

Chapter 12

Modeling Control Flow in WS-BPEL with Chu Spaces

Xutao Du

Institute of Electronic System Engineering, China

Chunxiao Xing

Tsinghua University, China

Lizhu Zhou

Tsinghua University, China

Ke Han

Institute of Electronic System Engineering, China

ABSTRACT

This paper presents a Chu spaces semantics of typical control flow of WS-BPEL including fault handling and link semantics. BPEL-CF is proposed as a simplification of this subset of WS-BPEL. For the compositional modeling of BPEL, the authors present a Chu spaces process algebra. This algebra allows faults to be thrown at any point of execution and take link-based synchronization into consideration. The paper gives the abstract syntax of BPEL-CF, the semantic algebra, and the valuation functions for computing the Chu spaces denotations of BPEL-CF programs.

INTRODUCTION

More and more business enterprises, governmental agencies, universities and other organizations provide their services on the Internet. Complex services can be achieved by orchestrating or composing smaller ones. WS-BPEL (OASIS, 2007) is

the de facto standard for Web service compositions and is supported by major software vendors such as IBM, Microsoft and Oracle. The logical correctness and reliability of WS-BPEL processes are important for both the service providers and consumers. But the WS-BPEL specification (OASIS, 2007) is non-formal and some inconsistent and unclear issues have been reported by researchers.

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To formally debug the WS-BPEL specification and verify interesting properties that are hard to be tested, various formal methods have been used, such as automata-related models (Fu, 2004; Pu, Zhao, Wang, & Qiu, 2005; Qian et al., 2007), Petri nets (Lohmann, Massuthe, Stahl, & Weinberg, 2008; Ouyang et al., 2007), and process calculi (Lucchi & Mazzara, 2007; Yeung, 2006).

In this paper, we use Chu spaces to formalize typical control flow in WS-BPEL. Compared with other formalisms, Chu spaces have both formal and practical characteristics that enable us to make the choice. First, Chu spaces support true concurrency semantics inherently which is very natural for WS-BPEL that is expected to be executed in a highly distributed manner. Second, Chu spaces are compositional and have extensible algebraic theory that allow complex Chu spaces to be composed from simpler ones, which will facilitate the definition of the denotational semantics of concurrent programming languages. Third, Chu spaces have unique structures that support efficient verification algorithms for process-algebraic specifications.

This paper is a step towards a complete formalization, in terms of Chu spaces, of the control flow in WS-BPEL. Currently, typical control flow constructs including fault handling and link semantics are modeled. However, the compensation mechanism is not taken into consideration in this paper and will be done as our future work.

The remainder of this paper is organized as follows: First, we introduce basic definitions of Chu spaces and present the denotational semantics of the control flow in WS-BPEL in terms of Chu spaces. We present two illustrative examples and make conclusions and discuss our future work.

RELATED WORK

Two kinds of related work need to be discussed: formal semantics of WS-BPEL and the study of Chu spaces process algebra.

Much research has been done on the formulating of WS-BPEL (or earlier versions) semantics. The main objectives of giving a formal semantics of WS-BPEL are twofold: to clarify the informal WS-BPEL specifications and to verify WS-BPEL processes. Because of the large number of publications, we will not (and cannot) give a full survey in this section (not so recent surveys can be found in Morimoto, 2008; van Breugel & Koshkina, 2006). We apologize to those authors whose excellent results are not mentioned here. According to the formalisms being used, these publications are categorized into three groups: automata (Fu, 2004; Kovács, Gönczy, & Varró, 2008; Nakajima, 2006; Pu et al., 2005), Petri nets (Lohmann, 2007a; Ouyang et al., 2007; Schlingloff, Martens, & Schmidt, 2005; Yang, Tan, Xiao, Liu, & Yu, 2006) and process algebras (Ferrara, 2004; Foster, 2006; Lapadula, Pugliese, & Tiezzi, 2007, 2008; Lucchi & Mazzara, 2007).

Two important factors in the formal semantics of WS-BPEL are (1) whether it supports the interleaving semantics or true concurrency; (2) whether it supports process-algebraic verification.

The debate between interleaving semantics and true concurrency lasts for decades. A full discussion is beyond the scope of this paper. But the large portion of concurrent executions in WS-BPEL forces us to look at this problem. Interleaving semantics use nondeterministic choice and sequential composition to simulate concurrent composition, i.e. $a \parallel b = a; b + b; a$. An obvious problem is that $a; b + b; a$ lacks the intermediate state of $a \parallel b$ in which both a and b are running. If a denotes “invoke service A” and b denotes “invoke service B”. Then if we want to verify “service A and service B should be invoked concurrently”, the process $a; b + b; a$ will also fulfill this property which counters our intuition. For example, the MWB (the primary tool for CCS and pi-calculus) verifies that $a \parallel b$ and $a; b + b; a$ are bisimilar (i.e., have the same semantics). We think in the modeling and verification of WS-

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