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Overcoming Unexpected Obstacles

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The present note illustrates how logical formalizations of common sense knowledge and reasoning can achieve some of the open-endedness of human common sense reasoning. A plan is made to fly from Glasgow to Moscow and is shown by circumscription to lead to the traveller arriving in Moscow. Then a fact about an unexpected obstacle---the traveller losing his ticket---is added without changing any of the previous facts, and the original plan can no longer be shown to work if it must take into account the new fact. However, an altered plan that includes buying a replacement ticket can now be shown to work. The formalism used is a modification of one developed by Vladimir Lifschitz, and I have been informed that the modification isn't correct, and I should go back to Lifschitz's original formalism.

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OVERCOMING UNEXPECTED OBSTACLES

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1 Introduction

In contrast to reasoning within a formal theory of the conventional sort used in science or operations research, common sense reasoning (McCarthy 1959) is open-ended. More facts than were originally taken into account may turn out to be relevant. Formalizing common sense requires a formal system that preserves this open-endedness. It can be done by formalizing nonmonotonic reasoning.

We present a straightforward example of how a system might take into account new facts. An unexpected obstacle vitiates the inference that the usual sequence of actions will achieve a goal. Then, without changing any existing premise, a system can infer that inserting a suitable new action in the sequence achieves the goal.

1. We use a general formalism for describing the effects of actions. It is a variant due to Vladimir Lifschitz (1987) of the situation calculus (McCarthy and Hayes 1969).

2. Specific facts concerning travel by airplane from one city to another are given. The need for a flight to exist and for the traveller to have a ticket are made explicit preconditions.

3. Facts relevant for flying from Glasgow to Moscow via London are mentioned, i.e. the flights are mentioned.

4. The circumscription formalism of (McCarthy 1980, 1986) is used to minimize certain predicates, i.e. *precond, noninertial, causes, occurs* while allowing the predicate *holds* to vary.

5. It can then be inferred (nonmonotonically) that flying from Glasgow to London and then flying to Moscow results in being in Moscow.

6. Facts giving the consequences of losing a ticket and buying a ticket are included. They do not change the result of the previous inference.

7. An assertion that the ticket is lost in London is then added to the previous facts. Now it can no longer be inferred that the previous plan succeeds. However, it can be inferred that the plan of flying to London then buying a ticket and then flying to Moscow does succeed.

This example shows that it is possible to make a formalism that (1) can be used to infer that a certain plan will succeed, (2) can no longer infer that the plan will succeed when an obstacle is asserted to exist, (3) can be used to infer that a different plan that includes actions to overcome the obstacle will succeed.

Our formulas include only the parameters needed to illustrate the reasoning. They don't even include the traveller, i.e. the person whose actions are reasoned about. From the point of view of demonstrating full common sense reasoning this is a blemish. However, we believe that the very formulas used here can be preserved provided we *enter* a suitable *context*. Formal reasoning about contexts is discussed in (McCarthy 1993).

2 The Formulas

Here are the formulas.

$$holds(not\ p, s) \equiv \neg holds(p, s)$$

This relates the operator *not* as applied to fluents to logical negation.

$$succeeds(a, s) \equiv (\forall p)(precond(p, a) \supset holds(p, s)).$$

This tells us that an action *succeeds* in a situation s if all its preconditions hold in the situation. Actually, it's a definition of the predicate *succeeds*.

$$succeeds(a, s) \wedge causes(a, p) \supset holds(p, result(a, s)).$$

If an action succeeds in a situation and it is one that causes a fluent to hold, then the fluent holds in the situation that results from the preformance of the action.

$$\neg noninertial(p, a) \wedge holds(p, s) \supset holds(p, result(a, s))$$

This tells us that unless an action affects a fluent, then the fluent holds after the action if it held before the action.

$$occurs(e, s) \supset outcome\ s = outcome\ result(e, s)$$

This and the next axiom give the effects of events different from actions.

$$\forall e \neg occurs(e, s) \supset outcome\ s = s$$

$$rr(a, s) = outcome\ result(e, s)$$

This is an abbreviation for the situation that results from an action after all the events that occur after it have happened.

$$causes(fly(x, y), at\ y)$$

This is the first axiom specifically about the effects of flying. It says that flying from x to y causes being at y.

$$precond(at\ x, fly(x, y))$$

You must be at x to fly from there to y.

$$precond(hasticket, fly(x, y))$$

Also you must have a ticket.

$$precond(existsflight(x, y). fly(x, y))$$

And there must be a flight.

$$causes(loseticket, not\ hasticket)$$

The effect of losing a ticket.

$$causes(buyticket, hasticket)$$

The effect of buying a ticket.

$$holds(at\ Glasgow, SO)$$

This is the first fact about the initial situation SO. The traveller is at Glasgow.

$$holds(husticket, SO)$$

He has a ticket in SO

$$holds(existsflight(Glasgow, London), SO)$$

$$holds(existsflight(London, Moscow), SO)$$

The necessary flights exist.

$$circum(Facts; causes, precond, noninertial, occurs; holds)$$

This is the circumscription of the predicates *causes, precond, noninertial* and *occurs* with *holds* allowed to vary that is done with the conjunction (called *Facts)* of these axioms. Understanding this may require reading (McCarthy 1986); (Lifschitz 1987) would also help. Once the circumscription has been done, we can show

$$holds(atMoscow, rr(fly(London, Moscow), rr(fly(Glasgow, London), SO))),$$

but not if we add

$$occurs(loseticket, result(fly(Glasgow, London), SO)).$$

However, in this case we can show

$$holds(atMoscow, rr(fly(London, Moscow), rr(buyticket, rr(fly(Glasgow, London), SO)))).$$

3 Avoiding Considering Preconditions

It is a precondition for air travel without additional actions that one be clothed, $holds(clothed(traveller), s)$, that one not be lame $holds(not\ lame(traveller), s)$, and $holds(speaks\text{-}English(traveller), s)$, etc. With a bow towards later explaining how to make this happen using formalized contexts (McCarthy 1989, 1991,1992) we'll abbreviate the above to the propositional fluents *clothed*, *not lame* and *speuks-English*. In one respect these conditions are similar to the condition that one have a ticket. However, one is willing to specify as part of the formalization of air travel that one have a ticket, but it is not reasonable to refer explicitly to these other conditions.

Here's an approach to doing it. The simplest approach would be to have a fluent $ab7(traveller)$, abbreviated $ab7$, and have sentences *not clothed* $\supset ab7$, etc. We then use *not ub7* as a precondition for flying. We then circumscribe *ub7.* This doesn't work well enough for two reasons. First we still have to mention all these other conditions in the circumscription and circumscribe them also. Second, suppose one of the conditions fails, e.g. the traveller is lame so a wheelchair must be provided. Then we lose *not* $ab7$, and we haven't got rid of the other conditions.

At present I think the first problem has to be solved by some form of *present* resembling the *scope* of Etherington, Perlis and Kraus (1989). If we circumscribe it, we are jumping to the conclusion that the interfering phenomena aren't present The second problem may perhaps be solved by introducing a parameter *exceptions* to *ub7* and requiring that none of the exceptions be unresolved.

Both of these ideas require details.

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