Formalizing Action using Set Theory and modified Pointwise Circumscription

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1 Introduction

One of the dominating directions of research in formalizing theories of action, is the discretization of the space of situations (Situation Calculus), and the solution of the Frame Problem one situation at a time. An example of this trend is [Lin and Reiter, 1994].

In this work I showed how the Missionaries and Cannibals Problem (MCP) can be "solved" using an action formalism that uses Zermelo–Frankel Set Theory and a modified version of Pointwise Circumscription. The last one is used to capture the idea of *solve the Frame Problem one situation at a time*, and the former is used for dealing with sets in that problem. The framework is then shown to allow carrying reasoning both forward and backwards in time.

2 Why?

The motivation for Set Theory is two-fold. First, I would like to represent the MCP using a commonsense theory of action. For that, Set Theory is (arguably) required, as seen from the theory itself (see the full paper - [Amir, 1997]). Taking ZFC for that purpose is then motivated by its simplicity and its intuitive semantics. The second motivation for Set Theory is *Elaboration Tolerance*. [McCarthy and Amir, 1996] argues that Set Theory contributes to Elaboration Tolerance, and we require a suitable language to demonstrate that.

Pointwise-Circumscription is then used as the fine-tuned scissors for doing the job of mathematically solving the Frame Problem one situation at a time.

3 How?

We follow the following steps in the construction of our theory:

- Refine Pointwise Circumscription to refer to Minimal elements rather than absolute Minimum. We show the semantics and some cases in which the difference is evident.
- Add ZFC and show how the semantics of Situation Calculus changes as a result: we use no sorts, Situations and Actions are simple objects in their relative sets of objects, fluents are objects in a set of fluents $Fluents$, $Holds$ is a relation object in our universe, and formulas are interpreted recursively using $Holds$
- We show how we solve the Persistence Problem and Qualification Problem, after adding the set of *Peano Axioms for the Situation Calculus*, and that our solution for the persistence problem has the same semantics as that of [Lin and Reiter, 1994].
- We demonstrate the language and reasoning with the MCP.

4 Conclusions

The theories of action that we examined (e.g., [Doherty and Lukaszewicz, 1994], [Kartha and Lifschitz, 1995], [Lin and Reiter, 1994]) were not suitable for the types of reasoning that we wished to carry. First, none included Set Theory. Also, we found that *ghost situations* (situations on which we know nothing) are not suitable for proving that the MCP with four missionaries and four cannibals is unsolvable.

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