Towards an ontological model for manufacturing: The case of resources

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Abstract

Representing resources in industrial engineering is of pivotal relevance across the entire production lifecycle, from design to planning, scheduling, and process execution, among others. When it comes to handle data about resources in information systems, however, the notion of resource is differently understood and characterized in data models, thus jeopardizing data analysis and classification, since heavy re-engineering work is needed to align multiple models. We present in the paper how an ontological-driven methodology for knowledge engineering can support the creation of a unified model for resource data that integrate multiple manufacturing perspectives.

1 Introduction

The identification and management of resources is fundamental in areas where activities must be planned in advance, like in manufacturing. Notwithstanding, the notion of resource has been typically used without searching for a shared definition. Its use in a community relies on the assumption that there is a shared view among the community's members. Apparently, this commonality should be the result of exposition to a common body of studies, of methodologies and (by and large) of similar experiences.

It suffices to read a few standards related to the concept of resource to understand that there are several possible interpretations and they all make perfect sense with a twist: they are mutually incompatible. This is not problematic *per se* but the lack of formal characterization, that is, the impossibility to systematically constrain the use of the language, makes possible mismatches in the understanding of the term which jeopardize efforts to share data models as well as to integrate information systems and services.

But are these differences so problematic? A *resource* can be understood according to generic linguistic definitions, like the Oxford Dictionary of English (ODE): a resource is "[a] stock or supply of money, materials, staff, and other assets that can be drawn on by a person or organization in order to function effectively [...]." Here, a resource is like an asset, i.e., an item that has value for and is owned by an agent. A resource does not need to be related to any action; what is required is that it has a value for some agent to "function effectively." For example, a wrench is of value to a mechanic for performing a job even though he does not use it. Once we move from broad dictionary definitions to application scenarios such as manufacturing, the intended meaning of resource-related notions narrows to match engineering views and interests. Despite this, there is little agreement among experts and stakeholders [Sanfilippo *et al.*, 2018; Sarkar e Šormaz, 2019] as the following definitions show: "Any device, tool and means, except raw material and final product components, at the disposal of the enterprise to produce goods and services" [ISO, 2004], "A resource is an entity that provides some or all of the capabilities required by the execution of the enterprise activities and/or business processes. The types of resources involved in manufacturing operational management are: personnel, material, equipment (role based and physical asset) and process segments" [IEC, 2013]; "Means used by an activity to transform input into output" [ISO, 2018]; "[T]he costs, schedule, and other impacts from the use of a thing in a process" [Liebich *et al.*, 2013].

We have developed an analysis of the domain to capture the differences across these views and to make possible the comparison of different interpretations. Figure 1 gives a hint of how the perspectives can be separated. This is only one part of the problem. The investigation of the foundational grounds for resource modeling in manufacturing is a component of the larger goal to develop formal and comprehensive models where different viewpoints can be aligned.

Indeed, the choice of relying on one or the other approach depends on the modeling problem a community is addressing, which can be made clear by the underlying ontology. Our contributions [Borgo *et al.*, 2021; Sanfilippo *et al.*, 2018; Sanfilippo *et al.*, 2021] was to clarify the characteristics of three general approaches for resource-based planning and to unify them in a single framework. In this way, end-users have the possibility of representing manufacturing resources by taking into account activities, goals, and activity occurrences happening in time. Hence, one can model application scenarios within and across various phases of factory lifecycle, e.g., design, planning, scheduling, or execution.

Further work on the treatment of resources is needed at both the foundational and application levels. First, we ha-

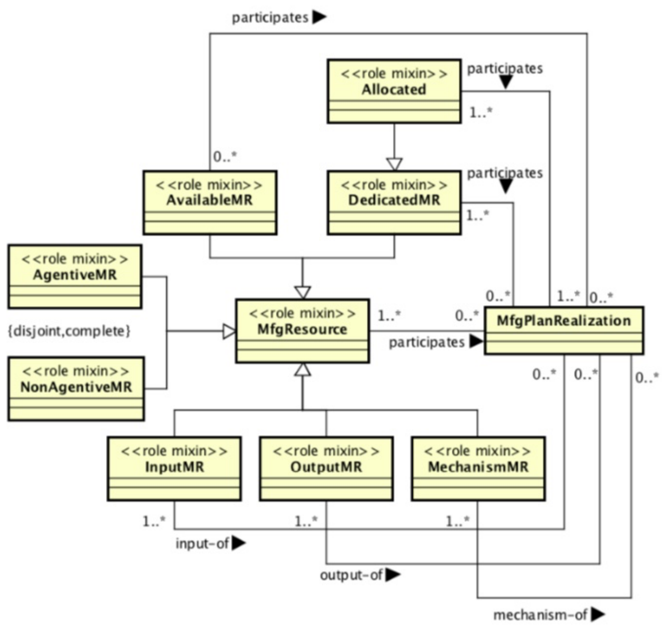

Figura 1: The integration of manufacturing notions (graphical view), from [Sanfilippo *et al.*, 2018]

ve tacitly assumed that resources are organized in different high-level classes, e.g., resources that execute manufacturing processes and resources that undergo processes, among others. The development of a taxonomy of resources is needed to properly classify and characterize them. Second, resources are sometimes understood in connection to ownership or availability conditions. Clearly, a resource has to be available in a specific environment to be used. Also, ownership of resources is particularly relevant in modern scenarios (e.g. Cloud Manufacturing) where one has the possibility of using third-party technologies. Therefore, characterizing the business dimension of resources can make a difference for application settings. Third, to effectively reason about resources one has to model their capabilities and functionalities. We have started this investigation [Mizoguchi *et al.*, 2016; Borgo *et al.*, 2021] but more work is needed, including a comparison of theories about engineering functionalities. Also, since capabilities can be more or less complex [Järvenpää *et al.*, 2019], a robust formal approach for their representation is needed.

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