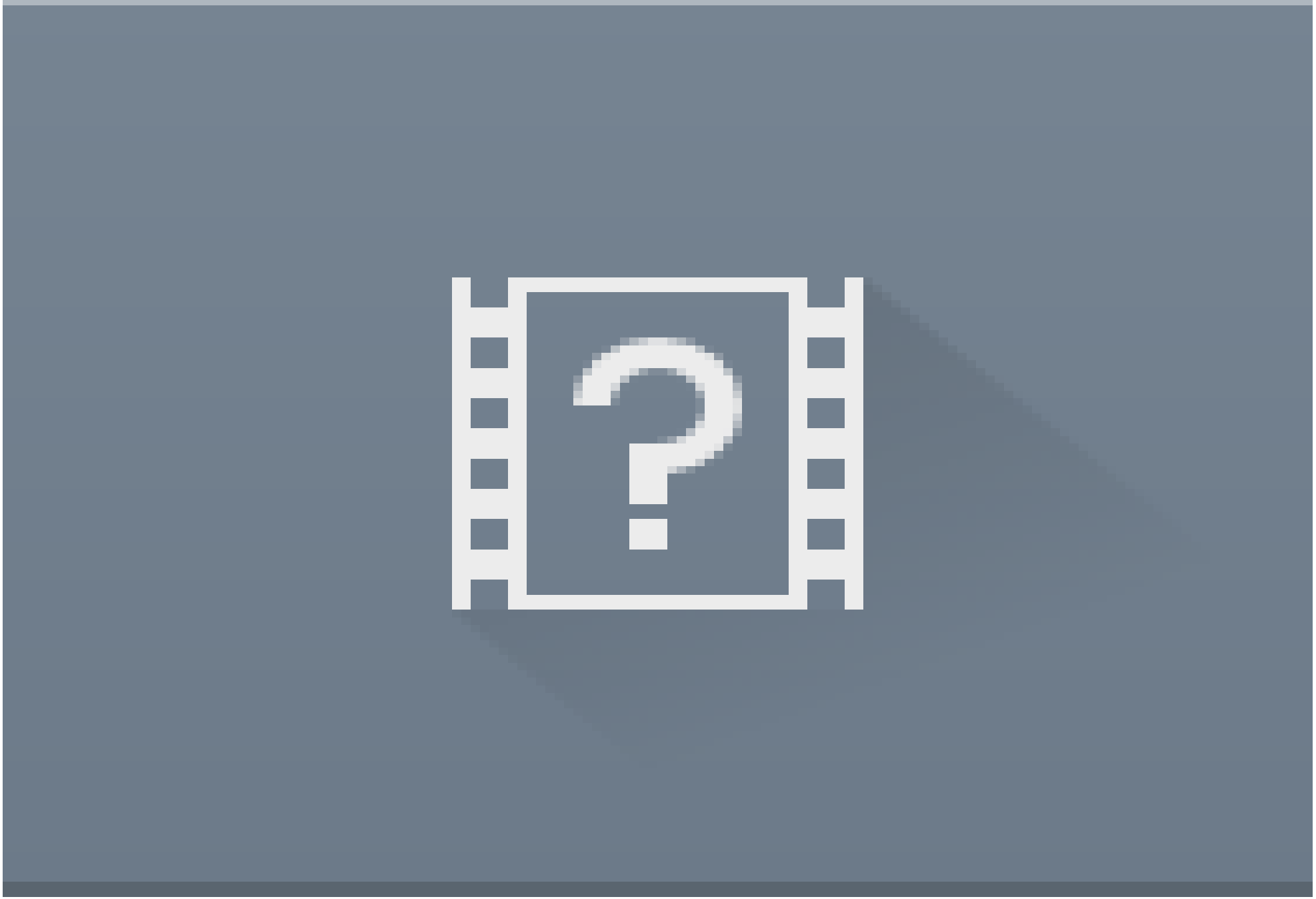
Thanks to Lana Sinapayen for providing the support

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

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

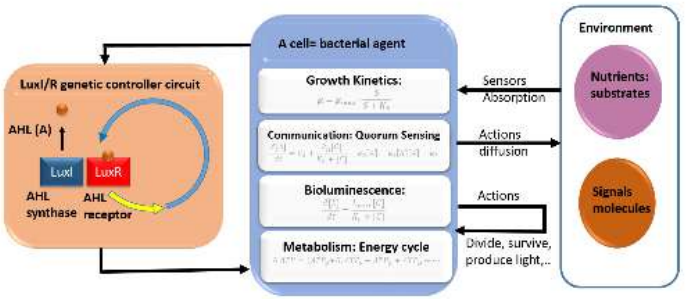
Autonomously Shaping Natural Climbing Plants: A Bio-hybrid Approach
M. Wahby, M. K.Heinrich, D. N. Hofstadler, E. Neufeld, I. Kuksin, P. Zahadat, T. Schmickl, P. Ayres, H. Hamann
Royal Society Open Science 2018 (under revision)
Thanks to Payam Zahadat for providing the support

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

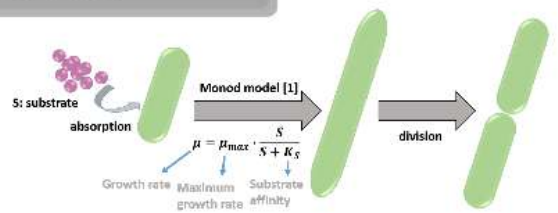


H. Haraldsen Roen, B. Bocquillon, S. Hoebeke, S. Nichele, K. Bergaust, H. Dahlsveen, H. Lieng
Emergence of Collective Intelligence: an Artificial Pheromone-Based Swarm Robotic System
The 3rd Open Fields Conference, RIXC Art Science Festival 2018 (IN PRESS)
Thanks to Stefano Nichele for providing the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

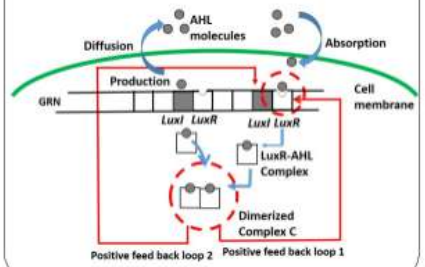
Computational agent-based model



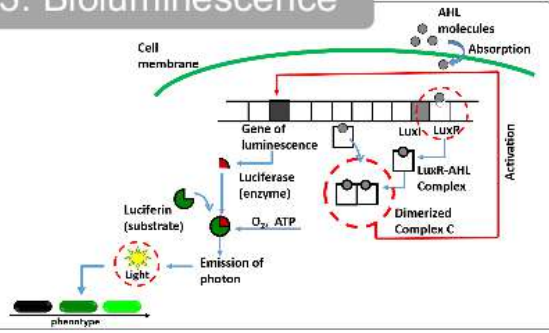
1. Growth



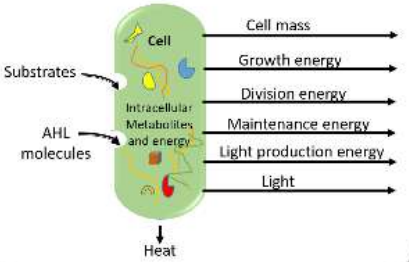
2. Quorum sensing



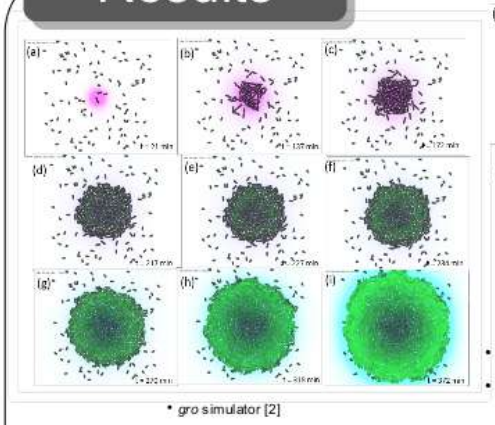
3. Bioluminescence



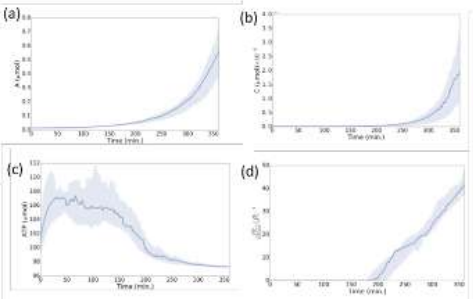
4. Metabolism



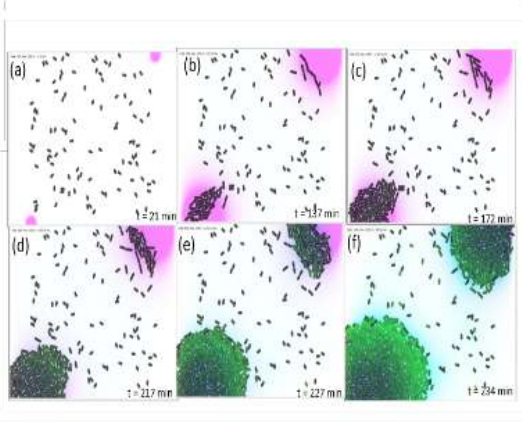
Results



- *gro* simulator [2]
- Growing bacteria colonies up to 1400 cells
- 73% of cells are bioluminescent
- Matching empirical rates in real bacteria [3]



- (a) *AHL* exceeds the rate achieved in [4] (0.6 *vs* 0.1)
- → self-sustainable behaviors that exploit metabolism to divide and survive, triggering bioluminescence
- (c) *t* > *300*: cells reach energetic self-sustainable state
- (d): quorum reached at *t* = *180*, cells produce *gfp*



- Self-organized emerging bioluminescence behavior
- Bioluminescence is directed toward the opposite colony

