Principles of AI Planning
Summer 2004

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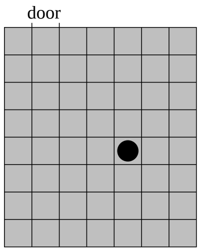
Exercise 9

To be returned on Monday, July 12, 2004

Assignment 9.1 (3 points)

Consider a variant of the unobservable robot navigation problem (lecture 18) with the difference that the robot does not know whether its nose initially points to north, south, east or west.



Show that the problem is still solvable (there is a sequence of operators after executing which the robot will be outside the classroom). We assume that the door is one-directional and the robot cannot get back to the classroom once it has left it.

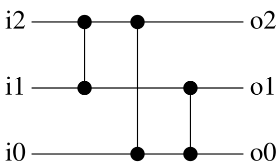
Assignment 9.2 (4 points)

What are the values of the following QBF?

1. $\forall A \exists B \exists C.(A \leftrightarrow B) \wedge (B \leftrightarrow C)$
2. $\exists B \forall A \exists C.(A \leftrightarrow B) \wedge (B \leftrightarrow C)$
3. $\exists A \exists B \exists C \exists D \exists E \exists F.(A \wedge B \wedge \neg C \wedge (E \vee F))$
4. $\forall A \forall B \forall C.((A \rightarrow B) \rightarrow ((B \rightarrow C) \rightarrow (A \rightarrow C)))$

Assignment 9.3 (6 points)

A sorting network (See e.g. D. E. Knuth, *Art of Computer Programming*, Volume 3; section 5.3.4 in 2nd edition) consists of a sequence of gates acting on a number of input lines. Each gate combines a comparator and a swapper: if the first value is greater than the second, then swap them. The goal is to sort any given input sequence. The sorting network always has to perform the same operations irrespective of the input, and hence constructing a sorting network corresponds to planning without observability. The following network sorts any sequence of three inputs.



An important property of sorting networks is that any network that sorts any sequence of zeros and ones will also sort any sequence of arbitrary numbers. Hence it suffices to consider Boolean 0-1 input values only.

Find a sorting network for 4 inputs by using greedy local search with the cardinality heuristic and by doing the search in forward direction.

The initial belief state consists of 16 states corresponding to all the 16 valuations of 4 Boolean state variables $0000, 0001, 0010, \dots, 1110, 1111$. The 5 goal states are $0000, 0001, 0011, 0111, 1111$. There are $6 = 3 + 2 + 1$ operators $o_{i,j}$ with $0 \leq i < j \leq 3$. Operator $o_{i,j}$ compares the values of variables i and j and swaps them if they are not increasing. E.g. the operator $o_{0,2}$ maps the sequence 1001 to 0011 and the sequence 0110 to itself.

Repeatedly at each stage, starting from the initial belief state, choose an operator that maps the current belief state to a successor belief states with the smallest cardinality (smallest number of constituent states), until you reach a belief state consisting of goal states only.

In your solution, give the sequence of belief states and report also the other belief states you had to consider (but that were not visited because they do not have a smaller cardinality than the chosen belief state.)

The shortest solution to this problem consists of 5 operators.

You may work on these assignments and submit your results ***in groups of two students****. Make sure to clearly indicate both names on your work.* ***You may write your answers in English or German.***