Chapter 2

Modeling Context-Aware Ubiquitous Systems Using Petri Nets

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ABSTRACT

A context-aware ubiquitous computing system is required to constantly perceive, understand, and react to dynamic information coming from its environment and users in real time. Guaranteeing correctness, flexibility, and verifiability in such systems demands sophisticated modeling techniques that can account for the aspects of concurrency, data semantics, and changing environments. In this chapter, Context-Aware Petri Nets (CAPNs) will be introduced as an approach to modeling ubiquitous systems. The formal notation of CAPNs will be described, important context aspects and their possible models will be discussed, as well as some basic guidelines on how to construct a CAPN. Finally, several methods for verifying

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the designed CAPNs will be presented, along with examples illustrating different applications of CAPNs, such as smart homes, healthcare, and Internet-of-Things systems.

1. INTRODUCTION

The concept of ubiquitous computing, which was originally formulated by Weiser and is gradually developed since then, refers to a kind of computing system that blends into the environment invisibly to provide services through adaptation. The current implementations of the concept include, among other things, the Internet of Things, cyber physical systems, smart cities, self-driving cars, and mobile applications that together produce an immense amount of heterogonous contextual data over time (Kong et al., 2022; Shi et al., 2016). In this sense, context, understood as information about situations related to interaction between users and applications, is the key input for the systems. At the same time, context management is an extremely complicated problem.

Three intertwined problems form the basis for the issue at hand. The first problem involves the need for the acquisition layer to manage inputs from geographically dispersed, semantically different, and sometimes even faulty sensors like GPS devices, inertial sensors, environmental sensors, physiological sensors, and social network APIs. Secondly, the representation layer needs to choose a modeling paradigm that can be both expressive enough to represent the semantics of multi-dimensional contexts and sufficiently manageable to enable automated reasoning and verification (Chen et al., 2014; Baldauf et al., 2007). Finally, the utilization layer has to ensure that the context model translates to effective behavior adaptation without causing any race conditions, deadlock situations, or data leakage.

Ad hoc approaches for context management via scripting and rule engines, although pragmatic and readily achievable, result in systems that are unverifiable for their correctness, unpredictable regarding new context combinations, and prone to accumulate technical debts over time, eventually making them un-maintainable. On the other hand, there is the

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