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

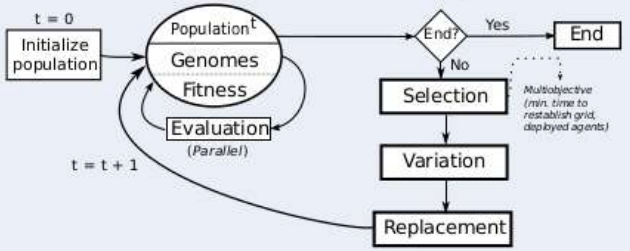
Evolutionary Algorithm [2] and Gene Regulatory Controller [1]

Offline Evolutionary Optimization — By extensively evaluating candidate solutions on a simulator

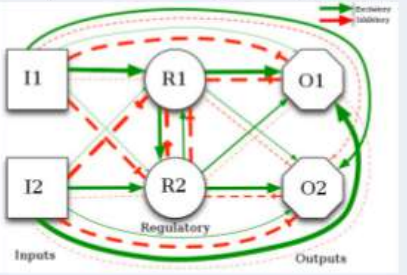
→ Produces →

Dynamic Team Allocation Controller — Dynamically exploited to allocate intervention teams to bases

EA: blind variations + selection pressure

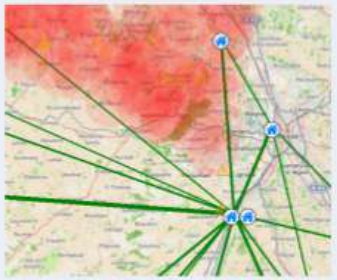


Example of Gene Regulatory Network

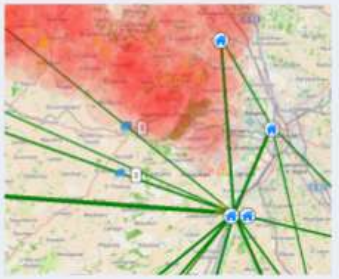


A test scenario: west-to-east storm

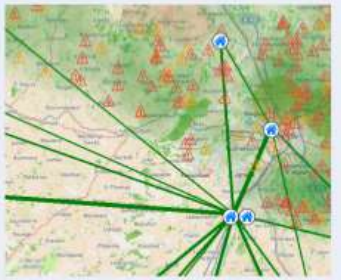
An storm approaches from the west generating faliures over the grid



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

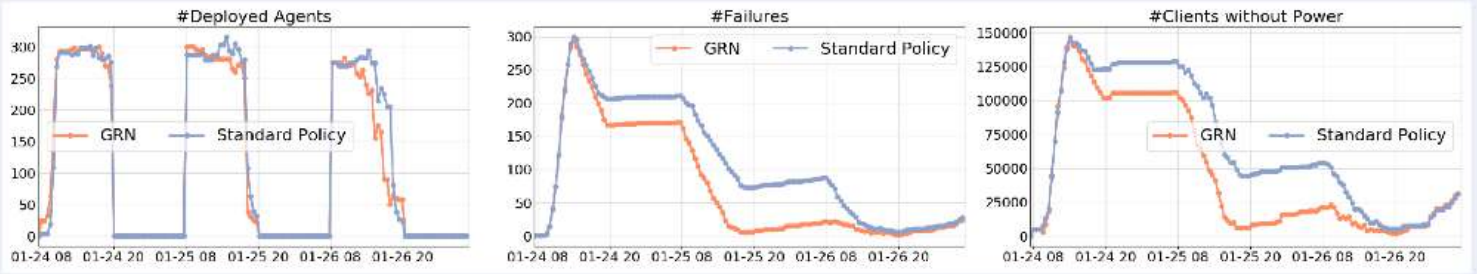


Teams are deployed and progressively repair the failures on the grid



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

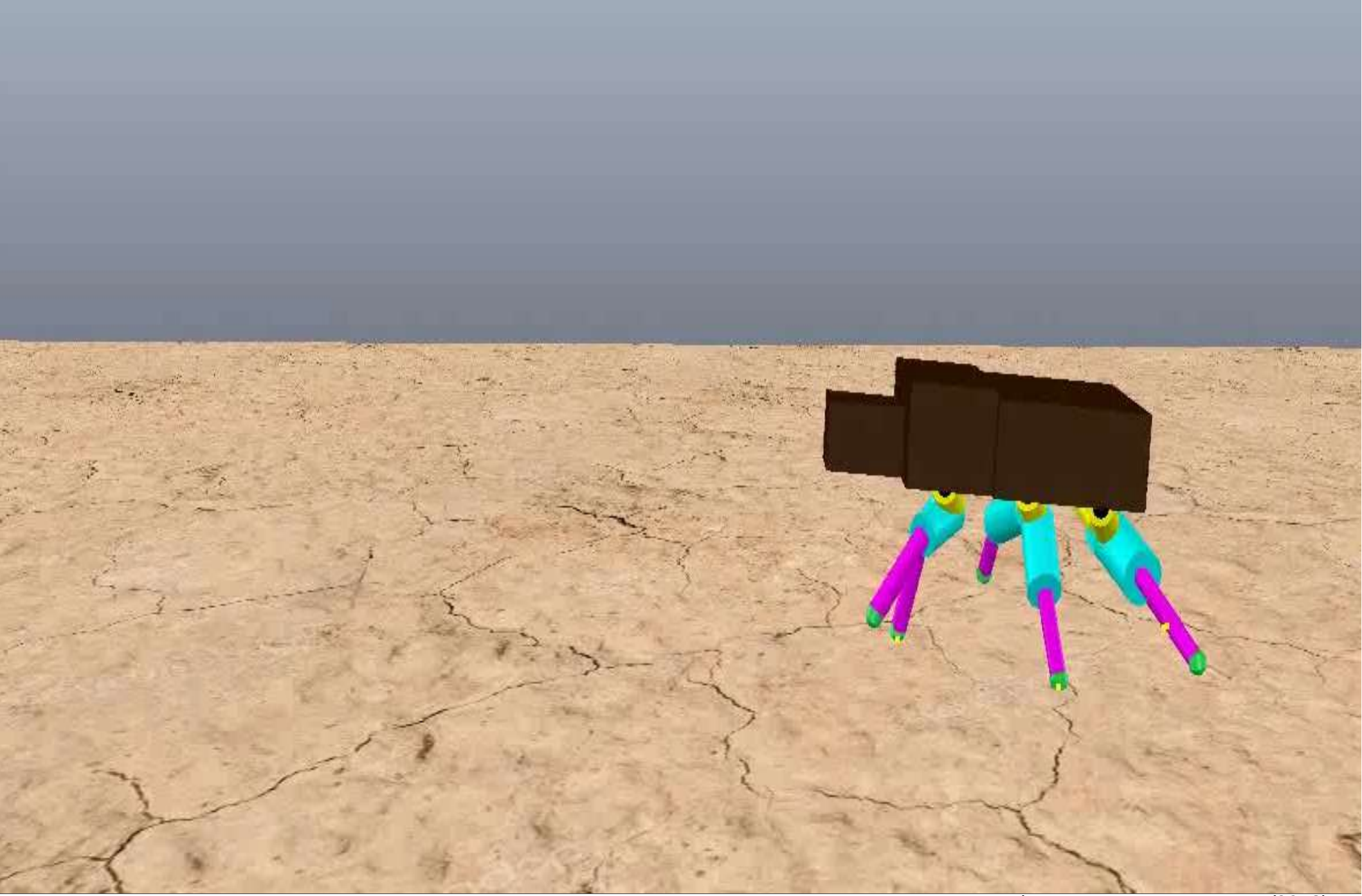
Learning Collaborative Foraging in a Swarm of Robots using Embodied Evolution

Iñaki Fernández Pérez, Amine Boumaza, François Charpillet
Université de Lorraine, Inria Nancy Grand-Est
Nancy (France)

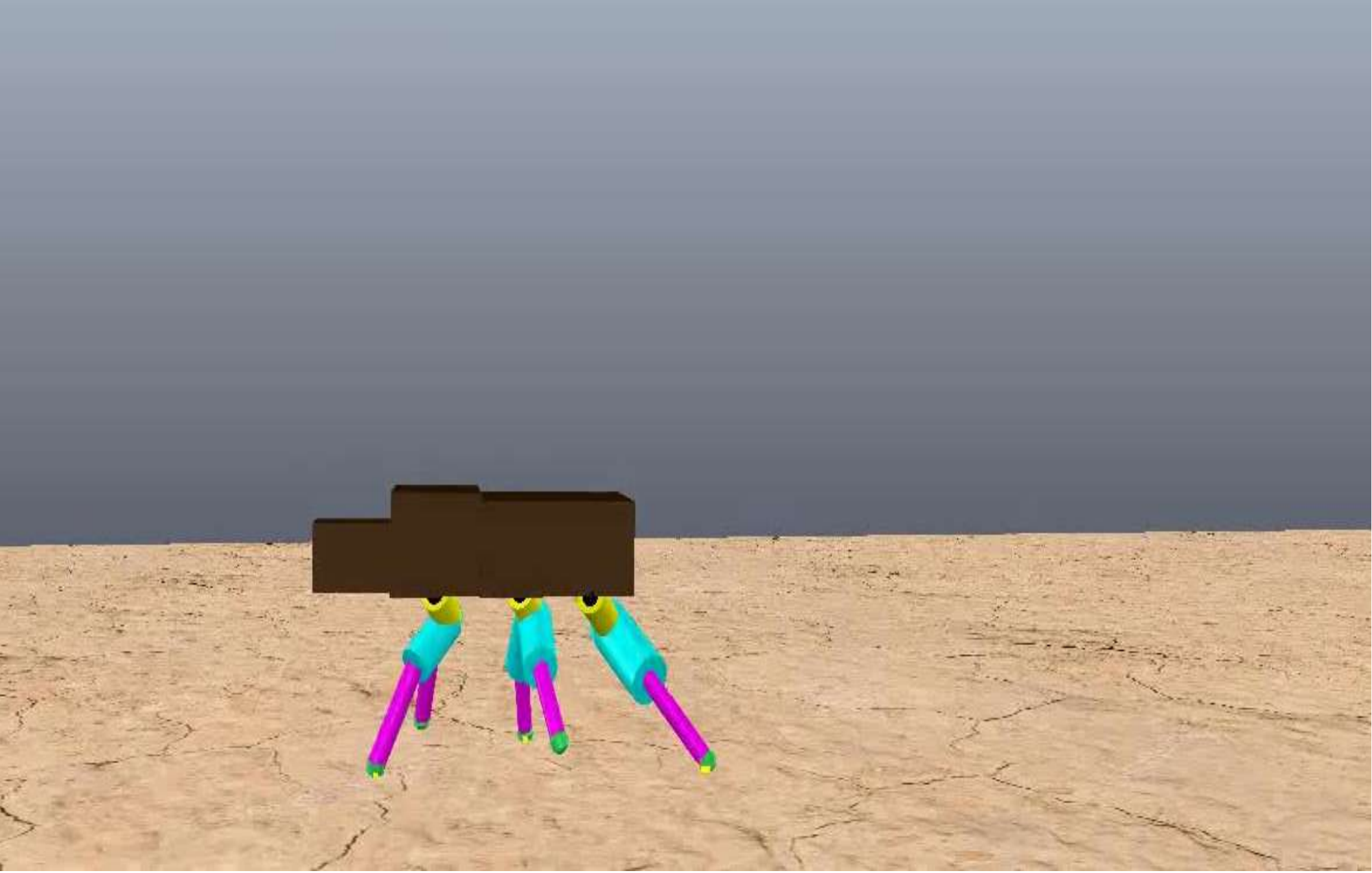
Paper at ECAL 2017, Lyon (France)

