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A Model to Guide Dynamic Adaptation Planning in Self-Adaptive Systems

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Abstract

Self-adaptive enterprise applications have the ability to continuously reconfigure themselves according to changes in their execution contexts or user requirements. The infrastructure managing such systems is based on IBM's MAPE-K reference model: a *Monitor* and an *Analyzer* to sense and interpret context data, a *Planner* and an *Executor* to create and apply structural adaptation plans, and a *Knowledge manager* to share relevant information. In this paper we present a formal model, built on the principles of constraint satisfaction, to address dynamic adaptation planning for self-adaptive enterprise applications. We formalize, modify and extend the approach presented in [1] for working with self-adaptation infrastructures in order to provide automated reasoning on the dynamic creation of structural adaptation plans. We use a running example to demonstrate the applicability of such model, even in situations where complex interactions arise between context elements and the target self-adaptive enterprise application.

Keywords: Self-Adaptive Enterprise Applications, Dynamic Adaptation Planning, Automated Reasoning.

1 Introduction

Currently many Enterprise Applications (EAs) live in dynamic execution contexts, interacting with other systems, and under the influence of stimuli from sources inside or outside the system scope. This may affect their behavior or the levels at which they satisfy agreed quality; however, regardless of these impacts, they still have to fulfill their service quality agreements. On the one hand, the fulfillment of quality agreements is completely and utterly dependent on system architectures,

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which comprises software architecture, hardware and network infrastructure. On the other hand, in response to ever increasing needs for strengthened responsiveness and resiliency, quality agreements may evolve to reflect this business reality.

Autonomic computing deals with the management of independent components capable of handling both external resources and their internal behavior, which are constantly interacting in accordance with high-level policies. Its required infrastructure usually integrates an autonomic manager, an implementation of the generic control feedback loop from control theory, and managed components. Most autonomic managers are based on the MAPE-K reference model [2], allowing software systems to be adapted to context changes in order to ensure the satisfaction of agreed Service Level Agreements (SLAs). Five elements make up the reference model: *Monitor*, *Analyzer*, *Planner*, *Executor* and *Knowledge Manager*. The *Monitor* continuously senses context conditions and the *Analyzer* interprets and compares the sensed data with SLAs, the *Planner* synthesizes and creates adaptation plans when required, and the *Executor* alters the system's behavior by modifying its structure in accordance with a given adaptation plan. All of them share information through the *Knowledge Manager* element.

In this paper we present a formal model, built on the principles of constraint satisfaction, to address the task of the *Planner* element, *i.e.* dynamic adaptation planning for self-adaptive enterprise applications. Our work in this paper is focused around changing quality agreements while EAs are already operational. This task, however, has a direct impact on system architecture. We consider in this work only the relationships of such quality agreements with software architecture in order to plan the necessary structural adaptations to meet the new quality specifications. We use a running example to demonstrate the applicability of such model, even in situations where complex interactions arise between context elements and the target self-adaptive enterprise application. In the context of product line engineering, decision and resolution models have been used for planning the composition of core assets according to variable configurations that include user requirements, *e.g.*, [3,4]. All of such approaches, however, deal with problems related to product configuration without taking into account the problem of planning dynamic adaptation of systems.

Some authors have explored different trends for generating reconfiguration plans. For instance [5,6] use artificial intelligence based on hierarchical task networks and situation calculus, respectively, to plan new web service compositions in an attempt to overcome faults. [7] calculates fuzzy values of quality of service (QoS) levels for available service variants and selects the variants with the nearest QoS levels that fit the context and user requeriements. There are other approaches that implement dynamic adaptation of service compositions, *e.g.*, [8,9,10]; however, they neither provide implementation details nor formal specifications of any formal model for planning activities.

In previous work [1], we presented an approach based on constraint satisfaction for product derivation planning in model-driven software product lines. There, we modeled the problem of planning the transformation workflow to derive products as a constraint satisfaction problem. In this paper, we base on such model and we fur-