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Communicating X-machines: a practical approach for formal and modular specification of large systems

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Abstract

An X-machine is a general computational machine that can model: (a) non-trivial data structures as a typed memory tuple and (b) the dynamic part of a system by employing transitions, which are not labelled with simple inputs but with functions that operate on inputs and memory values. The X-machine formal method is valuable to software engineers since it is rather intuitive, while at the same time formal descriptions of data types and functions can be written in any known mathematical notation. These differences allow the X-machines to be more expressive and flexible than a Finite State Machine. In addition, a set of X-machines can be viewed as components, which communicate with each other in order to specify larger systems. This paper describes a methodology as well as an appropriate notation, namely X-machine Description Language (XMDL), for building communicating X-machines from existing stand-alone X-machine models. The proposed methodology is accompanied by an example model of a traffic light junction, which demonstrates the use of communicating X-machines towards the incremental modelling of large-scale systems. It is suggested that through XMDL, the practical development of such complex systems can be split into two separate activities: (a) the modelling of stand-alone X-machine components and (b) the description of the communication between these components. The approach is disciplined, practical, modular and general in the sense that it subsumes the existing methods for communicating X-machines.

Keywords: X-machines; Communicating X-machines; Formal methods

1. Introduction

Although many software engineering methods and methodologies are devised in order to deal with the development of complex software systems, there is still no evidence to suggest that, apart from formal methods, any of them leads towards 'correct' systems. In the last few decades, academics and practitioners adopted extreme positions for or against formal methods [1], with the truth lying somewhere between but the necessity of formal methods in software engineering of industrial systems still apparent [2]. Software system specification has centred on the use of models of data types, either functional or relational models such as Z [3] or VDM [4] or axiomatic ones such as OBJ [5]. Although these have led to some considerable advances in software design, they lack the ability to express the dynamics of a system. Also, transforming an implicit formal description into an effective working system is not straightforward. Other formal methods, such as Finite State Machines (FSMs) [6] or Petri Nets [7] capture the dynamics of a system, but fail to describe the system completely, since there is little or no reference at all to the internal data and how this data is affected by each operation in the state transition diagram. Other methods, like Statecharts [8], capture the requirements of both the dynamic behaviour and modelling of data but are rather informal with respect to clarity and semantics, thus being susceptible to many interpretations. So far, little attention has been paid in formal methods that could facilitate all crucial stages of correct system development, namely modelling, verification and testing.

X-machines is a formal method that is able to deal with all these crucial stages. An X-machine is a general

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