Introduction to Evolutionary Computation

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The EvoNet Training Committee

Q   What is the most powerful problem solver in the Universe?

The (human) brain that created "the wheel, New York, wars and so on" (after Douglas Adams)

The evolution mechanism that created the human brain (after Darwin et al.)

Building problem solvers by looking at and mimicking:

- Brains $\rightarrow$ Neurocomputing
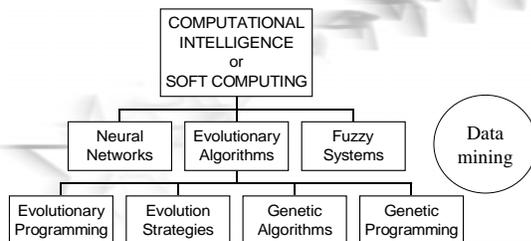
- Evolution $\rightarrow$ Evolutionary computing

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Taxonomy

COMPUTATIONAL INTELLIGENCE or SOFT COMPUTING

- Neural Networks
- Evolutionary Algorithms
- Fuzzy Systems
- Data mining

- Evolutionary Programming
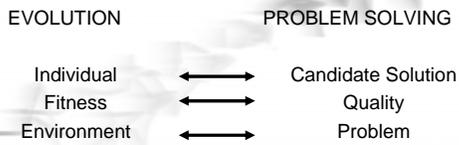- Evolution Strategies
- Genetic Algorithms
- Genetic Programming

History

- L. Fogel 1962 (San Diego, CA): *Evolutionary Programming*
- J. Holland 1962 (Ann Arbor, MI): *Genetic Algorithms*
- I. Rechenberg & H.-P. Schwefel 1965 (Berlin, Germany): *Evolution Strategies*
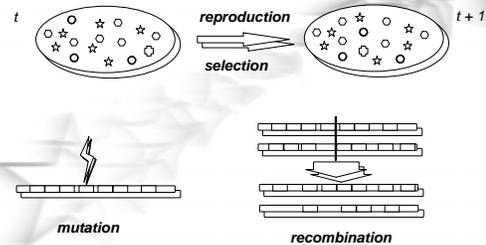- J. Koza 1989 (Palo Alto, CA): *Genetic Programming*

The Metaphor

EVOLUTION		PROBLEM SOLVING
Individual	⟷	Candidate Solution
Fitness	⟷	Quality
Environment	⟷	Problem

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The Ingredients

t   *reproduction*   *t + 1*

selection

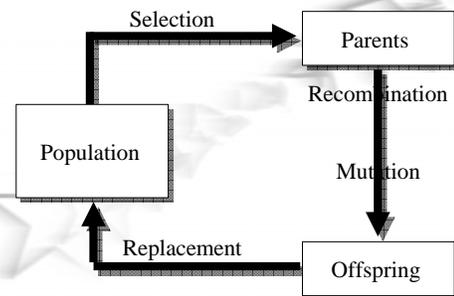*mutation*   *recombination*

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The Evolution Mechanism

- Increasing diversity by genetic operators
  - mutation
  - recombination
- Decreasing diversity by selection
  - of parents
  - of survivors

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The Evolutionary Cycle

Selection — Parents — Recombination — Mutation — Offspring — Replacement — Population

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Domains of Application

- Numerical, Combinatorial Optimization
- System Modeling and Identification
- Planning and Control
- Engineering Design
- Data Mining
- Machine Learning
- Artificial Life

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Performance

- Acceptable performance at acceptable costs on a wide range of problems
- Intrinsic parallelism (robustness, fault tolerance)
- Superior to other techniques for complex problems with
  - lots of data, many free parameters
  - complex relationships between parameters
  - many (local) optima

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Advantages

- No presumptions w.r.t. problem space
- Widely applicable
- Low development & application costs
- Easy to incorporate other methods
- Solutions are interpretable (unlike NN)
- Can be run interactively, accommodate user proposed solutions
- Provide many alternative solutions

Disadvantages

- No guarantee for optimal solution within finite time
- Weak theoretical basis
- May need parameter tuning
- Often computationally expensive, i.e., slow

Books

- Th. Bäck, Evolutionary Algorithms in Theory and Practice, Oxford University Press, 1996
- L. Davis, The Handbook of Genetic Algorithms, Van Nostrand & Reinhold, 1991
- D.B. Fogel, Evolutionary Computation, IEEE Press, 1995
- D.E. Goldberg, Genetic Algorithms in Search, Optimisation and Machine Learning, Addison-Wesley, '89
- J. Koza, Genetic Programming, MIT Press, 1992
- Z. Michalewicz, Genetic Algorithms + Data Structures = Evolution Programs, Springer, 3rd ed., 1996
- H.-P. Schwefel, Evolution and Optimum Seeking, Wiley & Sons, 1995

Journals

- BioSystems, Elsevier, since <1986
- Evolutionary Computation, MIT Press, since 1993
- IEEE Transactions on Evolutionary Computation, since 1996

Conferences

- ICGA, USA, 1985 +2
- PPSN, Europe, 1990 +2
- FOGA, USA, 1990 +2
- EP, USA, 1991 +1
- IEEE ICEC, world, 1994 +1
- GP, USA, 1996 +1

Summary

EVOLUTIONARY COMPUTATION:

- is based on biological metaphors
- has great practical potentials
- is getting popular in many fields
- yields powerful, diverse applications
- gives high performance against low costs
- AND IT'S FUN !