

# Chapter 15

## The Formal Design Model of an Automatic Teller Machine (ATM)

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### ABSTRACT

*An Automated Teller Machine (ATM) is a safety-critical and real-time system that is highly complicated in design and implementation. This paper presents the formal design, specification, and modeling of the ATM system using a denotational mathematics known as Real-Time Process Algebra (RTPA). The conceptual model of the ATM system is introduced as the initial requirements for the system. The architectural model of the ATM system is created using RTPA architectural modeling methodologies and refined by a set of Unified Data Models (UDMs), which share a generic mathematical model of tuples. The static behaviors of the ATM system are specified and refined by a set of Unified Process Models (UPMs) for the ATM transition processing and system supporting processes. The dynamic behaviors of the ATM system are specified and refined by process priority allocation, process deployment, and process dispatch models. Based on the formal design models of the ATM system, code can be automatically generated using the RTPA Code Generator (RTPA-CG), or be seamlessly transformed into programs by programmers. The formal models of ATM may not only serve as a formal design paradigm of real-time software systems, but also a test bench for the expressive power and modeling capability of exiting formal methods in software engineering.*

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## INTRODUCTION

The modeling and description of an Automated Teller Machine (ATM) are a typical design case in safety-critical and real-time systems (Laplante, 1977; Hayes, 1985; McDermid, 1991; Corsetti et al., 1991; Liu, 2000; Wang, 2002, 2007). As a real-time control system, the ATM system is characterized by its high degree of complexity, intricate interactions with hardware devices and users, and necessary requirements for domain knowledge. All these factors warrant the ATM system as a complex but ideal design paradigm in large-scale software system design in general and in real-time system modeling in particular.

There is a lack of systematical and detailed documentation of design knowledge and modeling prototypes of ATM systems and a formal model of them in denotational mathematics and formal notation systems (Wang, 2008a, 2008b). This paper presents the formal design, specification, and modeling of the ATM system using a denotational mathematics known as Real-Time Process Algebra (RTPA) (Wang, 2002, 2003, 2007, 2008a, 2008c, 2008d). RTPA introduces only 17 meta-processes and 17 process relations to describe software system architectures and behaviors with a stepwise refinement methodology (Wang, 2007, 2008c). According to the RTPA methodology for system modeling and refinement, a software system can be specified as a set of *architectural* and *operational components* as well as their interactions. The former is modeled by *Unified Data Models* (UDMs, also known as the component logical model (CLM)) (Wang, 2008c), which is an abstract model of system hardware interfaces, an internal logic model of hardware, and/or an internal control structure of the system. The latter is modeled by *static* and *dynamic processes* using the *Unified Process Models* (UPMs) (Hoare, 1978, 1985; Bjorner & Jones, 1982; Wang, 2007, 2008c; Wang & King, 2000).

This paper develops a formal design model of the ATM system in a top-down approach on

the basis of the RTPA methodology. This work demonstrates that the ATM system can be formally modeled and described by a set of real-time processes in RTPA. In the remainder of this paper, the conceptual model of the ATM system is described as the initial requirements for the system. The architectural model of the ATM system is created based on the conceptual model using the RTPA architectural modeling methodologies and refined by a set of UDMs. Then, the static behaviors of the ATM system are specified and refined by a set of processes (UPMs). The dynamic behaviors of the ATM system are specified and refined by process priority allocation, process deployment, and process dispatching models. With the formal and rigorous models of the ATM system, code can be automatically generated by the RTPA Code Generator (RTPA-CG) (Wang, 2007), or be seamlessly transferred into program code manually. The formal models of ATM may not only serve as a formal design paradigm of real-time software systems, but also a test bench for the expressive power and modeling capability of existing formal methods in software engineering.

## THE CONCEPTUAL MODEL OF THE ATM SYSTEM

An ATM system is a real-time front terminal of automatic teller services with the support of a central bank server and a centralized account database. This paper models an ATM that provides money withdraw and account balance management services. The architecture of the ATM system, as shown in Figure 1, encompasses an ATM processor, a system clock, a remote account database, and a set of peripheral devices such as the card reader, monitor, keypad, bills storage, and bills disburser.

The conceptual model of an ATM system is usually described by a Finite State Machine (FSM), which adopts a set of states and a set of state transition functions modeled by a transition dia-

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