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► **To cite this version:**

Sergio Benavent, Pedro Rosado, Lorenzo Solano, Nicola Guarino, Emilio Sanfilippo. How to Restructure PPDR and MIRC According to DOLCE. International Conference on Changeable, Agile, Reconfigurable and Virtual Production, Oct 2018, Nantes, France. 10.1016/j.promfg.2018.12.032 . hal-01997196

**HAL Id: hal-01997196**

**<https://hal.science/hal-01997196v1>**

Submitted on 2 Sep 2024

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International Conference on Changeable, Agile, Reconfigurable and Virtual Production

## How to Restructure PPDRC and MIRC According to DOLCE

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### Abstract

The use of ontologies in information systems for engineering applications calls for ontologies representing experts' knowledge in a principled and robust manner. The work we present in the paper brings together, on the one hand, two ontologies developed for the engineering domain, namely PPDRC and MIRC and, on the other hand, the DOLCE foundational ontology. The former two have been developed by taking DOLCE as reference model for distinguishing between the high-level entities they quantify over. However, the relation with DOLCE calls for improvements. The ultimate purpose of the paper is to show how the conceptual transparency of domain ontologies can be enhanced by (properly) using a foundational ontology.

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Peer-review under responsibility of the scientific committee of the International Conference on Changeable, Agile, Reconfigurable and Virtual Production.

*Keywords:* DOLCE, Manufacturing, Ontology

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## 1. Introduction

Ontologies are broadly adopted in engineering information systems like Product Lifecycle Management and Enterprise Resource Planning to represent experts' knowledge, handle and share data across and within organizations [1]. Scientists in academia and practitioners in industry recognize the need for reference ontologies in the (broadly speaking) engineering domain. This led to international initiatives like the Industrial Ontologies Foundry<sup>1</sup> (IOF), one of whose governing principles is the development of domain ontologies on the grounds of upper-level ontologies that have been already successfully used. The reasons are that, first, domain ontologies often need to model and reason over notions that have been axiomatized in upper-level ontologies. Second, the adoption of upper-level ontologies brings conceptual clarity into domain-specific representations [2]. Third, from a more practical perspective, different information systems have more chances to interoperate (at the semantic level) if the ontologies they implement are based on a set of common and well-established classes.

We discuss in the paper the relation between two ontologies for engineering, namely, the *Product and Processes Development Resource Capability* (PPDRC) and its specialization the *Manufacturing and Inspection Resource Capability* (MIRC) [3, 4] with respect to the foundational ontology called *Descriptive Ontology for Cognitive and Linguistic Engineering* (DOLCE) [6]. The purpose is to provide a robust specification for PPDRC and MIRC.

The paper is structured as follows. In the next section we shortly introduce DOLCE. In Section 3 we present some of the most general classes of PPDRC and MIRC. Their relation with DOLCE is presented in Section 4. Finally, Section 5 concludes the paper.

## 2. The DOLCE ontology

DOLCE is an upper-level ontology capturing the ontological categories underlying natural language and common-sense thinking. We rely on both the full DOLCE ontology [6] and its Core revisitation [5] by providing only a minimal introduction to the latter.<sup>2</sup> *DC:Particular* is the most general class for all entities in the quantification domain. It is specialized into *DC:Object*, *DC:Event*, *DC:AmountOfmatter*, *DC:Quality*, and *DC:Region*.<sup>3</sup>

Objects are entities that are primarily present in space like drillers and persons, differently from events like drilling or measuring, which extend through time. Objects and events are linked via the relationship of *participation*. Instances of both *DC:Object* and *DC:Event* can be characterized by *qualities*, which are partitioned into *quality kinds*, i.e., classes of maximally comparable qualities, e.g., the color-kind or the weight-kind. Qualities values are represented through *DC:Region*, which is used to define *quality spaces* as (structured) collections of values provided according to measurement scales. The relationship of *location* links a quality to its value (i.e., a region in a quality space) at a certain time. For example, if *driller1* and *driller2* are both *3kg* heavy, their different weight-qualities, *wq1* and *wq2*, respectively, are located in the same *3kg* region of the corresponding weight-space.

*DC:AmountOfmatter* refers to the quantities of material that may *constitute* material objects. DOLCE holds a basic distinction between objects and amounts of matter in that the former can lose or acquire portions of material while remaining the same objects. For instance, one may claim that a machining tool does not undergo a change in its identity when it wears as a result of machining.<sup>4</sup> *Constitution* is the relation binding objects to the amounts of matter constituting them.

A portion of the taxonomy of DOLCE extended with other classes is showed in Section 4 (see Fig. 2).

<sup>1</sup> <https://sites.google.com/view/industrialontologies>

<sup>2</sup> We prefix classes from the full DOLCE ontology by DL, and classes from DOLCE Core by DC.

