ISO 15926 templates and the Semantic Web

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ISO 15926 is a representation standard for information in the process industry. Based on an ontology approach to information, it lends itself to application using Semantic Web tools. We describe how OWL can be used with ISO 15926 to represent common industry classes and relations. Using rules and automated decution, we extend the approach to *templates*, patterns for complex statements of the industrial domain.

1 The standard

The life span of an Oil & Gas industry plant is typically more than 50 years. During the plant's lifetime, the information that describes it changes little compared to the turnover of computer systems and data formats. Ideally, information about an industrial facility should be treated as independent of concrete choices of data storage, use, or representation. The information standard ISO 15926, *Industrial automation systems and integration — Integration of life-cycle data for process plants including oil and gas production facilities* [12] has been defined with the aim of providing formats and methodology to support this need. It is currently supported by several major companies, with an international team of developers [2, 3, 4]. The standard avoids fixed schemas, to accommodate change and development of industry data. This paper is about using ISO 15926 to support data integration and exchange, and the application of automated reasoning to mapping.

2 Modelling patterns captured in *templates*

Industrial data stores need to provide rich, explicit representation to ensure reusability and interoperability. Flexible interchange between the diversity of purpose-built systems, which range from real-time monitoring to accounting, requires that information is represented in a language that is not tied to any particular purpose. For example, we wish to separate *functional* entities

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(tags), *activities* (pumping, separating), and *physical* entities (things that have serial numbers, such as installed pumps and tanks). When a process is designed, and later when equipment is installed, we wish to apply the same *vendor data*, as provided in product catalogues, in both design verification and real-time monitoring systems. ISO 15926 provides a standard means of expression that supports such goals.

The tradeoff of explicit representation and independence of purpose is complexity. Diagram 1 shows an ISO 15926 representation of a typical assignment of a temperature range to a class of equipment.[1] For the standard to be truly useful, we need to provide a suitable abstraction layer above the "assembly language" level of representation shown in the diagram. We need to represent the model constructs in a form familiar to professionals working in the domain, matching what is found in work documents. This typically means a tabular form, as shown in figure 2. The abstractions, and the rules that tie them to the underlying models, we call ISO 15926 *templates*.[2] A successful template captures a common statement pattern and is accessible using a simple interface. By instantiating a template with a row of data, then expanding according to the rules that define its meaning, we obtain the full, explicit structure.

To capture domain concepts for common use, ISO 15926 *Reference Data Libraries* (RDL's) are set up as registries of industry classes and relations, whether standard throughout the industry, specific to an industry subdomain, or company-specific (cf. [1, 5]). Companies can opt for different degrees of standardization or compliance. Standardizing on a given vocabulary, ensuring that the words used have a precisely agreed meaning, is a natural minimum. Systems that store information with reference to commonly recognized classes and relations already have an advantage with regard to facilitating communication.

On the sophisticated end of the spectrum, we have the adoption of standardized modelling structures, as will typically require a template interface. Here the goal is to standardize the representation of composite, complex facts. Examples include the breakdown and capabilities of a piece of equipment or the structure of a process as described in Process & Instrumentation Diagrams.

A main reason why traditional representation methods are inefficient in the long run is that the structures used leave much information implicit. Consider a system in which "impeller diameter" is represented as a primitive property of pumps – a typical case. Surely, an impeller diameter is *primarily* a property of the given pump's impeller, and only in a derived or indirect fashion a property of the pump itself. Different information will apply to the pump as a whole, as opposed to an impeller part: different maintenance cycles, performance standards, apply. The precision of a system in which "impeller diameter" is a primitive concept may well be insufficient for supporting lifecycle management over the long periods of time required by large industrial installations.

Traditional data sources in industry are in general developments of paper-based approaches, intended for human consumption. Templates can be developed to match the perspectives embedded in the existing systems, *without* having to abandon the aim of explicitness and precision of the semantic approach.

[1] The example is taken from a Sharecat data sheet for Emerson 3051CG pressure transmitters [23].

[2] The concept of a template has been developed over several years, originating in the work of Hans Teijgeler and others; see, e.g., Teijgeler's [22]. A normative account of ISO 15926 templates is due to be published in the upcoming *Part 7* of the standard.

3 Reference data as ontology

Development of ISO 15926 began in the mid-1990's. Experience showed early on that concepts from logic and set theory were essential in order to capture notions such as conditions for membership in an industry-standard class. In later years, this has developed into the realization that the general field of ontology research delivers the right methodology, with Semantic Web languages and tools for implementation: An ISO 15926 RDL is naturally viewed as an ontology. This outlook represents a modern approach to information integration challenges. In our experience, the continuous improvements in expressive power and performance of the Semantic Web toolbox greatly benefit the practical applicability of ISO 15926.

