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Distributed Reason Maintenance for Multiagent Systems

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Abstract

Reason maintenance technology has been successfully applied in many AI systems. Reason maintenance systems help to maintain logical dependencies between data and support assumption-based reasoning, which has useful applications in a wide spectrum of domains ranging from diagnosis to planning.

Most reason maintenance systems, however, have been developed with a single agent in mind, i.e. there is only one problem solver using the services of the reason maintenance system. Only few reason maintenance systems are known that claim to be suited for application in multiagent systems. None of these systems adequately supports multiple-context reasoning in a distributed environment, although this functionality is highly desirable in many domains, e.g. for distributed planning, scheduling, and control. Thus, as multiagent systems become increasingly attractive for solving larger and more complex problems, the need for adequate reason maintenance technology for multiagent systems arises.

This book provides an in-depth investigation of a restricted class of multiple-context assumption-based multiagent reasoning problems. Logics for formalizing the underlying kind of reasoning are provided and a description of the functionality desirable to adequately support the reasoning processes of such systems is derived. A revised reason maintenance system architecture is presented that lays a solid foundation for building distributed reason maintenance systems for use in multiagent systems. The architecture is applied in the construction of the two systems XFRMS and MXFRMS, which provide a solid foundation for building more complex utilities, such as plan or schedule maintenance systems.

The results of the problem analysis and task-specific requirements suggest several fundamental changes and extensions of existing reason maintenance technology in order to make it applicable in planning, scheduling, and control. The single agent reason maintenance system XFRMS is therefore developed first, which incorporates and illustrates the key ideas of those improvements and enhancements. XFRMS provides functionality that partially matches those of de Kleer's ATMS, but focuses on consequence finding, consistency checking, and context determination, while the generation of explanations or the construction of interpretations are neglected. The main improvement in comparison with the ATMS, however, is that XFRMS tackles the key problem of using ATMS-based systems in planning domains: computational complexity, especially the predictability of resource use for particular instances of a problem class. By making context management an explicit task of XFRMS and giving the problem solver explicit control over the number of contexts under consideration, the resource demands of XFRMS can be controlled by the problem solver. The potentially exponential growth of resource demands by the ATMS can be avoided especially in those cases, where the structure of the dependency net would force the ATMS to construct exponentially many contexts, although the problem solver is interested in comparatively few contexts (maybe several dozen or a few hundred). Furthermore, the XFRMS allows the problem solver to explicitly delete contexts it no longer considers relevant.

The technology developed for the single agent case is then further enhanced to the multiagent or distributed case. The problem analysis shows that standard approaches to formalize the underlying kind of assumption-based reasoning for the multiagent case is not well-suited for the intended domain. Facetted Horn Propositional Logic (FHPL) is then developed to present a more adequate tool for the formalization of such problems.

Next, we show that the value of full ATMS functionality is rather doubtful in a multiagent setting: it easily incurs large computational cost and may have side effects that endanger agent autonomy and other desirable properties of agents. Resolving design conflicts when implementing a full ATMS-type distributed reason maintenance system requires several decisions to be made with serious consequences for functionality, efficiency, and applicability of the system. Instead of taking too many such choices and thereby restricting its possible uses, the multiagent reason maintenance system MXFRMS provides a solid base layer functionality which can build the foundation of more specialized reason maintenance services. Also, MXFRMS extends the techniques developed for XFRMS to avoid or at least control the problem of computational complexity. In particular, the XFRMS labelling scheme proves to be much better suited for distribution while giving the programmer better control on how tightly agent autonomy is to be enforced.

The two systems XFRMS and MXFRMS now provide a solid foundation for building more complex utilities, such as plan or schedule maintenance systems. The final chapter gives a perspective on potential uses and future extensions.

Preface

This book investigates the problem of maintaining and managing data dependencies in multiagent systems, a particular type of distributed system. The work described in this text is part of my thesis work and was developed in the context of the PEDE research project [Stoyan et al., 1992], which dealt with planning and execution in distributed environments. The PEDE project served as a unifying framework for research done both at the Knowledge Acquisition Research Group (FG WE) at FORWISS Erlangen and at the Artificial Intelligence Department of the University of Erlangen (IMMD-8), both of which are led by Prof. Dr. Herbert Stoyan. The PEDE project was loosely associated with the Special Research Area 182 on Multiprocessor and Network Configurations (SFB 182, see e.g. [Wedekind, 1992] and [Wedekind, 1994]), a large nationally-funded research effort that was coordinated and headed by Prof. Dr. Hartmut Wedekind.

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I now work in the group of Prof. Dr. Günther Palm at University of Ulm and I am very grateful to Prof. Palm for making it possible for me to finish this work. With Prof. Dr. Bernhard Nebel I had several valuable discussions regarding the parts of my thesis related to logics. I am very grateful to

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More than everybody else, my wife Iris and my son Thomas had to take the heaviest load of long nights and weekends spent in the office. Iris and Thomas, I thank you with all my love.

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