COMP3411/9414/9814 Artificial Intelligence
Session 1, 2018

Tutorial Solutions - Week 8

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Activity 8.1 Cryptarithmetic

Solve the famous Cryptarithmetic puzzle

```
  S  E  N  D +
  M  O  R  E
  _____
M  O  N  E  Y
```

What heuristics and strategies did you use along the way?

The sum of two 4-digit numbers cannot exceed 1998, so M=1.
10+O = S+1 or S+1+1, i.e. S = O+9 or O+8, but 1 has already been used, so O=0.
Therefore S=9, because there is no possibility of a carry from E+O.
We then have E+1 = N and 10+E = N+R or N+R+1, so R = 8 or 9, but 9 has already been assigned, so R=8.
(Note how Minimum Remaining Values has been used at each step.)
The puzzle now looks like this:

```
  9  E  N  D +
  1  0  8  E
  _____
1  0  N  E  Y
```

This gives us the two constraints:
E+1 = N
D+E = 10+Y

The remaining values are 2,3,4,5,6,7.

We have D+E <= 6+7 = 13, so Y = 2 or 3. (Note: MRV again).
But if Y=3 (Most Constraining Value) then all three variables D,E,N would need to take values 6 or 7, which is impossible (Constraint Propagation).
Therefore Y=2, E=5, N=6 and D=7.

Activity 8.2 Forward Checking and Arc Consistency

Use Forward Checking to show that the Australia map-colouring problem has no solution when we assign WA=green, V=Red, NT=Red. If we apply Arc Consistency as well, can the inevitable failure be detected further up the tree?

|	WA	NT	Q	NSW	V	SA	T
initial domains	R G B	R G B	R G B	R G B	R G B	R G B	R G B
WA=Green	G	R B	R G B	R G B	R G B	R B	R G B
V = Red	G	R B	R G B	G B	R	B	R G B
NT = Red	G	R	G B	G B	R	B	R G B
SA = Blue	G	R	G	G	R	B	R G B
Q = Green	G	R	G		R	B	R G B

No options remain for NSW, so there is no solution.

If we also apply Arc Consistency, the question can be resolved further up the tree (but with extra computation at each node) as follows:

	WA	NT	Q	NSW	V	SA	T
initial domains	R G B	R G B	R G B	R G B	R G B	R G B	R G B
WA=Green	G	R B	R G B	R G B	R G B	R B	R G B
V = Red	G	R B	R G B	G B	R	B	R G B
NT→SA, Q→SA, NSW→SA	G	R	R G	G	R	B	R G B
Q → NT	G	R	G	G	R	B	R G B
Q → NSW	G	R		G	R	B	R G B

Activity 8.3 Local Search

Consider the following state for the 8-queens problem:
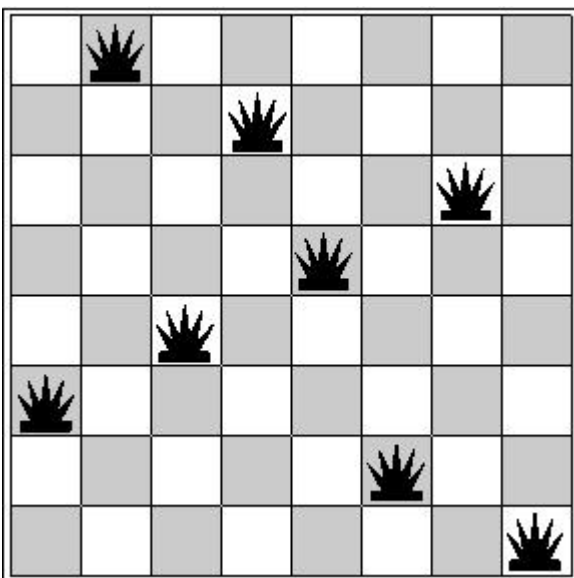
a. Is this a solution?

No, the queens on columns 2 and 5 are attacking each other.

b. What is the value of h?