The data model of ISO 15926 *Part 2* [11] is akin to an *upper ontology*; arguably, this is the core of the standard. It is formulated in the EXPRESS language, as mandated by the ISO TC184/SC4 system [13]. For the application of the standard in settings that don't use EXPRESS, translation from this canonical form into other representation languages is required. We have adopted a Description Logic (DL) representation that is faithful to the structure of the normative EXPRESS form.[3]The set of ISO 15926-2 entity types provides a framework of unary and binary predicates.[4] Reference entities populating this structure are all represented as individuals.[5]

A template may be considered a predicate of arbitrary arity, the interpretation of which is unambiguously given by means of rules expressed in a restricted form of predicate logic.[6] The abstraction layer of templates therefore requires us to adopt a more complex language than required for Part 2. The restriction to binary predicates, common in DL's, is lifted, and more powerful axioms given to capture the translation between templates and Part 2 representations. Figure 3 illustrates how the languages used are related.

Using templates, end users only need to be familiar with the template signatures in order to express themselves in a fully explicit form, using the language of ISO 15926. Conformance to the standard is then measured by means of logical definitions.

4 Storage, deployment, expressivity

For ISO 15926-compliant data, the EXPRESS format as given in Part 2 is the authoritative form. Our OWL implementation, using *reified* relations, provides a convenient and faithful format for applying this in practice. However, with its representation of classes as individuals, the format doesn't lend itself to direct use with common Semantic Web tools and formats. We wish to make taxonomies of industrial equipment types, as stored in RDL's, accessible for use as OWL

[3]This, with one notable exception: Inverse-functional datatype properties (see [20]). The representation is a Description Logic TBox [6], given as an OWL DL (cf. McGuinness and van Harmelen [17]) ontology.

[4]In addition, basic types may be assembled in ordered list structures.

[5]A core set of reference data has been standardized as 15926 *Part 4*. As a set of instances of the TBox, an RDL is a DL ABox. Note that this includes reference entities of all kinds, for instance all that are intuitively, in practical use, interpreted as classes. For this reason, our implementation in OWL of the Part 2 data model may be referred to as a "data carrier" format. It makes no attempt to make explicit the intended semantics of reference data. See section 4.

[6]It's likely that the expressive power of *regular* predicate logic is sufficient for the rules required; see e.g. [8].

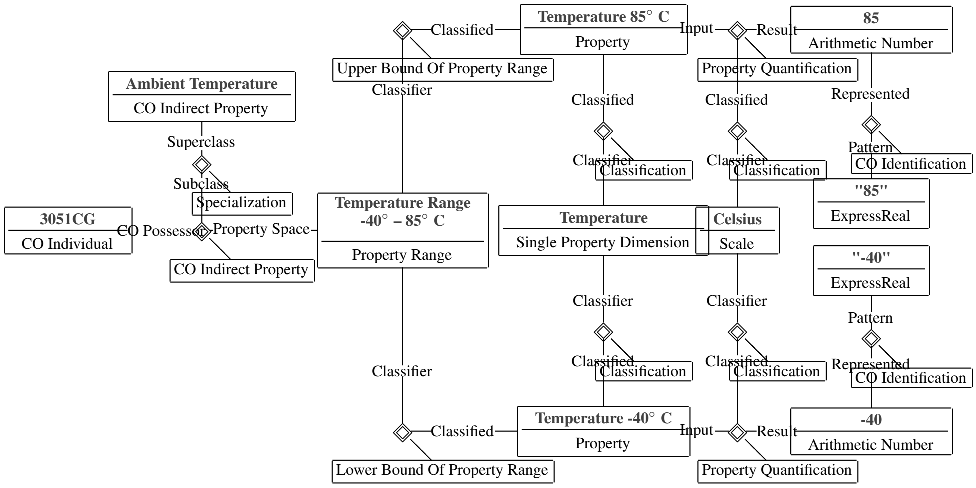

Figure 1: Range assignment, ISO 15926 model

Ambient temperature assignment.

Class	*Scale*	*Upper*	*Lower*
3051CG	Celsius	−40	85

Figure 2: Range assignment, user's template view

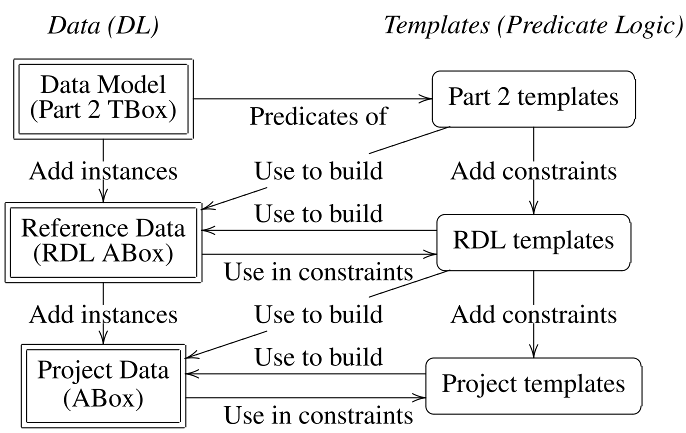

Figure 3: A stack of languages

ontologies: then reference data classes need to be represented as OWL classes. Transformations into RDF/OWL "native" formats are needed.

