CSC 486/2502, 2000 – Assignment 4

Due: Friday, December 8

[**100 Marks** (10 marks each)] (Actions)

In this assignment, we shall explore a formalisation of a simple delivery task. We consider a world consisting of way stations connected by pathways that can run north, east, south and west; at any location, there may not be pathways leading in all of the directions. You wish to navigate a robot around this world. The state of the robot is governed by two fluents: $Location(x,\ s)$—the robot is located at way station x in situation s; and, $Direction(x,\ s)$—the robot is facing direction x (*north, east, south, west*) in situation s. The robot is capable of performing the following actions: $forward$ which takes it to the next station in the direction it is facing; and, $turn\_clockwise$ changes its direction 90° by turning in a clockwise direction. You may also assume the following relation: $Connected(x,\ y,\ direction)$—the robot can go from location x to location y by moving forward if it is facing $direction$; and, $Clockwise(x,\ y)$—when facing direction x a clockwise turn by 90° will make it face direction y. There are also constant symbols for each of the way stations but for our purposes here it is sufficient to distinguish only two of them: *home* and *depot*. In the initial situation the robot is located at *home* facing *north*. You are to consider navigating the robot so that it ends up being located at *depot*.

1. Write the action precondition axioms for the actions *forward* and *turn_clockwise*.
2. Write the effect axioms for the actions *forward* and *turn_clockwise*.
3. Show how a successor state axiom for *Location* would be derived from these effect axioms. Is the successor state axiom logically implied by the effect axiom? Explain.
4. Show how a frame axiom is implied by this successor state axiom.
5. Write a sentence of the situation calculus whose only situation term is S_0, describing the initial situation. Write a sentence in the situation calculus of the form $\exists s.\alpha$ which asserts the existence of a goal situation.
6. Explain how you could use Resolution to automatically solve this puzzle for any initial situation: how would you generate the clauses and, assuming the process stops, how would you extract the necessary moves? *(Do not attempt to write down a derivation!)* Explain why you need to use the successor state axioms, and not just the effect axioms.
7. Suppose we are interested in solving the task in Prolog. Write but do not run the Horn clauses (using negation as failure) which define *Poss* and *Location*. Relate these clauses to the above axioms.
8. Explain the difficulty in using these clauses to solve the task in Prolog, given its depth-first search strategy. Would a breadth-first strategy do the job, assuming we were willing to wait for an answer?
9. Sketch briefly how the clauses might be modified to work with the depth-first search of Prolog, again assuming we were willing to wait as long as necessary for an answer.
10. Without any additional guidance, a very large amount of search is required to solve this task. There are, however, heuristics that can be used to reduce the amount of search. One possible heuristic is the following: *when deciding which location to move to next, choose the one that is closest to the goal location.* Assume that you have a predicate $Closer(x,\ y,\ z)$ which is true whenever location x is closer to location z than location y is to z (i.e., the distance between x and z is shorter than that between y and z). Explain how the complex actions of Golog could be used to define a more restricted search problem which incorporates heuristics like this. Sketch briefly what the Golog program should look like. What assumptions are needed to guarantee that this program finds a path to the goal?

11. [**Bonus Question:** 5 Marks]
In this assignment, we have treated location and direction as general relations, not as single-valued functions. However, prove that it follows from your formalization of the domain that if the robot starts at a unique location facing a unique direction in the initial situation that, at any given later situation, the robot is at a unique location facing a unique direction. [*Hint:* use induction on the number of actions performed.]