There is only one violation, so $h=1$.

c. Explain why Hill-climbing with Min Conflicts would get stuck in this state, but Simulated Annealing may be able to "escape" and eventually find a solution.

For each column, moving the queen on that column (while keeping the other queens in place) would result in an increase to h. Therefore, any such move will be rejected by Hill-climbing. Simulated Annealing, however, can accept such a move with probability $\exp(-(h_1-h_0)/T)$, thus bumping the system out of this local optimum and allowing it to continue the search for a global optimum.
(Note: when started from a random initial state, Hill-climbing will get stuck 86% of the time on this problem, and will need to be continually re-started from a new random state each time, until it succeeds.)

Activity 8.4 Logic Puzzle (Exercise 6.6 from R & N)

Consider the following logic puzzle: In five houses, each with a different color, live five persons of different nationalities, each of whom prefers a different brand of candy, a different drink, and a different pet. Given the following facts, the questions to answer are "Where does the zebra live, and in which house do they drink water?".

- The Englishman lives in the red house.
- The Spaniard owns a dog.
- The Norwegian lives in the first house on the left.
- The Green house is immediately to the right of the ivory house.
- The man who eats Hershey bars lives in the house next to the man with the fox.
- Kit Kats are eaten in the yellow house.
- The Norwegian lives next to the blue house.
- The Smarties eater owns snails.
- The Snickers eater drinks orange juice.
- The Ukranian drinks tea.
- The Japanese eats Milky Ways.
- Kit Kats are eaten in a house next to the house where the horse is kept.
- Coffee is drunk in the green house.
- Milk is drunk in the middle house.

Discuss different representations of this problem as a CSP. Why might we prefer one representation over another?
Bonus Challenge: Write a Prolog program to solve this puzzle.

We can arbitrarily assign a number between 1 and 5 to each attribute value, as follows:

Color	Nationality	Candy	Drink	Pet
1. Red	1. English	1. Hershey bar	1. Orange Juice	1. Dog
2. Green	2. Spanish	2. KitKat	2. Tea	2. Fox
3. Ivory	3. Norwegian	3. Smarties	3. Coffee	3. Snails
4. Yellow	4. Ukranian	4. Snickers	4. Milk	4. Horse
5. Blue	5. Japanese	5. Milky Way	5. Water	5. Zebra

We can then construct a 5 by 5 table where the columns are attributes, the rows are values and the interior entries indicate which house has the specified value for the specified

attribute. The constraints can then be encoded as follows:

	Color	Nation	Candy	Drink	Pet
1	A	A	D	G	B
2	C	B	E	H	D±1
3	C-1	1	F	C	F
4	E	H	G	3	E±1
5	2	J	J	W	Z

There is an additional constraint that all the numbers 1, 2, 3, 4, 5 must occur exactly once in each column.

We can deduce that E=1, and derive the following exclusions:

```
     1  2  3  4  5
   +----------------
 A|  x  x
 B|  x  x
 C|  x  x  x
 D|  x
 E|     x  x  x  x
 F|  x  x
 G|  x        x
 H|  x        x
 J|  x
   +----------------
```

Since G, H, C cannot be 1, this implies that W=1, i.e. Water is drunk in the first house on the left.

If C=4, then A=5, G=5, H=2, so F, B, J must be chosen from {2, 3} and two of them must be equal (which is not allowed).
Therefore C=5, and A=3.
If H=4, G=J=2 which is not allowed.
Therefore, H=2, G=4, J=5, B=4, F=3, D=2 and Z=5, i.e. the Zebra is in the last house on the right.

An alternative representation for the problem is a table where the rows are the house numbers and the interior entries indicate the value of the specified attribute for the specified house. This representation is not so convenient for solving the problem by hand (or with an imperative language like C). However, it can readily be encoded in a Prolog program, as shown here.

Solutions for a number of similar puzzles can be found at
www.ypologist.com/mmalita17/HOMEPAGE/logic

Yet another approach is to line up the houses in order, and treat the constraints as pieces of a jigsaw puzzle, as described here.