Artificial Intelligence and Knowledge Engineering Laboratory

Task 2. Constraint Satisfaction Problem

Authors: M. Piasecki, M. Antkiewicz

Task Objectives

Getting familiar with algorithms for Constraint Satisfaction Problems in practice through individual implementation of CSP solving program and investigating its properties for the tested problems.

Subtasks

- Become familiar with backtracking search algorithm.
- Become familiar with the whole MAC algorithm that combines together subsequent phases of searching and constraint propagation, as well as with constraint propagation algorithms, both, a simplified forward checking and the more in-depth AC-3. A proper and insightful implementation of AC-3 will be promoted by +1 extra point.
- Learn more about heuristics used during search phase, e.g. related to selection of variables and values.
- Analyse problems shortly described below and formulate both of them as a CSP problems, i.e. define: variables, their domains and constraints in a formal or at least semi-formal way.
- Implement a CSP solving algorithm based on the MAC scheme (i.e. interleaving searching and constrain propagation) in a way making the implementation suitable for application to several problems (i.e. not tightly connected to peculiarities of the test problem from this assignment), e.g. variables, their domains, and constraints should be overtly represented as objects (or similar code constructs), the domain representations should facilitate elimination of selected values, constraint representations should point to linked variables, as well a queue of active constraints in the case of AC-3.
- Propose heuristics adapted to the test problems for variable selection and value selection.
- Test effectiveness and efficiency of the implementation for the problems specified in this assignment:
    - perform tests for the full MAC scheme, it is worth to emphasise that in the case of using AC-3 the process starts with the 0 step of constraint propagation,
    - next, compare the efficiency of the full MAC-based version with versions in which selected elements are omitted (switched off), including: constraint propagation (or forward checking, depending on a version) and different heuristics; efficiency should be measured both in the number of searching steps, as well as processing time.
- Prepare a report describing the fulfilment of the above steps, please, remember to carefully analyse and discuss the obtained results.

Problem 1 Map Colouring

Exercise 10 from the materials of Rusell and Norvig:
https://aimacode.github.io/aima-exercises/csp-exercises/
“Generate random instances of map-coloring problems as follows: scatter n points on the unit square; select a point X at random, connect X by a straight line to the nearest point Y such that X is not already connected to Y and the line crosses no other line; repeat the previous step until no more connections are possible. The points represent regions on the map and the lines connect neighbors. Now try to find k-colorings of each map, for both k3 and k4, using min-conflicts, backtracking, backtracking with forward checking, and backtracking with MAC. Construct a table of average run times for each algorithm for values of n up to the largest you can manage. Comment on your results.”

Problem 2 Zebra Puzzle (also Einstein's Puzzle or Einstein's Riddle)

See a good description in Wikipedia: https://en.wikipedia.org/wiki/Zebra_Puzzle

The main gist:
"The following version of the puzzle appeared in *Life International* in 1962:

1. There are five houses.
2. The Englishman lives in the red house.
3. The Spaniard owns the dog.
4. Coffee is drunk in the green house.
5. The Ukrainian drinks tea.
6. The green house is immediately to the right of the ivory house.
7. The Old Gold smoker owns snails.
8. Kools are smoked in the yellow house.
9. Milk is drunk in the middle house.
10. The Norwegian lives in the first house.
11. The man who smokes Chesterfields lives in the house next to the man with the fox.
12. Kools are smoked in the house next to the house where the horse is kept.
13. The Lucky Strike smoker drinks orange juice.
14. The Japanese smokes Parliaments.
15. The Norwegian lives next to the blue house.

Now, who drinks water? Who owns the zebra?

In the interest of clarity, it must be added that each of the five houses is painted a different color, and their inhabitants are of different national extractions, own different pets, drink different beverages and smoke different brands of American cigarets [*sic*]. One other thing: in statement 6, *right* means *your* right.

— *Life International, December 17, 1962*"

Task rating

2 points – formulate the problems as CSP
4 points – implement algorithm for solving CSPs based on the MAC-scheme: backtracking interleaved with forward checking (+1 point if AC-3 is added)
2 points – compare efficiency of processing for various problem parameters
2 points – formulate an in-depth analysis and interpretation of the results in a report

Bibliography

1. Lecture notes
2. Russell and Norvig: http://aima.cs.berkeley.edu/2nd-ed/newchap05.pdf