Comprehensive Examination
Artificial Intelligence
Spring 2004

1. a. What is stereoscopic vision, and why is it useful?

   b. What is the epipolar constraint? Is it useful? Is it necessary?

   c. Specify a scene configuration in which correlation or SSD algorithms cannot work for stereo.

2. a. What is the Lambertian model of image formation, and why is it useful? b. Specify a scene configuration in which the Lambertian model does not hold.

3. a. Describe the difference between supervised learning and reinforcement learning.

   b. Provide an example of a problem that would best be solved with supervised learning and one which is best suited to reinforcement learning.

4. a. Describe the differences between the visibility graph algorithm and the potential field algorithm for robot motion planning.

   b. For a robot with very limited sensing capabilities in a very rich and complex environment, which of these two techniques are likely to be computationally viable? (Which, if any, could be reasonably expected to run in real time?)

5. The following conventions are part of a system for representing knowledge about an agent's actions and knowledge. Instead of thinking of a formula such as `(location agt-99 building-54)` as an atomic predication, we treat it as a term whose denotation is a function from situations to truth values. We use Lisp-style notation for formulas, so that nonatomic expressions are parenthesized lists of expressions, whose first element is a predicate, function, or logical symbol such as `forall` or `and`. The predicate `(holds` s p`)` asserts that the "occasion" p is true in situation `s0`. So the formula `(holds s0 (location agt-99 building-54))` asserts that in situation `s0`, `agt-99` is in `building-54`; in other situations, `agt-99` might be in other locations. Another example:

```
(forall (s a x c1 c2)
    (if (and (holds s (location x c1))
             (holds (result a s)
                    (location x c2)))
        (= a (move x c1 c2))))
```

   Here `(result a s)` is a term denoting the situation that results from performing action `a` in situation `s`. The formula states that if `x` changes location as the result of an action, the action must be the movement of `x` from one location to the other.

   Using these conventions, express the following facts, introducing other predicates and functions as necessary:

   a. "The time of situation `s903` is May 24, 2004."

   b. "It is always possible to send a message to any port of any host on the internet."

   c. "One effect of sending a query message to port 8079 of `www.amazon.com` is that a reply to the message is pending."

   d. "If a reply to a message is pending, then it is possible to receive a reply to it; one effect of receiving a reply is that a reply to the original message is no longer pending."

6. A *constraint-satisfaction problem* (CSP) is defined by specifying the following:

   - A finite set of *variables* $V = \{V_1, \ldots, V_n\}$.
   - A finite set of *values* $X = \{x_1, \ldots, x_k\}$.
     A *partial assignment* on V and X is a mapping from a subset of the variables to values. A *total assignment* is a partial assignment whose domain is V.
   - A set of *constraints* C. Each element $c \in C$ is a set of partial assignments on V and X, all with the same domain, which we denote *domain*(c).

   A solution to a CSP is a total assignment S such that for every constraint $c \in C$, S restricted to *domain*$(c) \in c$.

   For example, the graph coloring problem on a graph G can be expressed as a CSP where the set of variables is the set of nodes, the set of values is the set of available colors $L = \{l_1, \ldots, l_k\}$, and there is one constraint for each edge $\langle v_1, v_2 \rangle$, whose domain is $\{v_1, v_2\}$, consisting of the mappings

   $$\{\{\langle v_1, l_i \rangle, \langle v_2, l_j \rangle\} | l_i \neq l_j\}$$

   A solution is a coloring of all the nodes whose restriction to an adjacent pair is an assignment of two different colors to that pair.

   a. The satisfiability problem (SAT) is to find an assignment of truth values to a set of variables that satisfies a set of clauses. A *clause* is a disjunction of variables and negated variables. Express SAT as a CSP.

   b. Solving a CSP is a search problem, usually through a space of partial assignments. Using the notation above, give a set of search operators that will guarantee finding a solution if one exists.