ELL457/HSL622: Mid-Term Examination

February 26, 2024

Maximum Marks: 28

Instructions:

- **Please clearly indicate the question number, and part number if applicable, at the start of each response.**
- **Please read all questions carefully.**
- **Please ensure that your responses are to-the-point and that you write only what is asked for on the answer script you submit.**
- **While the exam is open-notes, all your answers must be written entirely in your own words, without any copying from anywhere.**
- **Please try to be clear and careful with all formal/mathematical notation, so that there is no ambiguity in the expressions/formulae you write down. Try to stick to the kind of notation used in class as far as possible.**

1. Consider a Turing machine specified as follows: $\Sigma = \{\text{A, B, C, ‘ ’}\}$, $S = \{s_1, s_2, \boldsymbol{s_3}\}$ (where the last symbol in the alphabet is the blank, and the last state is a halting state, denoted in bold). Let the FSM transition function be given as follows.

Current state	Symbol read	Next state	Symbol written	Move
s_1	A	s_1	A	R
s_1	B	s_1	B	R
s_1	C	s_2	C	L
s_1	‘ ’	$\boldsymbol{s_3}$	‘ ’	N
s_2	A	s_2	B	L
s_2	B	s_2	A	L
s_2	C	s_2	C	L
s_2	‘ ’	$\boldsymbol{s_3}$	‘ ’	N

Answer the following questions about the above Turing machine. In all cases, assume the following initial conditions: the machine is in state s_1, there is a single input string of non-blank symbols on the tape (with blanks on both sides of it), and the read-write head points to the first symbol in that string.

(a) For an input string containing N non-blank symbols, what is the maximum possible number of state transitions that the machine can have before halting? Explain your reasoning. **[3]**

Maximal case is when ‘C’ occurs only at the end of the string; in this case the full string is scanned both forwards and backwards. Hence the maximum possible number of transitions is $2N$.

(b) Give the final output string produced by the machine for each of the following input strings: ‘ABBABC’; ‘BBBAB’; ‘CABCBB’; ‘BAABCAC’. No working needs to be shown. **[4]**

‘BAABAC’; ‘BBBAB’; ‘CABCBB’; ‘ABBACAC’.

(c) Give a general description, in English, of what the processing or transformation is that this machine carries out on the input string. Be as concise as possible; your answer should not exceed two sentences. **[3]**

In the portion of the string before the first ‘C’, all ‘A’s are changed to ‘B’s and vice-versa. If the string has no ‘C’s, it remains unchanged.

(d) Out of the eight possible input conditions tabulated above, is there some condition that can never actually be true for this machine? If so, indicate which one and why. **[2]**

The input condition (s_2, 'C') can never occur, because the machine only gets to state s_2 after its scanning direction has reversed on encountering the first 'C'. Hence, when in state s_2 the machine only scans the portion of the string preceding the first 'C', *i.e.*, a portion which can only contain 'A's and 'B's.

2. Consider the following two production rules, which might be part of a production system for solving the 8-puzzle as discussed in class.

   (a) IF the tile with the number 1 can be moved one row upwards, THEN move it upwards

   (b) IF the tile with the number 8 can be moved one column leftwards, THEN move it leftwards

   Now let the current state of the game (represented in the global database) be as follows.

6	**2**	**3**
7		**8**
5	**1**	**4**

   Recall that the goal state is as follows.

1	**2**	**3**
8		**4**
7	**6**	**5**

   Let's say that rules (a) and (b) above are the only two applicable rules in the current state. Hence the control structure has to select one of these two rules.

   For this purpose, assume that the control structure defines the *goodness* value of a game state as follows: the number of tiles already in the correct position (as per the goal state), plus 0.5 times the number of tiles just a single shift (horizontally or vertically) away from the correct position. To illustrate this, consider the current state as shown above. The tiles already in the correct position in the current state are **2** and **3**. And the tiles a single shift away from the correct position are **4** and **7**. Hence, the goodness value of the current state is $2 + 0.5 \times 2 = 3$.

