Genetic Algorithms

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Evolutionary Algorithms

- Variants of stochastic beam search that are motivated by the metaphor of natural selection in biology
  - there is a population of individuals (states)
  - the fittest (highest value) individuals produce offspring (successor states) that populate the next generation, a process called recombination

Genetic Algorithms

- Each individual is a string over a finite alphabet
- Example
  - $\boldsymbol{\Sigma = \{0, 1\}}$
  - $\mathbf{x_i = 01000111001001}$

8-queens

- Goal
  - Place 8 queens on a chess board so that no queen attacks another
- State
  - One queen per column
- String representation
  - Use row letters indicating the queen location in each column as a string
  - Example
    - $\boldsymbol{\Sigma = \{A, B, C, D, E, F, G, H\}}$
    - $\mathbf{x_i = HCGDBEAF}$

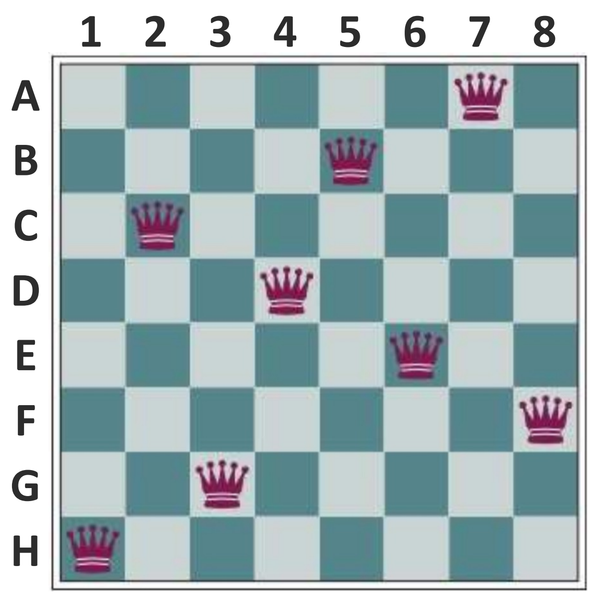

Figure 1. The 8-queens problem.

Genetic Algorithms

- Create an initial population with $\mathbf{N}$ random individuals $\mathbf{X} = \{\mathbf{x_1}, \mathbf{x_2}, \dots, \mathbf{x_N}\}$
- Then repeat the following steps until convergence
  - Selection
  - Recombination
  - Mutation

Selection

- Process of selecting the individuals who will become the parents of the next generation
- Example
  - Select from all individuals with probability proportional to their objective (fitness) function score

Selection

Initial population	Fitness	Probability	Selection	Recombination	Mutation
HEHHBEHC	11	0.104	BEDAHHCA		
DHHBGHHB	9	0.155	HEHHBEHC		
BEDFHBGB	7	0.254	BEDFHBGB		
BEDAHHCA	5	0.488	BEDAHHCA		

Table 1. Selection.

$$p_i = g(x_i) \,/\, \Sigma_j g(x_j)$$

$$g(x_i) = 1 \,/\, (1 + f(x_i)^2)$$

$f(x_i)$ = number of queen pairs attacking each other

Recombination

- Process of combining selected individuals to form offspring
- Example
  - Randomly select a crossover point to split each of the parent strings, and recombine the parts to form two children

Recombination

Initial population	Fitness	Probability	Selection	Recombination	Mutation
HEHHBEHC	11	0.104	BEDAHHCA	BEDHBEHC	
DHHBGHHB	9	0.155	HEHHBEHC	HEHAHHCA	
BEDFHBGB	7	0.254	BEDFHBGB	BEDFHHCA	
BEDAHHCA	5	0.488	BEDAHHCA	BEDAHBGB	

Table 2. Recombination.

Mutation

- Process of randomly modifying the offspring
- Example
  - Using a mutation rate, which determines how often offspring have random mutations to their representation
  - A random mutation is the exchange of one symbol in the string by a random symbol in the alphabet

Mutation

Initial population	Fitness	Probability	Selection	Recombination	Mutation
HEHHBEHC	11	0.104	BEDAHHCA	BEDHBEHC	BEBHBEHC
DHHBGHHB	9	0.155	HEHHBEHC	HEHAHHCA	HEHAHHCA
BEDFHBGB	7	0.254	BEDFHBGB	BEDFHHCA	BEDFHGCA
BEDAHHCA	5	0.488	BEDAHHCA	BEDAHBGB	BEDAHBGB

Table 3. Mutation.

$$\text{Mutation rate} = 0.5$$

Knowledge Check 1

If the probability of an offspring having a random mutation follows a mutation rate **$r=0.5$**, what is the probability of an entire population of **N** individuals being affected by mutations?

A r

B r^N

C $r^1 + r^2 + \ldots + r^N$

D $r \times N$

Optimizations

- Elitism
  - Keep a few top-scoring parents for the next generation

Initial population	Fitness	Probability	Selection	Recombination	Mutation
HEHHBEHC	11	0.104	BEDAHHCA	BEDHBEHC	BEBHBEHC
DHHBGHHB	9	0.155	HEHHBEHC	HEHAHHCA	HEHAHHCA
BEDFHBGB	7	0.254			BEDFHGGB
BEDAHHCA	5	0.488			BEDAHHCA

Table 4. Optimizations.

Optimizations

- Culling
  - Discard offspring below a threshold
  - Keep generation individuals until the target population size is reached
  - Threshold can change over time

Knowledge Check 2

When comparing Hill-climbing, Local Beam Search, and Genetic Algorithms, which method is:

(I) the fastest?

(II) less susceptible to finding a local minima?

- A (I) Hill-Climbing Search; (II) Local Beam Search
- B (I) Hill-Climbing Search; (II) Genetic Algorithms
- C (I) Local Beam Search; (II) Local Beam Search
- D (I) Local Beam Search; (II) Genetic Algorithms

You have reached the end of the lecture.

Image/Figure References

Figure 1. The 8-queens problem. Source: Russell & Norvig, Artificial Intelligence: A Modern Approach, 4th edition, Pearson, 2021.
Table 1. Selection. Source: Russell & Norvig, Artificial Intelligence: A Modern Approach, 4th edition, Pearson, 2021.
Table 2. Recombination. Source: Russell & Norvig, Artificial Intelligence: A Modern Approach, 4th edition, Pearson, 2021.
Table 3. Mutation. Source: Russell & Norvig, Artificial Intelligence: A Modern Approach, 4th edition, Pearson, 2021.
Table 4. Optimizations. Source: Russell & Norvig, Artificial Intelligence: A Modern Approach, 4th edition, Pearson, 2021.