An Upper Ontology based on ISO 15926

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Abstract

Ontologies reflect our view of what exists and developing ontologies for a given domain requires a common context. This context can be characterized explicitly by means of an upper ontology. Upper ontologies define top-level concepts such as physical objects, activities, mereological and topological relations from which more specific classes and relations can be defined. As an effort to support the development of domain ontologies, we are developing an OWL ontology based on the ISO 15926 standard. This paper presents the development to date of this standard and discusses its benefits and applications in the process engineering domain.

Keywords: ontologies, ISO 15926, temporal parts, four dimensionalism

1. Introduction

Ontologies describe a shared and common understanding of a domain that can be communicated between people and heterogeneous software tools. We construct an ontology by defining terms such as classes of concepts, their taxonomy, the possible relations between the concepts, and axioms for those relations. A class represents a category of similar things that share a set of properties. A relation is a function that maps its arguments to a Boolean value of true or false. Examples of relations are *less_than*, *connected_to*, and *part_of*. Class taxonomies are defined with the use of the *subclass* relation. A class is a subclass of another class if the former represents a set of things that subsumes the set of things represented by the latter.

A number of ontologies have been developed in the process engineering domain. Among these, OntoCAPE defines a comprehensive number of chemical engineering concepts implemented in DAML+OIL (Yang and Marquardt, 2004) based on CliP (Bayer, 2003) which use a systems-theoretic view of the world.

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Ontologies can be developed using top-down or bottom-up approaches. The bottom-up approach starts with the most specific concepts in a domain of application. A bottom-up approach results in ontologies that are difficult to modify and integrate with ontologies developed for other domains or applications (Uschold and Gruninger, 1996). Top-down approaches start with high-level concepts that are assumed to be common to many application areas. The top-down approach facilitates integration of applications with ontologies that are easier to maintain. Unfortunately, engineers using the top-down approach are susceptible of imposing arbitrary high-level categories which often tend to be prescriptive (what will be), not meeting the user's requirements. These problems can be avoided with an upper ontology.

Upper ontologies define top-level concepts such as physical objects, activities, mereological and topological relations from which more specific classes and relations can be defined. Examples of upper ontologies are SUMO (Niles and Pease, 2001), Sowa upper ontology (Sowa, 2000), Dolce (Gangemi et al. 2000), CliP (Bayer, 2003), and ISO 15926-2 (ISO 15926-2, 2003). Engineers can start by identifying key concepts by means of activity modeling, use cases and competency questions. This concepts are then defined based on the more general concepts provided by the upper ontology. This avoids reinventing the wheel while having a better integration and maintenance.

As an effort to support the development of process engineering ontologies, we are developing an upper ontology in the OWL language based on the ISO 15926 standard. Specifically, ISO 15926 Part 2 (standardized as ISO 15926-2:2003) specifies an ontology for long-term data integration, access and exchange. It was developed in ISO TC184/SC4-Industrial Data [1] by the EPISTLE consortium [2] (1993-2003) and designed to support the evolution of data through time. The upper ontology contains 200 concepts including a meta-model for extending the ontology through what is known as a Reference Data Library (about 20,000 concepts from the engineering domain).

We have translated the original EXPRESS code (ISO 10303-11, 1994) of ISO 15926-2 to the OWL language that can be used directly in a number of inference software packages (W3C, 2004). Axiomatic definitions are currently being added to implement some semantics of the standard that are not represented in the EXPRESS schema.

2. Temporal parts

ISO 15926-2:2003 is founded on an explicit metaphysical view of the world known as *four dimensionalism*. In four dimensionalism, objects are extended in space as well as in time, rather than being wholly present at each point in time, and passing through time. An implication of this is that the whole-part relation applies equally to time as it does with respect to space. For example, if a steel bar is made into a pipe then the pipe and the steel bar represent a single object. In other words, a spatio-temporal part of the steel bar coincides with the pipe and this implies that they are both the same object for that period of time. This is intuitive if we think that the subatomic particles of the pipe overlap the steel bar.