<sup>3</sup> DOLCE Core includes also the classes *DC:Concept* and *DC:ArbitrarySum*, which are not hereby introduced because not relevant for our study.

<sup>4</sup> One can indeed claim that a tool is more or less consumed without however claiming that it is not anymore the same tool.

### 3. The PPDRC and MIRC ontologies.

PPDRC [3] has been developed to provide some of the most general classes for engineering process development and, more specifically, for the planning of new product projects. Its core classes thus allow the representation of plans and resources. PPDRC is developed in the Web Ontology Language (OWL) and it has been extended into MIRC [4] to support the specification of plans for machining and inspection. For limits of space, we introduce only some of the classes in PPDR and MIRC, which – for their generality and relevance to manufacturing – are worth to be restructured according to DOLCE.

From a high-level perspective, the taxonomy of PPDRC consists of three disjoint classes (see Fig. 1)<sup>5</sup> which have been adapted from both DOLCE and the Process Specification Language (PSL) [7], namely, `PPDRC:Object`, `PPDRC:ActivityOccurrence`, and `PPDRC:Region` [3]. Instances of `PPDRC:Object` can be either material or immaterial items. This is grasped in the specialization of `PPDRC:Object` into `PPDRC:PhysicalObject`, `PPDRC:SocialObject`, and `PPDRC:Agentive`. The first class refers to objects that are located in space and are made of matter.<sup>6</sup> The second one models *descriptions* that are used to communicate and share pieces of information, e.g., a process plan. The third one refers to objects to which believes, desires, and intentions can be ascribed [8]. `PPDRC:Region` corresponds to DOLCE regions. Note that PPDRC lacks a class for qualities.

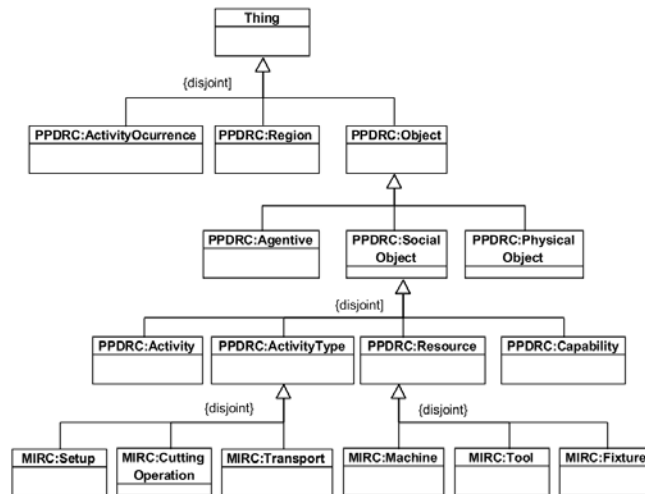


Fig. 1. Some of the classes in PPDRC and MIRC.

The distinction between `PPDRC:ActivityOccurrence` and `PPDRC:Activity` is adapted from PSL. The idea is to distinguish between an event occurring in time (an activity occurrence) and its repeatable pattern of behavior (an activity). `PPDRC:ActivityType` has been introduced to talk about kinds of behaviors. Activities can be specified at different levels of detail, for example, to represent elementary or complex activities. Also, PPDRC assumes that an activity is not necessarily realized in an activity occurrence, which amounts to say that the activity specified by a plan does not necessarily lead to an execution of the planned process. MIRC specializes the `PPDRC:ActivityType` with classes specific to manufacturing (see Fig. 1). Finally, the classes `PPDRC:Resource` and `PPDRC:Capability` extend `PPDRC:SocialObject` and refer to *descriptions* of resources and capabilities, respectively. Fig. 1 shows some of the resources classes in MIRC (see [4, 9]).

<sup>5</sup> Fig. 1 does not show relations between classes other than subsumption.

<sup>6</sup> Amounts of matter are not explicitly represented in PPDRC.

#### 4. Restructuring PPDRC and MIRC according to DOLCE

As said, PPDRC and MIRC have been developed by taking DOLCE as reference ontology. The relation with DOLCE calls however for some improvements. For example, we saw that PPDRC introduces a predicate for regions without referring to qualities. Also, the ontology lacks a class for amounts of matter, whereas their representation is relevant for certain manufacturing purposes. The work we present in this section is therefore aimed at revising PPDRC/MIRC to meet the modeling principles of DOLCE.

We saw that PPDRC is interested in characterizing a basic distinction common in the engineering domain between *descriptions* like plans and the processes that possibly satisfy them. It should be clear that the distinction applies also to objects, e.g., a product and the design model specifying the product's geometric properties.

