Robotics and Computer-Integrated Manufacturing 33 (2015) 56–67

Contents lists available at ScienceDirect

Robotics and Computer-Integrated Manufacturing

journal homepage: www.elsevier.com/locate/rcim

Knowledge-based instruction of manipulation tasks for industrial robotics

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ARTICLE INFO

Article history:
Received 30 April 2014
Received in revised form
15 July 2014
Accepted 25 July 2014
Available online 6 September 2014

Keywords:
Knowledge representation
Robot skill
Industrial robotics ontology
Assembly
Service-oriented architecture

ABSTRACT

When robots are working in dynamic environments, close to humans lacking extensive knowledge of robotics, there is a strong need to simplify the user interaction and make the system execute as autonomously as possible, as long as it is feasible. For industrial robots working side-by-side with humans in manufacturing industry, AI systems are necessary to lower the demand on programming time and system integration expertise. Only by building a system with appropriate knowledge and reasoning services can one simplify the robot programming sufficiently to meet those demands while still getting a robust and efficient task execution.

In this paper, we present a system we have realized that aims at fulfilling the above demands. The paper focuses on the knowledge put into ontologies created for robotic devices and manufacturing tasks, and presents examples of AI-related services that use the semantic descriptions of skills to help users instruct the robot adequately.

1. Introduction

The availability of efficient and cheap computing and storage hardware, together with intensive research on big data and appropriate processing algorithms on one hand, and on semantic web and reasoning algorithms on the other hand, makes the existing results of artificial intelligence studies attractive in many application areas.

The pace of adoption of the knowledge-based paradigm depends not only on the complexity of the domain, but also on the economic models used and the perspective taken by the leading actors. It may be quite well illustrated by opposing the service robotics area (mostly research-oriented, mostly publicly funded, using open source solutions, acting in non-standardized and not-yet-legally codified domain) with industrial robotics (application-oriented, privately funded, using normally closed software, enforcing repeatability and reliability of the solutions in legally hard-controlled setting).

When robots are working in dynamic environments, close to humans lacking extensive knowledge of robot programming, there is a strong need to simplify the user interaction and make the system execute as autonomously as possible (but only as long as it is reasonable). This also motivates the integration of AI techniques into robotics systems. For industrial robots working side-by-side with humans in manufacturing industry, AI-based systems are necessary to lower the programming cost with respect to the required time and expertise. We believe that only by building a system with appropriate knowledge and reasoning services, we can simplify the robot programming sufficiently to meet those demands and still get a robust and efficient task execution.

In this paper, we present a knowledge-based system aimed at fulfilling the above demands. The paper is focusing on the knowledge and ontologies we have created for the robotized manufacturing domain and is presenting examples of AI-related services that are using the semantic descriptions of skills to help the user instruct the robot adequately. In particular, the adopted semantic approach allows us to treat skills as compositional pieces of declarative, portable and directly applicable knowledge on robotized manufacturing.

The paper is organized as follows: first we introduce the robot skill, then we describe the system architecture. Next section introduces our robot skill ontology and other relevant ontologies available in the knowledge base, as well as some services provided by the system. Next we introduce the interface towards the user, i.e. the Engineering System, and briefly describe the program execution environment exploiting the knowledge in a non-trivial way, then we describe the related research. We conclude by suggesting future work.

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http://dx.doi.org/10.1016/j.rcim.2014.07.004
0736-5845/

