FOR INTERNAL SCRUTINY (date of this version: 11/5/2010)

UNIVERSITY OF EDINBURGH

COLLEGE OF SCIENCE AND ENGINEERING

SCHOOL OF INFORMATICS

COGNITIVE MODELLING (LEVEL 10)

COGNITIVE MODELLING (LEVEL 11)

Tuesday 1 April 2008

00:00 to 00:00

Year 4 Courses

Convener: G Plotkin
External Examiners: J Gurd, M Wooldridge

MSc Courses

Convener: A Smaill
External Examiners: J Carroll, M Hepple, E Hull, I Marshall

INSTRUCTIONS TO CANDIDATES

Answer QUESTION 1 and ONE other question.

Question 1 is COMPULSORY.

All questions carry equal weight.

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1. **You MUST answer this question.**

   (a) Experiments on human problem solving behaviour show that participants exhibit a range of problem solving strategies of varying levels of generality. Explain two of these strategies, using an example discussed in the lectures. [*6 marks*]

   (b) Your task is to build a cognitive model that models garden pathing in human sentence processing. Explain the facts that the model has to capture. [*2 marks*]

   Now discuss the suitability of the following two approaches for this modelling task:

   i. cognitive architectures [*3 marks*]

   ii. probabilistic modelling [*3 marks*]

   (c) In Cogent, what is the difference between:

   i. triggered rules and untriggered rules [*2 marks*]

   ii. propositional buffers and stack buffers [*2 marks*]

   iii. half-life decay and fixed decay [*2 marks*]

   (d) In Bayesian modelling, what is the difference between the maximum a posteriori hypothesis and the maximum likelihood hypothesis? Use formulae to illustrate your answer. [*5 marks*]

2. **You should either answer this question or question 3.**

Visual search is a standard task in cognitive psychology, illustrated in Figure 1. Participants have to find a target shape (here, the letter B) among a set of distractor shapes (here, the letter P). Experimental results show that the time required by participants to find the target increases with the number of distractors.

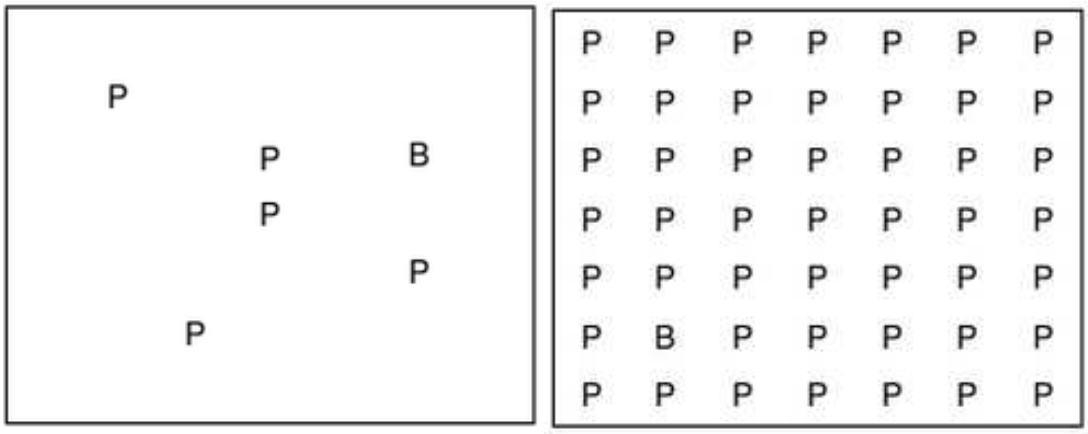

Figure 1: Examples for visual search. Left panel: small number of distractors; right panel: large number of distractors

(a) Which search strategy would you employ to model visual search, based on the experimental results cited above? [*3 marks*]

(b) Devise a set of symbolic representations required to model visual search in Cogent. Give examples of the predicates required. [*3 marks*]

(c) Based on your answers to questions (a) and (b), develop a Cogent model of visual search. Give the box-and-arrow diagram of the model, and explain the function of each of the buffers and processes you assume. (You do not have to give the production rules for the processes.) [*10 marks*]

(d) Explain how your model accounts for the fact that search time increases with the number of distractors. Which Cogent setting is crucial for this behaviour? [*3 marks*]

(e) There is also experimental evidence that shows if the target and the distractors are distinct in terms of a feature (e.g., the target is a red B among black Ps), then the search time is independent of the number of distractors. How do you have to change your model to account for this? [*6 marks*]

3. **You should either answer this question or question 2.**

Research on human sentence processing has shown that the disambiguation of an ambiguous sentence depends not only on the probabilities of the syntactic structures involved, but also on semantic probabilities. Consider the following locally ambiguous sentences:

(1) a. The athlete realised her goals were out of reach.
b. The athlete realised her shoes were out of reach.

The verb *realise* can take either a noun phrase (NP) or a sentence (S) as its argument. A garden path occurs in (1a), as the postverbal noun *goals* is both a plausible object (for the NP reading) and a plausible subject (for the S reading). On the other hand, (1b) shows no garden path, as *shoes* is not plausible as an object of *realise*.

Two other factors play a role in disambiguation. The presence of a complementiser (*realised that* instead of *realised*) influences whether the postverbal noun can be an object (this is only possible if there is no *that*). Also, some verbs have a bias towards occurring with the NP structure, which influences the probability of a garden path occurring.

(a) Design a Bayes net that captures the causal relationships expressed in the previous paragraphs. Use the following binary variables:

- *np*: the NP structure is correct;
- *obj*: the postverbal noun is plausible as an object;
- *nocomp*: there is no complementiser;
- *npbias*: the verb is biased towards the NP structure.

[*6 marks*]

(b) Assume the following conditional probabilities:

- $P(np = 1|X, \ldots) = 0.3$
- $P(obj = 1|X, \ldots) = 0.1$
- $P(nocomp = 1|X, \ldots) = 0.5$
- $P(npbias = 1|X, \ldots) = 0.4$

where each $(X, \ldots)$ stands for one or more conditioning variables being true (i.e., taking the value 1, as opposed to 0 for false). Fill in the conditioning variables based on the topology of your Bayes net. [*3 marks*]

(c) Assume the probabilities in (b), the information given in the preamble, and the following:

- $P(np = 1|obj = 0) = 0.1$
- $P(np = 1|npbias = 0, obj = 1) = 0.2$

Now compute these probabilities:

- $P(nocomp = 1|obj = 1)$
- $P(np = 1|npbias = 1, obj = 1, nocomp = 1)$
- $P(np = 1)$

[*6 marks*]

(d) One of the variables in the Bayes net can be subject to intervention. Which one? Explain the changes that the intervention entails for the model. [*4 marks*]

(e) The approach to modelling ambiguity resolution developed in this question has the problem that new variables need to be introduced ad hoc for each possible syntactic structure (NP and S in this case). A more systematic approach would be to use the Bayes net to implement a probabilistic context-free grammar. Outline how this could be achieved. [*6 marks*]