Cognitive Modeling (2009-2010)

School of Informatics, University of Edinburgh
Lecturer: Sharon Goldwater

Assignment 1

Due date:	8 February
Weighting:	10% of total mark

Please type all answers and turn in a hardcopy of your solution by 4:00pm on the due date to the Informatics Teaching Organization, Level 4, Appleton Tower. If you have questions regarding the assignment, please contact the lecturer, Sharon Goldwater, at `sgwater@inf.ed.ac.uk`.

Note that there are two paths through this assignment. One is for CM-4, the 4th year undergraduate version of this course, the other one is for CM-5, the MSc version of this course. Please make sure that you answer the right questions for your level!

Please remember that plagiarism is a university offense. Do not show your written/coded solutions to anyone else, or try to see anyone else's, and do not discuss the specifics of your solutions with other students (unless otherwise stated for particular questions). However, please also remember that, on any course, you learn as much or more from your peers as you do from your instructors. You should therefore feel free to discuss the general topics surrounding the problems with one another, ideally after you have considered them yourself. But at the end of the day what you write must be yours, and you must understand what you write, and why you didn't write other things. The approach should be one you have chosen to take. If you don't understand it don't write it — it will generally be obvious you don't understand. And if you have questions or problems involving the specifics of your solution, please contact me rather than your fellow students.

1 Levels of Analysis CM-4 + CM-5

This question is designed to get you thinking about the three levels of analysis that Marr (1982) proposed for studying information processing systems. For *this question only*, you may discuss the details with other students as much as you like, however you are still expected to write up your answers independently – any written work you turn in must be your own and reflect your own understanding and opinions. Your answer should be no more than one page long, and may well be less.

> **Question 1 (35%) CM-4 + CM-5**
> Think of an example of an information-processing system (either natural or man-made), try to analyze this system at the three different levels (computational, representation and algorithm, and hardware). Is it obvious how to separate the three levels, and what is going on at each level? Can you think of different possible algorithmic or hardware implementations? Explain any difficulties you have in making your analysis, and whether you think Marr's "three levels" approach is always appropriate.

2 Towers of Hanoi CM-4 + CM-5

The rest of this assignment deals with modeling the Tower of Hanoi task, but the following question does not require any modeling.

> **Question 2 (10%) CM-4 + CM-5**
> Consider the Tower of Hanoi task. In what sense is it a well-defined and knowledge-lean problem (see Section 4.1.2 of Cooper 2002)?

Now download the following file, which contains the model that you will work with in this assignment: `http://www.inf.ed.ac.uk/teaching/courses/cm/assignments/cm_a01.tar.gz`

Use `gunzip` and `tar` to unpack this file in the `projects` subdirectory of your Cogent directory (this is the user directory you specified during the installation). You should now see a research program called `Assignment 1` in the Cogent root window. Select this program and doubleclick on the only model within this research program, called `Tower of Hanoi`. This model corresponds to the model developed in Section 4.3.3 of Cooper (2002), which uses Goal-directed Selection.

To see the model in action, open the `Current State` buffer of the model and select the tab `Current Display`. Then open the `Goal Stack` buffer and select the tab `Current Stack`. This will give you graphical representations of the game board and of the goal stack, respectively. You can step through the model one cycle at a time by pressing '>' repeatedly, or run it to completion by pressing '≫'. (Remember to initialize the model by pressing '∘' before stepping through it. Also, if you use '≫', the display will not refresh fast enough to see all of the moves, and it may appear that the model has terminated in the wrong state. However, if you force the display to refresh by clicking on one of the other tabs in the `Current State` buffer, and then clicking on the display tab again, you will see that the model has actually terminated correctly.)

3 Exploring Different Search Methods CM-4

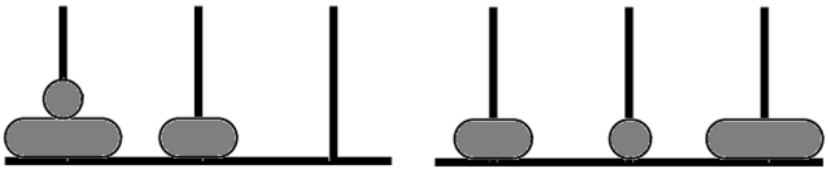
In lectures, we used the Tower of Hanoi to illustrate a range of different strategies for problem solving, including Goal-directed Selection (the model implemented already), and Selection without Search. We'll explore these in more detail here.

Question 3 (10%) CM-4
How many moves does the Goal-directed Selection model take to solve the task with four disks? How many cycles? If we assume that each cycle takes the same amount of time, what predictions does the model make about people's behavior in solving the task?

Question 4 (10%) CM-4
Let's assume that the person who is trying to solve Tower of Hanoi has to keep the goal stack in short term memory, the capacity of which is limited to three items, and that they are performing the task with six disks. Make a copy of the Goal-directed Selection model and modify it to reflect these constraints. Describe any differences in the behavior of the six-disk model with limited memory and unlimited memory. What happens with limited memory if the `On Excess` property is set to `Random`, `Youngest`, or `Oldest`, respectively? Which of these settings seems cognitively most plausible? Why?

Question 5 (25%) CM-4
Implement and complete the model described in class for solving the Tower of Hanoi task using Selection without Search. Don't develop a new model from scratch, but make a copy of the Goal-directed Selection model you downloaded and modify that. Show the box-and-arrow diagram for your new model and any rules you added or modified, and describe how the model works. Compare the performance of the original model and the one you developed, and discuss any aspects of your model that you think seem unrealistic.

Question 6 (10%) CM-4
Propose at least one plausible addition to the evaluation function that still uses only local information, and add it to your model. What effect does it have?



initial state goal state

Figure 1: An example for the initial state and the goal state for the generalized Tower of Hanoi task.

4 Modeling Learning and Brain Damage CM-5

In lectures, we used the Tower of Hanoi to illustrate a range of different strategies for problem solving. We made reference to work by Anzai and Simon (1979), who showed that experimental subjects initially adopt a simple strategy called Selection without Search, and later switch to Goal-directed Selection, the strategy implemented in the model you downloaded.

> **Question 7 (30%)** CM-5
> Make a copy of the Goal-directed Selection model and modify this to create a new model for solving the Tower of Hanoi task. Your model should be able to switch between the two strategies (Selection without Search and Goal-directed Selection). What do you think can trigger such a switch? How can this be implemented in the model?

The Tower of Hanoi task is one of the tests that can be used to diagnose patients with brain damage. Damage of the frontal lobe (through stroke or accident) is associated with impaired executive function, including impaired planning and problem solving abilities. Patients with frontal lobe damage show prolonged solution times and increased rule breaking when they have to solve the Tower of Hanoi.

> **Question 8 (25%)** CM-5
> Modify the original Goal-directed Selection model so that its behavior is similar to that of patients with frontal lobe damage: the model will break the rules of the games occasionally (come up with plausible ways of breaking the rules; this should occur at random intervals). Describe your model and explain why its behavior is similar to that of the patients. Give the box-and-arrow diagram of the model, the initial content of the buffers and the rules and conditions of the processes that are part of the model. (You only need to describe those parts of the model that differ from the original version.)

Literature

Anzai, Y., and H. A. Simon. 1979. The theory of learning by doing. *Psychological Review* 86: 124–140.

Cooper, Richard P. 2002. *Modelling High-Level Cognitive Processes*. Mahwah, NJ: Lawrence Erlbaum Associates.

Marr, David. 1982. *Vision: A Computational Investigation into the Human Representation and Processing of Visual Information*. New York: W. H. Freeman.