Lecture 9: Intelligence and expertise in problem solving

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Contents

1 Problem Solving

Problem Solving

- Many human and organisational activities involve problem solving.
- Generally, a problem can be characterised by some *goal*, an initial state and a set of admissible *actions* (or decisions) which 'move' the problem from one state to another, hopefully towards the goal.
- If we can represent the initial state s_0, the goal state g and all intermediate states s_t as elements of some set S, then this set is often called the *problem space*.
- Problem solving is a *search* in the problem space, where actions $a_1, \ldots, a_n$ define the transitions $s_t \xrightarrow{a_i} s_{t+1}$ between the states.
- Usually, the choice of actions or transitions is quite limited. For example, one cannot jump directly from initial state to the goal.
- The goal state can usually be reached by a sequence of actions $(a_1, a_2, \ldots, a_t)$.
- If at each moment we have a choice of n actions, then the number of all sequences of length t is n^t.

Example: The 'Water Jugs' Problem

Problem 1 (Water Jugs)**.**

- *There are 3 jugs with capacities of 3, 5 and 8 litres.*
- *Initially, the 8-litre jug is full of water, and the other two are empty.*
- *The goal is is to share the water equally between two people (i.e. 4, 4 litres).*
- *When moving the water, one has to fill up the target jug or empty the source jug.*

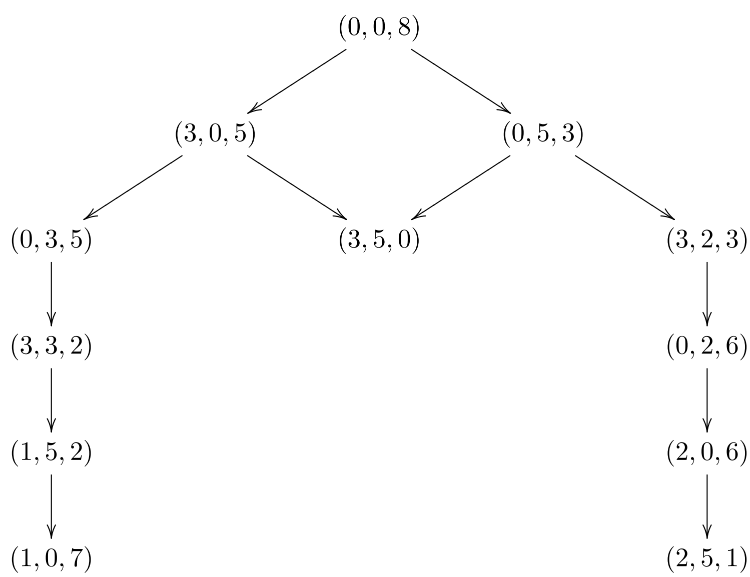
- Problem states can be represented as $s = (j_1, j_2, j_3)$, where j_i is the amounts of water in ith jug.
- The initial state is $(0, 0, 8)$, and the goal state is $(0, 4, 4)$.
- At each moment, there are 6 actions:

$$j_1 \mapsto j_2,\ j_1 \mapsto j_3,\ j_2 \mapsto j_1,\ j_2 \mapsto j_3,\ j_3 \mapsto j_1,\ j_3 \mapsto j_2$$

The 'Water Jugs' Problem Space

$$(0,8,0)$$
$$(1,7,0)(0,7,1)$$
$$(2,6,0)(1,6,1)(0,6,2)$$
$$(3,5,0)(2,5,1)(1,5,2)(0,5,3)$$
$$(4,4,0)(3,4,1)(2,4,2)(1,4,3)(0,4,4)$$
$$(5,3,0)(4,3,1)(3,3,2)(2,3,3)(1,3,4)(0,3,5)$$
$$(6,2,0)(5,2,1)(4,2,2)(3,2,3)(2,2,4)(1,2,5)(0,2,6)$$
$$(7,1,0)(6,1,1)(5,1,2)(4,1,3)(3,1,4)(2,1,5)(1,1,6)(0,1,7)$$
$$(8,0,0)(7,0,1)(6,0,2)(5,0,3)(4,0,4)(3,0,5)(2,0,6)(1,0,7)(0,0,8)$$

Decision Tree



Insight and Non-insight Problems

- In some problems, the intermediate states provide some information or intuition about how far is the goal state. This is usually the key characteristic of the *non-insight* problems.
- Non-insight problems are solved incrementally by a sequence of repeated and similar actions (small steps towards the goal).

