Practical Assignment Automated Reasoning

2IW15

Problems for improving the results from January 2012.

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The programs and files

Recommended programs to be used:

- `yices`: a program for satisfiability modulo theories (smt). It accepts smt format, but can also be used as a boolean SAT solver accepting dimacs format.
- `bddsolve`: a program based on BDDs. It can be used for satisfiability and counting the number satisfying assignments, and reachability.

For downloading these tools, description of the syntax and examples we refer to
`http://www.win.tue.nl/~hzantema/ar.html`

There you can also find the instructions for the original practical assignment, including guidelines for grading.

Each of the problems can be solved using one of these two tools. Several similar tools are freely available; if you prefer other SMT solvers or other SAT solvers, or a tool for pseudo boolean constraints like `minisat+`, this is allowed too.

The assignment

The practical assignment has to be **executed individually**. The results of **all three problems** have to be described in a report that has to reach the teacher not later than

April 2, 2012,

on paper. For all used formulas an extensive documentation is required, explaining the approach and the overall structure. A generic approach is preferred, since this may result in clearer descriptions, increasing the confidence in the correctness of the results. Formulas of more than half a page should not be contained in the report, instead the structure of the formula should be explained. From the output of the programs relevant parts should be contained in the report. The answers on the problems should be motivated. Every report should contain the name, student number and email address of the author.

Problem 1

Five jobs numbered from 1 to 5 have to be executed. These jobs need the consecutive use of three machines A, B and C, each of which only one copy is available. Within the use of the machines interrupts are not allowed.

- Job 1 first needs machine A for two hours, next it needs machine B for 13 hours, next it again needs machine A for one hour, next machine C for 4 hours, and finally again machine A for 3 hours.
- Job 2 first needs machine B for one hour, next it needs machine A for 3 hours, next it needs machine C for 7 hours, next machine B for 8 hours, and finally again machine A for 4 hours.
- Job 3 first needs machine A for one hour, next it needs machine C for 4 hours, next it needs machine B for 2 hours, next machine A for 9 hours, and finally machine C for 10 hours.
- Job 4 first needs machine B for 3 hours, next it needs machine C for one hour, next it needs machine A for 4 hours, next machine B for 11 hours, and finally machine A for 7 hours.
- Job 5 first needs machine B for 5 hours, next it needs machine A for 5 hours, next it needs machine C for 8 hours, next machine A for 3 hours, and finally machine C for 5 hours.

Find a solution of this scheduling problem for which the total running time is minimal.

Problem 2

Start by three marbles. Establish the minimum number of steps required to obtain exactly 4321 marbles, where in every step either

- the number of marbles remains the same, or
- the number of marbles is doubled, or
- n marbles are removed, where n is the number of the step (the first step is numbered by 1).

Problem 3

Consider the following protocol for sending a message through a directed network.

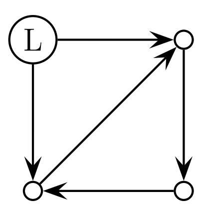
- Every node N has two bits: the bit $R(N)$ to indicate whether the message has been received by N and the bit $C(N)$ to indicate confirmation of receipt.
- One particular node L is the leader.
- Initially $R(L)$ is true, and $R(N)$ is false for all nodes $N \neq L$.
- Initially for all nodes N holds: if N has no outgoing edges then $C(N)$ is true, otherwise $C(N)$ is false.
- For all nodes N, N' holds: if $R(N)$ is true and there is an arrow from N to N', then $R(N')$ may be set to true.
- For all nodes N holds: if $R(N)$ is true and for all outgoing arrows $N \to N'$ it holds that $C(N')$ is true or $N' = L$, then $C(N)$ may be set to true.

The protocol is called correct for a particular network if the following two properties hold:

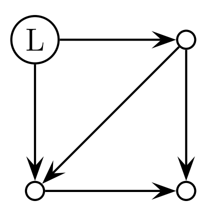
- The leader can get confirmation of receipt, that is, it is possible to reach a state in which $C(L)$ is true.
- If this confirmation is obtained (so: $C(L)$ is true) then the message has been received by all nodes, that is, $R(N)$ is true for every node N in the network.

Use the reachability version of the program `bddsolve` to establish for which of the following four networks the protocol is correct. Motivate your conclusions.

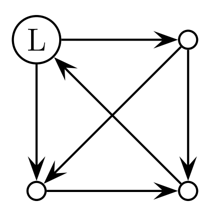
A :



B :



C :



D :