   So let's say the algorithm followed by the control structure is to pick whichever production rule, when executed, will lead to the highest goodness value. In the current state, which of the above two rules will it pick? Clearly write down your reasoning/working. **[4]**

   Rule (a) moves the tile '1' upwards to the centre square; but this tile still does not contribute to the goodness value, as it is still 2 shifts away from its correct position in the top left corner. So executing rule (a) does not change the goodness value, and it remains **3**.
   Rule (b) moves the tile '8' leftwards to the centre square; hence this tile becomes only one shift away from its correct position, and contributes 0.5 units to the goodness value, whereas it was contributing nothing earlier. So executing rule (b) increases the goodness value to **3.5**.
   Thus, the control structure will choose rule (b).

3. Newell and Simon (1976) suggest a very fundamental kind of relationship between computation and cognition: basically, that they are different manifestations of the same underlying mechanisms or processes. They say that the accomplishment of intelligent behaviour is a primary question for all of computer science. What is their basis for this belief, and why do they think that this fundamental connection between computation and intelligence has not been widely realised? Answer as precisely as possible, in your own words. **[6]**

   Key points:

   - The basis for the belief is the idea that *symbol processing* is the fundamental ingredient of both computation and intelligence, and that computer science has provided a formal framework for understanding symbol/representation formation and processing.
   - A more precise relationship is suggested via the *physical symbol system hypothesis*: the idea that any physical symbol system is both necessary and sufficient for achieving intelligence. Hence, on this view, both computers and minds are physical symbol systems: the differences between them would only be of degree (of complexity or sophistication), not of kind. And hence any type of computer, once it reaches a sufficient level of complexity, should be able to realise intelligence.

- However, this may not be easy to see in practice; the judgement of when the behaviour of such systems crosses the threshold of 'intelligence' is subjective and dependent on some notion of complexity (as per humans); so when these systems are carrying out less complex algorithmic tasks, tasks with less variability or unpredictability, then we may not regard them as 'intelligent' as their capacity for intelligence may be obscured.
- But the same kinds of systems and processes, once applied to tasks which involve adaptation to variation and contingency, exhibit their capacity for intelligent action (as per the hypothesis); and hence it is only a matter of computers/AI developing sufficiently, before the equivalence of this capacity of theirs with biological cognition becomes widely realised.

4. Recall that the *first cognitive science debate*, as discussed in class, was about behaviourism versus cognitive psychology. What is the relationship of this debate to *functionalism*, as a position on the philosophical mind-body problem? Try to organise your answer into two parts:

   (a) How exactly does functionalism relate to or differ from behaviourism? Would a functionalist typically be a behaviourist? **[3]**

   No, functionalists are typically not behaviourists. A functionalist would believe that behaviour (stimulus-response relationships) is only part of the characterisation of the mind; but one has to add on this a notion of more autonomous *mental states or processes* which are defined by their functional roles (as opposed to any physical properties or correlates). Such mental states/processes have causal powers, in relation to other states or processes as well as to outward behaviour. While behaviourists seek to reduce the mind just to direct stimulus-response mappings, functionalists believe that the core of the mind is in these functional states or processes, and behaviour is just a consequence of how they operate.

   (b) How does functionalism relate to a cognitivist stance in psychology? Is there some synergy between them? If so, try to characterise it precisely. **[3]**

   Yes, there has been an important synergy between cognitivism and functionalism, and cognitive scientists/psychologists have often tended to be functionalists. The basic reason is that cognitivism is about unpacking the 'black box' of the behavioural stimulus-response relationships: so it stems from an intuition that there is something interesting and worth analysing inside that black box, rather than just treating it as some arbitrary set of mappings or a big look-up table. And functionalism provides a natural framework within which to understand what that black box contains – *i.e.*, the idea that it is comprised of mental/cognitive states or processes with well-defined functional roles and relationships.