Nominated to best paper award at ECAL17 Lyon (4 nominees among 100+ papers)


Modular Neural Control for Bio-Inspired Walking and Ball Rolling of a Dung Beetle-Like Robot
Authors
Binggwong Leung
Mathias Thor
Prof. Dr. Poramate Manoonpong
BRAIN LAB (VISTEC), Thailand
ENS-LAB (SDU), Denmark
VISTEC
life
Iñaki Fernández Pérez @InakiFdezPerez · 26 juil.
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)



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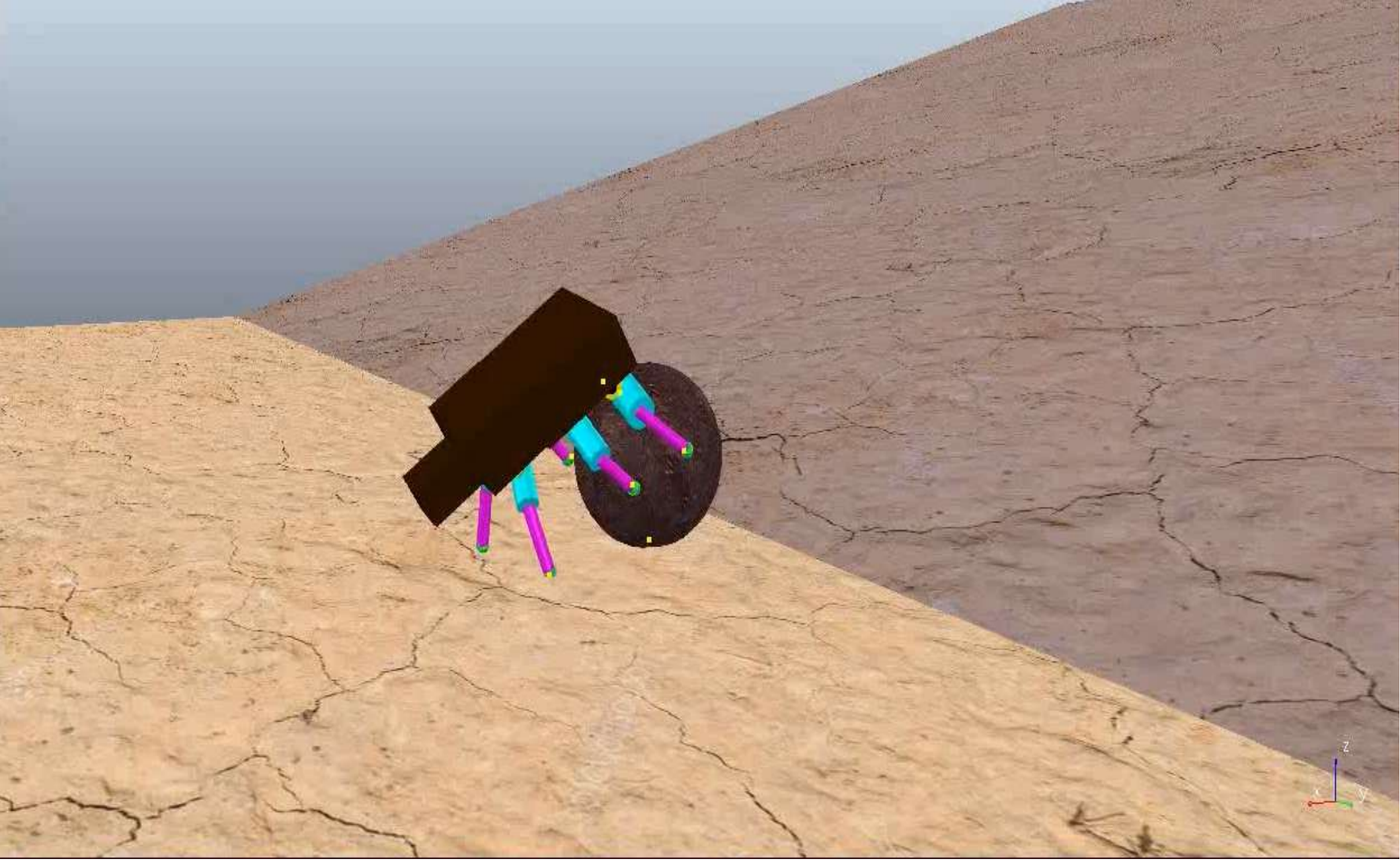

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Modular Neural Control for Bio-Inspired Walking and Ball Rolling of a Dung Beetle-Like Robot.
2018 Conference on Artificial Life, Tokyo, Japan (pp. 335–342)
Thanks to Binggwong Leung for providing the support

Tadahiro Taniguchi about Symbol Emergence at EVOSLACE workshop, Alife 2018

Ejemplos de ALife aplicada

- Redes de neuronas (~1955-…), aprendizaje profundo (~2005-...)
  - Clasificación, identificación, decisión, regulación,….

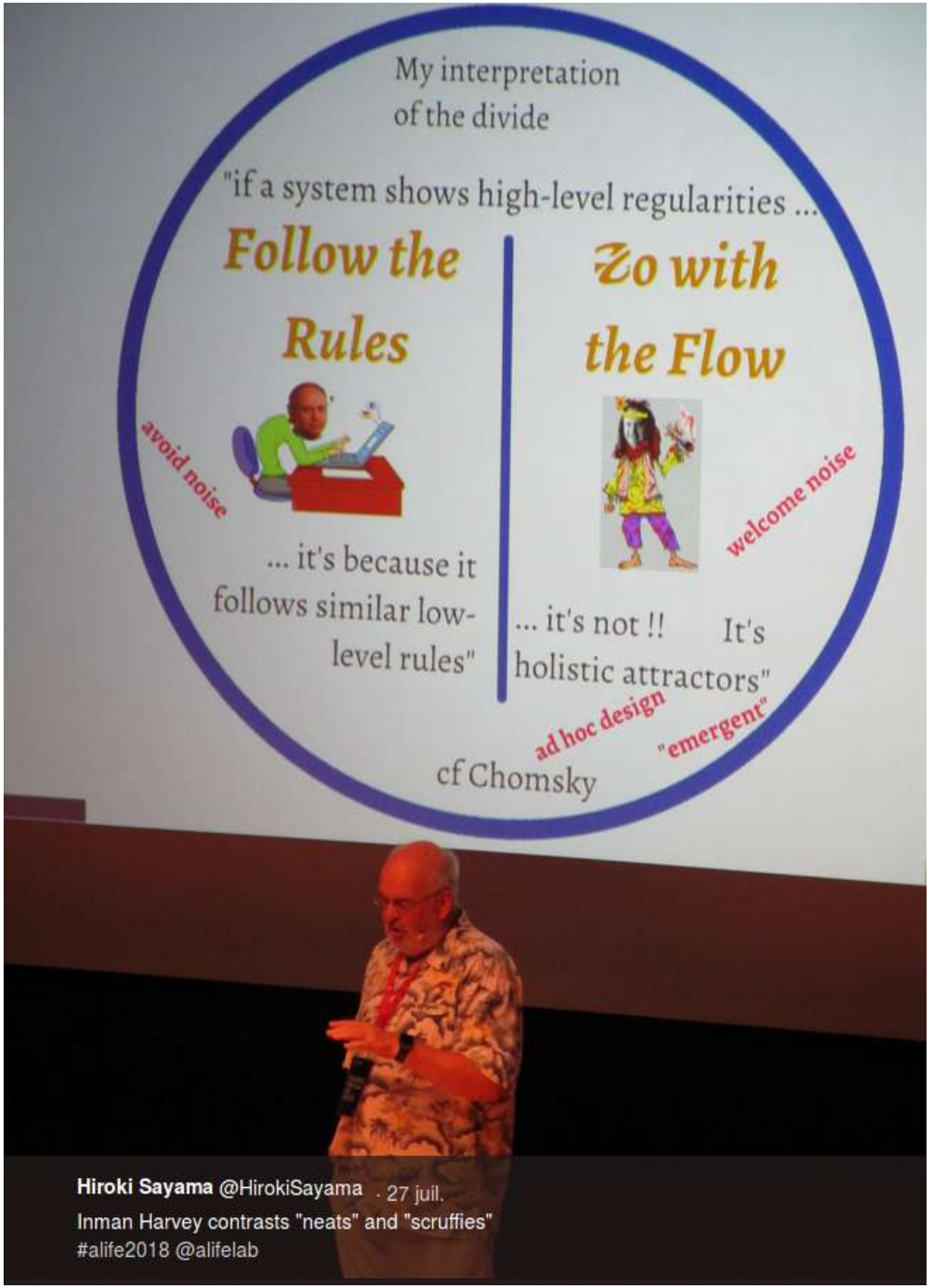
AlphaGo

- Diseño vía alg. genético (*e.g. antena* Hornby *et. al*)
  - Desplegada en 3 satélites NASA (2006)

- Otros alg. metaheurísticos de optimización
  - *Ant Colony Optimization, Artificial Immune Systems, Particle Swarm Optimization*
- Competición anual *HUMIES* en conferencia *GECCO*
  - Aplicaciones alg. genéticos con rendimiento a nivel humano
- Generación de escenas virtuales, modelización social, bioinformática,...