To grasp the description *vs* non-description dichotomy, the restructuring of PPDRC and MIRC builds on a taxonomy of different classes of objects (see Fig. 2). In particular, DC:Object is now specialized into DL:PhysicalObject and DL:NonPhysicalObject, where – differently from instances of the latter class – instances of the former are located in space. DL:NonPhysicalObject is then specialized into PPDRC:Description, which is further extended into PPDRC:Plan and PPDRC:PhysicalObjectDescription. The former is extended into MIRC:MfgPlan<sup>7</sup> to model explicitly manufacturing plans. Also, this class replaces PPDRC:Activity given that PPDRC and MIRC are explicitly thought to assist experts in process planning tasks, hence a class for plans is necessary. In principle, MIRC:MfgPlan may be used in tandem with PPDRC:Activity to model descriptions of the latter. We however prefer avoiding the use of both classes to simplify the complexity of the model.

The relationship *satisfies* is the most general link holding between a description and the entity that complies with it, e.g., a physical product satisfying a design model. The semantic of this relation can be characterized in various manners, e.g., as *total* or *partial* compliance. In the first case, a physical object (or process) satisfies all the properties specified in the corresponding description, whereas in the second case only some of such properties are met. Also, one may introduce a sort of *mandatory* compliance with respect to properties that *must* be satisfied if an entity has to be considered compliant with a description.

As it can be seen in Fig. 2, DL:PhysicalObject covers DL:AgentivePhysicalObject and DL:NonAgentivePhysicalObject. Examples of the first class are persons or software agents, whereas examples of the second class are ordinary drillers or tools. First, note that with respect to the original understanding of agents in PPDRC, we adopt now a weaker approach which is not committed to characterizing agents in terms of belief, desires, or intentions. For manufacturing purposes, an agent can be a physical object with sensors, actuators, and the capability of acting on the environment by adopting plans to reach some goals. Second, note that only physical objects can be agents, since non-physical objects lack the capability to interact with the environment.

Following DOLCE a class for qualities, DC:Quality, is now explicitly introduced to represent the characteristics of objects or processes. The class PPDRC:PlanRealization models executions (a.k.a. realizations) of plans. It is thus treated as a subclass of DC:Event, which replaces PPDRC:ActivityOccurrence<sup>8</sup>. PPDRC:PlanRealization is specialized by MIRC:MfgPlanRealization. As the label suggests, its instances are individual events that satisfy a manufacturing plan. It should be clear that in comparison with the notion of activity occurrence found in PSL, MIRC:MfgPlanRealization has a more specific meaning that is restricted to the manufacturing domain.

A fundamental notion in PPDRC is *resource* [10], which is then specialized in MIRC to cover various classes of manufacturing resources. Following the ontological analysis presented in [11], we assume that the notion of manufacturing resource refers to the *role* that a physical object or an amount of matter, which is now introduced through the class DC:AmountOfMatter, plays in a manufacturing plan realization according to a corresponding

<sup>7</sup> Mfg stands for 'manufacturing'. Note that MIRC:MfgPlan can be easily extended to cover both elementary and complex plans in line with the original spirit of the ontology.

<sup>8</sup> We prefer using DOLCE events instead of PSL activity occurrences because the semantic of the former notion is more general, since it is not restricted to the realizations of activity types.

plan. Consider, e.g., a specific driller. If considered on its own, the driller is an *artifact*, a material object that exists because it has been fabricated to meet some design descriptions. When the driller is meant to be used in a manufacturing event to create a hole, then it is a resource. As suggested in [11] different resource classes can be distinguished depending on their contribution to the event at stake.

