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Spatio-Temporal Planning for Mobile Ambient Agents

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Abstract

The algebraic language Time-AgLOTOS was recently proposed to describe the time-dependent behavior of an ambient intelligent agent. The Spatio-Temporal Planning System (STPS) is a contextual model capturing all possible evolutions of an agent plan including context changes. It provides formal description of the possible actions of a plan supporting timing constraints, action duration and spatial requirements. Thereby, it can be derived from Time-AgLOTOS behavior expressions. In this paper, we propose a finite and symbolic representation of the STPS based on a number of spatio-temporal regions, preserving both time progress and location modeling. The resulting structure offers new possibilities and strategies for taking agent real-time decisions in context-awareness manner.

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1. Introduction

Nowadays, the software engineering of Ambient Intelligence (AmI) systems is widely investigated. The needs comes from new applications which aim at taking profit from the ubiquitous computing, often involving the human life in its all, like in the development of smart and assisting environments [1]. As some major challenges, the building of intelligent systems requires holding together adaptation and sustainability properties within open, non-deterministic and uncertain environment. Several modeling approaches are already proposed to assist the designer of AmI systems. In fact, the major problem for the system entities consists in recognizing environmental context, including location identification, resource management, real-time planning, discovery of other agents, and handling information in a more *semantic* manner e.g. [2,3].

Face to such a complex framework, several research works propose to make use of intelligent agents, to support the AmI systems, e.g. [4,5]. At a first glance, this could include some well-known Multi-Agent System (MAS) approaches, BDI agent are designed to take rational decisions as practical reasoning [6]. However, this is not enough when conditions

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are highly dynamic like in AmI systems. This assumes an efficient context-awareness ability, dealing with unexpected situations and changes of context.

In the literature, different definitions were proposed to qualify the context of the agent. In[7], four types of context information are defined: *(1) computational context*−available resources, network quality and related information; *(2) user context*−profile of the user, people nearby, social situation; *(3) physical context*−lighting, temperature, traffic conditions, noise levels, etc., and *(4) time context*−time of day, date of the year. As two other types of contexts, the work of[8] introduces the *activity* of some agent where in[7], the *context history* is proposed.

In practice, most context modeling approaches only focus on a subset of the above types, depending on the requirements of the applications. In[9], the authors focus on sensor-based agents, since the aim is to learn physical measures and control the hardware devices of an automated house (lighting, warming...). To deal with mobility or real-time object tracking, spatial location are referred e.g.[10,11]. Dealing with both spatial and temporal information is useful each time. However, space and time cannot be reduced easily from one to each other. The real challenge in AmI systems is the reasoning about spatial change, the modeling of spatio-temporal interactions and planning.

In this paper, we aim at providing a behavioral analyzing technique of agents handling spatio-temporal contexts. To this end, we follow the work of[12] which introduces a timed action model, called STPS, to represent the possible plans of the agent, w.r.t. its set of intentions viewed as concurrent processes. In this model, the spatio-temporal properties relate to the simultaneous progression of time and location change implied by the performances of actions. Nevertheless, the STPS could be an infinite structure, since time ranges over a dense domain.

To allow model-checking of spatio-temporal properties, we now investigate the building of a finite representation of the STPS. Based on symbolic spatio-temporal regions, it preserves both the STPS time progression and location changes.

The remaining of the paper is organized as follows: Section 2 introduces the Time-AgLOTOS language providing a planning taking into account timing constraints and duration of actions. This language is used to associate plans with intentions. In Section 3, the underlying spatio-temporal model, called STPS, is automatically produced by applying the true-concurrency semantics of Time-AgLOTOS. In Section 4, we show how to build a finite and symbolic graph of spatio-temporal regions from the STPS. Throughout the paper, the scenario is taken up as an illustration of our approach. The last section concludes and outlines our perspectives.

2. Time-AgLOTOS: An algebraic Language for Plan Specification

2.1. Agent Plan Structure

In the approach of[5], an *agent plan* is structured as a tree structure within three level planning representations. The *agent plan* is obtained by composition of sub-plans, called *intention plans*, where each one is dedicated to achieve its corresponding intention ; Each intention plan is a composition of alternative sub-plans, called *elementary plans*. These elementary plans are assumed to be extracted from a library of plans, here called *LibP library*. They allow us to consider different ways to achieve the associated intention. The *Time-AgLOTOS* language, introduced in[12], deals with modular and concurrent aspects to compose and schedule these different sub-plans, viewed as processes. Let us briefly recall the *Time-AgLOTOS-based specifications* for plans.

Agent plan level. The set of intention plans can be handled globally, by using the concurrent $|||$ and/or sequential $\gg$ operators between intention plans. This leads to the specification of an agent plan. Let $\overline{\mathcal{P}}$ be the set of names qualifying the possible agent plans with $\overline{P} \in \overline{\mathcal{P}}$ and let $\widehat{\mathcal{P}}$ be the set of names used to identify the possible intention plans with $\widehat{P} \in \widehat{\mathcal{P}}$, such that $\overline{P}$ is any agent plan defined by:

$$\overline{P} ::= \widehat{P} \mid \overline{P} \,|||\, \overline{P} \mid \overline{P} \gg \overline{P}$$

Intention plan level. An intention plan corresponding to an alternative of elementary plans is specified by using the composition operator $\Diamond$. The associated intention is considered to be achieved iff at least one of the associated elementary plans is successfully terminated. Formally, we define an intention plan $\widehat{P}$ as:

$$\widehat{P} ::= P \mid \widehat{P} \Diamond \widehat{P}$$