Homework #5: Chapter 10,13

The following exercises are due at the beginning of class on Tuesday, April 11. Note, this homework is continued on the reverse side of the paper.

1. *[20 points]* Consider the PDDL actions defined for the air cargo problem in Figure 10.1 on page 369 of the book, and the problem instance described below:

   Initial State: At(P1,LAX) ∧ At(P2,JFK) ∧ At(C1,LAX) ∧ In(C2,P1) ∧ Plane(P1) ∧ Plane(P2) ∧ Cargo(C1) ∧ Cargo(C2) ∧ Airport(JFK) ∧ Airport(LAX) ∧ Airport(ORD)

   Goal: At(P1,JFK) ∧ At(P2,ORD) ∧ At(C1,JFK) ∧ In(C2,P2)

   a) *[10 points]* Using forward state-space search, draw a search tree to depth 1. Expand the root node, showing all actions that are applicable in the initial state, as well as the successor states that result from these actions. For convenience, your state descriptions may omit literals that use the Plane, Airport, and Cargo predicates. Note, you should show all applicable actions, even those that are spurious.
   b) *[10 points]* Now draw the search tree to depth 1, but use backward state-space search. Expand the root node, showing all actions that are relevant to the given goal, and show the predecessor states for these actions. In addition to omitting literals that use the Plane, Airport, and Cargo predicates as above, you may use variables as parameters for the actions.

2. *[30 points]* Consider the problem of devising a plan for cleaning the kitchen. Assume the following:

   - Cleaning the stove or the refrigerator will get the floor dirty.
   - To clean the oven, it is necessary to apply oven cleaner and then to remove the cleaner.
   - Before the floor can be washed, it must be swept.
   - Before the floor can be swept, the garbage must be taken out.
   - Cleaning the refrigerator generates garbage and messes up the counters.
   - Washing the counters or the floor gets the sink dirty.
   - Cleaning the sink does not create any additional mess.

   a) *[5 points]* Define a set of PDDL predicates for describing states of this problem. Hint: If you use constants to represent the various objects in need of cleaning, then four to six predicates should be sufficient.
   b) *[15 points]* Define a set of PDDL operators representing all of the actions mentioned in the description above. Be sure that your preconditions and effects accurately capture the information given in this description. You do not need to add any preconditions not mentioned (e.g. you do not need to mention that a broom is needed to sweep the floor).
   c) *[5 points]* Using PDDL, give a likely initial state for a kitchen in need of cleaning and a goal state that represents the ideal, clean kitchen.
   d) *[5 points]* Provide a plan that is a solution to the problem as you have defined it. You do not need to use an algorithm to find the plan, nor do you need to show your work.

3. *[30 points]* Consider the problem of putting on one's shoes and socks, described as follows:

   Goal(RightShoeOn ∧ LeftShoeOn)
   Init(∅)
   Action(RightShoe, PRECOND: RightSockOn, EFFECT: RightShoeOn)
   Action(RightSock, PRECOND: ¬RightSockOn, EFFECT: RightSockOn)
   Action(LeftShoe, PRECOND: LeftSockOn, EFFECT: LeftShoeOn)
   Action(LeftSock, PRECOND: ¬LeftSockOn, EFFECT: LeftSockOn)

   a) *[25 points]* Construct levels S_0, A_0, S_1, A_1, and S_2 of the planning graph. For each level, provide a table that indicates the pairs of literals (or actions) that are mutex, along with a short justification of why they are mutex (e.g., A and B have inconsistent effects on literal F, or A interferes with B on literal F).
   b) *[5 points]* Estimate the cost of the goal using the max-level, level sum, and set-level heuristics.

4. *[10 points, 2 points each]* A full joint distribution for the Boolean random variables *A*, *B*, and *C* is specified below. Assume that the true value of a random variable is the corresponding lower case letter (e.g., *P*(*b*) means *P*(*B*=*true*))

	b		¬*b*	
	c	¬*c*	*c*	¬*c*
a	0.1	0.15	0.2	0.25
¬*a*	0.2	0.05	0.01	0.04

   Use the distribution to compute the following probabilities. Show your work.

   a) $P(\neg a)$
   b) $\mathbf{P}(C)$
   c) $P(a \land \neg b)$
   d) $P(\neg c \lor a)$
   e) $P(\neg a \mid b \land c)$

5. *[10 points]* Consider the set of all possible five-card poker hands dealt fairly from a standard deck of fifty-two cards. Such a deck has 13 cards from each suit (hearts, clubs, spades, and diamonds). These 13 cards have ranks of Ace, Jack, Queen, King, and the numbers 2 through 10, inclusive.

   a) How many atomic events are there in the joint probability distribution (i.e. how many distinct five-card hands are there)? Remember, two hands are the same if they contain the same five cards, regardless of the order that the cards are dealt (i.e. we are interested in *combinations*, not *permutations*).
   b) What is the probability of each atomic event?
   c) What is the probability of being dealt a royal flush? Note: a royal flush is the Ace, King, Queen, Jack and 10 all in the same suit. Show your work.
   d) What is the probability of being dealt four-of-a-kind? Note: this is when four of the five cards have the same rank. Show your work.