AN APPROACH TO MODELLING GEOMETRIC OBJECTS WITH THE ISO 15926 STANDARD

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ABSTRACT

No matter in which area they are applied, information technologies are used to increase the productivity of companies that use different computer systems from different suppliers. Most of time, data are stored in proprietary format. This fact creates difficulties for the integration and interoperation between the computer systems, forcing companies to invest money to simply mitigate this problem. Specifically in the field of Oil & Gas, the ISO 15926 standard (Industrial automation systems and integration – Integration of life-cycle data for process plants including oil and gas production facilities) proposes a standard for integration, sharing, exchange and delivery of data between computer systems based on the standardization of data formats and on an ontology approach to represent common industry classes and relations. Due to the structure and the large number of terms defined at the ISO 15926 standard, the complexity to model objects using that library is high. This work presents a methodology to model geometric objects following structure of the standard, harmonizing Parts 2, 3, 4 and 7 of ISO15926. The writers take into account the need for complete abstraction between geometry and business data, as well as the requirement for a federated architecture for managing process plant project item symbology.

Keywords: Geometry, Ontology, Semantic Web, Interoperability, Oil & Gas

1. INTRODUCTION

The National Institute of Standards and Technology -NIST- reported in 2004 that the costs generated by lack of proper interoperability between systems used in capital projects in the United States was around $15.8 billion per year. This was in great part due to the absence of international standards for interoperability between systems used in projects that were analyzed by NIST. In other words, the use the information technologies effectively to integrate design, construction and business processes. For instance, "*inadequate interoperability increases the cost burden of construction industry stakeholders and results in missed opportunities that could create significant benefits for the construction industry and the public at large.*" [Gallaher, M.P. et al (2004)]

With the objective to promote interoperability at industrial automation systems for process plants, the ISO 15926 standard is designed to facilitate the integration of data to support the life-cycle activities and processes of production facilities.

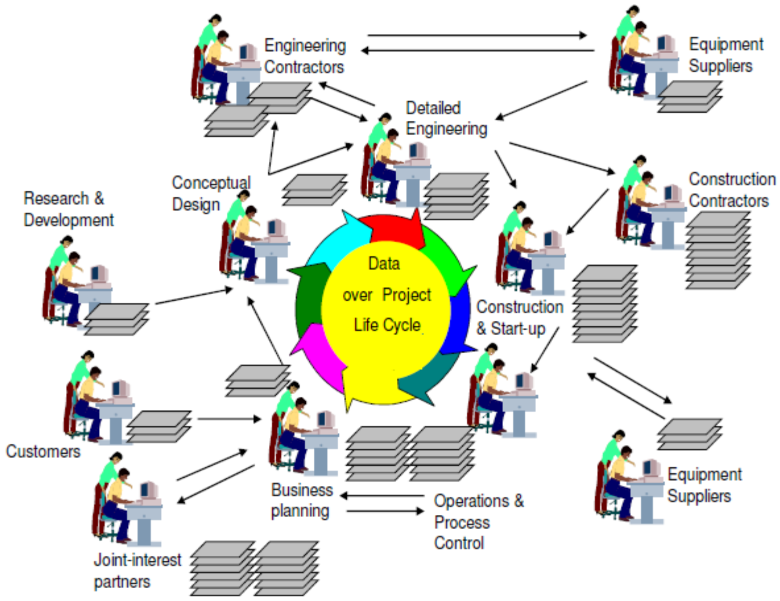

Figure1. Data over Project Life Cycle - Modified from [Pawsey:2010]

The ISO 15926 standard is concerned with the storage of information, constructing knowledge bases for integration of life-cycle data for process plants including oil and gas production facilities [ISO 15926-1:2004]. These knowledge bases are modeled with structures in "First-Order Logic" and implemented based on an ontology approach to information, consistent with the W3C Web Ontology Language (OWL) [OWL:2004].

The OWL standard is used to represent common industry terms, that are mapped to the ontology with classes and relations [Batres, R.et al (2007)]. These terms are modeled using the data model [ISO 15926-2:2003] and the initial reference data [ISO 15926-4:2007] which are shared databases or data warehouses used to describe industrial project lifecycle concepts. The ISO15926 standard consists of several parts. Some of them are published, as parts 1, 2, 3 and 4 [ISO 15926-1:2004] [ISO 15926-2:2003] [ISO 15926-3:2007] [ISO 15926-4:2007], and the new ones are under development or will be developed in the future.

There are different challenges to establish methodologies to model the ontology. One of them relates to the complexity of modelling the concepts. To minimize this issue, the standard proposes the use of templates (ISO15926 - Part 7), a set of first order logic axioms that relate instances of ISO15926- Part 2 entities to represent information. One advantage of this approach is the possibility to specialize the model to accommodate any field of knowledge related to Engineering. One such field of knowledge is geometry, relevant for all digital Engineering schematic, 3D model, datasheet etc.

