Genetic Algorithms

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Genetic Algorithms (Overview)

- Search based techniques to optimization problems
- Inspired by the biological evolution process
- Suitable for hard problems
- Applications in science, engineering, business, etc.

Main Idea

A genetic algorithm maintains a population of candidate solutions for the problem at hand, and makes it evolve by iteratively applying a set of stochastic operators

Components of GA

- **Individual** - Any possible solution
- **Population** - Group of all individuals
- **Search Space** - All possible solutions to the problem
- **Fitness Function -** Defines the optimality of a solution

Encoding

Possible individual's encoding

- Bit strings (0101 ... 1100)
- Real numbers (43.2 -33.1 ... 0.0 89.2)
- Permutations of element (E11 E3 E7 ... E1 E15)
- Lists of rules (R1 R2 R3 ... R22 R23)
- ... any data structure ...

Selection

- **Selection**
  - **Purpose:** to focus the search in promising regions of the space
  - **Inspiration:** Darwin's "survival of the fittest"
  - **Trade-off:** between exploration and exploitation of the search space

Stochastic Operators

- Crossover (Recombination)
  - Decomposes two distinct solutions and then randomly mixes their parts to form novel solutions

- Mutation
  - Simulate the effect of errors that happen with low probability during duplication
  - Randomly perturbs a candidate solution

Simple Genetic Algorithm

produce an initial population of individuals

evaluate the fitness of all individuals

while termination condition not met do

    select fitter individuals for reproduction

    recombine between individuals

    mutate individuals

    evaluate the fitness of the modified individuals

    generate a new population

End while

Example: MAXONE problem

Problem: Maximize the number of ones in a string of / binary digits

Chromosome:

String of / binary digits

Fitness Function:

Number of ones in each string

MAXONE (Cont.)

Suppose l = 10 and N=6

We toss a fair coin 60 times and get the following initial population

$$s_1 = 1111010101 \quad f(s_1) = 7$$

$$s_2 = 0111000101 \quad f(s_2) = 5$$

$$s_3 = 1110110101 \quad f(s_3) = 7$$

$$s_4 = 0100010011 \quad f(s_4) = 4$$

$$s_5 = 1110111101 \quad f(s_5) = 8$$

$$s_6 = 0100110000 \quad f(s_6) = 3$$

MAXONE (Selection)

Probability: (Roulette Wheel method)

$$P(i) = \frac{f(i)}{\sum_i f(i)}$$

With this probability individuals are selected from parent population.

MAXONE (Selection)

Suppose that, after performing selection, we get the following population:

s_1 = 1111010101	$f(s_1) = 7$	s'_1 = 1111010101	(s_1)
s_2 = 0111000101	$f(s_2) = 5$	s'_2 = 1110110101	(s_3)
s_3 = 1110110101	$f(s_3) = 7$	s'_3 = 1110111101	(s_5)
s_4 = 0100010011	$f(s_4) = 4$	s'_4 = 0111000101	(s_2)
s_5 = 1110111101	$f(s_5) = 8$	s'_5 = 0100010011	(s_4)
s_6 = 0100110000	$f(s_6) = 3$	s'_6 = 1110111101	(s_5)

MAXONE (Crossover)

- Apply crossover for each couple according to crossover probability (ex. 0.6)

- Before Crossover

s'_1 = 1111010101 s'_5 = 0100010011

s'_2 = 1110110101 s'_6 = 1110111101

- After Crossover

s''_1 = 1110110101 s''_5 = 0100011101

s''_2 = 1111010101 s''_6 = 1110110011

MAXONE (Mutation)

Mutation rate = 0.1

Before:

s''_1 = 1110110101

s''_2 = 1111010101

s''_3 = 1110111101

s''_4 = 0111000101

s''_5 = 0100011101

s''_6 = 1110110011

After:

s'''_1 = 1110100101 $f(s'''_1)= 6$

s'''_2 = 1111110100 $f(s'''_2)= 7$

s'''_3 = 1110101111 $f(s'''_3)= 8$

s'''_4 = 0111000101 $f(s'''_4)= 5$

s'''_5 = 0100011101 $f(s'''_5)= 5$

s'''_6 = 1110110001 $f(s'''_6)= 6$

MAXONE Example

- In one generation, the total population fitness changed from 34 to 37, thus improved by ~9%
- At this point, we go through the same process all over again, until a stopping criterion is met

Thank You