

David Basin
Michaël Rusinowitch (Eds.)

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Automated Reasoning

Second International Joint Conference, IJCAR 2004
Cork, Ireland, July 2004
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Preface

This volume constitutes the proceedings of the *2nd International Joint Conference on Automated Reasoning* (IJCAR 2004) held July 4–8, 2004 in Cork, Ireland. IJCAR 2004 continued the tradition established at the first IJCAR in Siena, Italy in 2001, which brought together different research communities working in automated reasoning. The current IJCAR is the fusion of the following conferences:

CADE: The International Conference on Automated Deduction,
CALCULEMUS: Symposium on the Integration of Symbolic Computation and Mechanized Reasoning,
FroCoS: Workshop on Frontiers of Combining Systems,
FTP: The International Workshop on First-Order Theorem Proving, and
TABLEAUX: The International Conference on Automated Reasoning with Analytic Tableaux and Related Methods.

There were 74 research papers submitted to IJCAR as well as 12 system descriptions. After extensive reviewing, 26 research papers and 6 system descriptions were accepted for presentation at the conference and publication in this volume. In addition, this volume also contains papers from the three invited speakers and a description of the CADE ATP system competition.

We would like to acknowledge the enormous amount of work put in by the members of the program committee, the various organizing and steering committees, the IJCAR officials, the invited speakers, and the additional referees named on the following pages. We would also like to thank Achim Brucker and Barbara Geiser for their help in producing this volume.

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Rewriting Logic Semantics: From Language Specifications to Formal Analysis Tools

José Meseguer and Grigore Roşu

University of Illinois at Urbana-Champaign, USA

Abstract. Formal semantic definitions of concurrent languages, when specified in a well-suited semantic framework and supported by generic and efficient formal tools, can be the basis of powerful software analysis tools. Such tools can be obtained *for free* from the semantic definitions; in our experience in just the few weeks required to define a language's semantics even for large languages like Java. By combining, yet distinguishing, both equations and rules, rewriting logic semantic definitions unify both the semantic equations of equational semantics (in their higher-order denotational version or their first-order algebraic counterpart) and the semantic rules of SOS. Several limitations of both SOS and equational semantics are thus overcome within this unified framework. By using a high-performance implementation of rewriting logic such as Maude, a language's formal specification can be automatically transformed into an efficient interpreter. Furthermore, by using Maude's breadth first search command, we also obtain for free a semi-decision procedure for finding failures of safety properties; and by using Maude's LTL model checker, we obtain, also for free, a decision procedure for LTL properties of finite-state programs. These possibilities, and the competitive performance of the analysis tools thus obtained, are illustrated by means of a concurrent Caml-like language; similar experience with Java (source and JVM) programs is also summarized.

1 Introduction

Without a precise *mathematical semantics* compiler writers will often produce incompatible language implementations; and it will be meaningless to even attempt to formally verify a program. Formal semantics is not only a necessary *prerequisite* to any meaningful talk of software correctness, but, as we try to show in this paper, it can be a key technology to develop powerful software analysis tools. However, for this to happen in practice we need to have:

- a well-suited semantic framework, and
- a high performance implementation of such a framework.

We argue that rewriting logic is indeed a well-suited and flexible framework to give formal semantics to programming languages, including concurrent ones.

In fact we show that it unifies two well-known frameworks, namely equational semantics and structural operational semantics, combining the advantages of both and overcoming several of their respective limitations.

High performance is crucial to scale up both the execution and the formal analysis. In this regard, the existence of the Maude 2.0 system [19] implementing rewriting logic and supporting efficient execution as well as breadth-first search and LTL model checking, allows us to automatically turn a language's rewriting logic semantic definition into a quite sophisticated software analysis tool for that language *for free*. In particular, we can efficiently interpret programs in that language, and we can formally analyze programs, including concurrent ones, to find safety violations and to verify temporal logic properties by model checking.

The fact that rewriting logic specifications provide in practice an easy way to develop executable formal definitions of languages, which can then be subjected to different tool-supported formal analyses, is by now well established [83, 8, 84, 78, 74, 45, 80, 16, 65, 81, 27, 26, 38]. However, ascertaining that this approach can scale up to large conventional languages such as Java and the JVM [27, 26], and that the generic formal analysis methods associated to semantic definitions can compete in performance with special-purpose analysis tools developed for individual languages, is a more recent development that we have been investigating with our students and for which we give evidence in this paper.

1.1 Semantics: Equational Versus SOS

Two well-known semantic frameworks for programming languages are: equational semantics and structural operational semantics (SOS).

In *equational semantics*, formal definitions take the form of *semantic equations*, typically satisfying the *Church-Rosser* property. Both higher-order (denotational semantics) and first-order (algebraic semantics) versions have been shown to be useful formalisms. There is a vast literature in these two areas that we do not attempt to survey. However, we can mention some early denotational semantics papers such as [75, 67] and the survey [56]. Similarly, we can mention [89, 31, 12] for early algebraic semantics papers, and [30] for a recent textbook.

We use the more neutral term *equational semantics* to emphasize the fact that denotational and algebraic semantics have many common features and can both be viewed as instances of a common equational framework. In fact, there isn't a rigid boundary between both approaches, as illustrated, for example, by the conversion of higher-order semantic equations into first-order ones by means of explicit substitution calculi or combinators, the common use of initiality in both initial algebras and in solutions of domain equations, and a continuous version of algebraic semantics based on continuous algebras.

Strong points of equational semantics include:

- it has a *model-theoretic*, denotational semantics given by *domains* in the higher-order case, and by *initial algebras* in the first-order case;