The National School of Artificial Intelligence
المدرسة الوطنية العليا للذكاء الاصطناعي

2nd Year /Semester4 (2023-2024)

Introduction to Artificial intelligence

<u>Tutorial Sheet 4 (Beyond Classical Search)</u>

Exercise 1:

You are given sentences in a language that you know nothing about, where the word order has been lost. Given the words, you are requested to put them back in a sequence, that has a sensible meaning. For example, in English language, the words {fun, exams, term, are, mid} can be put together in this valid ordering: "mid term exams are fun". As stated, the language used is completely unknown to you. Luckily, you can use an oracle that assigns a score to every sequence you introduce, according to how ridiculous it is (for example, in English, the sequence "exams mid term" is considered less ridiculous than "term exams mid").

1. Given a set of n words, what is the problem search space size? (you may assume that all words are unique.)
2. Define a neighborhood (a move set, that can be reached in a single step of search). Give two examples of neighbors for the sequence "fun exams term are mid".
3. Will hill-climbing search always find a valid sentence?
4. Will stochastic hill-climbing search always find a valid sentence?
5. In order to apply a genetic algorithm search, you'd need to define a cross-over operation. Can you suggest a cross-over operation here? If yes, describe your suggestion. If not, explain why in at most two sentences.

Exercise 2:

For each statement, decide whether it's True or False, and give a one-sentence justification.

(a) There can be more than one global optimum.

(b) It is possible that every state is a local optimum. (A local optimum is defined to be a state that is NO BETTER than its neighbors)

(c) Hill climbing with random restarts is guaranteed to find the global optimum if it runs long enough on a finite state space.

(d) Suppose the temperature schedule for simulated annealing is set to be constant up to time N and zero thereafter. For any finite problem, we can set N large enough so that the algorithm returns an optimal solution with probability 1.

(e) For any local-search problem, hill-climbing will return a global optimum if the algorithm is run starting at any state that is a neighbor of a neighbor of a globally optimal state.

(f) There is no relation between Local beam search and hill-climbing.

(g) Is there a problem where the whole state space is a plateau. If yes, can you formulate it.

Exercise 3:

Consider the following Map of Romania. The initial city is **Lugoj** and the target one is **Bucharest**. The heuristic values are provided on the right side.

- What is the result of a greedy search?
- What is the result of beam search using a beam of size 2 and then of size 3?

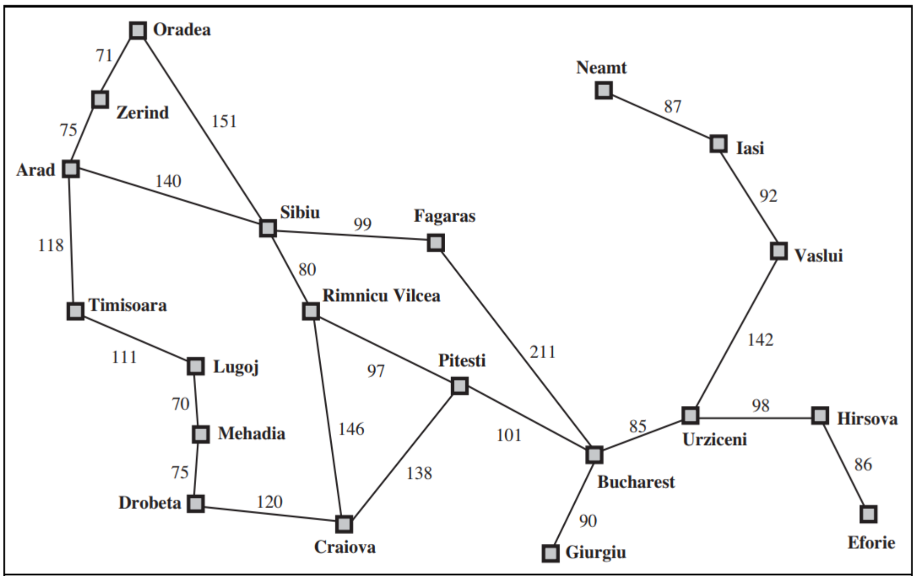

Figure 3.2 A simplified road map of part of Romania.

Arad	366	Mehadia	241
Bucharest	0	Neamt	234
Craiova	160	Oradea	380
Drobeta	242	Pitesti	100
Eforie	161	Rimnicu Vilcea	193
Fagaras	176	Sibiu	253
Giurgiu	77	Timisoara	329
Hirsova	151	Urziceni	80
Iasi	226	Vaslui	199
Lugoj	244	Zerind	374

Values of h_{SLD}—straight-line distances to Bucharest.

Exercise 4:

Consider the problem of finding the shortest route through several cities, such that each city is visited only once and in the end return to the starting city (the Travelling Salesman problem). Suppose that in order to solve this problem we use a genetic algorithm, in which genes represent links between pairs of cities. For example, a link between London and Paris is represented by a single gene 'LP '. Let also assume that the direction in which we travel is not important, so that LP = P L.

a) How many genes will be used in a chromosome of each individual if the number of cities is 10?

b) How many genes will be in the alphabet of the algorithm?

Exercise 5:

Suppose a genetic algorithm uses chromosomes of the form x = abcdefgh with a fixed length of eight genes. Each gene can be any digit between 0 and 9. Let f(x) be the fitness of individual x where the goal is to find the individual that **maximizes** f.

$$f(x) = (a + b) - (c + d) + (e + f) - (g + h)$$

and let the initial population consist of four individuals with the following chromosomes:

$$\begin{aligned} x_1 &= 65413532 \\ x_2 &= 87126601 \\ x_3 &= 23921285 \\ x_4 &= 41852094 \end{aligned}$$

a) Evaluate the fitness of each individual, showing all your workings, and arrange them in order with the fittest first and the least fit last.

b) Perform the following crossover operations:

- i) Cross the fittest two individuals using one–point crossover at the middle point.
- ii) Cross the second and third fittest individuals using a two–point crossover (points b and f).
- iii) Cross the first and third fittest individuals (ranked 1st and 3rd) using a uniform crossover.

c) Suppose the new population consists of the six offspring individuals received by the crossover operations in the above question. Evaluate the fitness of the new population, showing all your workings. Has the overall fitness improved?

d) By looking at the fitness function and considering that genes can only be digits between 0 and 9 find the chromosome representing the optimal solution (i.e. with the maximum fitness). Find the value of the maximum fitness.

e) By looking at the initial population of the algorithm can you say whether it will be able to reach the optimal solution without the mutation operator?

Exercise 6 (genetic algorithms):

A budget airline company operates 3 plains and employs 5 cabin crews. Only one crew can operate on any plain on a single day, and each crew cannot work for more than two days in a row. The company uses all planes every day. A Genetic Algorithm is used to work out the best combination of crews on any particular day.

a) Suggest what chromosome could represent an individual in this algorithm?

b) Suggest what could be the alphabet of this algorithm? What is its size?

c) Suggest a fitness function for this problem.

d) How many solutions are in this problem? Is it necessary to use Genetic Algorithms for solving it? What if the company operated more plains and employed more crews?