Part I Evolutionary Computation

Chapter 2

Introduction to Evolutionary Computation

Evolution

- Evolution is this process of adaption with the aim of improving the survival capabilities through processes such as natural selection, survival of the fittest, reproduction, mutation, competition and symbiosis.

人倾向于线性地思考问题，而进化（Evolution）则常常以人们意象不到的方式解决问题。

——弗格《什么是进化计算》

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Evolutionary Computation

- Evolution is an optimization process where the aim is to improve the ability of an organism(or system) to survive in dynamically changing and competitive environmens.
- Darwin（1809～1882）is generally considered as the founder of both the theory of evolution and the principle of common descent进化理论和共同起源法则的奠基人
- Lamarck（1744-1829）was possibly the first to theorize about biological evolution生物进化理论化的第一人。

Jean-Baptiste Lamarck

- Individuals adapt during their lifetimes and transmit their traits to their offspring. The offspring then continue to adapt.
- The method of adaptation rests on the concept of use and disuse: over time, individuals lose characteristics they do not require and develop those which are useful by “exercising ”them.

Charles Darwin

- Natural selection -------the foundation of biological evolution

–In a world with limited resources and stable populations, each individuals competes with others for survival. Those indiduals with the “best” characteristics are more likely to survive and to reproduce, and those characteristics are inherited by the following generations and（over time）become dominant among the population.

Charles Darwin

– During the production of a child organism, random events couse random changes to the child organism's characteristics.If these new characteristics are a benefit to the organism, then the chances of survival for that organism are increased.

EC

- **Evolutionary computation**refers to computer-based problem solving systems that use computational models of evolutionary processes, such as natural selection, survival of the fittest and reproduction, as the fundamental components of such computational systems.

2-1 Generic Evolutionary Algorithm

- Natural selection of a randomly chosed population of individuals can be thought of as a search through the space of possible chromosome values.
- EA is a stochastic search for an optimal solution to a given problem.
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  - 编码（encoding）：the solutions to the problem as a chromosome.
  - 适应度函数（a fitness function）：survival strength of individuals
  - 初始化（initialization）：initial population
  - 选择（selection）：
  - 繁殖（reproduction）：

Darwin's theory

- Natural selection occurs within the reproduction operation where the “best” parents have a better chance of being selected to produce offspring, and to be selected for the new population.
- Random changes are effected through the mutation operator.

Algorithm

1. Let t=0 be the generation counter;
2. Create and initialize an n_x-dimensional population C(0), to consist of n_ξ individuals;
3. while stopping condition(s) not true do
4. Evaluate the fitness f(x_i(t)) of each individual x_i(t);
5. Perform reproduction to create offspring
6. Select the new population C(t+1)
7. Advance to the new generation,t=t+1;
8. end

- Each iteration of an EA is referred to as a generation

2-2 Algorithm designing

- representation
- initial population
- fitness function
- selection
- reproduction operators
- stopping conditions

1. Representation-The Chromosome

- In nature, organisms have certain characteristics that influence their ability to survive and to reproduce. These characteristics are represented by long strings of information contained in the chromosomes of the organism.
- 染色体（chromosome）are structures of compact interewined molecules of DNA, found in the nucleus of organic cells.
- Each chromosome contains a large number of genes,where a gene is the unit of heredity.
- Each individual has a unique sequence of genes.

Chromosome

- In the context of EC, each individual represents a candidate solution to an optimization problem.
- 个体的特征由染色体（也叫基因组，genome）表示。
  - these characteristics refer to the variables of the optimization problem. Each variable that needs to be optimized is referred to as a gene---the smallest unit of information.

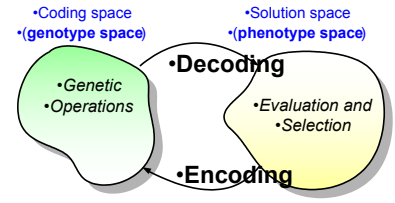
Representation

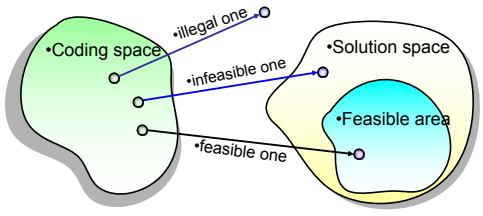
- two classes of evolutionary information：基因型和表现型。
  - A genotypes describles the genetic composition of an individual, as inhertied from its parents.
  - A phenotype is the expressed bahavioral traits of in individual in a specific environment, it defines what an individual looks like.

Representation

- An important step in the design of an EA is to find an appropriate representation of candidate solutions(chromosomes)
- The efficiency and complexity of the search algorithm greatly depends on the representation scheme.
- Most EAs represent solutions as vectors of a specific data type.

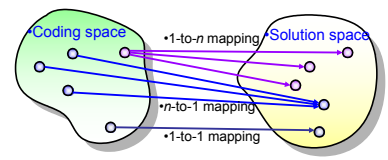
- Genetic operations work on coding space (chromosomes)
- While evaluation and selection work on solution space.





Uniqueness

- The mapping from chromosomes to solutions (decoding) should belong to 1-to-1 mapping.



