Annals of DAAAM for 2010 & Proceedings of the 21st International DAAAM Symposium, Volume 21, No. 1, ISSN 1726-9679
ISBN 978-3-901509-73-5, Editor B. Katalinic, Published by DAAAM International, Vienna, Austria, EU, 2010
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DAAAM Symposium

AN ONTOLOGICAL APPROACH FOR MANUFACTURING RESOURCES MODELING

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Abstract: *Ontological developments are emerging techniques which allow us to successfully manage the stringent demands of exchanging and sharing information and knowledge in the field of manufacturing. In this work, we present an ontology that models the capabilities and capacities of manufacturing resources to enable the allocation of these resources during Process Planning and Production Planning and Control activities. The paper includes a description and graphic representation of the principal entities and relations of the proposed ontology, as well as the classification taxonomy of the physical manufacturing resources.*
Key words: *Resources Ontology, Manufacturing, Capability, Capacity*

1. INTRODUCTION

The need to exchange and share information and knowledge in a complete and coherent way –interoperability– is a key factor in the development and manufacturing process of a product in the domain of the extended and collaborative enterprise. In the case of manufacturing resources, this need is reflected in various stages of product life cycle, such as resource allocation or resource configuration in workstations, virtual cells, and so on. These decisions must be made collaboratively between the Process Planning (PP) and Production Planning and Control (PP&C) activities, using data to describe capabilities and capacities of manufacturing resources. The integration of PP and PP&C requires a common semantic representation especially for resources. With this objective in mind, ontologies such as PSL –Process Specification Language– (ISO-18629, 2005) have been developed, which establishes a formal description of the entities in the manufacturing domain, the properties they possess, the relationships they participate in, the constraints they are subject to, and the patterns of behavior they exhibit. However, PSL deals only with the process plan modeling, but does not model the information or knowledge required during process planning.

The TOVE enterprise model (Fox and Gruninger, 1998) includes an ontology for managing manufacturing resources with a resource description basically oriented to the purposes of PP&C. In a more general framework for business processes, the work of (Lin et al., 2004) handles the concept of resource with emphasis on providing a homogeneous understanding of the terms related to manufacturing, and on improving semantic interoperability and the reuse of knowledge within manufacturing teams in the extended enterprise.

In a previous paper (Solano et al., 2009), the authors have assessed the ability of PSL to represent the process plan, but have found shortcomings when modeling the resource information needed during the different stages of plan generation, such as resource allocation, resource configuration, and so on.

In this paper, we present an ontological proposal focusing on the description and composition of the capabilities and capacities of the available physical manufacturing resources (machines, tools and fixtures) which offer a common semantic for the tasks of PP and PP&C. This semantic allows the configuration of resources, which are defined in a recurrent way from the states and properties of the resources which make them up.

2. MANUFACTURING RESOURCES

The MANDATE initiative –MANufacturing DATa Exchange– (ISO-15531, 2005) defines resources as devices, tools and means –including human– at the disposal of the enterprise to produce goods or services. MANDATE introduces the concepts of capability –ability or possibility of carrying out an activity with quantifiable benefits– and capacity –capability of a resource to perform its expected function, in particular in term of amount of production– as means to characterize and utilize resources.

In the ontology of manufacturing resources established within the framework of the TOVE project, the concept of a resource is not the innate properties of an object, but rather a property derived from its behavior in relation to an activity. This ontology reasones over how the properties of resources can change as a result of the activity in question, and also considers the allocation of resources in a scheduling task through recognition of its capacities.

The PSL ontology presents a similar concept of resource: any object that is required for an activity. PSL includes various explicit references to resources, focusing on representing its capacities and on the alternatives for structuring and grouping of resources.

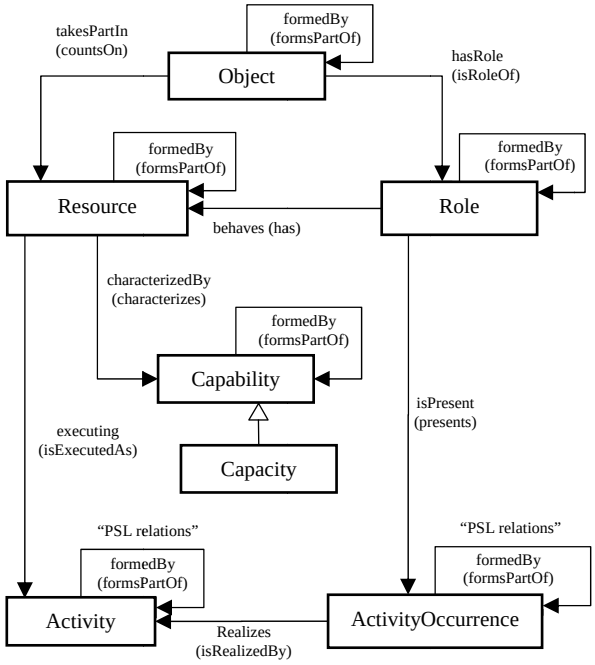

Fig. 1. UML representation of the basic entities and relations of the proposed ontology

3. RESOURCES ONTOLOGY

The proposal assumes and integrates PSL and MANDATE concepts, and develops or specializes some concepts or properties to answer competence questions which are the subject of the ontology.