Modern day Engineers working on Capital projects always use Computer-Aided Design and Drafting systems (CADD), which, for representing 3D and 2D schematics, ultimately use geometric objects (or primitives), such as: ellipses, polylines etc. Therefore, to interoperate geometry related information, a standard is required for the structured data that describes the geometric objects. This is precisely what is offered by the ISO 15926 - Part3 [ISO 15926-3:2007], which defines the catalog of geometry and topology terms.

According to ISO15926 - Part3, it is necessary to model the geometric objects following the ISO15926 - Part2 and ISO15926 - Part4. There are some repositories [DNV] [RDS/WIP: 2008] that show the ontology and the connections between the classes and relationships to model the concepts(a class of information is defined by common properties).

Due to the structure and the large number of terms defined in ISO 15926 it’s difficult to model a concept without a methodology and one example of how to do it.This work presents a methodology to model geometric objects of the standard ISO 15926.

The next section has a brief introduction to the standard ISO15926. Section 3 will present the methodology to model the geometry concepts and properties through a diagram language. The conclusion and future works are the last section.

2. ISO15926

The ISO 15926 standard— Industrial automation systems and integration, integration of life-cycle data for process plants including oil and gas production facilities [ISO 15926-1:2004] — consists of several parts. Some of them are published, like parts 1,2,3 and 4 [ISO 15926-1:2004][ISO 15926-2:2003][ISO 15926-3:2007][ISO 15926-4:2007]. At the time of this publication, parts 7 and 8 of ISO15926 had been submitted to the ISO standard approval process, under TC184/SC 4.

What follows are brief introductions to the ISO 15926 parts:

- Part 1 - Overview and fundamental principles [ISO 15926-1:2004] - This document specifies a representation of information associated with engineering, construction and operation of process plants. This representation supports the information requirements of the process industries in all phases of an industrial plant's life-cycle and the sharing and integration of information amongst all parties involved in the plant's life cycle.

- Part 2 - Data Model [ISO 15926-2:2003] - It describes the entities used by the standard to represent the process plant life-cycle information (changes over time of functional requirements, physical components, object types and objects as well as individual activities). It organizes and describes the meaning of information. The data model is designed to be used in conjunction with reference data [ISO 15926-4:2007]: default instances that represent information common to users and process plants.

- Part 3 - Geometry and Topology [ISO 15926-3:2007] - This part defines objects in the reference to data library for geometry and topology, for example: topological relationships between vertices, edges, faces, and volumes; points and directions in space and their definition with respect to Cartesian or non-Cartesian coordinate systems; classes of curve, classes of surface, classes of solid, and the properties necessary to define them; etc.

It is based on ISO 10303[ISO 10303-1:1994] and the dictionary of standard shapes are extracted from the ISO 10303-42[ISO 10303-42:2003] and ISO 10303-104[ISO 10303-104:2000].

- Part 4 - Reference Data Library [ISO 15926-4:2007] - The support for a specific life cycle of an activity depends on the use of appropriate reference data based on the data model [ISO 15926-2:2003]. The Reference Data Library stores information about physical objects, activities, properties and other reference data necessary to include all information concerning a process plant, for example: Valves, Pumps and characteristics of the objects and processes; etc.

- Part 6 - The Part 6 defines a methodology for development and validation of reference data.

- Part 7 - Templates Implementation methods for the integration of distributed systems
A template is seen as a data schema and the part 7 describes a catalog of templates and defines an implementation-independent template methodology for definition, verification, expansion of templates, as well as presenting an initial set of templates to allow the use of the conceptual model ISO15926- part2. The definition of a template consists of the definition of the signature and axioms in first-order logic; the verification and expansion are done with software Template Expander [EXPANDER]. It will be used to hide the modelling complexity of concepts using concepts of the ISO 15926 part 2 and part 4. - Part 8 - Implementation methods for the integration of distributed systems - OWL implementation - This part defines the specification for data exchange and lifecycle information integration using RDF and OWL to describe the templates of part 7.

The other parts - ISO15926 parts 9, 10, 11 - are open to research; there are concentrate efforts from industry and academies to accelerating the standardization activities and basic software tools [IRING].

3. TO MODEL GEOMETRIC OBJECTS

The objective of ISO15926 - Part3 is to define a standard of how to represent the geometry and topology of the manufactured and geological objects of an industrial process. This definition followed the standard ISO [ISO 15926-1:2004][ISO 10303-1:1994][ISO 10303-42:2003][ISO 10303-104:2000].

According to ISO15926, the geometric objects and properties must be modelled using **Templates** (ISO15926 - Part7, 4.2). They are defined by decompositions of terms into simpler ones, in finite steps, until they are reduced to basic (or primitive) geometric terms. These basic terms (CoreTemplates) must be ISO15926 - Part2 compliant. This characteristic ensures data integration, portability and interoperability.