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[1] http: //www.tc184-sc4.org/
[2] http: //www.epistle.ws/

Information systems have to support the evolution of data over time. For example, let us assume that a pump was designed and identified as P-101. Some time later, a manufacturer delivers a pump with serial number 1234 that meets the design specifications of P-101. Pump 1234 is installed and after a period of operation the pump fails. Therefore, maintenance decides to replace it with pump 9876. This situation can be easily modeled using the concept of temporal parts as shown in Figure 1. ISO 15926-2:2003 defines the class *functional_physical_object* to define things such as pump P-101 which have functional, rather than material continuity as their basis for identity. In order to say that pump 1234 is installed as P-101, P-101 is defined as consisting of S-1 (temporal part of 1234). In other words, S-1 is a temporal part of 1234 but is also a temporal part of P-101. In fact, because S-1 and P-101 have the same spatio-temporal extent they represent the same thing. Similarly, after a period of operation 1234 was removed and pump 9876 takes its place. In this case, S-2 (temporal part of 9876) becomes a temporal part of P-101. Objects such as P-101 are known as replaceable parts which is a concept common in artifacts in many engineering fields such as the process, automobile, and aerospace industries (West, 2003).

3. Top level concepts

thing is the root concept in the ontology that subsumes *abstract_object* and *possible_individual* classes. A *thing* is anything that is or may be thought about or perceived, including material and non-material objects, ideas, and activities. Every *thing* is either a *possible_individual*, or an *abstract_object*. Members of *possible_individual* are entities that exist in space and time, including physical objects like a compressor or ideas that exist in our imagination. Individuals that belong to *abstract_object* can be said to exist in the same sense as mathematical entities such as numbers or sets but they cannot exist at a particular place and time. *possible_individual* is divided into *arranged_individual*, *actual_individual*, *whole_life_individual*, *activity*, *physical_object*, *period_in_time* and *event* (see Figure 2).

4. Mereotopology

Mereology expresses the part-whole relations of an object, which means that a

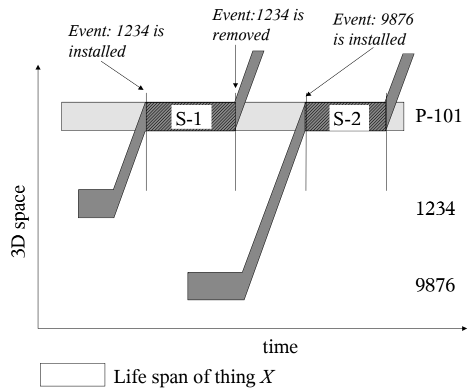


Figure 1. A pump and its temporal parts

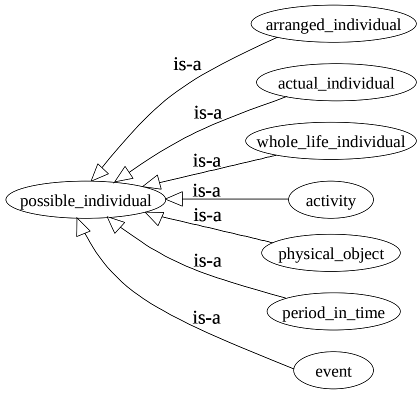
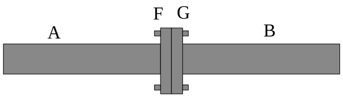


Figure 2. Subclasses of possible_individual

component can be decomposed into parts or subcomponents that in turn can be decomposed into other components. Mereological descriptions are possible by means of *composition_of_individual* and its subproperties. *composition_of_individual* is transitive. Subproperties of composition_of_individual include containment_of_ individual (used to represent things that are inside others) and relative_location (used to locate objects on a particular place).

Topology refers to the connectivity between Objects. Topological descriptions are based on the use of the property *connection_of_individual* which is defined as symmetric and transitive. For example, a reasoner can infer that pipes A and B are connected because their flanges F and G are connected (Figure 3).




```
<pipe rdf:ID="A">
   <connection_of_individual>
       <flange rdf:ID="F">
          <connection_of_individual>
             <flange rdf:ID="G"/>
          </connection_of_individual>
       </flange>
   </connection_of_individual>
</pipe>
<pipe rdf:ID="B">
    <connection_of_individual rdf:resource="#G"/>
</pipe>
```

Figure 3. Connected pipes and flanges and its corresponding OWL code

4. Physical objects

A *physical_object* is a *possible_individual* that is a distribution of matter, energy, or both. Examples of physical_object are a table, a pump, a piece of metal, a laser beam.

Physical objects can be instances of *arranged_individual* which defines those possible individuals that have parts each of which plays a distinct role. Instances of physical objects can be related to instances of *abstract_object*. For example, the liquid contained in a tank that has the phase liquid. In the ontology, *phase* is abstract.

