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Formal Resource and Capability Models supporting Re-use of Manufacturing Resources

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Abstract

In the field of manufacturing the responsiveness has become a new strategic goal for the enterprises alongside with quality and costs. Efficient responsiveness requires production reconfiguration ranging from layout to equipment. The production system capabilities originate from the tool and equipment level. While a resource is being used, its condition and capability may change. It is crucial to consider the resources' individual lifecycle, their actual capabilities and condition during the system design and reconfiguration. Thus, the lifecycle perspective in the capability management is of utmost importance. This paper presents the development of the Manufacturing Resource Capability Ontology (MaRCO), focusing on describing the functional capabilities of manufacturing resources. Special emphasis is placed on the lifecycle management aspect of the resource descriptions.

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Keywords: Capability model; Production system representation; Adaptive manufacturing; Ontology

1. Introduction

Responsiveness has become a new strategic goal for the manufacturing enterprises alongside with quality and costs [1]. The responsiveness is related to the need to reconfigure and adjust the production and corresponding production

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system as efficiently as possible to the required changes in processing functions, production capacity, and the dispatching of the orders. Furthermore, the trend towards sustainability requires that the resources are being utilized and re-used in their maximum potential and maintained throughout their life-cycle. Thus, the maintenance function becomes an important factor in terms of improving the system availability, reliability and safety, as well as product quality [2][3].

Information that is needed for reconfiguration and re-use decisions comes from different fields of expertise such as product design, process planning, system design and integration, operation, condition monitoring and maintenance, as well as usage history and prior adaptation experiences. The management of such information in industry is not currently sufficient to generate reliable plans for re-configuration and re-use. The real capabilities of the resources are not known in every lifecycle phase, which causes difficulties in making maintenance, re-configuration and re-use decisions. In large manufacturing facilities, or complex research environments there can be a huge amount of individual assets to manage. Document-based management of this information is inefficient. What makes the management of this information difficult is its rapidly evolving nature. Another problem, discussed by multiple researches, is the poor interoperability between different information models created by different design systems. The information is presented via different models that are usually complementary, but sometimes redundant, sometimes incoherent and always heterogeneous [4] as the majority of these systems use their proprietary data structures and vaguely described semantics. The design knowledge remains locked inside the authoring system and a lot of data may be lost during format conversions [5][6]. Retrieving and utilizing information from multiple diverse sources puts high demands on semantic integration solutions [1][7][8]. Therefore, a formal and semantic way to model the resources and their lifecycle information is needed in order to convey this information to the planning and decision-making activities.

As engineering practices are becoming more and more distributed and decentralized, formal engineering ontologies are emerging as popular solutions for addressing the semantic interoperability issue in heterogeneous environments and bridging the gap between the legacy systems and organizational boundaries [7][8]. The European Commission funded project ReCaM (Rapid Reconfiguration of Flexible Production Systems through Capability-based Adaptation, Auto-configuration and Integrated Tools for Production Planning) aims to develop a set of integrated tools for rapid and autonomous reconfiguration of production systems. The approach relies on a unified functional description of resources, providing a foundation for rapid creation of new system configurations through capability-based matchmaking of product requirements and resource offerings. This paper presents the development of the Manufacturing Resource Capability Ontology (MaRCO), intended to support such matchmaking. Special focus is placed on the lifecycle management aspect of the resource descriptions.

2. Formal information models for describing resources

The aim of bringing automation to the system design, re-configuration and order dispatching requires a formal, structured representation of the product requirements as well as resource's capabilities, properties and constraints. For the past two decades, there has been an increasing interest in manufacturing domain on using emerging technologies such as ontologies, semantics and semantic web, to support the collaboration, interoperability and adaptation needs. Table 1 shows the literature review on the developed product, process and system ontologies and other formal information models. These models describe a set of product and system characteristics relevant to that specific domain. The table classifies the main developments from product, system, production control and operational maintenance strategy aspects. The identified gap is the lack of detailed capability descriptions of constantly evolving production systems.

Table 1. Existing ontologies and other formal information models for different life-cycle phases of products and systems.

Category	Existing works
Product design	Closed-loop product lifecycle management [5]; Reference ontology to support product life-cycle management [9]; Machine design process and associated ontology for design and lifecycle information of a specific machine [10].
System descriptions	Ontology for modelling evolvable, modular, ultra-precision assembly systems [6][11]; Emplacement concept [12]; Ontological model for assembly device capabilities based on the function-behaviour-structure (FBS) framework [13]; Manufacturing Service Description Language (MSDL) for representing capabilities of