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

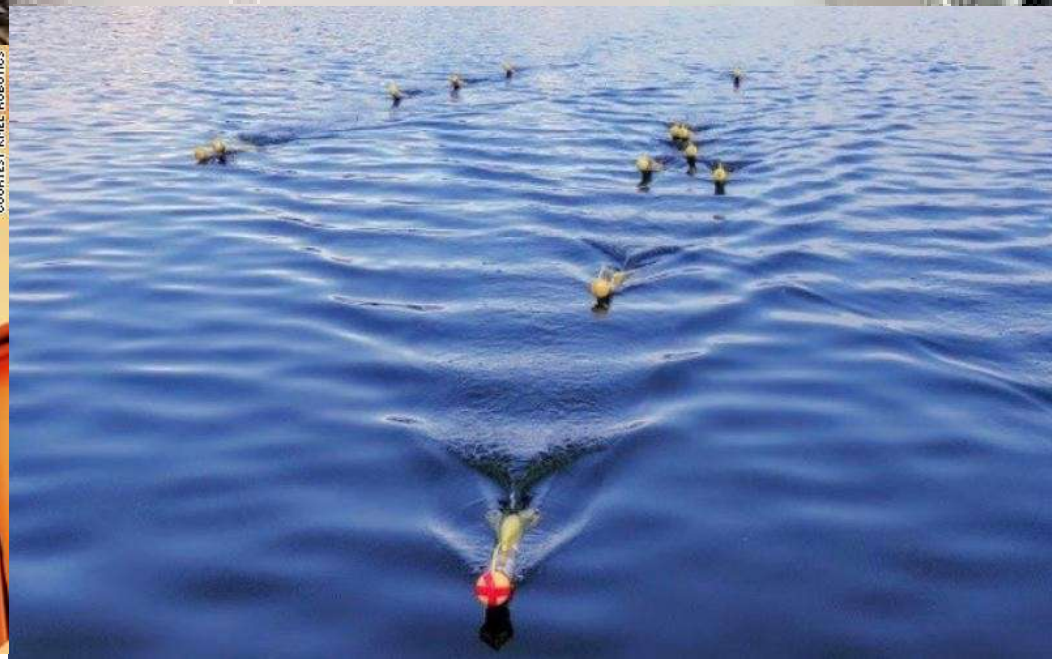
Art competition winner at Alife 2018, Tokyo, Japan: Thamesiology by Olivia Guigue



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

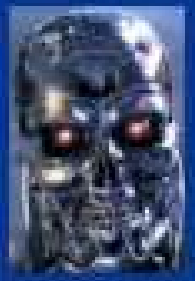

ALIFE 2018
ALIFE 2018 @alifelab · 27 juil.
ALIFE 2018 has just finished!
We appreciate your support and cooperation!!!
#alife #ALife2018
2018.alife.org

Robótica en Enjambre



NO FLIPARSE

Lea detenidamente las noticias sobre inteligencia artificial



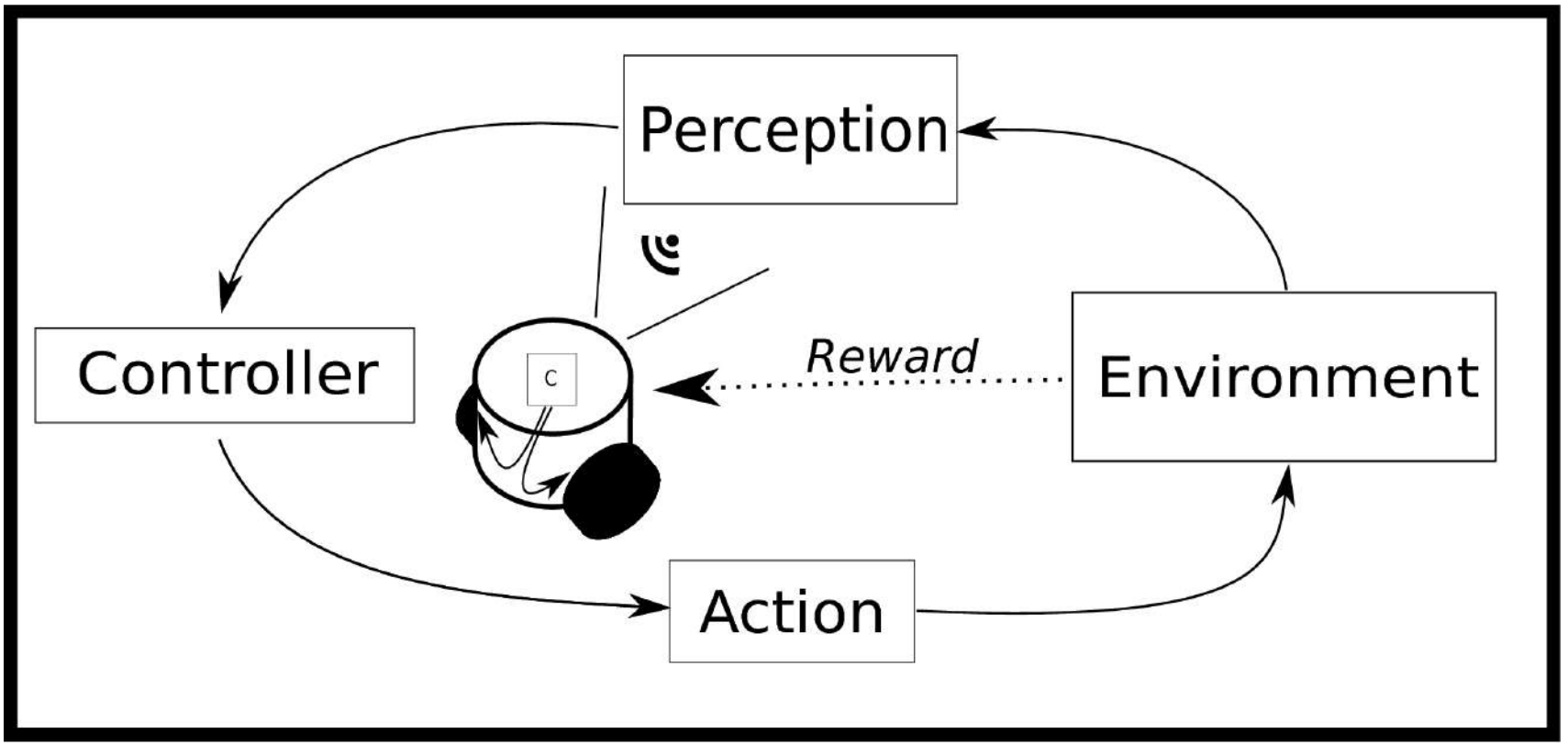
Las obras de ciencia ficción son obras de **FICCIÓN**

En caso de duda, consulte con su investigador de confianza

Robótica en Enjambre

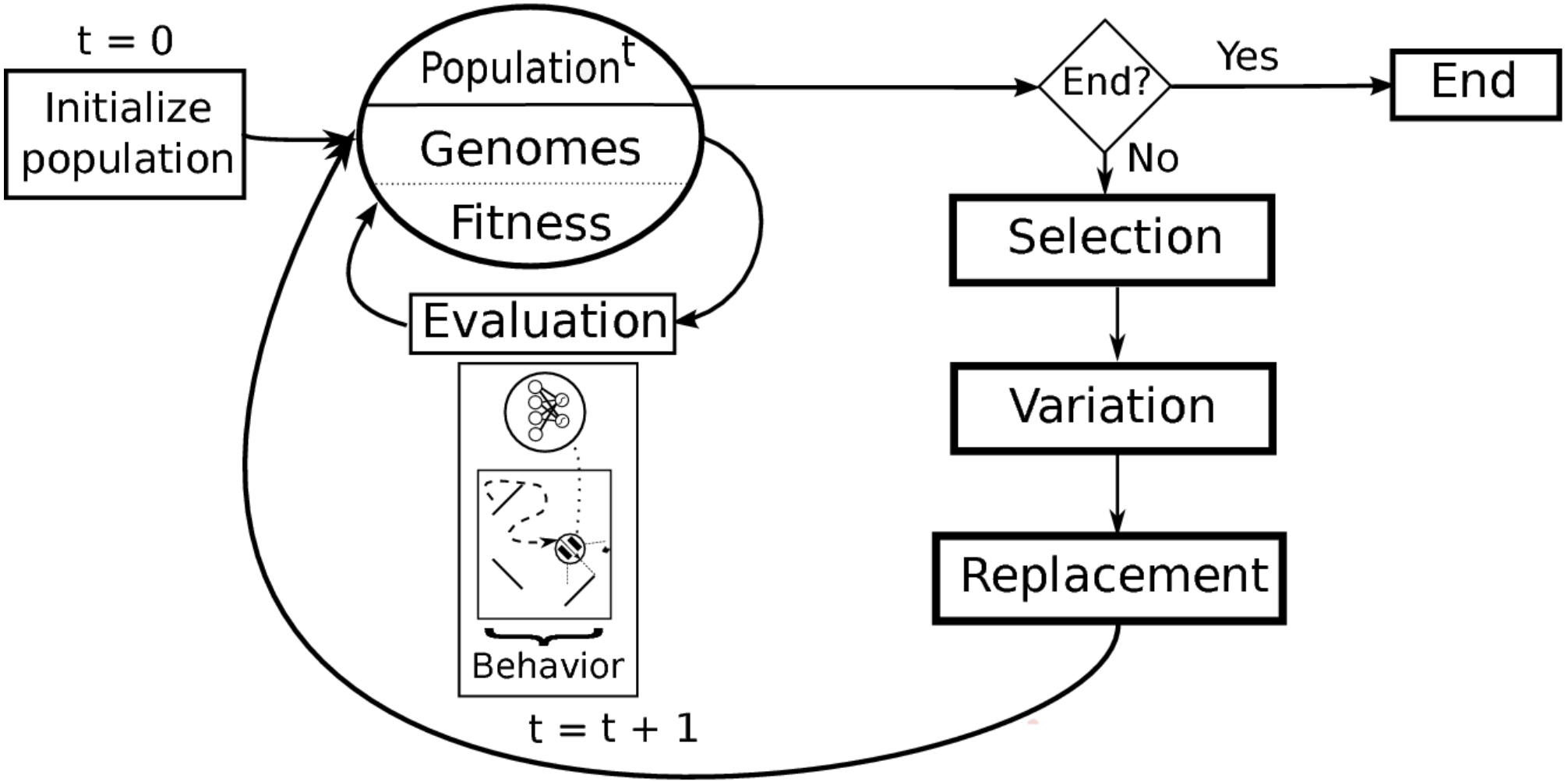
- Sistemas colectivos y adaptativos de robots
- Comportamiento auto-organizado y distribuído
  - Sin elemento central / cuello de botella
- Propiedades emergentes globales
  - a partir de reglas simples e interacciones
- Sistemas robustos, escalables, flexibles,…
- … pero difíciles de diseñar

