

Nature-Inspired Computing

Introduction to Evolutionary Computation

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BIOLOGICAL BACKGROUND

Evolution

- Darwin
 - "Origin of Species"
 - natural selection analogous to artificial selection practiced by cattle breeders
 - natural selection gives direction to evolution

Evolution

- Darwin's theory of evolution
 - species arise as adaptation to niches in environment based on:
 - a population of organisms compete for resources
 - variation within population that affect individuals' chances for reproduction
 - inheritance of favorable characteristics

Evolution

- (*Darwin cntd.*)
 - variations occur purely by chance
 - variations are the real fabric of evolution
 - natural selection acts on these variations

Evolution

- Genetics answer questions Darwin's theory couldn't:
 - transmission of genetic traits
 - how traits can disappear and reappear
 - how variations arise
- Darwinian evolution + Mendelian principles = Population Genetics
- Evolution is defined as any change in the gene pool.

Evolution

- *population*: any group of individuals of one species that occupy a given area at the same time; in genetic terms, an interbreeding group of individuals; defined by its gene pool.
- *adaptation*: the evolution of features that make a group of organisms better suited to live and reproduce in their environment

Evolution

- *fitness*: the relative ability to leave offspring and survive
- *natural selection*: a process of interaction between organisms and their environment which results in a differential rate of reproduction of different phenotypes in a population (survival of the fittest)

Classical Mendelian Genetics

- *inheritance*: propagation of genetic material from parent to offspring
- *gene*: smallest unit of heredity
- *gene pool*: all the genes of all the individuals
- *chromosome*: one of the bodies in the cell nucleus, along which the genes are located

Classical Mendelian Genetics

- *genotype*: the genetic constitution of a cell or an organism
- *phenotype*: observable properties of an organism
- *mutation*: the inheritable change of a gene from one allelic form to another

Classical Mendelian Genetics

- *recombination*: the formation of gene combinations through mixing that differ from the combinations present in the parents
 - *crossing over*: exchange of genetic material between paired chromosomes

EAs \Leftrightarrow Real World Terminology

- *individual*: one point in the search space of all possible solutions
- *population*: whole of the solution points currently under consideration
- *gene*: an encoding of a parameter or a part of a solution

EAs \Leftrightarrow Real World Terminology

- *chromosome*: an encoding of all the parameters or the whole current solution candidate
- *crossing over*: a recombination operator used during reproduction phase
- *mutation*: abrupt change in gene value

EAs \Leftrightarrow Real World Terminology

- *genotype*: the actual numerical values of the genes (binary, integer, real, etc)
- *phenotype*: what the actual value of each gene corresponds to with respect to the problem encoding

EAs \Leftrightarrow Real World Terminology

- *fitness*: how much the current solution meets the requirements of the objective function
- *natural selection*: selection of individuals to go into reproduction through some artificial methods
- *generation*: one loop of the genetic algorithm

Evolutionary Computation

What is EC?

- Methods based on
 - Mendelian genetics
 - units of inheritance
 - Darwin's survival of the fittest
 - a *population* of animals/plants/etc that compete for resources
 - *variations* within population that affects individuals' chances for reproduction
 - *inheritance* of favourable characteristics

What is EC?

- Work on a population of solutions
- Incorporate some form of
 - selection
 - recombination
 - mutation

What is EC?

Algorithm EA:

```
INITIALIZE population randomly
CALCULATE_FITNESS of each individual
while not STOP_CRITERIA do
  SELECT parents
  RECOMBINE pairs of parents
  MUTATE offspring
  CALCULATE_FITNESS of new individuals
  REPLACE (some) parents by offspring
end_do
```

What is EC?

- $SC = EC + ANN + FL$

- $EC = GA + ES + EP + GP$

GA \Rightarrow Holland 1975

ES \Rightarrow Rechenberg 1973

EP \Rightarrow Fogel, Owens, Walsh 1966

GP \Rightarrow Koza 1989

Performance

- for a wide range of applications
 - acceptable performance
 - acceptable cost
- implicit parallelism
 - robustness
 - fault tolerance
- acceptable performance even under uncertainties and change

EAs and Other Search Heuristics

- EAs
 - avoid converging to local optima
 - exploration of the search space
 - exploitation of promising areas
 - not dependent on initial starting point(s)
 - start search from many points in the search space

EAs and Other Search Heuristics

- conduct search in parallel over the search space
 - implicit parallelism
- reach better solutions by combining already found good solutions
- may be used together with other approaches (hybrids)