2012 Aero-Astro Field Exam – Autonomous Systems

In this field exam you are responsible for the core question and the elective question for the elective area that you declared on your exam application.

Core Question: Solving Mixed Logic Linear Programs

In this question we ask you to design an algorithm to solve a new family of constraint programming problems, called a *Mixed Logic Linear Program (MLLP),* which unifies Mathematical Programming and Propositional Logic. Your solution algorithm will draw upon your knowledge of various approaches to informed search, splitting and inference.

Specifically, an MLLP is defined over a set of propositions P (e.g., P={q,r,s}), each of which is true or false, and a set of real valued variables V (e.g., V={a,c}), each of which ranges over the Reals. Assignments to propositions and real-valued variables have associated costs, called *attribute costs*, and the cost of an MLLP is the sum of these attribute costs, (e.g., "a+c"). Each constraint in an MLLP is a formula in propositional logic in which this formula is generalized to include linear inequalities over V as propositions, as well as elements of P. An example of such a formula is "not q or a + c ≤ 5."

In this problem we just expect you to *rough out* an initial solution. Coming up with a flawless, detailed solution will likely take more time than you have.

a) State the MLLP precisely as a constraint optimization problem.
b) Sketch an algorithm for finding the best solution to an MLLP. Assume that memory is limited.
    - Hint 1: Think of how you can leverage the structure and elements of the branch and bound algorithm for Binary Integer Linear Programming (BILP and the Davis-Putnam-Logeman-Loveland (DPLL) algorithm for propositional satisfiability).
    - Hint 2: Don't get mired by making your pseudo-code too detailed.
c) Time Permitting: Sketch an algorithm for enumerating the k best solutions to an MLLP. Again assume that memory is limited.

Elective Question: Cognitive Robotics

The ability to perform robust execution of tasks under uncertainty is central to developing real-world, cognitive robots. A central component of execution is robust scheduling. Two well-studied approaches to framing the scheduling problem are Simple Temporal Problems (STPs) and Simple Temporal Problems Under Uncertainty (STPUs).

In this problem we would like you to apply your insights from the core question to scheduling.

a) State the problem of generating an **optimal** schedule off line for a set of activities with the following properties:
   - Cost is the sum of the durations of every activity, and
   - Events are activity start and end times.
   - Temporal constraints between events are expressed as propositional logic formula, in which all propositions are simple temporal constraints.
b) Sketch an algorithm for constructing the optimal solution to this problem. Assume that the solver needs to return a feasible solution quickly.
c) Restate this problem so that events are divided into controllable and uncontrollable events, and so that simple temporal constraints are replaced with simple temporal constraints under uncertainty.
d) Modify your algorithm from Part b in order to handle the problem of Part c.

Once again, in this problem we just expect you to *rough out* an initial solution. Coming up with a flawless, detailed solution will likely take more time than you have.

Elective Question: Estimation and Inference

You look outside the window and see that the grass is wet. You also see that the sun is shining, although you know the sun can shine during a rainstorm. You know that there is a sprinkler system to water the grass, but you do not know if the sprinkler system has been used this morning.

a) Please draw a Bayes' Net that can be used to predict whether it is raining.
b) Please enumerate all the conditional probability tables required to represent this Bayes Net.
c) Please give an algorithm for determining the probability that it is raining.
d) Please give an algorithm for learning the CPT parameters.
e) Please draw the equivalent undirected graph.
f) Please give an algorithm for determining the probability that it is raining using the undirected graph, and please state the advantages and disadvantages of this new graph.