1) In one of the lisp lectures we looked at the logical connective NAND. NAND has the property that it can replace all other logical connectives, although the expressions get very complex. Another connective which has this property is NOR.

The truth table for NOR is:

<table>
<thead>
<tr>
<th>p</th>
<th>q</th>
<th>p NOR q</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>T</td>
<td>F</td>
</tr>
<tr>
<td>T</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>F</td>
<td>T</td>
<td>F</td>
</tr>
<tr>
<td>F</td>
<td>F</td>
<td>T</td>
</tr>
</tbody>
</table>

Use the rewriting rules below to define a lisp function which transforms an expression with AND, OR and NOT to an expression with just NOR.

(\text{not } p) \rightarrow (\text{nor } p \ p) \\
(\text{and } p \ q) \rightarrow (\text{nor } (\text{nor } p \ p) \ (\text{nor } q \ q)) \\
(\text{or } p \ q) \rightarrow (\text{nor } (\text{nor } p \ q) \ (\text{nor } p \ q))

You may define auxiliary functions if you want. \[5\]

2) Suppose we have a graph with nodes S, A, B, and C, where S is the start and G the goal node. The distances between connected nodes are given in this table:

<table>
<thead>
<tr>
<th></th>
<th>S</th>
<th>A</th>
<th>B</th>
<th>G</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>4</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>4</td>
<td>1</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>6</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>6</td>
<td>4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Perform a search with method A:
- Draw the tree with the g and h values for all nodes.
- Show in what order the nodes are examined and
- Discuss whether the heuristic function is optimistic and/or monotone and how this affects the search.

Do this for the three cases when the estimated remaining distances are:

a) h(A) = 4, h(B) = 1
b) h(A) = 9, h(B) = 6
c) h(A) = 4, h(B) = 3 \[6\]
3) In a Bayesian network we have the following nodes:

- x1: smoking
- x2: visit_to_Africa
- x3: lung_cancer
- x4: bronchitis
- x5: tuberculosis
- x6: coughing
- x7: positive_chest_x_ray

x1 can cause x3 and x4
x3 can cause x6
x4 can cause x6 and x7
x2 can cause x5
x5 can cause x7

a) Draw a graph which shows the dependencies.
Suppose we learn that x6 is true.
b) How does this affect the probabilities of the other nodes?
Then we learn that x7 is true.
c) How does this affect the probabilities of the other nodes?
Then we learn that x2 is true.
d) How does this affect the probabilities of the other nodes?  

4) In the book the following context-free rules are used to describe noun phrases:

- noun_phrase \leftrightarrow noun
- noun_phrase \leftrightarrow article noun
- noun \leftrightarrow man
- noun \leftrightarrow dog
- article \leftrightarrow a
- article \leftrightarrow the

a) Extend the grammar to include preposition phrases. A preposition phrase is a preposition followed by a noun phrase. Prepositions are in and on.
A noun phrase can now be a noun, a noun followed by a preposition phrase, an article followed by a noun, or an article followed by a noun followed by a preposition phrase.

b) Show also the parse tree for the phrase:

    the dog in the house on the prairie

(You have to include two more nouns too.)
5) We want to learn if a creature lives or dies, based on its genome. For simplicity we consider creatures with genomes of only 6 letters (each letter can be A, C, G or T). We find the following examples.

- CATCAT – lives
- TACCAT – dies
- GATCAG – lives
- ACTAAC – dies
- TTTCCC – dies
- GATCTA – lives
- AATTGA – dies

a) Use the Candidate Elimination algorithm on this example to learn the category of living creatures. Candidate categories are strings of 6 letters from {A,C,G,T,*}. Use the examples in the above order, and show the sets S and G for each step.

b) Use the ID3 algorithm to learn a decision tree for the above examples. Decisions are of the kind “What is the n:th letter?” (NOTE: normally, you would need to know how to compute information gain values. But this particular case relies only the principle of ID3.)

c) Explain how the characteristics of the two algorithms (CE and ID3) differ, and explain in general terms how they can come to such different conclusions.

d) Suppose that you had not 7 but a million measurements (which is about 25 per possible genome) and that they are inconsistent. What method would you use in that case to predict if a creature with a known genome lives or dies? [10]

6) What steps need to be taken to go from a problem description in natural language to a solution based on resolution-based theorem proving? [4]

7) Describe the architecture of a typical rule based expert system. [3]

8) Explain in a few sentences the essence of the following concepts:
   a) horizon effect (in minimax search)
   b) non-monotonic logic
   c) the frame problem [3]

Good Luck!

Roland & Mats