Nemos: A Framework for Axiomatic and Executable Specifications of Memory Consistency Models*

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Abstract

Conforming to the underlying memory consistency rules is a fundamental requirement for implementing shared memory systems and writing multiprocessor programs. In order to promote understanding and enable automated verification, it is highly desirable that a memory model specification be both declarative and executable. We have developed a specification framework called Nemos (Non-operational yet Executable Memory Ordering Specifications), which employs a uniform notation based on predicate logic to define shared memory semantics in an axiomatic as well as compositional style. In this paper, we present this framework and discuss how constraint logic programming and SAT solving can be used to make these axiomatic specifications executable for memory model analysis, thus supporting precise specification and automatic execution in the same framework. To illustrate our approach, this paper formalizes a collection of well known memory models, including sequential consistency, coherence, PRAM, causal consistency, and processor consistency.

1 Introduction

Two emerging trends – the tremendous advances in multiprocessor machines and the integrated support of threads from programming languages such as Java – have combined to make concurrent programming a vitally important software engineering domain. A multiprocessor program relies on a memory consistency model to determine how memory operations should appear to execute. In particular, it specifies what values may be returned by read operations considering various ordering relaxations allowed.

The design of a memory system typically involves a tradeoff between programmability and efficiency. As a natural extension of the uniprocessor model, sequential consistency (SC) [1] requires all memory operations to exhibit a common total order that also respects program order. Since SC is very restrictive, many weaker memory models (see [2] for a survey) have been proposed to provide higher performance. For example, coherence [3]

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