Re-examination in
Knowledge Representation and Reasoning

Date: Thursday, 24th March, 2011
Time: 10.30 – 12.30
Room: HG 00.062

This exam consists of *two* problems. For each of your solutions to these problems you can earn a maximum of *50* points. You are allowed to consult the slides presented during the lectures of the course as well as the Lecture Notes. However, it is *not allowed to consult the exercises made during the tutorials.* Finally, note that it is allowed to use Dutch for your solutions. Good luck!

Problem 1

a. Consider the following diagnostic system $\mathrm{SYS} = (\mathrm{SD}, \mathrm{COMPS})$, with $\mathrm{COMPS} = \{I, O\}$, where I is an inverter $\mathrm{Inv}(I)$, O represents a logical OR-gate $\mathrm{Org}(O)$, and SD is the system description defined as follows (See Figure 1):

$$\forall x((\mathrm{Inv}(x) \wedge \neg \mathrm{Ab}(x)) \rightarrow (out(x) \neq in(x)))$$
$$\forall x((\mathrm{Org}(x) \wedge \neg \mathrm{Ab}(x)) \rightarrow out(x) = or(in_1(x), in_2(x)))$$
$$out(I) = in_1(O)$$

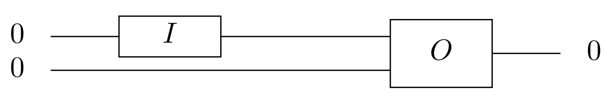

Figure 1: Inverter-OR circuit.

The set of observations for the diagnostic problem $\mathrm{DP} = (\mathrm{SYS}, \mathrm{OBS})$ is: $\mathrm{OBS} = \{in(I) = 0, in_2(O) = 0, out(O) = 0\}$. Show how you can use default logic to solve this diagnostic problem, and give the diagnoses in terms of default logic.

b. Consider the causal specification $\Sigma = (\Delta, \Phi, \mathcal{R})$ with:

- $\Delta = \{d_1, d_2, d_3, \alpha_1, \alpha_2\}$ with set of defects (d_1, d_2, d_3) and assumption literals (α_1, α_2);
- $\Phi = \{f_1, f_2, f_3\}$ is a set of observable facts;
- $\mathcal{R} = \{d_1 \rightarrow d_3,$
  $(d_3 \wedge \alpha_2) \rightarrow f_3,$
  $d_3 \rightarrow f_1,$
  $(d_1 \wedge d_2 \wedge \alpha_1) \rightarrow f_1,$
  $d_2 \rightarrow f_2\}$

  represents a causal model of abnormal behaviour.

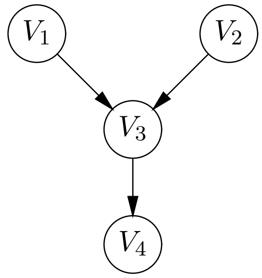

Figure 2: Bayesian network.

Let $\mathcal{P} = (\Sigma, F)$ be a diagnostic problem, where $F = \{f_1, f_2\}$ represents the set of observed facts. Determine all abductive diagnoses of $\mathcal{P}$.

c. Determine the solution disjunction following from the predicate completion of $\mathcal{R}$ and the set of observed facts F under the assumption that all elements in Δ, with the exception of d_3, are abducible. Compare your answer to that of problem 1(b).

Problem 2

a. Consider the Bayesian network $\mathcal{B} = (G, P)$ shown in Figure 2, where $G = (V(G), A(G))$ is an acyclic directed graph and P is a joint probability distribution defined on $V(G) = \{V_1, V_2, V_3, V_4\}$. The probability distribution P is defined as follows:

$$\begin{array}{lll} P(v_4 \mid v_3) = 0.4 & P(v_4 \mid \neg v_3) = 0.7 & P(v_1) = 0.3 \\ P(v_3 \mid v_1, v_2) = 0.2 & P(v_3 \mid \neg v_1, v_2) = 0.5 & P(v_2) = 0.4 \\ P(v_3 \mid v_1, \neg v_2) = 0.6 & P(v_3 \mid \neg v_1, \neg v_2) = 0.8 & \end{array}$$

Compute $P(v_3)$ and $P(v_1, v_2, v_3)$.

b. Consider the following (uncertain) rules with regard to v_1, v_2, v_3, v_4 from Problem 2.a:

$$v_1 \rightarrow v_{3x}$$
$$v_2 \rightarrow v_{3y}$$
$$v_3 \rightarrow v_{4z}$$

Here we have that $x = \mathrm{CF}(v_3, v_1)$, $y = \mathrm{CF}(v_3, v_2)$, and $z = \mathrm{CF}(v_4, v_3)$ are certainty factors. Try to explore *as much as possible* the relationship between Bayesian networks and the certainty factor calculus in computing $\mathrm{CF}(v_4, e')$, i.e., the certainty factor taking into account all uncertain knowledge and evidence with respect to v_i, $i = 1, \ldots, 4$.

c. The frame formalism allows defining generic knowledge of objects in the real world, assuming that all properties of these objects are completely certain. Show how you can extend the frame formalism by incorporating reasoning with uncertainty and show by a small example that your method is sound.