Formal methods at work 2018
Project
Vacuum-cleaning world

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1 General information

This project should be solved in groups of two students and project reports must be sent to `luca.aceto@gmail.com` by **Friday, 30 November 2018, at 23:00**.

2 Specification of the project

In the project, you will be working with a vacuum-cleaning-robot problem from the book *An Introduction to MultiAgent Systems - Second Edition* by Michael Wooldridge. On pages 67–69 of that book, which you can find here, Wooldridge describes an example of a small robotic agent that will vacuum clean a room. In our version of the example, the room is a 3-by-3 grid and at any point the robot can move forward one step or turn right 90 degrees. The problem is to find a deterministic, memoryless strategy for the robot in which

1. its next action only depends on its current square and orientation (one of north, west, south, east), and
2. all squares are visited infinitely often.

Wooldridge gives a partial specification of such a strategy using a number of rules. Ignoring the actions of the robot having to do with sucking dirt and focussing only on the actions related to movement, the rules given by Wooldridge are:

- If $In(0,0)$ and $Facing(north)$ then $Do(forward)$.
- If $In(0,1)$ and $Facing(north)$ then $Do(forward)$.
- If $In(0,2)$ and $Facing(north)$ then $Do(turn)$.
- If $In(\mathit{0},\mathit{2})$ and $Facing(east)$ then $Do(forward)$.

According to Wooldridge, 'similar rules can easily be generated that will get the agent to $(2, 2)$, and once at $(2, 2)$ back to $(0, 0)$.'

3 Tasks

- Your first task is to make a model of the above scenario and to use Uppaal to determine whether Wooldridge's claim is true; if so, find the other rules.
- Next, you should verify using Uppaal whether there is a (shorter) strategy meeting Wooldridge's criteria that follows the above-given rules for positions $(0, 0)$ and $(0, 1)$; if so, find the other rules.
- Having done so, use Uppaal to find out whether there is a (shorter) strategy meeting Wooldridge's criteria that follows the above-given rules for position $(0, 0)$; if so, find the other rules. Is there a shorter strategy for the robot that has no constraint for position $(0, 0)$?
- Finally, assume that the robot is very fast at turning, but slow moving: turning 90 degrees takes 1 unit of time, whereas moving forward takes 5 units of time.
  - Can you find the *fastest* strategy for the robot that follows the above-given rule for position $(0, 0)$ and visits each square?
  - Is there a fastest or shortest strategy that assumes no preset rule?

  What would a fastest strategy for the robot, which follows the above-given rule for position $(0, 0)$ and visits each square, look like if turning 90 degrees takes 4 units of time, whereas moving forward takes 2 units of time? Is it also a shortest strategy? Does your conclusion depend on the time the robot takes to rotate or to move forward, provided the rotation time is at least as large as the time it takes the robot to move forward?

3.1 Bonus problems

- Find all the possible numbers of forward moves and rotations in a cycle.
- What would the shortest and fastest strategies be if we applied all of the rules proposed by Wooldridge in a room that is a 4-by-4 grid?

4 Deliverables

Each project group must deliver a .zip file containing the following pieces of information:

- A report (in the form of a PDF file) describing the model of the vacuum-cleaning scenario in Uppaal, the queries used to determine the answers to the above-stated questions and the results of the verifications. Make sure that you include clear pictures describing visually the strategies for the robot you found using Uppaal.

- The files for your Uppaal models and queries.
- A PDF file containing an essay of at most one page describing

  1. what you think is the take-home message of the part of the course devoted to semantics and formal methods at work,
  2. what you liked about this part of the course and
  3. what you think should be improved.

Have fun!