Farhad Arbab
Marjan Sirjani (Eds.)

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Preface

The present volume contains the post-proceedings of the second IPM International Symposium on Fundamentals of Software Engineering (FSEN), Tehran, Iran, April 17–19, 2007. This event, FSEN 2007, was organized by the School of Computer Science at the Institute for Studies in Fundamental Sciences (IPM) in Iran, in cooperation with the ACM SIGSOFT and IFIP WG 2.2, and was additionally supported by the University of Tehran, Sharif University of Technology, and the International Scientific Meetings Office (ISMO). This symposium brought together researchers and practitioners working on different aspects of formal methods in software engineering. FSEN 2007 covered many aspects of formal methods, especially those related to advancing the application of formal methods in the software industry and promoting their integration with practical engineering techniques.

A truly international program committee of top researchers from 23 different academic institutes in 9 countries selected the technical content of this symposium. We received a total of 73 submissions, out of which the PC selected 22 as regular papers and 8 as short papers to be published in the post-proceedings, and 6 papers accepted for poster presentations at the symposium. Each submission was reviewed by at least 3 independent referees, for its quality, originality, contribution, clarity of presentation, and its relevance to the symposium topics. We had 93 registered participants at the symposium from 12 countries.

We had 4 distinguished keynote speakers at FSEN 2007: James C. Browne, University of Texas at Austin, Texas, USA, on *Unification of Verification and Validation Methods for Software*; Masahiro Fujita, University of Tokyo, Japan, on *Hardware-Software Co-design for SoC with Separated Verification Between Computation and Communication;* Davide Sangiorgi, University of Bologna, Italy, on *Bisimulation in Higher-Order Languages*; and Peter D. Mosses, Swansea University, Wales, UK, on *Fundamentals of Semantics Engineering.*

In conjunction with FSEN 2007, the Working Group 2.2 of IFIP organized 2 full-day tutorials by internationally recognized researchers on the semantics of programming languages (Peter D. Mosses), and the semantics of concurrency (Davide Sangiorgi). These well-attended and well-received tutorials strengthened the impact of FSEN 2007, and we would like to take this opportunity to express our appreciation for the contribution of IFIP WG 2.2 and the tutorial speakers.

We are grateful for the support and the assistance of the IPM staff in the organization of this symposium, especially Dr. Larijani, Dr. Sarbazi-Azad, Ms. Arfai and Mr. Shahrabi. We thank the members of the program committee for their time, effort, and contributions to making FSEN 2007 a quality symposium. Last but not least, our thanks go to our authors and workshop partici-

pants, without whose submissions and participation FSEN 2007 would not have materialized.

April 2007

Farhad Arbab
Marjan Sirjani

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Table of Contents

Finite Abstract Models for Deterministic Transition Systems: Fair Parallel Composition and Refinement-Preserving Logic

Harald Fecher and Immo Grabe

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Abstract. Since usually no scheduler is given at the programming or modeling language level, abstract models together with a refinement notion are necessary to model concurrent systems adequately. Deterministic transition systems are an appropriate model for implementations of (concurrent) reactive programs based on synchronous communication. In this paper, we develop a suitable setting for modeling and reasoning about deterministic transition systems. In particular, we (i) develop a class of abstract models together with a refinement notion; (ii) define parallel composition guaranteeing fairness; and (iii) develop a 3-valued logic with a satisfaction relation that is preserved under refinement.

1 Introduction

The execution of concurrent reactive programs, where the scheduler is given, e.g., by the operating system, behaves (if no real random generator exists) deterministically up to the environment, i.e., the system behaves in the same way whenever the environment behaves in the same way (including points in time). Deterministic transition systems, where no two transitions leaving the same state have the same label, are an appropriate model for reactive systems based on synchronous communication, whenever the environment will provide at most one action (resp. will request at most one of the actions provided by the system) at once. For example, they are in particular an appropriate model for implementations of a UML state machine [1], where only synchronous communication between the state machine and its event pool, which can provide at most one 'event' at the same time, occurs.

Deterministic transition systems are also appropriate as model for components of closed concurrent systems, whenever every component has its own scheduler, i.e., determines which process(es) of the component performs the next action. Here, a global scheduler decides if a (and which) communication between the component and its environment takes place or if an internal computation takes place.