Bucle sensorimotor

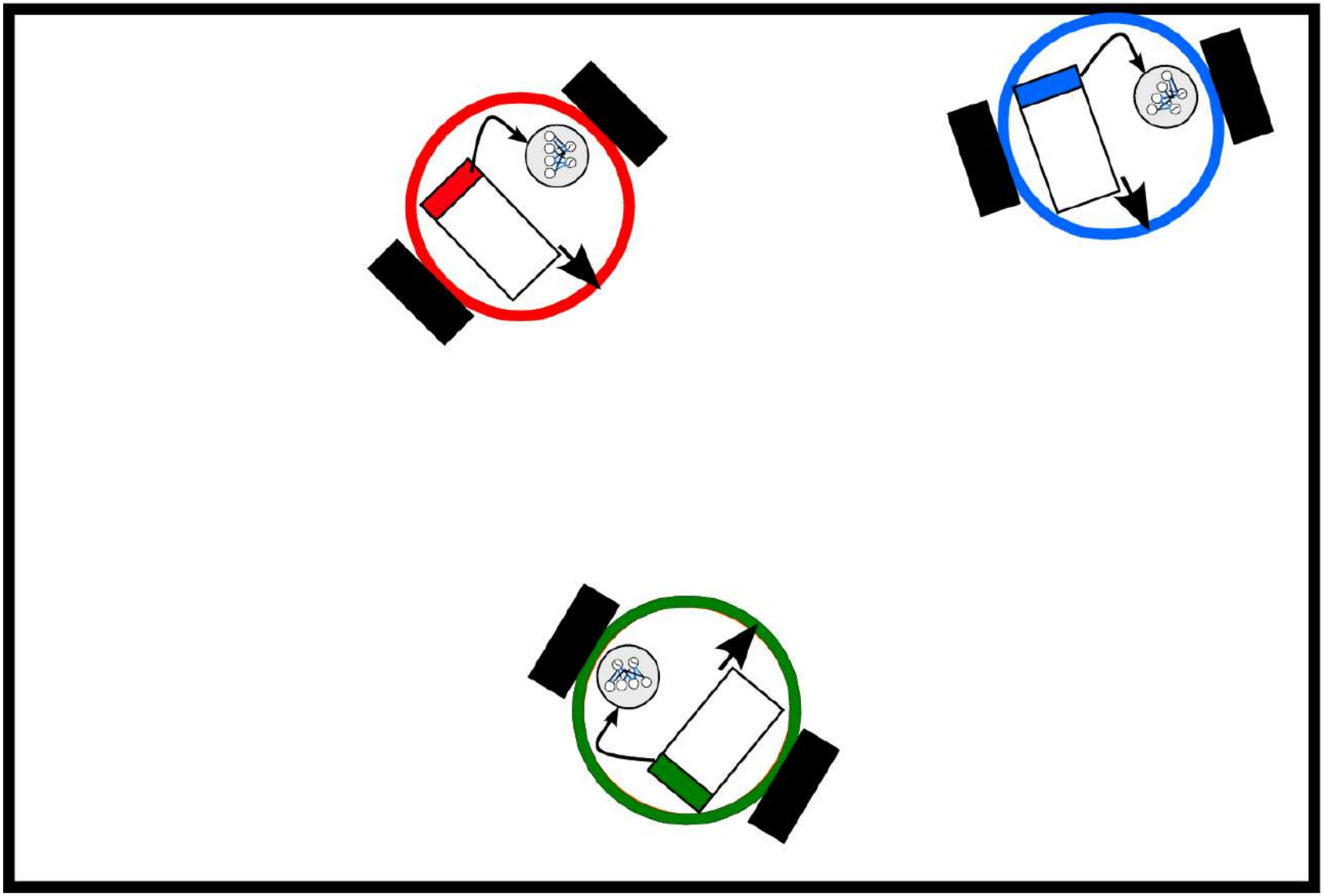


A simple reactive robotic agent and its sensorimotor loop

Evolutionary Algorithms



(Distributed) Embodied Evolution



