

CS540 Introduction to Artificial Intelligence

Lecture 20

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Based on lecture slides by Jerry Zhu and Yingyu Liang

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Local Search

Motivation

- Local search is about searching through a state space by iteratively improving the cost to find an optimal or near-optimal state.
- The successor states are called the neighbors (sometimes move set).
- The assumption is that similar (nearby) solutions have similar costs.

Local Search Application

Motivation

- Optimization problems (gradient descent methods are all local search methods)
- Traveling salesman
- Boolean satisfiability (SAT)
- Scheduling

Hill Climbing (Valley Finding)

Description

- Start at a random state.
- Move to the best neighbor state (one of the successors).
- Stop when all neighbors are worse than the current state.
- The idea is similar to gradient descent.

Simulated Annealing

Description

- Each time, a random neighbor is generated.
- If the neighbor has a lower cost, move to the neighbor.
- If the neighbor has a higher cost, move to the neighbor with a small probability.
- Stop until bored.
- It is a version of Metropolis-Hastings Algorithm.

Genetic Algorithm

Description

- Start with a fixed population of initial states.
- Find the successors by:
 - ① Cross over.
 - ② Mutation.

Reproduction Probability

Definition

- Each state in the population has probability of reproduction proportional to the fitness. Fitness is the opposite of the cost: higher cost means lower fitness. Use F to denote the fitness function, for example, $F(s) = \frac{1}{f(s)}$ is a valid fitness function.

$$p_i = \frac{F(s_i)}{\sum_{j=1}^N F(s_j)}, i = 1, 2, \dots, N$$

- A pair of states are selected according to the reproduction probabilities (using CDF inversion).

Cross Over

Definition

- The states need to be encoded by strings.
- Cross over means swapping substrings.
- For example, the children of 10101 and 01010 could be the same as the parents or one of the following variations.

(11010, 00101) , (10010, 01101)

(10110, 01001) , (10100, 01011)

Mutation

Definition

- The states need to be encoded by strings.
- Mutation means randomly updating substrings. Each character is changed with small probability q , called the mutation rate.
- For example, the mutated state from 000 could stay the same or be one of the following.

one of 001, 010, 100, with probability $q(1 - q)^2$

one of 011, 101, 110, with probability $q^2(1 - q)$

and 111, with probability q^3

Cross Over, Modifications

Definition

- The previous cross over method is called 1 point cross over.
- It is also possible to divide the string into N parts. The method is called N point cross over.
- It is also possible to choose each character from one of the parents randomly. The method is called uniform cross over.

Mutation, Modifications

Definition

- For specific problems, there are ways other than flipping bits to mutate a state.
- ① Two-swap: ABCDE to EBCDA
- ② Two-interchange: ABCDE to EDCBA

Genetic Algorithm TSP Example

Discussion

Fitness Example 1

Quiz

Fitness Example 2

Quiz

Variations

Discussion

- Parents can survive.
- Use ranking instead of $F(s)$ to compute reproduction probabilities.
- Cross over random bits instead of chunks.

Genetic Algorithm Performance

Discussion

- Use hill-climbing first.
- State design is the most important.
- In theory, cross over is much more efficient than mutation.

Summary

Discussion