Models for programming languages that contain concurrency are usually nondeterministic, since the scheduler is not known at that level (i.e., will be provided by the operating system). Therefore, those models as well as models for

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modeling languages should contain nondeterminism, which will be resolved (via refinements) in later design phases and/or by the operating system until deterministic computations are reached. Properties valid on the abstract level, i.e., on the model containing nondeterminism, should be preserved under refinement to maintain the relation between the model and the system. Furthermore, a model for the abstract level should provide a compact and finite description of sets of implementations, especially to improve verification. Moreover, it should be closed under standard operators to be suitable for defining semantics of programming languages and for compositional reasoning. Note that often programmers, software engineers, and computer scientists stay on the abstract level and never reach the concrete level in their contribution to the software development process. Nevertheless, it is important to know what exactly the systems are, since the definition of, e.g., sound satisfaction at the abstract level heavily depends on this information.

Contribution. We develop a setting for modeling and reasoning about deterministic transition systems.

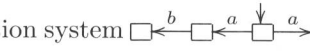
In particular:

- We develop a class of abstract models together with a refinement notion, where exactly the deterministic transition systems are the concrete ones. Our model allows finite/compact modeling by (i) abstracting labels, (ii) having a predicate over labels indicating whether the removal of all transitions having a label is allowed as a refinement step or not, and (iii) having Streett acceptance conditions for restricting infinite computations.
- We define parallel composition for our model that (i) preserves refinement, (ii) preserves satisfiability (i.e., the existence of a refining implementation), and (iii) guarantees fairness, in that, roughly speaking, every component as well as internal synchronization gets an infinite number of opportunities to execute. Here, Streett acceptance conditions are naturally generated by parallel composition between deterministic transition systems.
- We develop a logic together with its satisfaction relation. The logic has as its basic operator $\langle\!|\, \alpha \,|\!\rangle q$ indicating that α can be executed and after executing α property q is guaranteed to hold. This logic yields a 3-valued satisfaction relation on our model, but is 2-valued on concrete abstractions (implementations). We show soundness, i.e., that satisfaction is preserved under refinement. Furthermore, deciding our satisfaction relation is in NP and approximates the EXPTIME-hard language inclusion problem which asks whether all implementations that refine abstraction $\mathcal{M}$ satisfy property ϕ. The PSPACE-complete LTL model checking problem is also approximated.

Related work. Kripke structures (with Streett fairness constraints) together with trace inclusion as refinement notion are used as abstract settings for linear time, where implementations are traces. In this context, LTL [2] is an appropriate logic. Abstract models used for abstraction of linear time settings are not appropriate for our purpose, since they do not model the branching time sensitivity obtained by communications on different actions.

Transition systems with (forward or backward) simulation [3, 4] are not an appropriate setting for abstraction of deterministic transition systems, since deterministic transition systems can be refined further and, therefore, refinement preserving satisfaction relations are in general not 2-valued on them. Therefore, alternating refinement [5] also yields no appropriate setting for our purpose, since it coincides with simulation on labeled transition systems.

On the other hand, transition systems with ready simulation [6] yield an appropriate setting if deterministic transition systems are the implementations. The predicate over labels and the fairness constraint in our setting allow a more compact representation than ready simulation, which will be illustrated later. Note that ready simulation coincides with our refinement notion for the canonical embedding of transition systems into our setting. Transition systems are already extended in [7, 8] by a predicate over labels indicating divergence (infinitely many internal computations are possible). Therefore, the relation introduced there, called *prebisimulation*, does not yield a comparable refinement notion. The refinement notions of failure, failure trace, ready, and ready trace inclusion [9] are also appropriate settings if deterministic transition systems are the implementations. Their trace based approach makes it hard to define an approximated, compositional satisfaction relation that is preserved under refinement.

Standard branching time logics, which are interpreted on transition systems, are, e.g., CTL [10] and the μ-calculus [11]. But these logics are not appropriate for our setting, since these logics are not preserved under ready simulation: the property that "there is a transition labeled a such that b is possible afterwards" holds in the labeled transition system 

but not in its refinement 

. μ-automata [12], (disjunctive) modal transition systems [13, 14] and their variants [15, 16, 17, 18] are used as abstraction model for transition systems in order to improve verification of full branching time properties, as, e.g., in [19, 20, 21]. These models are not appropriate for our purpose, since they consider transition systems rather than deterministic transition systems as implementations. Consequently, these models contain additional complex structures that are unnecessary if the implementations are guaranteed to be deterministic. For example, a state in a modal transition system can have more than one outgoing must-transitions, which makes it, e.g., hard to determine satisfiability w.r.t. deterministic transition systems.

To the best of our knowledge there is no abstract model (beside the model developed here) that can create finite abstraction of labeled (deterministic) transition systems in case infinitely many different transition labels are used.

Outline. Our model together with its refinement notion is formally introduced in Section 2, whereas in Section 3 the parallel composition is presented. Section 4 introduces the logic together with the satisfaction relation and Section 5 presents illustration how the setting can be used for modeling and for verification. Section 6 concludes the paper and discusses future work.