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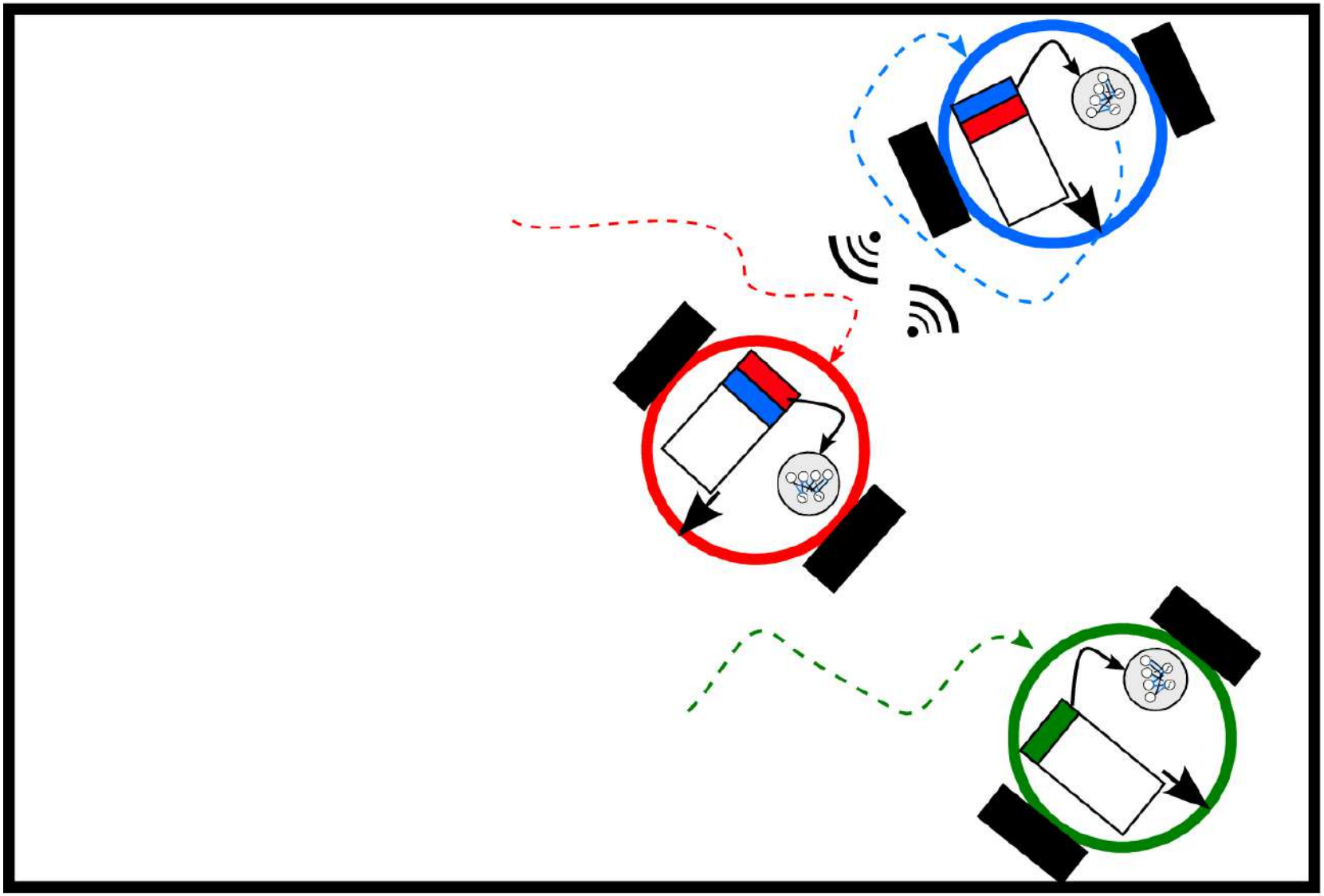
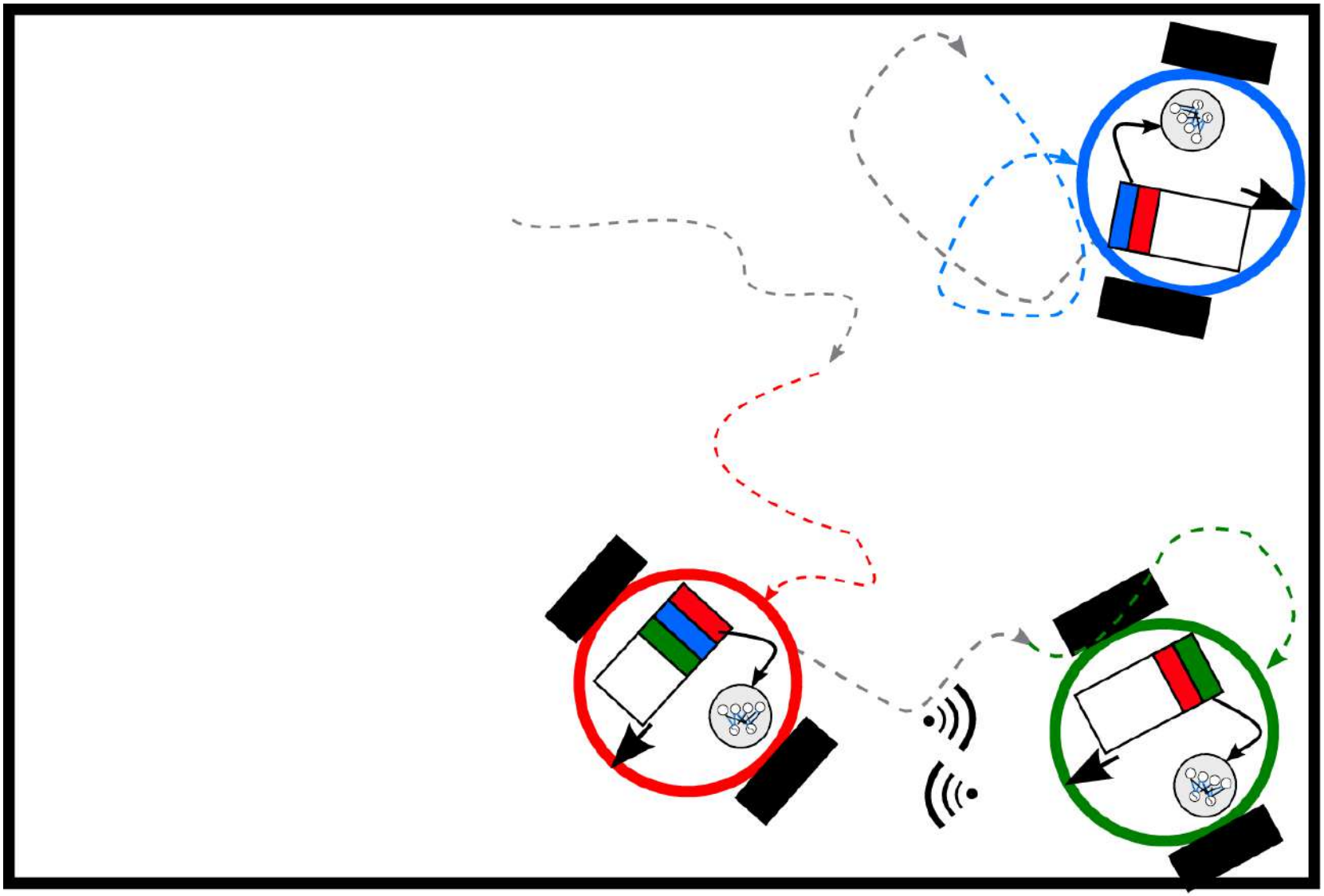
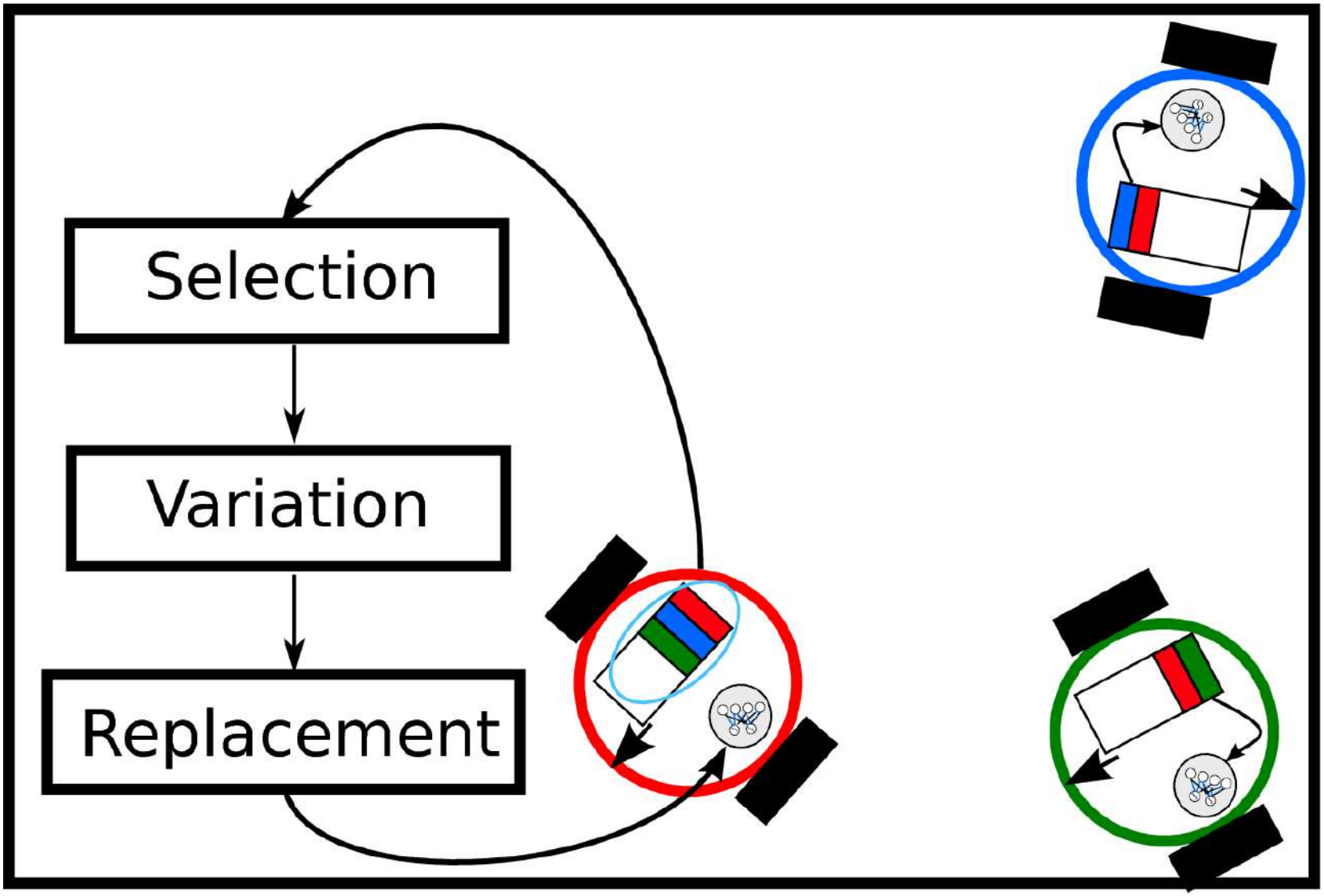


