Categorical Approaches to Models and Behaviors of Autonomic Agent Systems

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ABSTRACT

A new computing paradigm is currently on the spot: interaction based on series of actions. Most of autonomic agent systems (AASs) exploit this type of interaction to self-adjust their autonomous behaviors as a fundamental operational paradigm. At an interaction interface, actions evolve over time, hence series of actions occurs as a royal candidate for modeling, specifying, programming, and verifying AASs. For considering AASs, series of actions and adaptation relations; our formal approach consists, in particular, of categorical models and behaviors such that, firstly, AASs, series of actions and adaptation relations will categorically be modeled to provide algebraic frameworks for development of reasoning on their behaviors and, secondly, categorical behaviors of AASs, series of action and adaptation relations will be investigated and developed taking advantage of their categorical models.

Keywords: autonomic agent systems; categorical approaches; self-* computing; series of actions; series of adaptation relations

INTRODUCTION

For autonomic agent systems (AASs), autonomic computing is a generic property delineating capability to self-adjust their goal-driven computational behaviors without direct human interventions. Autonomic computing has been described as the set of concepts, technologies, and tools that enable AASs to become more self-managing. This potentiality is often related to possessing learning capabilities through analysis of past behaviors and interactions (Vinh, 2006; Vinh, 2007; Vinh & Bowen, 2007, 2008). Autonomic computing has intensely been studied by various areas of engineering including agent systems, computational intelligent systems and human orientated systems (Jin & Liu, 2004; Pacheco, 2004; Witkowski & Stathis, 2004; Parashar & Hariri, 2006; Wang, 2007b; Ko, Gupta, & Jo, 2007; Yang & Liu, 2007; Butera, 2007; Calisti, Meer, & Strassner, 2008). With regard to AASs, autonomic computing (Wang, 2007b) and cognitive informatics (Wang, 2007a) have been set as two major pillars to support such systems. By the
latest developments of autonomic computing (Parashar & Hariri, 2006; Calisti, Meer, & Strassner, 2008) and cognitive informatics (Wang & Kinsner, 2006), AASs are now at a crucial point in their evolution, marked by research activities being booming (Topaloglu & Bayrak, 2008; S.A. DeLoach & Matson, 2008; F.E. Walter & Schweitzer, 2008; K. Zoethout & Molleman, 2008). AASs pose new challenges for the development and application of autonomic computing techniques, due to their special characteristics including: nondeterminism, context-awareness and goal- and inference-driven adaptability (Wang, 2007b).

AASs are agent systems, which implement autonomic computing mechanisms such as: nondeterminism, context-awareness and goal- and inference-driven adaptability. For autonomic computing techniques applicable to AASs, a new computing paradigm is currently on the spot: interaction based on series of actions. Most of AASs exploit this type of interaction to self-adjust their autonomous behaviors as a fundamental operational paradigm. At an interaction interface, actions evolve over time, hence series of actions occurs as a royal candidate for modeling, specifying, programming, and verifying AASs.

In this paper, we focus on modeling AASs, series of action and adaptation relations, and then developing reasoning on their behaviors. Our formal approach consists mainly of categorical models and behaviors such that,

- **Firstly**, algebraic frameworks of AASs, series of action and adaptation relations will be constructed for development of reasoning on their behaviors using categorical language and,
- **Secondly**, categorical behaviors of AASs, series of action and adaptation relations will be considered taking advantage of their categorical models where the behavior-oriented notions will be formed for our approach.

The rest of paper is organized as follows: Section 2 briefs some basic terms of categorical language. Section 3 presents categorical models and behaviors of AASs. In section 4, models and behaviors of series of actions in AASs are developed by categorical approach. Quantitative behaviors of series of actions are presented in section 5. Section 6 is a place to abstract models and develop behaviors of series of adaptation relations. Some discussions and further work are considered in section 7. Finally, a short summary is given in section 8.

**SOME CATEGORICAL TERMS**

In categorical language (Adamek, Herrlich, & Strecker, 1990; Asperti & Longo, 1991; Lawvere & Schanuel, 1997; Bergman, 1998), there are some significant concepts which we recall in this section.

**Some Basic Terms**

Category \( \mathbf{Cat} \) can be viewed as a graph \((\text{Obj}(\mathbf{Cat}), \text{Arc}(\mathbf{Cat}), s, t)\), where

- \( \text{Obj}(\mathbf{Cat}) \) is the set of nodes we call objects,
- \( \text{Arc}(\mathbf{Cat}) \) is the set of edges we call morphisms and
- \( s, t: \text{Arc}(\mathbf{Cat}) \rightarrow \text{Obj}(\mathbf{Cat}) \) are two maps called source and target, respectively.

We write \( f: A \rightarrow B \) when \( f \) is in \( \text{Arc}(\mathbf{Cat}) \) and \( s(f) = A \) and \( t(f) = B \).

Associated with each object \( A \) in \( \text{Obj}(\mathbf{Cat}) \), there is a morphism \( 1_A = A \rightarrow A \), called the identity morphism on \( A \), and to each pair of morphisms \( f: A \rightarrow B \) and \( g: B \rightarrow C \), there is an associated morphism \( f; g: A \rightarrow C \), called the composition of \( f \) with \( g \).

\[
\begin{array}{c}
\text{A} \\
\downarrow_{1_A} \\
\downarrow_f \\
\text{B} \\
\downarrow g \\
\text{C}
\end{array}
\]
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