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ScienceDirect

Procedia Computer Science 83 (2016) 675 – 679

Procedia Computer Science

The 7th International Conference on Ambient Systems, Networks and Technologies (ANT 2016)

Self-Adaptive Model Generation for Ambient Systems

Julien Nigon*, Marie-Pierre Gleizes, Frédéric Migeon

Université Fédérale de Toulouse, France, 118 rte de Narbonne, 31062 Toulouse Cedex, France

Abstract

Ambient systems are composed of many interacting entities, and their behaviour is constantly changing. Under these conditions, static models are insufficient to understand and control such systems. In this paper, we investigate the possibility to generate real-time dynamic model of an ambient system. For this, we present AMOEBA, a multi-agent system designed to address this problem. It is based on a set of cooperative mechanisms from the Adaptive Multi-Agent System theory. Experiments on simulated physical systems highlight the interesting properties of AMOEBA.

Peer-review under responsibility of the Conference Program Chairs

Keywords: Self-Organisation; Context; Learning; Adaptation; Multi-Agent System; Cooperation; Pattern recognition

1. Introduction

In contexts of large scale systems composed of numerous connected objects, animals or people, called ambient systems, the need of designers is to cope with dynamics due to mobile devices but also to users' preferences evolution and users' current task. Designers have to model them in order to enable the software to find its best behaviour to serve the users. So an efficient calibrated model for one typical user will not be efficient in real time, and in real situations with different users. Static way to model systems are not relevant to deal with the dynamics of their environment they are plunged into. The work presented in this paper proposes AMOEBA, a self-adaptive model generation which enables the model to evolve in function of its interaction with its environment. The experiment presented in this paper shows that the system is able to learn a behaviour. But AMOEBA aims at being deployed in a real ambient systems applications in the scope of neOCampus project. neOCampus is a project which goal is to transform the Toulouse university campus in a connected, smart and sustainable campus. One of the first application will concern the well-being of the user in terms of light, heating and purity of the air in a classroom. The next section is a positioning of the work. Section 3 details our system called AMOEBA, a system based on multi-agent systems. Section 4 concludes and proposes some perspectives.

* Corresponding author. Tel.: +33-6-02-34-24-31.
E-mail address: julien.nigon@irit.fr

Peer-review under responsibility of the Conference Program Chairs
doi:10.1016/j.procs.2016.04.150

2. Model Generation

Ambient systems are complex systems. Establishing mathematical relationships to model a complex system, and thus better understand it and control it, is a classic approach. In this paper, we consider a model as a mathematical representation of a selected part of the world[6]. The building of such models requires to be able to recognise pattern, and to map to specific pattern a specific output.

To build a model of an ambient system, it is possible to use the different perceptions of systems (sensors, effectors state, etc ...) to establish correlations. We wish to establish a mapping of these perceptions (the system inputs), with an output, which is the information that we want to model. To determine this mapping, we consider that we know the output value during the learning phase, which puts us in the context of supervised learning[10]. Formally, we say that the pair $(x, f(x))$ is an example, with x the input and $f(x)$ the output[12]. It is therefore desired to generate a function h (the hypothesis) such that for any x, the difference between $f(x)$ and $h(x)$ is as low as possible.

There are a variety of approaches trying to address this complex problem. Among them, one of the most widely used (not only for supervised learning) is the artificial neural networks approach. Artificial neural networks (a detailed description is provided by Haykin[7]) has a large number of interesting properties. In particular, artificial neural networks are adaptive, are able to treat nonlinear problems are easily parallelizable and are resistant to errors[7]. However, these networks are limited by the learning time and the difficulty to adapt to a new application (need to choose a suitable topology, etc ...).

Schema learning is another interesting approach. Designed by Drescher[5], this approach comes from the philosopher Jean Piaget's work. It was recently improved by several authors like Chaput[4], Perotto[11] or Mazac[8]. It is inspired by the learning mechanisms of the human brain. Schema learning is able to construct a model that associates to a state of the world and an action performed on this world, a new state of the world as output. Among the strengths of this approach we can note the ability to abstract new perceptions and the understandability of the generated model. However, this approach requires direct interactions with the environment to learn.

Some works, based on AMAS (Adaptive Multi-Agent System) approach[13], were performed using multi-agent systems to interact with complex real world systems. Among the applications of this approach, we can mention engine optimization[2] or learning in robotics[14]. Although not directly seeking to build a model, these works are interested in adaptation and openness properties and are based on the cooperation of autonomous agents. These agents have only partial information about their environment. The approach proposed in the next section of this paper is directly inspired of these works.

In the next section, we present an overview of the Agnostic MOdEl Builder by self-Adaptation (AMOEBA), a multi-agent system designed to build models of ambient systems.

3. AMOEBA: Agnostic MOdEl Builder by self-Adaptation

Agnostic MOdEl Builder by self-Adaptation (AMOEBA) is a multi-agent system designed to generate models of complex systems at real time. Real time generation needs to be able to adapt the model quickly. So, AMOEBA is built using the Adaptive Multi-Agent System (AMAS) theory[13], a bottom up approach based on cooperation mechanism, designed to build self-adaptive systems. The cooperation between agents in an AMAS allows the system to self-organize. The structure of AMOEBA was designed to be compatible with the SACL pattern[1].

AMOEBA uses its entries to build a mapping between its perceptions and a desired output. To build this mapping, AMOEBA uses some examples of correct outputs. The source of these correct outputs is called the *oracle*, and could be enabled or disabled at any time. When the oracle is disabled, AMOEBA is in exploitation mode, and doesn't learn anymore. The oracle is only a source of data, and AMOEBA try to build a model of the behaviour of this oracle using its own perceptions. It could be a sensor, a mathematical model, a database, etc... All inputs and outputs of AMOEBA are real numbers.

3.1. AMOEBA Agents

Being an AMAS, AMOEBA is composed of a set of agents. Figure 1 presents a global view of AMOEBA. There are three kinds of agents in the system: