HARNESSING EVOLUTION TO COMPUTE

Evolution of technical, social and biological systems & applications to real-life complex problems of search, design, optimization, and innovation

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ICT and Darwinian Evolution

- Predicted **shift in computing**
  - Stochastic states (memory subject to errors)
  - Probabilistic switching (noisy circuit operation)
  - Explosion of the number of parallel computing units
  - Programming → Assembling components at different scales
    - Unbearable complexity
    - Design and maintainance out of reach
  - Continuous processing of dynamic data streams required

- Darwinian Evolution: the **highest-level process** in Nature
  - Reliable functions from unreliable elements
  - Randomness as a source of creativity
  - Unrelenting competition between parallel processes
  - Openness to environment
  - Open-endedness of processes

AMBITION

- Transfer recent advances in evolutionary and molecular biology to ICT

- Solve new complex problems that
  - cannot be completely specified *a priori*;
  - depend on temporal variations;
  - mix relevant and irrelevant information;
  - cannot presume human intervention.

- Transfer the findings back to biology

- Mandatory in all fields
  - IT, Cognition, Complex Systems
  - Optimization, Design

Breakthrough problems:
- Hypothesis generation
- Innovative design
- Real time data mining
- Environmental sensing
- Genomic organization.

Scientific challenges:
- Physicality and embodiment
- Genotype-phenotype mapping
- Exaptation / Innovation

Technological challenges:
- Open-ended problems
- Unpredictable conditions
- Unexpressed specifications.

IMPACT

- **Leverage effect**

  Strong mutidisciplinary and technical requisites

  - closes the beneficial loop between biology and computing
  - contributes to NBIC convergence
  - harvests the performance of future computers

- **Competitiveness**

  Impact on Optimization and Design

  - accelerates the innovation cycle, with a strong impact on European industry, economy and employment;
  - pervades all application fields of Complex Systems approaches
    - Technological networks (transport, energy, communication)
    - Software and hardware, adaptive and automated design (GP, cellular rep.)
    - Health (epidemiology, systems & synthetic biology)
    - Nutrition (food web, resource management)
    - Economics, Politics, Sociology, Law, ...

INTEGRATION

- **Scientists, engineers** from **WE ARE OPEN**
  - software engineering
  - evolutionary electronics
  - robotics and control
  - physics of disordered states
  - network science
  - evolutionary biology
  - systems & synthetic biology, artificial life
  - + application fields (previous slide)

- **Infrastructure & resources** **WE ARE EFFICIENT**
  - Networked research institutes across Europe
  - Education and Training (Intl Master program, Scholarships, Internships)
  - EU support as a catalyst → national, industrial and institutional support
  - Strong international outreach (Exchange programs, Fellowships)

- **Liaison** **WE ARE UNAVOIDABLE**
  - Pervasive Self* Computing
  - Boosting any project: Brain, Internet, Nanotechnologies, Care, Superman, …
  - Give us a man, we will send him on the moon

PLAUSIBILITY

- **ICT**: Pioneering attempts of the AE field already point the way
  - Multi-objective optimization
  - Co-evolution
  - Developmental representations (Design)
  - Enzyme-based control
  - Exaptation and open-ended evolution (Robotics)

- **Biology**: Modern concepts in evolutionary / molecular biology already there
  - 2005 workshop → coarse-grained research agenda
    Nature Reviews Genetics 7: 729, 2006.
  - Other foundational workshops in 2010 (?), 2011 and 2012

- **Building on** early FP6 Coordination Actions, and FP5-7 Streps

EXPECTED SUPPORT

- **41 Institutions** from **15 countries** have signed up for support of this initiative
- Constitutive scientific communities are around
  - GECCO alone has annually appprox 500 participants
  - NSF BEACON Institute – Evolution in Action ($ 25M)
- Impetus will come from becoming conscious of
  - the gap between AE and current evolution concepts
  - self-censorship (usage shapes expectations)
- Everybody wants better solutions to more complex problems
  - keep away from quick promises
- International links easy to set up
  - *e.g.* see article authors