Homework 1: Chapters 1 - 5

The following exercises are due at the beginning of class on Tuesday, September 28. Some of these problems may take a while to solve, so I recommend that you work on this assignment over the course of multiple days.

1. ***[10 pts.]*** Prove the following:
   a) For every purely reactive agent, there is a behaviorally equivalent standard agent.
   b) There exist standard agents that have no behaviorally equivalent purely reactive agent.
2. ***[10 pts.]*** There were two ways of specifying tasks by utility functions, by associating utilities with either states ($u : E \rightarrow \Re$) or with runs ($u : R \rightarrow \Re$). The second type of utility function is strictly more expressive than the first. Give an example of a utility function over runs that cannot be defined simply by associating utilities with states.
3. ***[15 pts.]*** Consider the vacuum-world example from Chapter 3 (pp. 51-53) (Note: This is different from the environment we used for our programming assignment). Now imagine that your agent must be able to perform the task in environments of arbitrary size. Assume that the agent's internal state includes a ground atom of the form worldSize(*width*, *height*). Write a set of general rules that will allow the agent to function properly regardless of the world size. Try to keep this set of rules as small as possible.
4. ***[20 pts.]*** Once again, consider the vacuum-world example from the book and think about how the problem would be described using situation calculus.
   a) Give precondition and effect axioms for the *forward* action. Note, you may need to modify some of the domain predicates so that they become fluents. You may assume that you can use arithmetic expressions as terms (in fact, arithmetic operations are typically viewed as functions where the operands are the terms of the function).
   b) Now think about the frame problem. Give a successor state axiom for the fluent Facing(d,s).
5. ***[10 pts.]*** Consider the Concurrent MetateM program in Figure 3.7 (p. 63). Explain the behavior of the agents in the system.
6. ***[10 pts.]*** Yet again, return to the vacuum-world example from Chapter 3. Formulate the operations available to the agent using the STRIPS notation.
7. ***[15 pts.]*** Consider the Jam system shown in Figure 4.6 (p. 85). Assume that PERFORM move $OBJ1 $OBJ2 has the following effects: add the fact that $OBJ1 is on $OBJ2, delete the fact that $OBJ2 is CLEAR (unless it is the table), and delete the fact that $OBJ1 is on whatever it used to be on. Trace the execution of this PRS agent until it has achieved its top-level goal. Show beliefs, intention stack, and executed action (if any) at each step. Be sure that the intention stack includes information that allows the agent to resume executing a plan that was suspended in order to accomplish a subgoal. If you wish, you may use a more compact representation for the agent's beliefs than that used by Jam (e.g., you might choose to use first-order logic).
8. ***[10 pts.]*** Use Brook's subsumption architecture approach to design an agent for the vacuum-world example described in Chapter 3. How does it compare with the logic-based example?