Bigraphical Reactive Systems Based Approaches for Modeling Context-Aware Systems

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ABSTRACT

In the past few years, context-aware computing has become one of the most promising topics of ubiquitous (pervasive) computing where computers are integrated and vanish in the background of users everyday activities. A context-aware system is a ubiquitous system, which is able to adapt its behavior automatically according to the gathered context information. However, due to the increasing complexity and diversity of such systems, the modeling process has become a major challenge for the ubiquitous computing community. In order to address this critical issue, different bigraphical reactive systems based approaches have been proposed to ease the modeling of some aspects of context-aware systems. Therefore, this paper presents a study attempting to show how bigraphs work under these approaches, and to illustrate the efficiency of our proposed approach in terms of addressing various aspects of context-aware systems.

Keywords: Bigraphical Reactive Systems, Context-Aware Systems, Context-Awareness, Formal Modeling, Ubiquitous Computing

1. INTRODUCTION

Recent years have witnessed the appearance of a new generation of technologies where mobile devices have become the personal assistants of our daily life. In this regard, ubiquitous computing is becoming increasingly important and more popular. As introduced by Weiser (2002), “the highest ideal of ubiquitous computing is to make a computer so embedded, so fitting, and so natural, that we use it without even thinking about it”. Thus, the idea behind the ubiquitous computing is to focus on the user and his tasks rather than technical issues that assumed to be vanished in the background.

Context-aware systems represent an important field in the wide range of ubiquitous computing. These emerging systems are able to autonomously adapt their behavior at runtime on behalf of users.

In the literature, numerous research studies have tried to find an exact definition to the term “context”, but until now there is no universal one. Within the challenging task to define what context actually includes, Abowd and Dey
(1999) gave a generic definition which covers the existing ones and referred to context as:

_any information that can be used to characterize the situation of an entity. An entity is a person, place or object that is considered relevant to the interaction between a user and an application, including location, time, activities and the preferences of each entity (Abowd & Dey, 1999, p. 304)._

Nevertheless, the lack of a solid formal foundation in the most existing definitions, combined with the increasing complexity and diversity of context-aware systems, represent a clear challenge to model such systems. Therefore, the formal modeling represents a crucial and delicate step to reduce complexity and enhance the verification of context-aware systems. As a result, many formal modeling approaches have been introduced; Zimmer (2005) has introduced a new process calculus, called Context-Aware Calculus (CAC in short), to formally describe the context-aware systems. In the same way, authors in (Siewe, Cau, & Zedan, 2009) have proposed a logical language, namely Calculus of Context-aware Ambients (CCA).

Furthermore, graph-based approaches are commonly used within this field. In (Nguyen, Lim, & Choi, 2008), authors have introduced a framework of context-awareness based on contextual graphs. Moreover, Milner (2004) has introduced a new graphical formalism, called bigraphical reactive systems, where the main purpose of its theory is to model and understand ubiquitous systems.

A bigraphical reactive system (BRS in short) (Milner, 2009), consists of a bigraph emphasizing both locality and connectivity that can be used to simulate the location and interconnection of mobile system entities, and a set of reaction rules providing to bigraphs the ability to reconfigure themselves. Furthermore, BRS have a logical algebraic language useful to formally model the context-aware systems.

The objective of this paper lies in providing a brief study of BRS-based approaches for modeling the context-aware systems. In this paper, we attempt to analyze the similarities and differences among these approaches in order to identify the impact and limits of each approach in separate, and illustrate the simplicity and effectiveness of our approach against the others.

The rest of this paper is organized as follows. Section 2 gives a brief overview about bigraphical reactive systems. Section 3 presents a detailed case study of a smart home system. Section 4 introduces some formal approaches based on bigraphical reactive systems and illustrates how these approaches can be applied to model context-aware systems. Section 5 provides an evaluation and discussion of these approaches and then shows the robustness of our proposed approach. Finally, conclusion and future work are presented in Section 6.

2. BIGRAPHICAL REACTIVE SYSTEMS

In this section, we first give a brief overview about the various aspects of bigraphical reactive systems and then present their algebra. For more details, the reader is referred to (Milner, 2004).

2.1. Static Structure

According to Milner (2004), bigraphical reactive systems (or BRS in short) are an emerging graphical formalism for designing, simulating and analyzing ubiquitous computing systems. Structurally, BRS is a graphical meta-model which emphasizes both locality and connectivity of mobile systems.

Figure 1 below is designed to illustrate the anatomy of bigraphs.

The dashed line rectangles with rounded corners represent roots (also known as regions) that are used to distinguish significantly different spaces in which nodes can be nested. Unlike an ordinary graph, nodes can be nested inside of each other. Nodes and edges are denoted by $v_i$ and $e_i$ respectively. The small bold points which link nodes to edges are called ports. Each node is characterized by a control represented...
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