Due to the structure and the large number of terms defined at the ISO 15926 standard it's hard to model and to visualize the modeling process. This section discuss a methodology to model geometry concepts and properties of the ISO 15926 standard generating a model through a diagram language proposed in ISO15926 - Part2.

The methodology will show how to find the parts of the decomposition of the geometry elements and how to use the relations through diagrams, defined at ISO15926 - Part2. This process turns explicit implicit information of the model and it will help to visualize the relationship between concepts and properties making easier further implementation.

The documents ISO15926 Part 2, Part 3, Part 4 and Part 7 are the basic references that will assist the decisions during the modeling process.

The modeling process is exemplified through case studying one geometric object: a circle.

Remarks: This formalization expands all the templates, so it is modelled using just the ISO15926 - Part2.

3.1. Notation

1- The diagrams used are presented at the ISO15926 - Part2 (Figure 2).

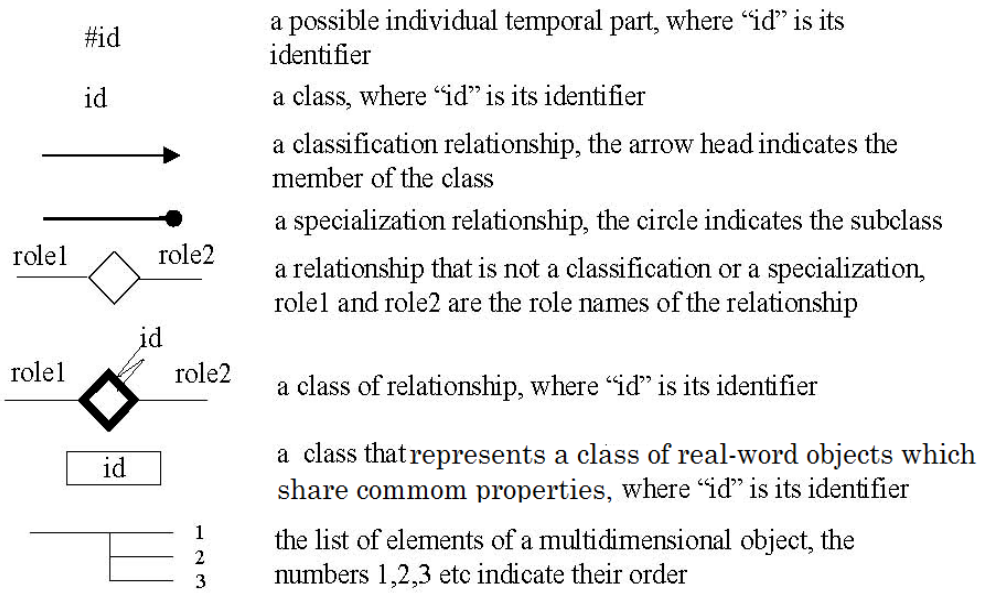

Figure 2. Diagram Language- Modified from [ISO 15926-2:2003]

3.2. Subclass Relation

At ISO 15926, a class has one of the basic principles of set theory: the subclass relation, a class (subclass) contained in some other class (superclass) in the same way that a subset is a set contained in some other set. Following the subclass relation, the members of a subclass are members of the superclass, so the subclass inherits the superclass rules.

In the context of the ISO 15926, the subclass relation is divided in two types: specialization and classification depending of some properties.

3.2.1 Classification

Classification is a type of superclass relation that describes the behavior inherited by the subclass, this relation can be understood as membership. The behavior is formalized by rules, at this relation the subclasses have inherited the rules of the superclass, but may have other rules. When classification refers to a class as the member, the members of the member class are not necessarily members of the classifying class. So this relation is not transitive.

EXAMPLE 1[ISO 15926-2:2003] the figure below shows a category of things known as 'Pump' which is a class. #1234 is an *arranged_individual* that enables pumping activity. The *arranged_individual* referred to as #1234 is a 'Pump'. The relationship that indicates that #1234 is a member of 'Pump' is a classification. So in the case of the 'Pump' class, membership of it is not affected by the type of the *arranged_individual*, (which can be a *whole_life_individual* or a temporal part of a *whole_life_individual).*

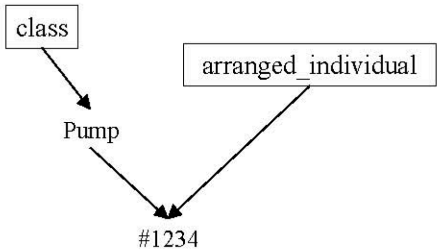

Figure 3. Classification of Pump [ISO 15926-2:2003]

3.2.2 Specialization

Specialization is a type of relationship between two classes indicating the members of the subclass are members of the superclass. It is a transitive relationship, so the members of a subclass of a subclass are members of the most general superclass.

