Semantic Shared Spaces for Task Allocation in a Robotic Fleet for Precision Agriculture

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Abstract. Task allocation is a fundamental problem in multi-robot systems where heterogeneous robots cooperate to perform a complex mission. A general requirement in a task allocation algorithm is to find an optimal set of robots to execute a certain task. This paper describes how coordination capabilities of the space-based middleware are extended with the semantic model of robot capabilities to improve the process of selection in terms of flexibility, scalability and reduced communication overhead during task allocation. We developed a framework that translates resources into a newly defined semantic model and performs automatic reasoning to assist the task allocation. We conducted performance tests in a specific precision agriculture use case based on the robotic fleet for weed control elaborated within European Project RHEA-Robot Fleets for Highly Effective Agriculture and Forestry Management.

Keywords: Task Allocation, Space-Based Computing, Semantics, Robotic Fleet.

1 Introduction

Today cooperating robots are commonly used in controlled and structured environments, such as factories, where they are managed from a central place that supervises mission execution. Due to the advances in the perception and locomotion technology there is a great potential to use multiple cooperating robots in heterogeneous and unstructured environments. This however imposes new requirements on communication and coordination of actions in teams, and the well-established centralized coordination approach needs to either be enhanced or replaced with a distributed approach.

Task allocation is a fundamental problem in multi-robot systems where the core requirement is to find an optimal set of heterogeneous robots that have to cooperate in order to execute a complex mission [1]. Critical enabler for distributed task allocation is an efficient coordination. The shared space-based coordination model defines a centralized tuple space as a shared message repository exploiting generative communication among processes. This work extends coordination capabilities of the space-based middleware XVSM (eXtensible Virtual Shared Memory) [2], [3], particular its

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Java-based implementation MozartSpaces. XVSM is based on a Linda [4] tuple space model. Our framework, Semantic MozartSpaces [5] introduces a new data model based on RDF and SPARQL where RDF is used to construct nested blank nodes in a triple store and SPARQL facilitates query and update interactions with the triple store.

The remainder of this paper is structured as follows: Section 2 introduces motivating use-case while section 3 summarizes related work. Section 4 presents developed approach, section 5 evaluates the framework, and finally section 6 concludes the paper and presents future work.

2 Precision Farming as a Motivating Scenario

Precise management of agricultural land is aimed to diminish the use of chemical inputs and improve crop quality, humans' safety, and reduce production costs by using a fleet of heterogeneous robots equipped with advanced sensors and actuators.

Precision farming scenario introduced in the RHEA project [6] provides motivation for presented work. The scenario starts with the field inspection facilitated by two aerial mobile units equipped with high-resolution cameras taking the field photos to elicit growth stage of a crop and the diffusion of the weed. After that, the centralized fleet management system assists the system operator in choosing a suitable strategy for field treatment taking into account weed infestation map and available field robots, their implements and sensors. The selection of the treatment strategy takes into account many parameters, e.g., the type of tasks to be performed, the number and features of available robots and field information. The treatment strategy can be applied in two use cases: (1) when a weed infestation map is known in advance and all tasks are defined before a mission starts (e.g., spraying in a wheat field), and (2) when there is no weed infestation map and weed patches (tasks) are identified (using a camera mounted on a tractor) during a mission execution (corn field).

3 Related Work

The use of semantics in task and resource modeling in robotics systems is an emergent research field. In [7] authors explore a novel usage of semantic information for an improvement of a task planning in complex scenarios, e.g., robots operating in unstructured environments with a great number of objects. In [8] authors study joint collaboration of Web Service paradigm and ontology for a service discovery, composition and a task allocation. In their solution all entities expose their functionalities as Web Services allowing their discovery and composition. Our work differs from the reviewed work as we use semantic approach for both the resource and task modeling. Rational for using semantic is twofold: (1) it provides the basis for policy-based automatic mapping between task requirements and available resources and thus makes the whole process more flexible and (2) it provides a general task description language that most of the reviewed frameworks lack.

Several research projects as well as commercial products have adopted the space-based model to construct robust coordination platforms. Linda made the shared