(Distributed) Embodied Evolution



(Distributed) Embodied Evolution



Evolución de la Colaboración

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
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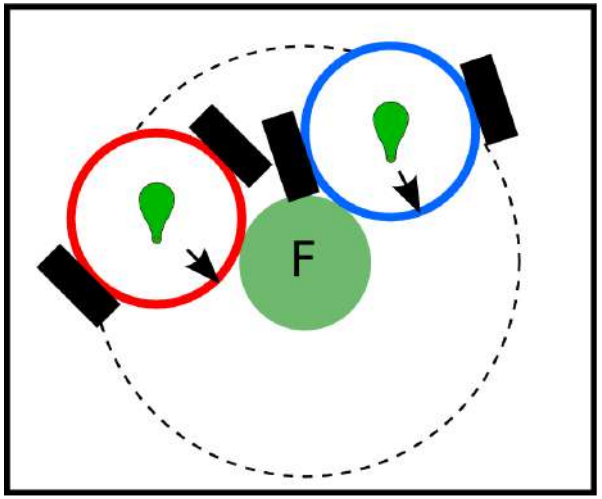
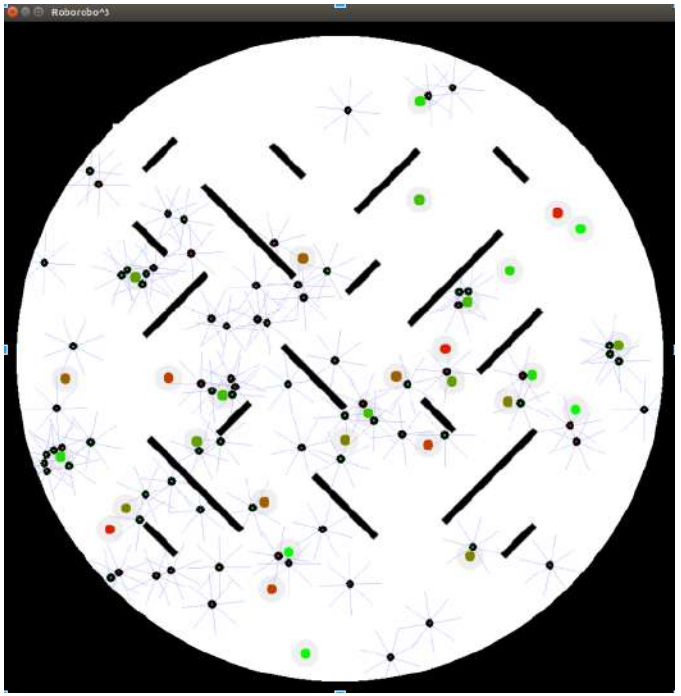
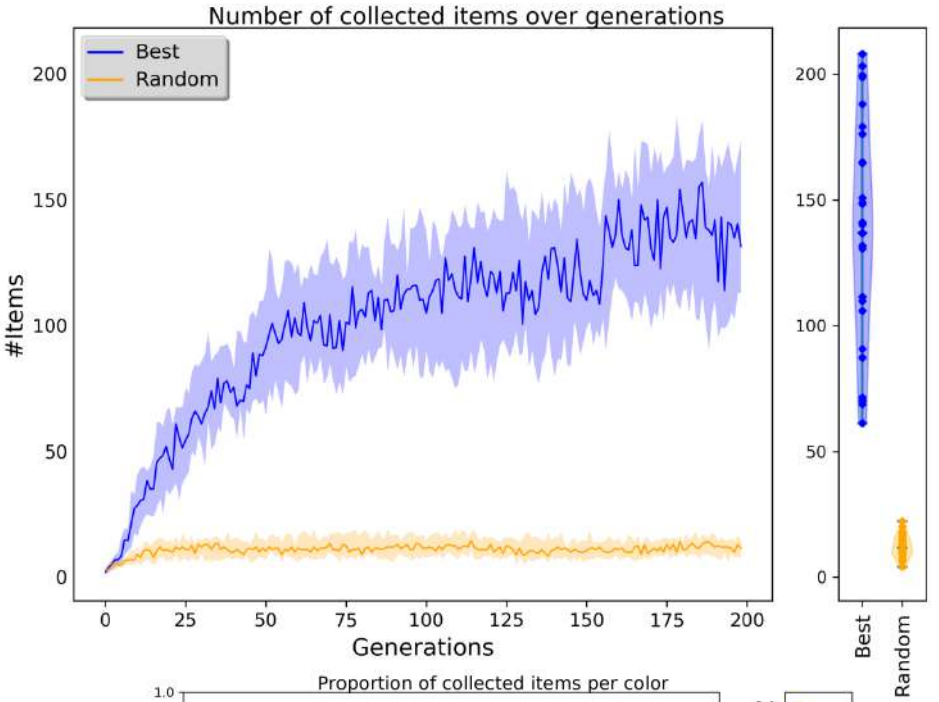
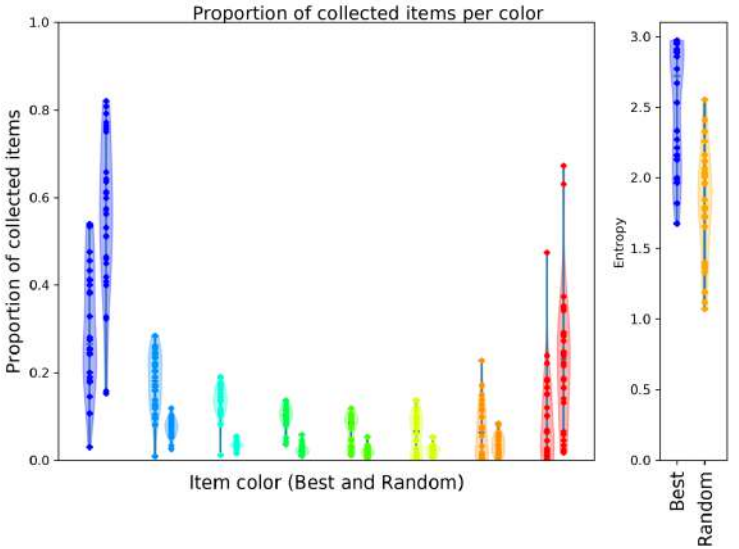
Evolución de la Colaboración







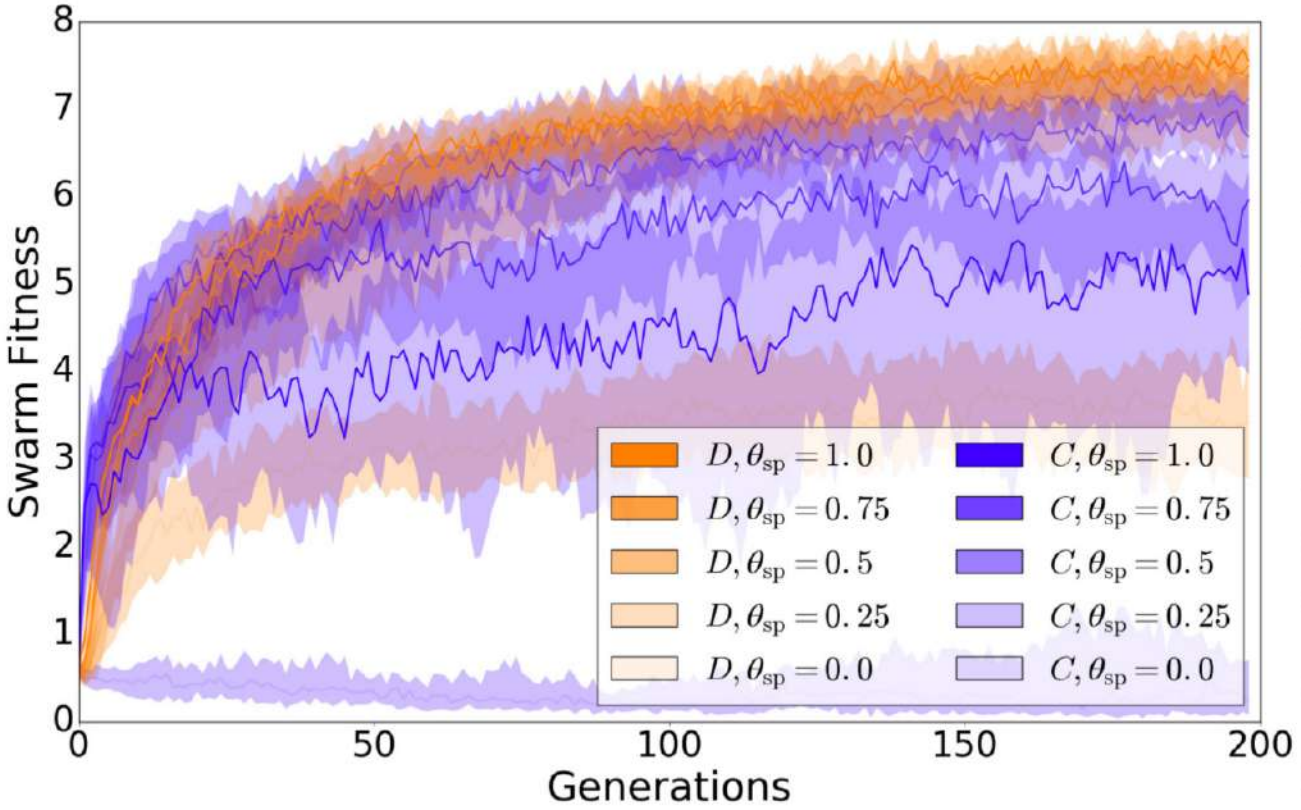


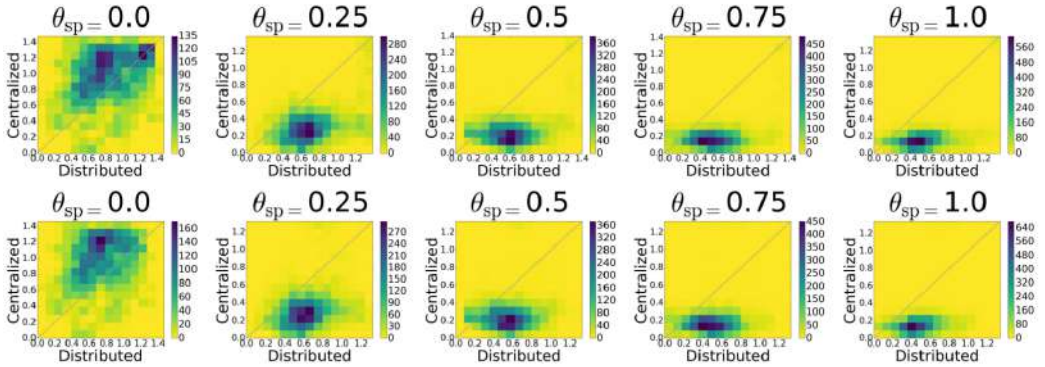
Mantener Diversidad sobre el Enjambre

- Diversidad → positiva para la adaptación
  - A entornos desconocidos, a cambios, a dif. tareas,…
- Algoritmo evolucionista centralizado *vs.* distribuído
  - O visto de otro modo:
    - 1) comunicación global
    - 2) larga distancia
    - 3) media distancia
    - 4) corta distancia
  - ¿Cuál mantiene más diversidad (útil),

    mejorando la adaptación del enjambre?

Mantener Diversidad sobre el Enjambre






```
1  g_a ← random()
2  while true do
3      l ← ∅, f ← 0
4      for t ← 1 to T_e do
5          exec(g_a)
6          f ← evaluate()
7          broadcast(g_a, f)
8          l ← l ⋃ listen()
9      l ← l ⋃ {(g_a, f)}
10     selected ← select(l)
11     g_a ← mutate(selected)
```

Paper at ANTS, Rome (October 2018)

Pero entonces…

¿qué es exactamente la Vida Artificial?

¿Una definición de la Vida Artificial?

