Problem Solving with Diagrams : Modelling the Learning of Perceptual Information

Peter C.R. Lane, Peter C-H Cheng and Fernand Gobet
ESRC Centre for Research in Development, Instruction and Training,
Department of Psychology, University of Nottingham,
University Park, Nottingham NG7 2RD, UK
{pcl,pcc,frg}@psychology.nottingham.ac.uk

This project attempts to model the process by which humans improve their ability to solve problems using diagrams. In order to achieve this, we have chosen an established model for human perceptual memory, and extended it with an ability to learn and manipulate plans for drawing schematic diagrams. This model is applied to the learning of planning information in a specific problem-solving domain: the construction of a diagrammatic representation for electric circuits.

The Computer Model The general form of a model for problem solving with diagrams has been established in earlier work on reasoning and inferencing with external representations (e.g. Tabachneck-Schijf, Leonardo & Simon, 1997). In brief, the model must interact with its external environment (e.g. the sheet of paper) using an eye for input and a pen for output. The model will require both short-term and long-term memories for visuo-spatial, verbal and planning information. However, this earlier work has not addressed the question of learning information about external representations, which is the focus of our project.

The long-term memory in our model is based on a model for the recall of chess positions, CHREST (Gobet & Simon, in press). CHREST is a development of EPAM (Feigenbaum & Simon, 1984) and uses a discrimination network to index chunks of perceptual information. However, CHREST is unable to learn complex problem-solving behaviour, because it lacks the ability to form and represent plans. Accordingly, we have adapted CHREST to handle multiple external representations: one set of representations corresponding to the problem space, one set corresponding to the solution space. A discrimination network is learnt which uses perceptual information to index each space. When a solution is given for a specific problem, an *equivalence link* is formed, linking the two representations. When confronted with novel problems, this new model will attempt to match the problem with a previous entry in its memory. If such a match exists, any equivalence link will suggest a possible solution to the current problem based on what was learnt earlier.

Problem Solving with Diagrams The work in this project attempts to simulate a specific example of problem-solving behaviour: the construction of a diagrammatic representation for a given electric circuit. We use AVOW diagrams as a representation for electric circuits (Cheng, 1998). An AVOW diagram represents each load in a circuit as a separate rectangle, known as an AVOW box. The dimensions of the AVOW boxes represent various electrical properies in their loads. Simple composition rules enable separate AVOW boxes to be combined to form a representation for a complete circuit. The visual nature of the representation makes it suitable for use by a model of perceptual memory, such as CHREST.

We can compare problem-solving behaviour with electric circuits with that in other domains, e.g. the construction of geometry proofs studied by Koedinger and Anderson (1990). This and related work has suggested that experts use *schemas* when solving problems, and it is the propagation of domain specific information in these schemas which explains the superiority of experts over novices.

However, our proposal extends such work by attempting to explain how schemas may be acquired whilst the learner is being taught to solve problems. In brief, schemas may be identified in our model with the chunks of diagrammatic information stored in the discrimination networks. Perceptual similarities ensure that each chunk may be generalised to a range of future examples, showing how our novel version of CHREST learns to improve its problem-solving ability. Further details of the project may be found in Lane, Cheng and Gobet (1999) and at our website:

`http://www.psychology.nottingham.ac.uk/research/credit/projects/problem_solving/`

The authors wish to thank the Economic and Social Research Council for funding this project.

References

Cheng, P. C-H. (1998). A framework for scientific reasoning with law encoding diagrams: Analysing protocols to assess its utility. In M. A. Gernsbacher & S. J. Derry (Eds.) *Proceedings of the Twentieth Annual Conference of the Cognitive Science Society* (pp. 232-235). Mahwah, NJ: Erlbaum.

Feigenbaum, E. A., & Simon, H. A. (1984). EPAM-like models of recognition and learning. *Cognitive Science*, 8, 305-336.

Gobet, F. & Simon, H. A. (in press). Five seconds or sixty? Presentation time in expert memory. *Cognitive Science*.

Koedinger, K. R., & Anderson, J. R. (1990). Abstract planning and perceptual chunks: Elements of expertise in geometry. *Cognitive Science*, 14, 511-550.

Lane, P. C. R., Cheng, P. C-H., & Gobet, F. (1999). Problem solving with diagrams: Modelling the learning of perceptual information. *Technical Report No.59. ESRC CREDIT, University of Nottingham.*

Tabachneck-Schijf, H. J. M., Leonardo, A. M., & Simon, H. A. (1997). CaMeRa: A computational model of multiple representations. *Cognitive Science*, 21, 305-350.