Norwegian University of Science and Technology
Department of Computer and Information Science

Contact person during exam:
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EXAMINATION IN LOGIC AND REASONING SYSTEMS (TDT4136)

Thursday 1. December 2011
Hours: 09:00 – 13:00

Language: English
Allowed aids: D
No printed or handwritten material is allowed.
An approved simple calculator is allowed.

Results deadline 22. December 2011

Read the text of each assignment carefully. Make sure that you understand the assignment.

If you consider the information given in an assignment incomplete or inaccurate, then make a note of the assumptions you find necessary to make in order to solve the assignment.

Problem 1 (25%)

Our world consists of birds. There are many kinds of birds. Some birds are seabirds, others are land birds. All birds have wings and can fly. Seabirds eat fish. Bob is a seabird. There are two kinds of land birds: eagles and swallows. Sam is an eagle.

a) Formulate the knowledge base above in First-Order Predicate Logic.

After closer inspection by a group of ornithologists, it turns out that Bob is a penguin. Penguins are seabirds, but they can't fly.

b) What effect does this new information have on our knowledge base? Show by converting any necessary sentences to clausal form and construct a resolution proof.

c) Create a model of the knowledge base in a) as a semantic net. Use this semantic net to show whether Sam can fly.

d) What happens with the semantic net as we introduce the new information from b)? Modify your semantic net and explain. Compare with your answer in b).

Problem 2 (15%)

In Tic-Tac-Toe two players compete to get three of their symbols, either `X` or `O`, in a row - either horizontally, vertically or diagonally. The first player to achieve this has won the game.

O	O	X
	X	
O	X	

Figure 1: Tic-Tac-Toe

a) Explain the principles behind analyzing game trees by means of the Minimax analysis.

b) Construct a game tree from the situation in figure 1 down to the game's end and analyze it by means of Minimax. It is `X`'s turn to move. Given that the opponent plays optimally, is it possible for `X` to win?

c) Briefly explain what is meant by Alpha-Beta pruning of game trees, and clearly mark in the game tree above which branches would not be expanded.

Problem 3 (20%)

Whenever an oil spill happens at sea, it is important to get response vessels there as fast as possible to limit the damage of the spill. Given the situation as in figure 2 it's our task to find the shortest possible route. For this assignment we divide the area into a grid where each cell represents possible positions. Additionally, we assume that the response vessel only can move in the cardinal directions: North, East, South and West.

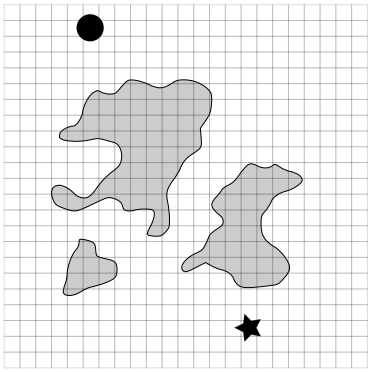

Figure 2: Oil spill. The response vessel needs to get as fast as possible from its current position (star) to the oil spill (circle) by finding a route around land (grey areas).

a) Describe how one can formulate this problem as a heuristic search problem.

b) Explain the concepts admissible and consistent (monotone) heuristics.

c) Suggest two different heuristics for this problem. They should both be admissible and consistent.

d) Explain the concept of dominance, and show how one of your heuristics dominates the other. What effect does this have on the efficiency of the search algorithm?

Problem 4 (20%)

The objective in Sudoku is to fill a grid with digits so that each row, column and box does not contain that digit more than once. In this assignment we study a simple variant with four different digits.

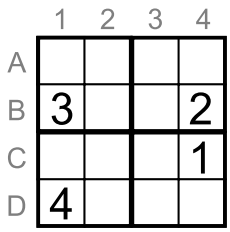

Figure 3: In Sudoku each digit can only appear once in each row, column and 2-by-2 box.

a) Explain in general terms what a Constraint Satisfaction Problem (CSP) is.

b) Formulate a 4-by-4 Sudoku problem as a CSP and draw the associated constraint graph. Use squares to denote constraints over multiple elements.

c) Describe briefly what "backtracking search" with "forward checking" means. Draw a figure to illustrate the first 2 steps of this method. Use the situation in figure 3 as initial state.

d) Explain briefly what the concept of arc-consistency means. With the same initial state as in the previous question, what effect on the search algorithm would it have if we made sure that the CSP is arc-consistent before we start? What is the cost to perform this step?

Problem 5 (20%)

It has become more and more common to use robots in larger distribution centres around the world. A typical task is to fetch packages from different places in the warehouse to fulfill various orders. In this assignment, let us assume we have a robot with the following possible actions:

- Move from the present location `x` to `y`: `Move(x,y)`
  The pre-condition `At(Robot,x)` establishes that our robot is in location `x`.
- Pick up a box `b` from the present location: `Pickup(b,x)`
  To perform this action the robot first needs to be in the same location as the box. Additionally we assume that our robot only can carry one box at a time, so we introduce the state `Empty` that must be true here.
- Release the box `b` it is currently carrying: `Drop(b,x))`
  The robot must be in location `x` and already carry box `b` to perform this action. The state `Holding(b)` is introduced to represent that the robot is carrying box `b`.

a) Describe these actions in the PDDL/STRIPS formalism.

From time to time it is important to optimize the flow of packages through the warehouse. Let us assume that as part of a larger plan our robot has to pick up a package $\texttt{P}_2$ and place a package $\texttt{P}_1$ at the same location. The robot is already carrying $\texttt{P}_1$ and is at the correct location.

b) Formulate the initial condition and the goal condition. Draw a planning graph for this part of the plan down to the needed level to fulfill the goal condition. Clearly mark those states and actions that are mutually exclusive (mutex) at each level.

To avoid an unnecessarily large graph, disregard the condition `At(x,y)`.

c) Explain roughly how planning graphs can be used to extract plans directly, and extract a plan from this graph by clearly marking on the graph from the previous question.