5. Activities

Activities can have temporal boundings linking *events* as well as *points_in_time* because *activity* is a subclass of *possible_individual* which has a life cycle bounded by *beginning* and *ending*. The activity concept can be used to represent physicochemical behaviors, plant operations, abnormal situations, etc. Activities bring about change by causing an *event*. Causality is described by means of the cause_of_event relation. Events mark the *beginning*, or the *ending* of a *possible_individual*. An *activity* consists of the temporal parts of those members of *possible_individual* that participate in the activity. For example, the mixing activity shares the temporal parts of the tank and agitator. An example of the use of activities, events and participating objects is shown in Figure 4.

```
<activity rdf:ID="loading-fluid-in-the-tank">
 <ending>
   <event rdf:ID="pump-off">
     <cause_of_event rdf:resource="#loading-fluid-in-the-tank"/>
   </event>
 </ending>
```

```
  <participation>
    <physical_object rdf:ID="pump-during-operating-period"/>
  </participation>
  <beginning>
    <event rdf:ID="pump-on"/>
  </beginning>
</activity>
<physical_object rdf:ID="pump">
  <ending rdf:resource="#pump-off"/>
  <temporal_whole_part rdf:resource="#pump-during-operating-period"/>
  <beginning rdf:resource="#pump-on"/>
</physical_object>
```

Figure 4. OWL code that shows the use of activities, events and participating objects.

6. Physical quantities

Following the arguments presented by Gruber and Olsen (1994) the upper ontology supports the idea that physical objects and activities should not be allowed to define quantities as attributes because a quantity is not an inherent property. For example, the setpoint of a temperature controller (a physical object) can be defined as an instance of class_of_indirect_property. The class_of_indirect_property is a rdfs:subClassOf owl:FunctionalProperty whose domain is given by members of class_of_individual and whose range is given by members of property_space. It is a relation whose range is temperature_quantity. temperature_quantity is an instance of property_space. Furthermore, property_space is a subclass of class_of_property, which means that temperature_quantity is also an instance of class_of_property (Figure 5).

For the units of measure ISO 15926-2:2003 suggests to classify the property_quantification, in other words a classification relation is used to map an instance of property_quantification to an instance of scale. The approach used here defines scale as an OWL:property.

```
<property_space rdf:ID="temperature_quantity"/>

<owl:FunctionalProperty rdf:ID="temperature_setpoint">
    <rdf:type rdf:resource="&lis;class_of_indirect_property"/>
    <rdfs:domain rdf:resource="&lis;whole_life_individual"/>
    <rdfs:range rdf:resource="#temperature_quantity"/>
</owl:FunctionalProperty>

<lis:physical_object rdf:ID="TIC_01">
  <rdfs:comment>Temperature Controller TIC-01</rdfs:comment>
</lis:physical_object>

<owl:ObjectProperty rdf:ID="kelvin">
  <rdf:type rdf:resource="#scale"/>
</owl:ObjectProperty>

<lis:physical_object rdf:ID="temporal_part_of_TIC_01_at_800K">
    <lis:temporal_whole_part.whole rdf:resource="#TIC_01"/>
    <temperature_setpoint>
      <rdf:Description>
        <rdf:type>
           <owl:Class rdf:about="#temperature_quantity"/>
        </rdf:type>
        <kelvin>
          <rdf:Description>
            <real>
              <content>
                <xsd:float rdf:value="800.0"/>
              </content>
            </real>
          </rdf:Description>
        </kelvin>
```

```
      </rdf:Description>
    </temperature_setpoint>
</lis:physical_object>
```

Figure 5. OWL Code illustrating the definition of physical quantities.

We can also specify temporal boundings (beginning and ending) to temporal_part_of_TIC_01_at_800K to indicate the time interval in which the setpoint of TIC-01 was at 800K.

6. Conclusions

Industries around the world recognize that some of the keys to compete in the ever-increasing global markets, as well as to meet increasingly tighter safety and environmental constraints lie in improved work flow processes and in the integration of information systems. However, many current information systems can be integrated only at great cost because of their incompatible proprietary representations of information. One approach to integration of information systems is by means of shared ontologies. In particular, upper ontologies define top-level concepts such as physical objects, activities, mereological and topological relations from which more specific classes and relations can be defined.

We have provided a brief overview of an upper ontology based on ISO 15926-2:2003 which has been implemented in OWL. The ontology is being used as an approach to represent and query knowledge generated during Hazards and Operability Studies, and it is also the upper ontology for defining and searching modeling services. It would be of great benefit to the process engineering community to explore the integration with other efforts such as the OntoCAPE ontology.

The upper ontology in OWL format can be downloaded from:
http://www.ompek.org/

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