REPRESENTING SEMANTIC INFORMATION
IN PULLEY PROBLEMS

George F. Luger & Alan Bundy
Department of Artificial Intelligence
University of Edinburgh
Scotland

Several recent research reports have focussed on the representation and solution of problems in semantically rich domains (1),(2),(3),(4). These include analysis of algebra word problems as well as problems in mechanics and thermodynamics. The term "semantically rich" characterizes these domains well in that successful problem solvers possess large amounts of problem specific information and task related knowledge. Compare this with the knowledge and information needed to solve tasks such as the Tower of Hanoi or cryptarithmetic.

The MECHO group (2) has employed the familiar protocol analysis technique in an attempt to determine what information the person attempting to solve pulley problems has available, and further, how this information is organized and stored. Although the MECHO project has much broader goals than characterizing the world of pulley problems, the representation and solution of pulley problems will be the focus of this paper.

Like (1) & (3) we employ a problem-type schema to represent the problem solver's knowledge. We are also attempting to describe the content of the problem-type schema and characterize this content by a computer program (4).

The term schema is used, after Bartlett and Piaget, to refer to a structuring of information, a loose condederation of relationships that represent a capacity to perform a function or task. Each schema is made up of sets of facts and relations about an ideal object configuration, a set of inferences about these facts and relations, and a set of default values.

Consider the pulley problem: A man of 12 stone and a weight of 10 stone are connected by a light rope passing over a pulley. Find the acceleration of the man. If the man pulls himself up the rope so that his acceleration is one half its former value, what is the acceleration of the weight?

The facts or declaration of the problem above include a fixed pulley, a light rope passing over the pulley, and two objects one at each end of the rope.

The inferences about the pulley system will include the fact that both halves of the string will have the same tension if the pulley is smooth. Also, the magnitude of the acceleration of each object will be the same - the directions of course, are different - if the length of the rope between the objects remains constant. This acceleration inference is necessary if the solver is able to answer both questions in the problem. In the first instance, with the length of rope between the objects constant, the acceleration of the objects will be equal - though in opposite directions. In the second instance, the length of rope between objects changes so the magnitude of the acceleration will be different for each object.

The default values of the problem schema contain information such as, if nothing is said to the contrary, the pulley will be light and frictionless. Also, it is assumed the pulley is fixed if nothing is said to the contrary.

The following pulley system schema (in PROLOG (5)) will partially represent this situation:

```
Schema(pullsys(_sys,_pulley,_string,_direction1,
       _direction2,_time),
  [cue(stringsys(_string,_leftend,_midpt,_rightend,
     _time))],
  [problemtype(_pulley),particle(_pulley),
    incline(_leftend,_direction1,_midpt),
    incline(_rightend,_direction2,_midpt),
    tension(_leftend,_T,_time):- friction(_pulley,
      zero), tension(_string,_T, _time)),
    tension(_rightend,_T,_time):- friction
      (_pulley,zero),tension(_string,_T,_time))],
  [friction(_pulley,zero), mass(_pulley,zero,_time)
    fixed_contact(_pulley,_earth,_time) :-
      refpoint(_pt), diff(_pt,earth),
      nlc(thnot(fixed_contact(_pulley,_pt,_time))}]).
```

Each schema, as above, consists of four parts:
(1) the key, e.g., pullsys(....) used for calling in the appropriate schema.
(2) the declaration, e.g., cue(stringsys(...) list of subgoals for linking this schema to information in the database or declaring new information.
(3) the assertions, e.g., tension(...) :- (....) for adding facts or inferences to the database.
(4) the defaults, e.g., friction(...) a list of facts or inferences asserted as default values.

The problem schema represents the condition driven aspect of the MECHO program. It asserts the facts, inferences and defaults that make up the semantic content of the problem domain. The MECHO system is also goal driven. A simple means-ends analysis is incorporated in an algorithm that takes a sought unknown (the acceleration of the man) and by creating intermediate unknowns (the tension in the string) generates a linearly independent set of equations that will solve the problem. Thus MECHO is both a condition and goal driven system.

The problem-type schemata outlined in this paper are developed further in (4). There human protocols are presented and used to justify the pulley problem schemata. The MECHO system is also discussed as a model of human performance in the solution of pulley problems.

References

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