Research Review of The Frame Problem

The frame problem was described first by (McCarthy, et al., 1969) and it is the problem of having to formally to describe which fluents do not change when a given action is performed. Given that most actions only affect very few fluents at a time describing all combinations of fluents and actions is a huge overhead. To describe the problem better the concept of Frame Axioms was introduced. Frame Axioms describe what fluents do not change given a certain action.

(Pednault, 1989) later described a mechanism for deriving frame axioms from effect axioms that worked under the assumptions that the effect axioms are complete. This approach helped formulating frame axioms but didn't reduce the huge number of frame axioms needed. The assumption of completeness also forces one to describe all the effects even some effects seem "vacuous" or unnatural in the context of a given problem. Sometimes it's even unlikely that one can describe all effects completely (Reiter, 1991).

(Schubert, 1990) introduced with the explanation closure axiom the idea that one can solve the problem by explicitly enumerating all the actions that change a fluent in an axiom. As a logical consequence this would also describe all the actions that don't change a fluent. The number of explanation closure axioms is muss less than the number of frame axioms in Pednault's proposal but unfortunately, they can't be derived in a domain independent fashion.

(Reiter, 1991) refined Pednault's and Schubert's idea and introduced the successor state axiom and a single action precondition axiom for each action. It was now possible to describe a problem with one axiom per fluent and one axiom per action which made the Frame Problem less pressing. But the Frame Problem was still considered to be unsolved (Kamermans, et al., 2004).

But in more recent years two solutions to the problem have emerged and both are now widely accepted. One is Circumscriptive Event Calculus (Shanahan, 1997) and the other Fluent Calculus (Thielscher, 2001). Shanahan refined earlier ideas of an event calculus which introduces the notion of linear time and events that happen at a certain point in time and adopted it to work well with Circumscription which was first described by (McCarthy, 1980). Specifically, Shanahan introduced the notion of states which describe situations. A state is a set that can contains positive and negative fluents on which the "common sense law of inertia" would inherently apply. This idea made frame axioms obsolete.

Thielscher's solution is similar to Shanahan's as it also uses states that contain a number of fluents which can be changed by positive and negative effects. The use of state update axioms make sure that one only describes changes. This also eliminates the frame axiom problem.

The key for overcoming the Frame Problem was to introduce a state that could hold positive and negative fluents without the state being a complete description of a given situation (Kamermans, et al., 2004)

It's fascinating that it took 30 years to come up with the first generally accepted solution and the impact of having solved the problem cannot be overestimated. For a long time, it was unclear if formal logical can be used to fully describe real world problems and people started to look at alternative approaches (Kamermans, et al., 2004). These alternatives sought to solve the problem by not using formal logic at all. Some thought about using statistics and probability, others thought about not internalising the world at all (physical grounding) and some thought about using connectionism (neural networks) as they work without a complete formal description of a given problem domain. The solution of the Frame Problem established formal logic as a valuable tool in the field of AI.

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