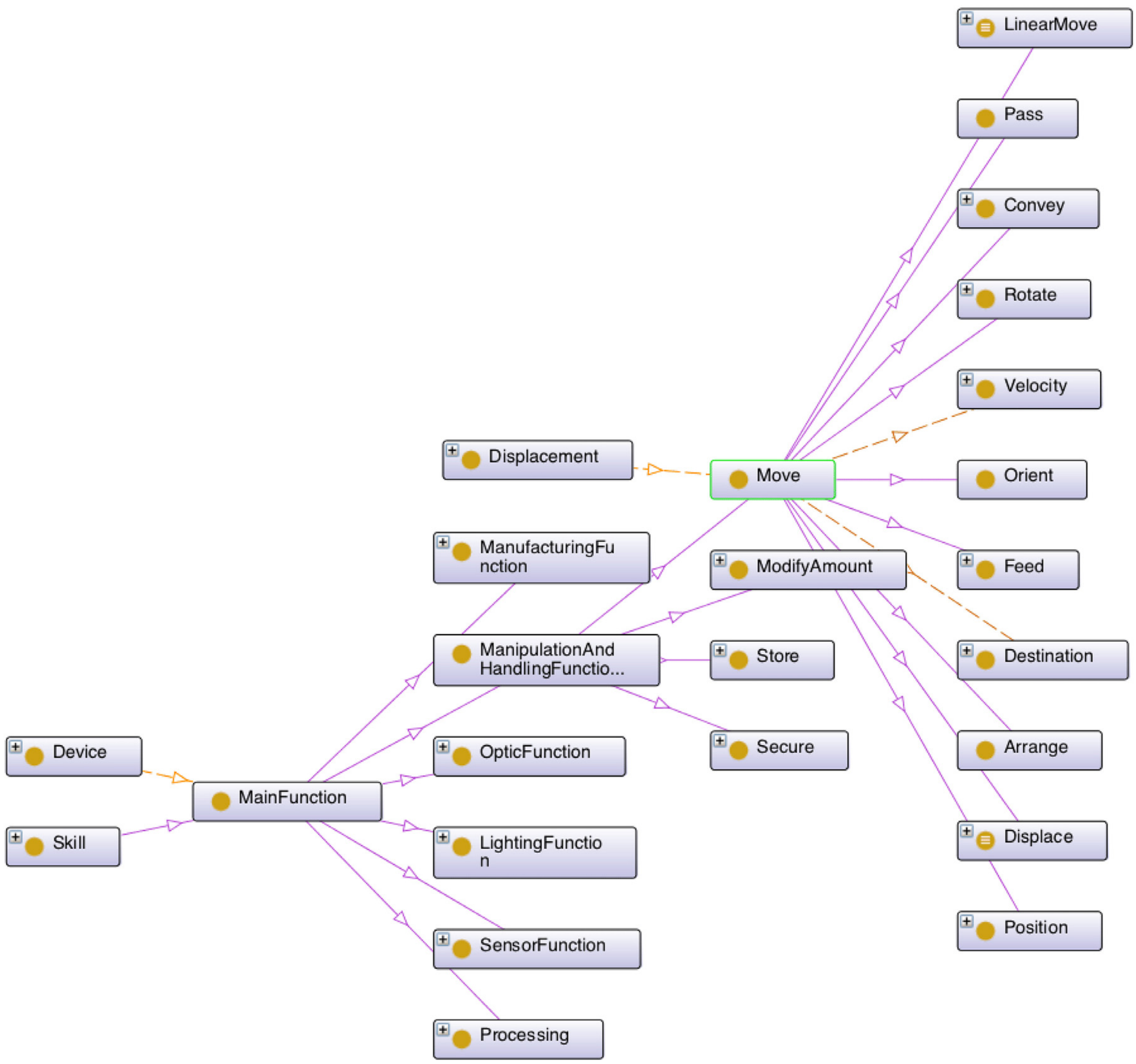

Fig. 1. Manipulation and handling skills, as defined by SIARAS ontology.

2. Robot skills

Our approach is anchored on the concept of a *robot skill*. As it may be understood in many different ways, both by humans and machines, it needs to be properly defined and made usable in the context of our domain of applications. The presentation in this section adopts a historical perspective, showing how our understanding of skills pushed forward the capacities of systems we have created.

Our earliest deployed system has been developed in the context of the EU project SIARAS: *Skill-Based Inspection and Assembly for Reconfigurable Automation Systems*. Its main goal was to build fundamentals of an intelligent system, named *the skill server*, capable of supporting automatic and semi-automatic reconfiguration of the existing manufacturing processes. Even though the concept of skill was central, we have assumed *devices* as the origin of our ontology. Our idea then has been that skills are just capabilities of devices: without them no (manufacturing) skill can exist. A device can offer one or more skills and a skill may be offered by one or more devices. We have not introduced any granularity of such distinction; all the skills were, in a sense, primitive, and corresponded to operators as understood by AI planning systems (models of operations on the world, described using preconditions, postconditions, sometimes together with maintenance conditions). This understanding laid ground to the development of a robotic skill ontology, `siaras.owl`, that has been used to verify the configurability of particular tasks given current robotic cell program expressed as a (linear) sequential function chart (SFC). This approach has been proven to be valid, but the ontology grew quite fast and became problematic to maintain, given dozens of robots with a number of variants each, thus multiplying the number of devices. The details of SIARAS approach have been described in [16]. Figs. 1 and 2 illustrate the basic hierarchy of skills available in the `siaras.owl` ontology.

The dual hierarchy, that of devices, has been illustrated in Figs. 3 and 4, while Fig. 5 shows some of the properties that can be attributed to devices.

The deficiencies of the SIARAS ontology, that is, atomicity of skills and devices, fixed parameterizations and scalability issues, have led us to reconsider the idea. These time devices did not play a central role any longer, but rather skills have been put in the center. In the ROSETTA project[1] the definition of skills has been based on the so-called production (PPR) triangle: *product*, *process*,

[1] RObot control for Skilled ExecuTion of Tasks in natural interaction with humans; based on Autonomy, cumulative knowledge and learning, EU FP7 project No. 230902, http://www.fp7rosetta.org/.