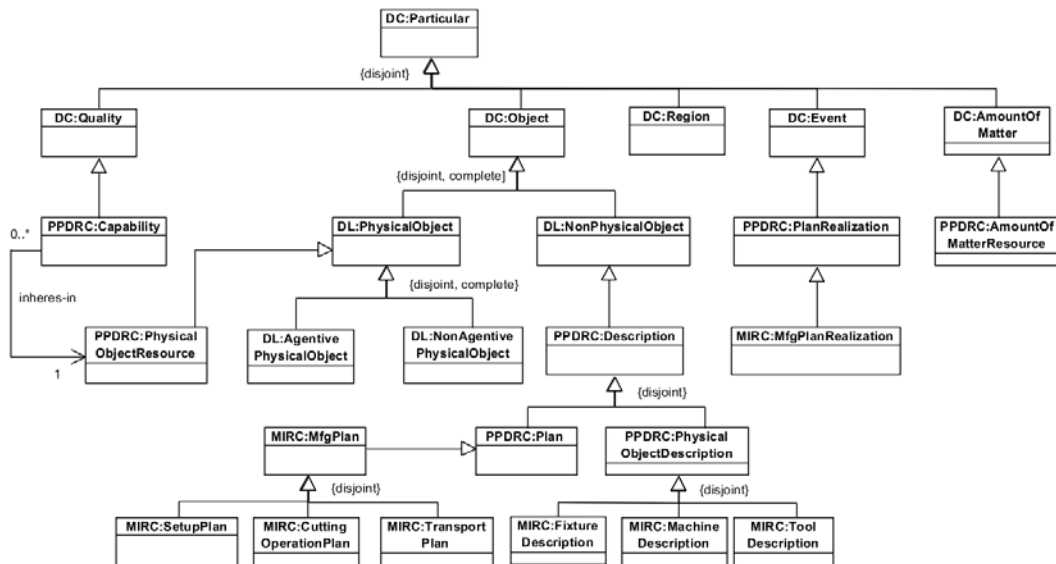


Fig. 2. Restructured taxonomy of PPDRC/MIRC according to DOLCE

Roles can be represented through various approaches in ontologies, e.g., by treating them as reified properties in the quantification domain [5,12], or – more standardly – as classes properly subsumed in the taxonomy of the ontology at hand [13]. Following the latter approach, which is simpler than the former because it does not introduce (reified) properties in the ontology, we introduce the classes `PPDRC:PhysicalObjectResource` and `PPDRC:AmountOfMatterResource` as subclasses of `DL:PhysicalObject` and `DC:AmountOfMatter`, respectively, to model the general resource roles that physical objects and amounts of matter may play.<sup>9</sup>

Recall that PPDRC assumes that the participation of resources in manufacturing events is strictly dependent on resources' capabilities. According to the MANDATE standard [14], a capability is the “quality of being able to perform a given activity”. From an ontological perspective, a capability may be understood as a resource's characteristic, a `DC:Quality` indeed, which makes a resource usable to achieve the goal that an event is meant to bring about. The characterization of capabilities is challenging for at least two reasons. First, they seem to be *complex* qualities resulting from the ‘composition’ of other qualities. Second, a capability seems to be *manifested* only in certain circumstances. In formal ontology, qualities that can be manifested are called *dispositions* [15].

With respect to both issues related to capabilities, i.e., their complex and dispositional nature, their conceptualization and formal treatment deserves further work. We just introduce the primitive predicate `PPDRC:Capability` subsumed by `DC:Quality` and link it to `PPDRC:PhysicalObjectResource` referring to the capabilities of physical object resources. The intended meaning is that physical objects can play the role of manufacturing resources only if they bear certain capabilities. Resources that are amounts of matter do not bear capabilities, since they simply ‘undergo’ manufacturing processes. The new taxonomy of PPDRC, partially extended with MIRC classes, is showed in Fig. 2.

<sup>9</sup> Note that in Fig. 2 `PPDRC:PhysicalObjectResource` is directly subsumed by `DL:PhysicalObject`. Since the latter is a partition of agent and non-agent physical objects, all physical object resources are either agents or not. The reader can refer to [11] for more details on the ontological representation of resources in our approach.

## 5. Conclusion

The aim of the presented work was to restructure the basic elements of PPDR and MIRC to meet DOLCE modeling principles in order to make both ontologies more tenable from an ontological perspective. Our contribution has to be thus understood as a step towards the definition of ontologies for the manufacturing domain grounded on foundational ontologies to distinguish and characterize domain entities in a principled manner.

With respect to Fig. 1 the work we propose changes significantly the taxonomy of PPDR and, consequently, of MIRC. New classes are indeed added, e.g., to represent qualities and amounts of matter, but also to distinguish in a clear manner between the *description* (e.g., design models or plans) and the *physical* levels (e.g., processes or products) of engineering knowledge representation. Also, some classes have been removed. For instance, the distinction between `PPDR:Activity` and `PPDR:ActivityType` is not anymore present in the ontology; first, because the distinction between them was not clear from an ontological modeling perspectives (recall that PSL activities are indeed activity types); second, because a single class for descriptions (e.g., `MIRC:MfgPlan`) can be used to represent and distinguish between different plans, as we saw.

For lack of space, we cannot present a case study, but various advantages have been reached concerning the conceptual transparency of the ontologies with respect to ontological modeling principles. E.g., PPDR and MIRC characterize now the distinction between qualities and their values, as well as between plans and their realizing processes. These distinctions can hopefully lead to clearer data models and reasoning procedures.

As future work, a mature analysis and formal representation of resources' capabilities are needed, since – as we saw – the latter have a fundamental role to model manufacturing resources in tight connection with processes and plans. In addition, we have mainly showed how the core elements of PPDR and MIRC are changed according to DOLCE. The formal representation in a language like OWL remains to be done along with the restructuring, where necessary, of the relationships holding among PPDR and MIRC classes other than subsumption.

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