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 deduction, 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. We here describe how ISO 15926 can support data integration and exchange, with automated reasoning applied to information mapping.

2 Information patterns captured in *templates*

Industrial data stores need to provide rich, explicit representation to ensure reusability and interoperability. We wish to separate *functional* entities (tags), *activities* (pumping, separating), and *physical* entities (things that have serial numbers, such as installed pumps and tanks). 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. 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 design verification as well as real-time monitoring. ISO 15926 provides a standard means of expression that supports such goals. In order to capture domain concepts for common use, ISO 15926 *Reference Data Libraries* (RDL's) are set up as registries of industry

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classes and relations, whether standard throughout the industry, specific to an industry subdomain, or company-specific (cf. [1, 5]).

Different degrees of compliance between an industrial data store and an RDL are possible. Standardizing on vocabulary, ensuring that classes and relations used have a precisely agreed meaning, is a natural minimum that already brings benefits to communication and exchange. At the sophisticated end of the spectrum, we have the adoption of standardized modelling structures to represent composite, complex facts. Examples include the breakdown and capabilities of equipment types, or process topology as described in Process & Instrumentation Diagrams.

A weakness of traditional representation methods is that the structures used leave much information implicit. For a typical case, consider a system in which “impeller diameter” is represented as a primitive property of pumps. Surely, an impeller diameter is *primarily* a property of a 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 therefore be insufficient for supporting lifecycle management over the long periods of time required by large industrial installations.

However, explicit representation and independence of purpose has a tradeoff in increased complexity. Figure 1 shows an ISO 15926 diagram of the assignment of a property range to a class of industrial equipment.[1] The level of detail is greater than what users would like to see. For the rich representa-

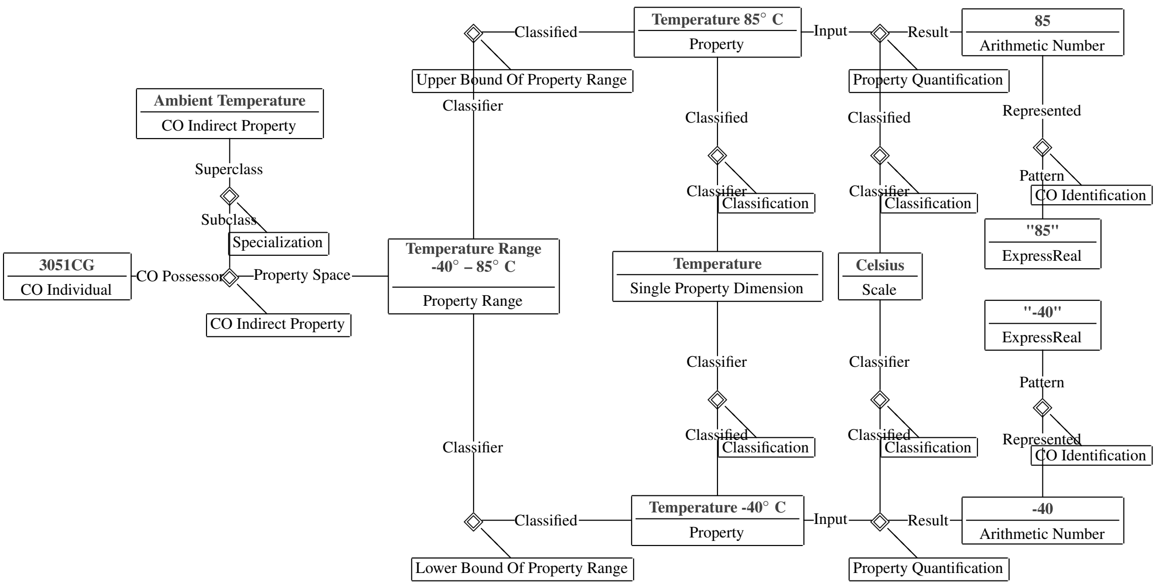

Figure 1: A range assignment, ISO 15926 model

tion to be truly useful, we need a suitable abstraction layer for the “assembly language” shown in the diagram. We need to provide an interface to the modelling patterns that is familiar to professionals working in the industrial domain, matching what is found in work documents. This typically means a tabular form, as shown in figure 2.

