Towards a Temporal Logic for Causality and Choice in Distributed Systems

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ABSTRACT: Which kind of properties of nonsequential systems should be considered essential for specification and abstraction purposes, is still an open problem. In this paper we discuss some particular properties such as absence of delay and various notions of concurrency. They turn out to be adequately representable in partial order semantics. The most fundamental version of Petri Nets appears to be convenient for such investigations. A (generalized) temporal logic is introduced, covering the intricate relationship among causality (sequentiality), choice and concurrency appearing in distributed systems.

Key words: Concurrent System Properties, Temporal Logic, Petri Nets

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Introduction

Temporal Logic provides a recognized technique to specify systems, particularly nonsequential systems and to formulate and prove properties of such systems. It refers to conventional operational semantics, conceiving single runs of systems as sequences of states and transitions. Such sequences are gained by interleaving (arbitrarily ordering) transitions which occur independently in the reality to be modeled.

In recent years (and in Petri Nets more than a decade ago) it was understood that arbitrary interleavings conceal essential properties of runs of nonsequential systems: It is not clear whether two given sequences are different interleavings of the same run. Arbitrary interleavings furthermore introduce global states which do not correspond to the realm of nonsequential systems. So, the concept of partial order semantics found its way from Petri Nets to a couple of other system models. Properties such as absence of system-prone delay, the existence of alternatives in distributed situations, or particular questions of fairness can adequately be treated in this framework.

The first part of this paper concentrates on intuitive notions and concepts. We start with properties considered essential for nonsequential systems, and discuss their representability in conventional temporal logic. It turns out that new concepts are mandatory. Those new concepts concern the underlying semantic model. So, operational semantics is re-considered and the adequacy of partial order semantics is shown. As partial order semantics does not fit with conventional temporal logic, its roots in Modal Logic are discussed and a revised version of Temporal Logic is glanced.

The second part turns at formal aspects. The most elaborated system model for partial order semantics is introduced, viz elementary net systems, the basic system model of Petri Nets. Then a logical language, \( \mathcal{F}(B) \) is introduced, fitting to the partially ordered concept of runs of elementary net systems.

The third part, finally, shows what is gained with partial order semantics and its logic. It is shown that a couple of essential system properties can be formulated in this language, including absence of delay and some notions in the area of concurrency.