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

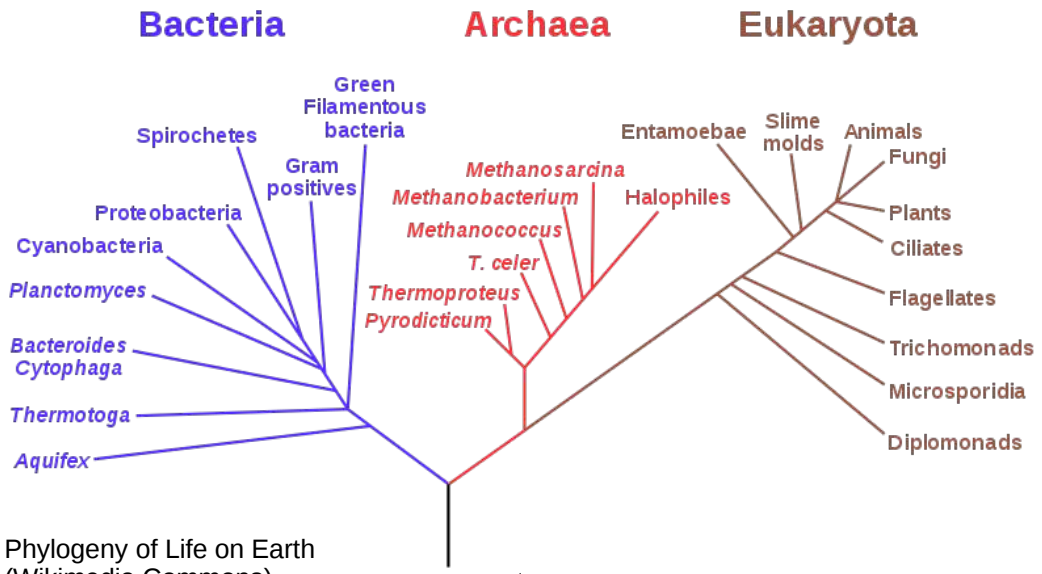
Biología

Estudio

Uso

Naturaleza

Sistemas Artificiales



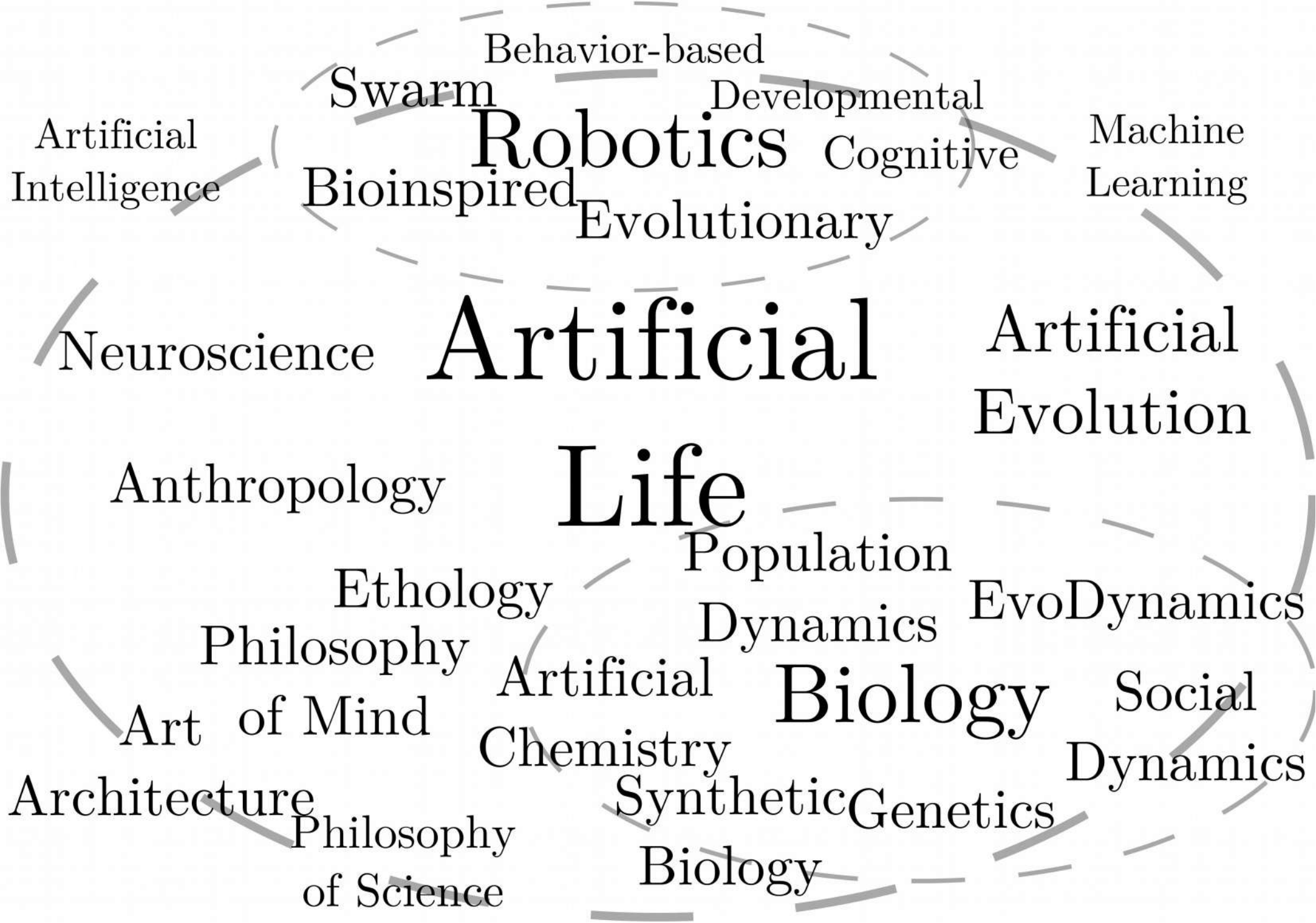
Phylogeny of Life on Earth
(Wikimedia Commons)

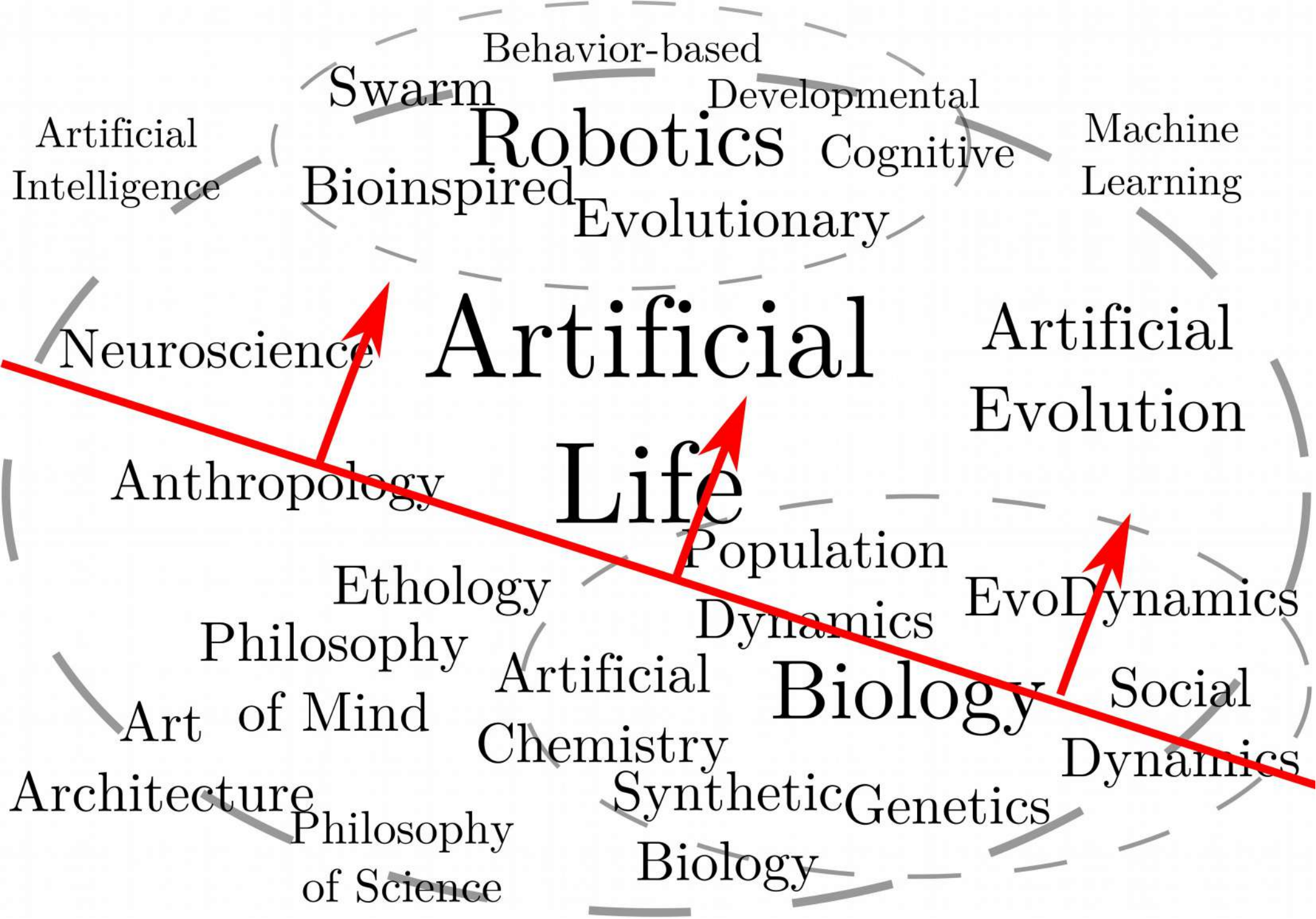
Postcard, Insil Choi,
Alife 2014

Inspiración (++)

Ingeniería

Construcción


Behavior-based
Swarm
Developmental
Artificial
Intelligence
Robotics
Cognitive
Machine
Learning
Bioinspired
Evolutionary
Neuroscience
Artificial
Artificial
Evolution
Anthropology
Life
Population
Ethology
EvoDynamics
Dynamics
Philosophy
Artificial
Biology
Social
of Mind
Art
Chemistry
Dynamics
Architecture
Synthetic
Genetics
Philosophy
of Science
Biology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ALife: herramientas y métodos compartidos (y desarrollados) por la comunidad

- Estudio de sistemas (evo/devo, social, celular,…)
- *Soft, hard and wet Alife* (digital, robótico o biosintético)
- Herramientas estadísticas, matemáticas, de simulación,…
- Enfoques experimentales y analíticos, **método científico**

Disclaimer: esto lo digo yo, otros pueden tener una visión diferente

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

La naturaleza está optimizada para la eficiencia

Sacar inspiración hasta de debajo de las piedras

E investigar el sujeto de estudio de manera rigurosa: método científico

@ISALStudents and postdoc:

- Diversas actividades Alife: journal club, discusiones temáticas, colaboraciones, premio anual, eventos en conferencias, representante en el consejo de ISAL, intervenciones previstas en *Artificial Life journal*
- *http://isalstudents.org/*

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www.irit.fr/~Inaki.Fernandez-Perez