CS 188 Introduction to AI
Spring 2002 Stuart Russell

Midterm

You have 1 hour and 20 minutes. The exam is open-book, open-notes. 100 points total.

You will not necessarily finish all questions, so do your best ones first.
Write your answers in blue books. Check you haven't skipped any by accident. Hand them all in. Panic not.

1. **(20 pts.) True/False**
   Decide if each of the following is true or false. If you are not sure you may wish to provide a *brief* explanation to follow your answer.
   (a) (2) A system must think like a human in order to pass the Turing Test reliably.
   (b) (3) An agent that senses only partial information about the state cannot be perfectly rational.
   (c) (3) Every definite clause is a Horn clause.
   (d) (3) The clauses $P(F(A, G(A)))$ and $P(F(x, y))$ resolve to produce the empty clause.
   (e) (3) $h(n) = 0$ is an admissible heuristic for the 8-puzzle.
   (f) (3) There are STRIPS planning problems for which a partially ordered solution exists but no totally ordered solution.
   (g) (3) The number of open conditions is an admissible heuristic for partial-order plans.

2. **(20+10 pts.) Search**
   A basic Brio™ railway set contains the pieces shown in Figure 1. The task is to connect *all* these pieces into a *single* railway that has *no loose ends* where a train could run off onto the floor and no *overlapping* tracks.
   (a) (10) Suppose that the pieces fit together *exactly* with no slack. Give a precise formulation of the task as a search problem.
   (b) (5) Identify a suitable uninformed search algorithm for this task and explain your choice.
   (c) (5) Explain briefly why removing any one of the "fork" pieces makes the problem unsolvable.
   (d) (5 extra credit) Give an upper bound on the total size of the state space defined by your formulation. (Hint: think about the maximum branching factor for the construction process and the maximum depth, ignoring the problem of overlapping pieces and loose ends. Begin by pretending that every piece is unique.)
   (e) (5 extra credit) Now consider the real problem, in which pieces don't fit together exactly but allow for up to 10 degrees of rotation to either side of the "proper" alignment. Explain how to formulate the problem so it could be solved by simulated annealing.

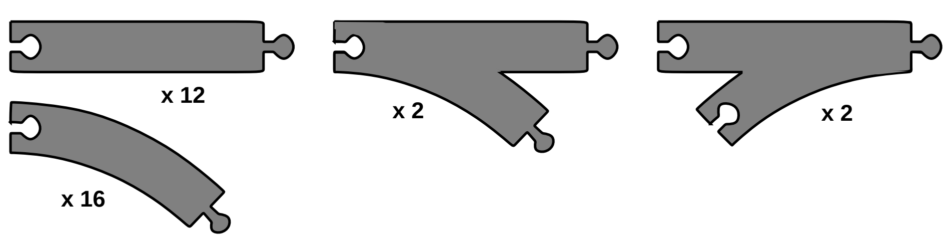

Fig. 1: The track pieces in a basic Brio™ set. Note that curved pieces and "fork" pieces ("switches" or "points") can be flipped over, so they can curve in either direction. Each curve subtends 45 degrees.

3. (20 pts.) Propositional Logic

Consider the following sentence:

$$[(Food \Rightarrow Party) \lor (Drinks \Rightarrow Party)] \Rightarrow [(Food \land Drinks) \Rightarrow Party]$$

(a) (6) Determine whether this sentence is valid, satisfiable (but not valid), or unsatisfiable, using enumeration. (You may abbreviate the proposition symbols in your answer.)

(b) (6) Convert the left-hand and right-hand sides of the main implication into CNF, showing each step, and explain how the results confirm your answer to (a).

(c) (8) Prove your answer to (a) using resolution.

4. (20 pts.) First-order logic

For each of the following sentences in English, decide if the accompanying first-order logic sentence is a good translation. If not, explain why not and correct it.

(a) "Any apartment in Berkeley has lower rent than some apartments in Palo Alto."

$$\forall x\ [Apt(x) \land In(x, Berkeley)] \Rightarrow \exists y\ [[Apt(y) \land In(x, PaloAlto)] \Rightarrow (Rent(x) < Rent(y))]$$

(b) "There is exactly one apartment in Palo Alto with rent below \$1000."

$$\exists x\ Apt(x) \land In(x, PaloAlto) \land \forall y\ [Apt(y) \land In(y, PaloAlto) \land (Rent(y) < Dollars(1000))] \Rightarrow (y = x)$$

(c) "If an apartment is more expensive than all apartments in Berkeley, it must be in San Francisco."

$$\forall x\ Apt(x) \land [\forall y\ Apt(y) \land In(y, Berkeley) \land (Rent(x) > Rent(y))] \Rightarrow In(x, SanFrancisco)$$

(d) (6) Which of the first-order logic sentences above may be converted to definite clauses?

5. (20 pts.) Planning

Consider a robot whose operation is described by the following STRIPS operators:

$$Op(\text{ACTION:}Go(x, y), \text{PRECOND:}At(Robot, x), \text{EFFECT:}\neg At(Robot, x) \land At(Robot, y))$$
$$Op(\text{ACTION:}Pick(o), \text{PRECOND:}At(Robot, x) \land At(o, x), \text{EFFECT:}\neg At(o, x) \land Holding(o))$$
$$Op(\text{ACTION:}Drop(o), \text{PRECOND:}At(Robot, x) \land Holding(o), \text{EFFECT:}At(o, x) \land \neg Holding(o))$$

(a) (5) The operators allow the robot to hold more than one object. Show how to modify them with an *EmptyHand* predicate for a robot that can hold only one object.

(b) (5) Assuming that these are the only actions in the world, write a successor-state axiom for *EmptyHand*.

(c) (10) Suppose the initial state has

$$At(Apple, Room_1) \land At(Orange, Room_1) \land At(Robot, Room_1)$$

and the goal is

$$At(Apple, Room_2) \land At(Orange, Room_2)$$

Consider the operation of the POP algorithm on this problem, for the STRIPS operators as modified in part (a). Diagram the partial plan that has been constructed at the point where the first threat to a causal link appears. Explain what the threat is and how it can be resolved (if at all).