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

With ISO 15926, we call the abstractions, with the rules that tie them to the underlying models, *templates*.[2] A successful template captures a common statement pattern and is accessible using a simple interface. To instantiate a template with a row of data is to make a statement. Expanding according to the rules that define its meaning, we obtain the full, explicit structure.

Ambient temperature assignment.

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

Figure 2: Range assignment, user's template view

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.

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. 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]

To express the abstraction layer of templates, we need a richer language than is required for Part 2. The restriction to binary predicates, common in DL's, is lifted, and axioms that go beyond DL capture the relationship between templates and Part 2 patterns. A template *signature* may be considered a predicate of arbitrary arity. The interpretation of a template statement (an instantiated template) is unambiguously given by means of rules expressed in a restricted form of predicate logic.[6] Figure 3 illustrates how the languages used are related.

Users only need to be familiar with template signatures in order to express themselves using ISO 15926. Conformance to the standard is ensured, or measured, by formal logical definitions.

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

[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. [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].

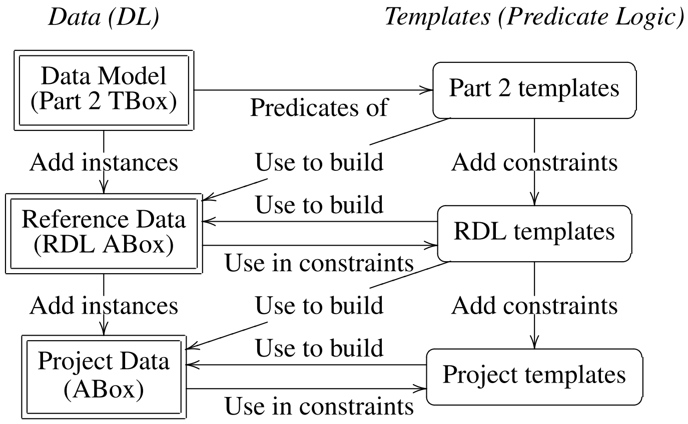

Figure 3: A stack of languages

4 Compliance, 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, it diverges from common Semantic Web formats. We wish to make taxonomies of industrial equipment types, as stored in RDL's, readily accessible for use as OWL ontologies: then reference data classes need to be represented as OWL classes. Transformation into RDF/OWL "native" form is needed.

To some extent, this aim can be straightforwardly supported. From the "full", reified format that mimics the EXPRESS norm, various native representations can be generated (typically with some, intentional, loss of information). Translation of class hierarchies into OWL can be achieved by means of standard techniques and query languages. At the same time, we wish to point out that the scope and expressivity of ISO 15926 goes well 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] another is the complex notion of *approval*.

Innovations in the upcoming OWL 2 language [14] already provide for a more seamless translation than has been possible in OWL DL. We can surely expect that the expressive power of OWL and related languages will develop so that 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.[8]

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. The main features are as follows. Input is from *traditional*, proprietary sources (specifically, equipment data sheets

[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] One example of great practical interest is part-whole relations, which represents a field of research in itself. In ISO 15926, parthood is represented by the entity type Composition of individual. Implementation in OWL has been discussed in [19].

that are in use in industry today), mapped into a simple XML format that matches the signatures of suitable templates. This is mapped onto complex predicates, represented in OWL by means of the list format described in [9] and conformant with the reified ISO 15926 representation.[9] Rules written in SWRL [15] are executed to interpret the templates, producing a set of statements in the Part 2/RDL language. Automated reasoning for OWL is applied in order to infer implicit typing, and 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 into a semantic format; for output into a different proprietary format, a simpler "lowering" can also be carried out.[10]

We can demonstrate that a statement made using a template expands 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.

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 are made in industrial projects. This makes the information standard accessible for use by domain experts. 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

We wish to mention some challenges for further development.

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 also support 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].

Automated reasoning should be applied to test consistency of the library of templates as a whole.[11] The restriction to the reified Part 2 format means we can do with a highly restricted predicate logic, which lends itself to application of automated reasoning.[12]

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

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

[11] I.e., as an axiomatic theory. This can be done in an analogous fashion to current work on *Basic Formal Ontology*, which applies the first order logic reasoner Isabelle [21].

[12] This, as far as compliance with ISO 15926-2 *itself* goes. For native representation of the full set of Part 2 relations, highly expressive languages will be required.

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