CS 411: Artificial Intelligence I
Written Homework 2
Due: Sunday of Week 2, 11:59pm

You may discuss the assignment with other students, but if you do you must note on your submission who you discussed it with. The actual submission must be entirely your own work. It must be submitted via gradescope. Please make sure to tag which page(s) each problem is answered on at the appropriate step in the submission process.

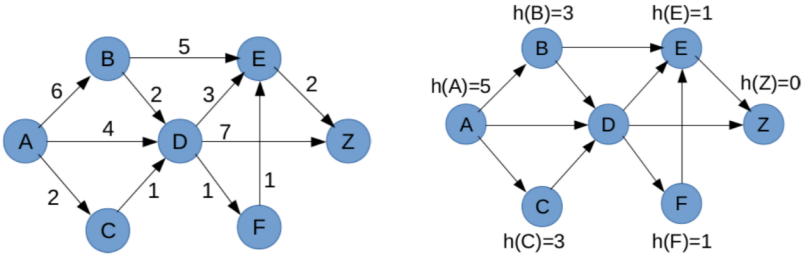

Figure 1: Search cost graph (left) and heuristic function for reaching goal Z (right).

1. **Heuristics**

   (a) **Heuristic Admissibility** The heuristic value for D, $h(D)$ has not been provided. What range of values can $h(D)$ have and still be admissible?

   (b) **Heuristic Consistency** What range of values can $h(D)$ have and still be consistent?

2. **Cryptarithmetic** Consider the following cryptarithmetic problem:

$$\begin{array}{cccc} & \mathrm{O} & \mathrm{N} & \mathrm{E} \\ + & \mathrm{O} & \mathrm{N} & \mathrm{E} \\ \hline & \mathrm{T} & \mathrm{W} & \mathrm{O} \end{array}$$

   (a) **Problem Formulation** Formulate this problem as a CSP. Make sure to clearly identify the variables, their domains, and the constraints. Remember that each symbol is required to represent a different digit. Assume the ones and tens carry bits are X_1 and X_2 respectively with domains $\{0, 1\}$ (Important!).

   (b) **Backtracking with Forward Checking** Show a trace of backtracking with forward checking to solve this problem. Use the minimum remaining values variable selection heuristic (breaking ties in alphabetical order) and try values in ascending order. (Deviating from these may make life much harder!) It will help us assign you partial credit and help you prevent errors if you draw a new table indicating the remaining domain values for each variable at each step.

3. **Reduction to Binary Constraints** We mostly focused on CSPs with binary constraints. Show how the constraint $X < Y + Z$ can be converted to three binary constraints. Hint: introduce an additional variable whose domain is pairs (or triples!) of values from other domains and consider constraints such as A is the first element of the pair B.

4. **Special Cases of Local Search Algorithms** Give the name or a brief description of the algorithm that results from each of the following special cases

   (a) Local beam search with $k = 1$.

(b) Local beam search with one initial state and no limit on the number of states retained.

(c) Simulated annealing with $T = 0$ at all times (and omitting the termination test).

(d) Simulated annealing with $T = \infty$ at all times.

Grading standards:

- Full Credit (1.0) - All questions attempted, most with minor or no errors
- Partial Credit (0.5) - A number of questions may have significant errors
- Some Credit (0.25) - Many questions attempted with answers demonstrating some understanding of relevant concepts
- Insufficient evidence (0) - Many questions either not attempted or with answers not demonstrating understanding of relevant concepts