  Example 2 (Noninstight problem). When building a house, it is usually possible to see at any moment how far is the house from being finished.
- In some problems, there is no sense of how far is the goal, and the solution often requires a *eureka* moment (an insight). These are the *insight* problems.

  Example 3 (Insight problem). A prisoner in a tower has a rope, which is half long enough to reach the ground safely. He divided the rope in half, tied the two parts together and escaped. How did he do this?
- See (Metcalfe & Wiebe, 1987) for more examples.

Importance of Expertise

- Problem solving requires both intelligence, but some problems also require expertise.

- Experience or expertise in solving some kinds of problems helps to solve new but similar problems faster.
- Expertise is characterised by the ability to recognise certain *pattern* in problem states, and to apply the correct actions or *rules*.
- Acquiring expertise requires time (e.g. doctors' training).
- Expertise in non-insight problems can often be acquired by practice.
- It is believed that insight problems require the ability to make the right representations of problem states (imagination).

2 Human Experts

Types of Experts

Schreiber et al. (1999) classify human experts into the following types:

Academic praise theoretical understanding of the domain, which they try to organise logically and make generalisations of the laws and behaviours in the domain. Their function is often to explicate, clarify and teach others. Knowledge is well structured and accessible, but more theoretical.

Practitioner solving day- to-day problems in the domain. Focus on specific solutions that work within the constraints and resource limitations. Knowledge is more heuristic, less generalised or structured.

Samurai focus on perfecting their skills and actions to achieve optimal performance. Training is practice-based, their responses are often automatic.

Human Limitations and Biases

Context of recall : human memory is influenced by the *context* and *recentcy*. Which facts are more likely to be recalled depends on the context and previously recalled facts.

Biases in probability judgement : estimation of the likelihood of some events can be very subjective, based on limited personal experience or prejudice.

Contrapositive statements : the logical inference rule *modus tollens* states:

$$\begin{array}{ll} \texttt{IF} & (A \text{ implies } B) \quad \texttt{AND} \quad (B \text{ is false}) \\ \texttt{THEN} & A \text{ is false} \end{array}$$

People usually make errors when reasoning with such statements.

3 Task Analysis and Modelling

Task Analysis and Modelling

- Many KM systems are designed to support workers in performing their tasks by providing relevant information, documents and procedures.
- One of the first steps in designing such KM systems is *task analysis*, which involves:
  - Identifying the goal, input and output information of the task.
  - Breaking down the task into subtasks.
  - Analysis of the subtasks.
  - Diagram representation of the task, subtasks and information flow.
  - Validation of the task model.
- Successful model of the main tasks in an organisation can be used to set up an *Electronic Performance Support Systems* (*EPSS*).
- Examples of EPSS include SunWEB (Sun Microsystems), Solstra (British Telecommunications).

Knowledge Elicitation Techniques

- Task analysis requires knowledge elicitation from the experts.
- Knowledge elicitation techniques include:
  - Structured interviews
  - Protocol or talk aloud analysis
  - Questionnaires and surveys
  - Concept sorting and laddering
  - Observation
  - Simulation

4 Knowledge Application and Reuse

Knowledge Internalisation, Application and Reuse

- One of the main aims of KM is to support learning in organisations and provide corporate memory.
- According to the Nonaka and Takeuchi (1995) spiral model of knowledge creation, after the socialisation, externalisation and combination phases (capture, representation and making knowledge available), the last phase is *internalisation*.

- *Internalisation* requires conscious decision of accepting the existing or new knowledge, such as facts and procedures, so that this knowledge can be applied and reused.
- Knowledge *application* occurs at an individual or at a group and organisational levels.
- Knowledge *reuse* involves recall, recognition and application.

Knowledge Repositories

- Knowledge repositories are intranets and portals used as *organisational memory.*
- They may contain a document management system, a database and a record management system.
- There are repositories for external and internal knowledge.
- They also can be classified into general and specific knowledge repositories.

Additional Reading

- Read the article: Metcalfe and Wiebe (1987) '*Intuition in insight and noninsight problem solving*'.

References

Metcalfe, J., & Wiebe, D. (1987). Intuition in insight and noninsight problem solving. *Memory and Cognition*, *15*(3), 238–246.

Nonaka, I., & Takeuchi, H. (1995). *The knowledge-creating company: How japanese companies create the dynamics of innovation.* Oxford University Press.

Schreiber, G., Hoog, R. de, Akkermans, H., Anjewierden, A., Shadbolt, N., Velde, W. V. de, et al. (1999). *Knowledge engineering and management: The CommonKADS methodology.* The MIT Press.