- 多对一存在资源浪费
- 一对多存在适应度评价问题

Encoding Issue(分类)

- According to what kind of symbol is used(使用的符号):
  - Binary encoding
  - Real number encoding
  - Integer/literal permutation encoding(整数排列编码)
  - A general data structure encoding
- According to the structure of encodings(结构):
  - One-dimensional encoding
  - Multi-dimensional encoding
- According to the length of chromosome(长度):
  - Fixed-length encoding
  - Variable length encoding
- According to what kind of contents is encoded(内容):
  - Solution only
  - Solution + parameters（进化策略）

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Encoding

– Binary encoding
– Gray encoding（格雷码）
– Real number encoding
for constrained optimization problems（适合函数优化）

– The integer coding
for combinatorial optimization problems.（组合优化）

2.Initial Population

- EAs are stochastic, population-basedsearch algorithms.
- Each EA maintains a populationof candidate solutions.
- The first step in applying an EA to solve an oimization problem is to generate an initial population.

Generating

- The standard way of generating an intial population is to assigna random value from the allows domain to each of the genes of each chromosome.
- The goal of random selection is to ensure that the initial population is auniform representation of the entire search space.
- If regions of the search space are not coverd by the initial population, chances are that those parts will be neglected by the search process.

Size

- The size of the initial population has consequences in terms of computational complexity and exploration abilities.

- Large
- increase diversity and improve theexploration abilities
- increase execution time
- Small
- cover small part of the search space
- need more generations to converge
- need to increase the rate of mutation

3. Fitness function

- In order to determine the ability of an individual of an EA to survive, a mathematical function is used to quantify how good the solution represented by a chromosome is.

- maps a chromosome into a scalar value

$$f:\ \Gamma^{n_x} \rightarrow \mathrm{R}$$

式中，Γ代表n_x维染色体的数据类型。

Fitness function

- Usually,the fitness function provides an absolute measure of fitness.
- The solution represented by a chromosome is directly evaluted using the objective function.

- 适应度函数f可以用目标函数Ψ来表示，因为目标函数描述了最优化问题。
- 适应度越大，个体越优。
- 适应度之间的差异应该能反映个体之间的差异。
- 目标函数的设计直接决定算法的收敛速度和效率。

4.Selection

- Selection is one of the main operators in EAs, and related directly to the concept of survial of the fittness.
- The main objective of selection is toemphasize better solutions.
- Selection of the new populations
- A new population of candidate solutions is selected at the end of generation to serve as the population of the next generation. The new population can be selected from only the offspring, or from both the parents and the offspring. The selection operator should ensure that good individuals do survive to next generations.

Selective pressure

- 选择压力又叫接管时间（takeover time）
- It is defined as the speed at which the best solution will occupy the entire population by repeated application of the selection operation alone.
- 选择算子单独反复作用使得最优解占整个种群的速度。

Selective pressure

- High
- dicrease diversity of the population
- limit the exploration abilities of the population
- lead to premature convergence to suboptimal solutions.

5.Reproduction operators

- Reproduction is the process of producing offspring from selected parents by applying crossover and/or mutation operators.
- Crossover is the process of creating one or more new individuals through thecombination of genetic material randomly selected from two or more parents.

Reproduction

- Mutation is the process of randomlychanging the values of genes in a chromosome.
- The main objective is to introduce new genetic material into the population, thereby increasing genetic diversity.
- Should be applied with care not to distort the good genetic material in high fit individuals.

Reproduction

- Reproduction can be applied with replacement, in which case newly generated individuals replace parent individuals only if the fitness of the new offspring is better that of the corresponding parents.
- EC paradigm dependent

6. Stopping conditions

- The evolutionary operators are iteratively applied in an EA until a stopping condition is satisfied.
- The simplest stopping conditions is to limit the number of generations.

终止条件

- Convergence criterion
- Terminate
  - when no improvement is observe over a numer of consecutive generations.
  - when there is no change in the population.
  - when an accepted solution has been found.
  - when the objective function slope is approximately zero.

2-3 EC versus Classical optimization

- 经典优化算法已经在线性、二次型、强凸型、单模及其它某些特定问题上取得了成功。
- 进化算法则对不连续、不可微、多模和带噪问题更为有效。
- 进化算法与经典优化算法（classical optimization：CO）的主要不同在于搜索过程及搜索过程中使用的信息。

进化计算与经典优化算法

- 搜索过程
  - 经典优化算法使用确定的规则从搜索空间中的一点移动到另外一点。进化计算则使用概率变换规则。
  - 进化计算还对搜索空间进行并行搜索，而经典优化算法则使用顺序搜索。
  - 进化算法从不同的初始点开始搜索，这样能并行搜索大量空间。经典优化算法只能从一个点，连续地向最优点调整和移动。
- 搜索过程中使用的信息
  - 经典优化算法使用搜索空间的偏导数信息（通常为一阶或二阶）来启发搜索路径。另一方面，进化计算不使用偏导数信息，它使用个体的适应度来指导搜索。

2-4 Performace evaluation

- 一、性能评价
- 成功率
- 有效性
- 效率
- 二、测试
- 标准测试函数
- 实际问题实例