Chapter 11
A Denotational Semantics of Real–Time Process Algebra (RTPA)

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ABSTRACT

Real-time process algebra (RTPA) is a form of denotational mathematics for dealing with fundamental system behaviors such as timing, interrupt, concurrency, and event/time/interrupt-driven system dispatching. Because some key RTPA processes cannot be described adequately in conventional denotational semantic paradigms, a new framework for modeling time and processes is sought in order to represent RTPA in denotational semantics. Within this framework, time is modeled by the elapse of process execution. The process environment encompasses states of all variables represented as mathematical maps, which project variables to their corresponding values. Duration is introduced as a pair of time intervals and the environment to represent the changes of the process environment during a time interval. Temporal ordered durations and operations on them are used to denote process executions. On the basis of these means, a comprehensive set of denotational semantics for RTPA are systematically developed and formally expressed.

INTRODUCTION

a rich set of process operations including timing, interrupt, concurrency, and event/time/interrupt-driven dispatches with a rigorous algebraic structure.

The conventional forms of denotational semantics were designed to deal simple and sequential computation behaviors (Louden, 1993; McDermid, 1991; Wang, 2007a; Winskel, 1993). Efforts to represent parallel and concurrent behaviors in the denotational semantic approach focused on communications between components (Schneider, 2000). Various treatments for time and durations have been introduced (Baeten & Bergstra, 1991; Boucher & Gerth, 1987; Corsetti, Montanari, & Ratto, 1991; Dierks, 2000; Fecher, 2001; Milner, 1980; Schneider, 1995) in order to describe the real-time mechanisms in denotation semantics. Because the mathematical structure of RTPA cannot be described adequately in conventional denotational semantics paradigms (Hoare, 1978, 1985; Schneider, 2000; Wang, 2007a; Winskel, 1993), a new extension on conventional denotational semantics is introduced for modeling time and processes in RTPA, where relative time is modeled by the elapse of process execution, and a process is modeled by temporal ordered duration sequences.

The article attempts to handle the sequential, parallel, concurrent, and real-time behaviors of RTPA in a coherent system. The abstract syntax of RTPA is presented. The system environment is introduced to describe instantaneous behaviors of processes and durations. Temporal ordered duration sequences are introduced to present the semantics of RTPA meta processes and process operations. The denotational semantics for RTPA can be used as rules for correctness checking and system verification in system design and modeling using RTPA. It also facilitates the rigorous understanding of a comprehensive set of fundamental computing system behaviors as modeled in RTPA.

THE ACTIVITY DURATION CALCULUS

The activity duration calculus (ADC) is developed to describe system behaviors over time where each activity happens in a timely order and will last for a period of time or an interval. At any specific time moment, the state of the system is represented by the values of its variables at the moment (Wang, 2006a, 2008b). The time sequence of the instantaneous moments expresses the behaviors of a system. ADC uses a semantic environment, which is a map from variables to values, to record an instantaneous system state (Wang, 2006a, 2008b). It uses a duration adopted as a 2-tuple of an interval and an environment to represent a system state for a given period of time. A temporal ordered duration sequence is therefore a semantics model of system behaviors.

Variables and Values

ADC uses variables with a universal type by default. When different types of variables, such as integer, real, and Boolean, are needed, it can be considered that the various variables are in the form of set sum (Winskel, 1993), as used in the denotational semantics of RTPA.

\[ \mathbb{X} \text{- The set of all variables.} \]  
(1)

\[ \mathbb{V} \text{- Domain of all possible values.} \]  
(2)
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