Context-Aware Service Modeling and Conflicts Discovery Based on Petri Net

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ABSTRACT

In smart environments, context-aware service sense various kinds of context information and reacts automatically to adapt to changing circumstances. These adaptions may lead to context changes which trigger other services elsewhere in the environment and thus produce cascading reactions. Conflict adaptions or unexpected side effects may exist in this process. This article focuses on service conflicts related to frustrations in service execution and violations of the service’s objective. A petri net-based approach is proposed to model and simulate context changes as well as services execution, and a conflicts discovery mechanism was built to detect potential conflicts. The case study of smart home scenarios shows how the method helps locate conflicts caused by different services, validating the effectiveness of the proposed approach.

KEYWORDS
Conflicts Discovery, Context-Aware Service, Modeling and Simulation, Pervasive Computing, Petri Net

INTRODUCTION

Pervasive computing is considered as a promising scheme which enables users to enjoy services anytime and anywhere in transparent manner (Weiser, 1991; Xu, Shi, & Xie, 2003). A pervasive computing system aims to serve the users without distracting their attention from the tasks (Dey et al., 2001; Abowd et al., 1999). Therefore, the system needs to be aware of the context and adjust its action accordingly.

Context awareness refers to an ability to adapt to changing circumstances based on contextual information. By unobtrusive sensing, collecting, reasoning, and acting on context information, context-aware systems react automatically, which makes the environment truly smart (Preuveneers & Joosoen, 2016). A smart environment can be regarded as a complex system made up of every kind of services, especially context-aware services.

Context-aware service gathers context information by sensors deployed in the environment, interpreting information, determining necessary action and commanding the actuator to take appropriate action (Carreira, Resendes, & Santos, 2014; Hoareau & Satoh, 2009). The actuators in turn affect its surrounding physical environment, i.e., influence the context (Carreira et al., 2014). The context change may trigger service elsewhere in the environment, and thus produce cascading reactions. Conflict adaptions or unexpected side effects may exist in the process.

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Therefore, understanding the impact of services and side effects are important tasks for the service developer. Ensuring reliability of the smart environment is a complex task due to its dynamic and distributed nature, as well as the number of services (Guilly et al., 2016). Moreover, services may come from different developers or be deployed at different times. The potential consequence of unexpected side effects from subsequent reactions may not always be clear. There is need for better design support to analyze adaptations and discover potential conflict.

The definition of conflict in a pervasive computing environment varies from application to application (Carreira et al., 2014). From the resolution perspective, some conflicts cannot be avoided (e.g. users with different intentions in multiuser environments, two services exclusively applying for the same resource at the same time). The only thing that the system can do is to detect and resolve these conflicts. However, apart from that, there are conflicts that can be avoidable by increasing the flexibility and adaptability of service through improving service logic. In this case, it is important to detect these conflicts at design time.

From the detection perspective, some conflicts can be determined in semantic level, such as services with the same triggering conditions and contradictory actions. Semantic analysis is useful at design time as well as at run time. However, some conflicts cannot be easily determined in semantic level. These services are conflict not only due to their contradictory actions, but also that they are wrongly triggered in certain situations. Simulation and formal verification are effective methods to detect these conflicts and determine their occurring situation.

Applications of formal methods is essential to analyze and verify such systems. There are a lot of research trying to increase the reliability of different aspects of intelligent environments, particularly in using formal verification techniques (Corno & Sanaullah, 2013; Coronato & De Pietro, 2010; Guilly et al., 2016). Such approaches and tools would aid software developers at design time, and would be useful in configuration and reconfiguration processes.

The main concerns of this paper are two types of conflict: (1) one service frustrating the execution of another; and (2) one service violating another service’s objective. The former may occur when services are simultaneously executed. The latter is asynchronous and generally does not directly cause another service to be unable to work, thus more hidden than other types of conflict.

Smart environment is complex due to the number of contexts, services and the user’s activity. The approach presented in this paper aims to show what will occur by simulating complex environment change and service execution, particularly to detect the potential conflicts and determine their occurring situation.

Petri net is a graphical and mathematical modeling tool, which is widely used to describe the system characterized as being concurrent, asynchronous, distributed and/or stochastic. Moreover, petri net can also simulate the dynamic and concurrent activities in the system.

Therefore, we propose a petri net-based model to simulate context change and service running. A conflicts discovery mechanism is built based on this model. We validate our method in smart home scenarios, and demonstrate how the work helps locate conflicts caused by different services. Potential faults can be discovered at design time, by which the developer improves service logic and minimizes the occurrence of undesired side effects at runtime.

Unlike some context awareness simulators, such as CASi in Cassens et al. (2012), which provides simulation environment with virtual sensors, virtual actuators and virtual users to test context-aware system, simulation based on petri net is employed on the abstract model of service. Service logic needs to be decoupled from application and translated into petri net model. User’s behavior pattern and environment change pattern are also abstracted and described in petri net model.

The remaining of this paper is organized as follows. In section 2, the context and service petri net (CSPN) model is defined, and the modeling method is presented. Section 3 proposes a conflicts discover mechanism. In section 4, the case of smart home is used to validate the proposed approach. Section 5 discusses the related work and section 6 concludes the paper.
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