In this ontology (figure 1), an *Activity* is a change, a transformation or a behavior that gives a result and that can be repeated. An *Object* is any element, tangible or untangible, that exists (e.g. a machine, a person or information). *Resources* are entities that participate in *Activities* and which are sustained by *Objects* (e.g. a machine carrying out a machining operation). An *ActivityOccurrence* is the specific execution of an *Activity* and a *Role* is the specific use of a *Resource* in an *ActivityOccurrence*. These specific realizations or executions are represented through the *realizes* (*ActivityOccurrence, Activity*) and behaves (*Role, Resource*) relations, respectively, whose inverse relations are *isRealizedby (Activity, ActivityOcurrence)* and *has (Resource, Role)*. Therefore, the entities *ActivityOccurrence* and *Role* represent all possible instances/executions of an *Activity* and of a *Resource* respectively.

The entity *Capability* represents the characteristics that describe the type of benefit that a *Resource* may develop in an *Activity.* The *Capabilities* describe the ability modeled and its level of completion, qualitatively or quantitatively. A particular type of *Capability* is the *Capacity* entity, which represents the capability of a *Resource* to perform its expected function in term of amount of production, as defined in MANDATE.

All the entities of the ontology allow the *formedBy* relation or its inverse *formsPartOf,* which express the possibility of recurrent aggregation (composition or decomposition) between entities of the same type. The *hasRole* relation, between *Object* and *Role*, together with the *isPresent* relation, between *Role* and *ActivityOccurrence* represent the role played by an *Object* when it participates in a specific *ActivityOccurrence*. The *takesPartIn* relation, between *Object* and *Resource*, together with the *executing* relation, between *Resource* and *Activity,* represent the potential of an *Object* to perform a type of *Activity –Resource-*. The *characterizedBy* relation, between *Resource* and *Capability* and its inverse *characterizes (Capability, Resource)* express the particular *Capabilities* of the *Resource*.

The entities *ActivityOccurrence* and *Activity* of the Resources Ontology are equivalent to the homonim entities of the PSL ontology, and this allows the possibility of using specific PSL relations (*"PSL relations"*) between these entities of our ontology (figure 1).

Figure 2 shows the classification of physical manufacturing resources using three criteria. One of these establishes the difference between *Resources* according to their contribution (*Machine*, *Tool*, *Fixture* and *Other_Resource*). Another of the criteria establishes that the resources can be *Generic_Resources*, *Specific_Resources* and *Individual_Resources*, which allows us to group their capabilities in order to respond to the allocation of generic resources for the purposes of PP and PP&C with different levels of abstraction/concretion. Finally, there is the possibility to configure types of resources (*Resource_Groups*) which have a collection of abilities which must be understood as a single complex ability with different levels of detail (*Machine_Configurations*, *WorkStations* and *WorkCells*).

4. CONCLUSION

In this work the authors have proposed an ontology to represent manufacturing resources that facilitates the management and sharing of information/knowledge through a unified semantics for the activities of PP and PP&C. This proposal incorporates concepts from others sources such as MANDATE, TOVE and PSL.

In future work, we will extend the scope and domain of this ontology to create a capability ontology for the collaborative development of products and processes in the environment of the extended enterprise, as well as its integration in a foundational ontology.

5. ACKNOWLEDGEMENTS

This work has been possible thanks to funding received from the Ministry of Science and Education through the COAPP Research Project - reference DPI2007-66871-C02-01/02.

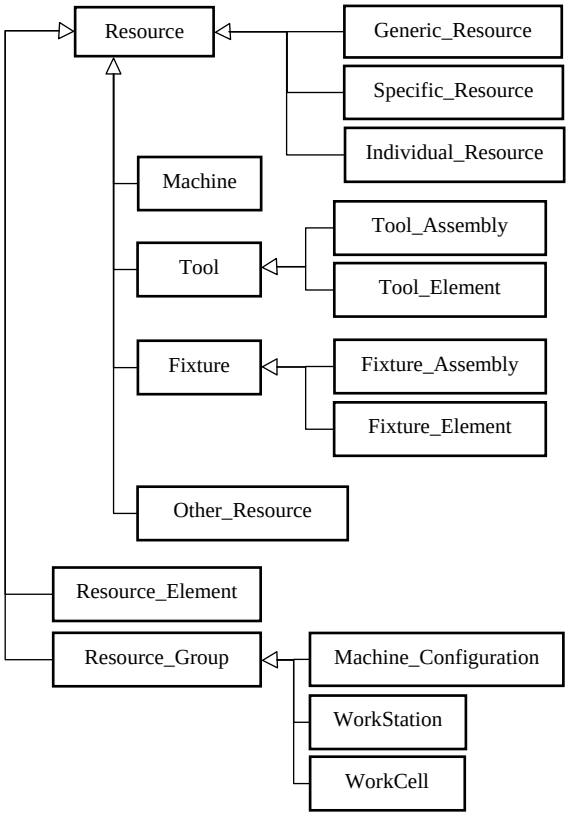

Fig. 2. UML representation for *Resources* classification

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