Engineering the future
About the author and the institution

~50 staff
~100 researchers

1 staff (+2)
3 Ph.D. students
~4 undergrad
iTuna

BatBot

SMA-based and piezo-electric artificial muscles

SMA muscles

SMA wires attached to metal strips

6.7 mm

4 mm of stroke

tendon-like chord attaching the muscle to the elbow

hema

MCP-III

MCP-IV

MCP-V

thumb

radius bone

humerus bone

leg

SMA muscles biceps, triceps

shoulder joint

elbow joint

wrist joint

wing membrane

Backbone

Red muscles

Fixed ends: SMA wire Ø 1.6 mm screws

T 8.3 cm

7 cm

5 cm

SMA-based and piezo-electric artificial muscles
Testbed for alternative technologies

Long-term view

✱ *motor-less* and *gear-less* robots
  - devoid of “conventional” electro-magnetic/pneumatic/hydraulic technology, no rotating parts ➔ lighter, simpler, safer
Three Applications of Evolutionary Algorithms to Robotics

Claudio Rossi

2nd Extract-IT workshop, Brussels, June 2013
Evolutionary Algorithms (EAs)

**Evolution**
- Environment
- Individual
- Fitness

**Problem Solving**
- Problem
- Candidate Solution
- Quality

Population-based, stochastic search

Evolutionary loop:
- Parent selection
- Recombination ("crossover")
- Mutation
- Survivor selection ("replacement")

Termination

Slide source: A.E. Eiben and J.E. Smith, Introduction to Evolutionary Computing
encoding = chromosome = genotype

candidate solution = phenotype

mutation

recombination

Slide source: EvoNet Flying circus
1. EAs in pattern marching for vision-based relative navigation
Vision-based satellite relative navigation

Ballistic stage

Reaching stage

Inspection stage

Docking
Model-based pose estimation → optimization

$$\min(d = \sum_i |p_i - m_i(s)|),$$

$$p_i, m_i \in \mathbb{R}^2$$

$$s = (T_x, T_y, T_z, \alpha, \beta, \gamma)$$
1. EAS in pattern matching

Relative localisation
2. EAs in agent-based negotiations for robot coordination
2. EAs as negotiators

Requirements:
- Can be instantiated for different tasks
- Suitable for heterogeneous robots
- Distributed approach

A task is described by a set of $n$ "parameters"

\[
T(x) = \{T_1(x^{(1)}), \ldots, T_R(x^{(R)})\}, \quad R = \text{number of robots}
\]

\[
\bigcup_{i=1}^{R} T_i = T \quad T_i \cap T_j = \emptyset.
\]
2. EAs as negotiators

Bargaining: based on Rubinstein’s uni-dimensional good alternate-offers protocol

Extension to n-dimensional goods:
- Evaluate offer (search!)
- Search for good counter-offer

Co-evolution!
2. EAs as negotiators
2. EAs as negotiators

Mission starts
2. EAs as negotiators
2. EAs as negotiators
3. Evolutionary Robotics
EAs - evolutionary robot controllers (learning)

Much work on it!

Population of candidate controllers (genotypes)

Instantiation (phenotype, e.g. neural network)

Evaluation (run!)

Off-line, off-body
3. EAs for learning

Our approach:

- On-line: an ecosystem of individuals (in a virtual world)
- “Real” mating: new morphologies derived from crossing over
- Newborns shall learn...
  - how to move
  - to find energy sources
  - to find mates
  ...before being released into the world (“robot school”, A.E. Eiben)

- Open-ended evolution: robots just have to survive
  - but environment can be tailored to drive evolution towards desired behaviors
Learning by evolving controllers for modular robots

Modules:
- 6 connection points (front, rear, left, right, top, bottom), 2DOF
- Head: 2 range sensors
- Encoding: tree
3. EAs for learning

Phase 1: individual learning
Phase 2: morphology crossover (in progress!)
3. EAs for learning

**Evobody** (EU FET Proactive Initiative SA on AWARENESS)
Also discussed in EVLIT

“Embodied evolution”

- Towards self-replicating non-biological systems
- Use e.g. of 3D printing on-the fly, plus basic actuators/sensors modules
- Recycling of materials and building blocks (“closed ecosystem”)

Genotype ➔ blueprint
Phenotype ➔ physical agent (i.e. “robot”)

-- more in general, “evolution of “things”
EAs - evolutionary modular robots

Again, a lot of work done and on-going

→ Sims: evolved virtual creatures (1994!)
→ Replicator/Symbion: evolution of symbiotic multi-robot organisms
→ J. Bongard (on the role of morphology)
→ SwarBots (evolution of cooperation)
References


• José Baca, Prithvi Pagala, Claudio Rossi, Manuel Ferre, “Modular robot systems towards the execution of cooperative tasks in large facilities”, Robotics and Autonomous Systems 01/2015 (in press).

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Thanks!

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