To some extent, this aim can be straightforwardly supported. Translation of, e.g., class hierarchies and breakdown structures into OWL can be done by means of transformations using standard techniques and query languages. From the "full" format that mimics the EXPRESS norm, various native representations can readily be generated using transformations (which will typically be, intentionally, lossy).

At the same time, it's important to be aware that the scope and expressivity of ISO 15926 goes beyond what can readily be expressed in the semantic standards of currency, in particular in the current OWL variants. One case in point is second-order classes (classes whose members are first-order classes).[7] Innovations in the upcoming OWL 2 standard [14] already provide for a more seamless translation that has been possible in OWL DL.[8] We can surely expect that the expressive power of OWL and related languages will develop so more constructs in ISO 15926 gain obvious, natural translations. This is however an open-ended process, and in various relevant cases, there is little consensus on correct or best solutions for ontological constructs. A case in point is the field of part-whole relations, which represents a field of research in itself.[9]

5 Implementation: A prototype for templates

As part of the Intelligent Data Sets project [2], DNV has developed a software prototype that brings together the parts of ISO 15926 sketched above in an executable environment. We can experimentally test that each statement made using a template corresponds to a set of statements in the basic language of reference data conformant with ISO 15926-2. Indeed, this is a defining criterion of what belongs in the template language: Every appropriate statement *must* be equivalent to a set of statements in the RDL language. In order to secure that the requirement is met, application of automated reasoning is essential, for checking of correctness as well as in transformations.

The main features of our prototype are as follows. Input is from *traditional*, proprietary sources, specifically equipment data sheets that are in use in industry today, mapped into a simple XML format that matches the target templates. This is mapped onto complex predicates in OWL, using the list format described in [9] and conformant with the "reified" RDL representation.[10] Rules written in SWRL [15] are executed to interpret the templates, producing a set of statements in the RDL language. Automated reasoning is applied to this OWL ontology in order to infer implicit typing, and then to check for consistency. A positive consistency check shows that a set of ISO 15926-compliant data has been generated. The process is one of "lifting" traditional data

[7]Practical experience in data modelling for industrial applications, over the last two decades, has demonstrated a clear need for representing a methodology for representing second-order classes, and for keeping them apart from first-order classes. Indeed, confusion between these two levels has been common in earlier systems, leading to difficulties with preserving sound taxonomical structure.

[8]I.e., using *punning* as "syntactic sugar" [14].

[9]In ISO 15926, parthood is represented by the entity type Composition of individual. Implementation in OWL has been discussed in [19].

[10]This works around the OWL DL restriction to binary predicates. An alternative representation could use the "n-ary relations" approach of [18].

into a semantic format; for output into a different proprietary format, a simpler “lowering” can also be carried out.[11]

Once a comprehensive set of templates is developed, this approach will deliver a language and a tool that meets two essential requirements on a standard for information integration. First, templates can be designed to match the kinds of statements that engineers make in their work in actual projects. This makes the information standard accessible for use. Second, the use of a Semantic Web technology, in particular automated reasoning, allows for true verification of correctness, and transformation into generic representations, as required for reliable exchange and cooperation.

6 The road ahead

Some challenges for further development should be mentioned in closing.

The current rule languages for OWL are not as settled as the OWL itself. While it has gained a certain currency, SWRL is still not standardized. We anticipate that developments around W3C’s Rule Interchange Format (RIF) will contribute to a solution [7].

For adoption in industrial information systems, design guides that relate the semantic approach to object-oriented software design, showing how semantic methods can support also existing systems, will be required (see, e.g., [16]).

For dissemination of reference data, we will continue to collaborate with the ADI project to develop suitable data stores [1].

In the longer term, automated reasoning should be applied to test consistency of the entire library of templates, to verify that the theory as a whole is consistent.[12] The commitment to Part 2 entity types means we can do with a highly restricted predicate logic, which is likely to lend itself to application of automated reasoning. This, of course, as far as ISO 15926-2 compliance *itself* goes. For checking correctness of intended meaning, a representation of the full range of ISO 15926 entity types, in various highly expressive languages, will be required.

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[11] The terms “lifting” and “lowering” should match their use in the SAWSDL standard [10].

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