EXAMPLE [ISO 15926-2:2003]- The figure above shows that a manufacturer's 'model 106' is a *class* that is a specialization of the "pump" class – all members of 'model 106' are also members of 'pump'. Types 'A' and 'B' are both specializations of 'model 106'. A member of type 'A' is a member of 'model 106' and a member of 'pump'.

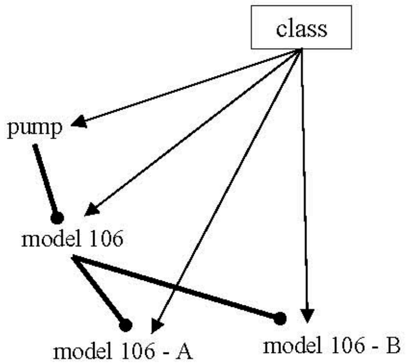

Figure 4. Transitive specialization [ISO 15926-2:2003]

3.3. Methodology

During the modeling process of concepts is essential to access the ISO15926 repositories that contain the ontology: classes and relationships described at ISO15926 - Part 2 and ISO15926 - Part 4 of the standard [DNV] [RDS/WIP: 2008].

The modeling process is performed on two levels. Formerly is necessary to read ISO15926 – Part 3 to understand the definition of the geometric concepts presented at the template signature of the modeled object following the ISO15926 – Part 7. The second step - with the entities presented at ISO15926 – Part 2 and ISO15926 – Part 4 and the templates defined in ISO15926 – Part 7 - is to define the internal structure to represent geometry object, where the relationships and implicit entities are set.

The template signatures of geometric objects are being discussed at Geometry Special Interest Group [SIG: 2010]. The example below presents some of the proposed signature templates for the *circle* and the concepts necessary to the circle´s model.

3.3.1. Step 1: Understanding the Template Signature

A template in ISO15926 - Part7 is used to represent and store data by expressions of predefined units of semantics allowing the use of the model in a convenient way. A template signature may be seen as a representation of the full template definition and it shall be specified as an ordered list of template roles (Named and numbered argument in a template with required type given as entity type, data type, or reference data class. **Entity type** is class of real word objects which share common properties. **Data type** is a domain of values. **Reference Data** is a process plant life-cycle data that represents information about classes or individuals which are common to many process plants or of interest to many users). For each role the following shall be given:

a) A role name. Role names are required to be unique within a signature;

b) A type constraint for individuals filling the role, given as an entity type, RDL class or data type.

Example of template signature: The *circle* is composed by the templates **Radius** and **ReferencePointAndDirection**

Templates signature

Template name: Radius (A, B). It means that B is a Metric_Space_Length (Real Number) and B refers to A.

Order	Role name	Role type
1	hasObject	OBJECT_WITH_RADIUS
2	hasRadius	METRIC_SPACE_LENGTH

Template name: ReferencePointAndDirection (A, B, C). It means that B is a Metric_Space_Point (Coordinate System), C is a Direction(Coordinate System). B and C refers to A.

Order	Role name	Role type
1	hasObject	OBJECT_WITH_AXIAL_REFERENCE_PLACEMENT
2	hasReferencePoint	METRIC_SPACE_POINT
3	hasReferenceDirection	DIRECTION

3.3.2. Step 2: Modeling Internal Structure

The template signature may be seen as a representation of the full template definition for which relations between the roles are not included. So, it shall define these relations to model the templates of the geometry objects using the Reference Data Library.

At this step, it is necessary to examine the classification of the concepts at the ontology trying to recognize the relation to be used to connect them, according to desired semantics. This information will be extracted from the Reference Data Library repositories [DNV] [RDS/WIP:2008].

Here it will be showed how to examine the template signature using as an example the template signature of ***Radius*** (section 3.3.1).

The template **Radius** means that a *Metric_Space_Length* refers to an *Object_with_radius*. In this template the *Metric_Space_Length* represents a length and by ISO15926–Part 3 it can be a *Real Number*. A *length* is a *Property* and by ISO15926–Part 7 a *Property* is connected by the entity *PropertyQuantification* with a *Real Number* and a *Property* using the relation *hasResult* and *hasInput* respectively. **Figure 5** shows the specialization of *length* to a *radius*, this was done to specify the type of *length*. To satisfy the semantic of template **Radius**, the relation between the *Metric_Space_Length* and *Object_with_radius* must be implied. This is done by the relation G*eometryRadius*, which is a classification of *other_relationship.* and *axial_reference_placement*. By the ISO15926–Part 7 an entity *other_relationship* connects anything with the relations *hasEnd1* and *hasEnd2*. (Figure 5).

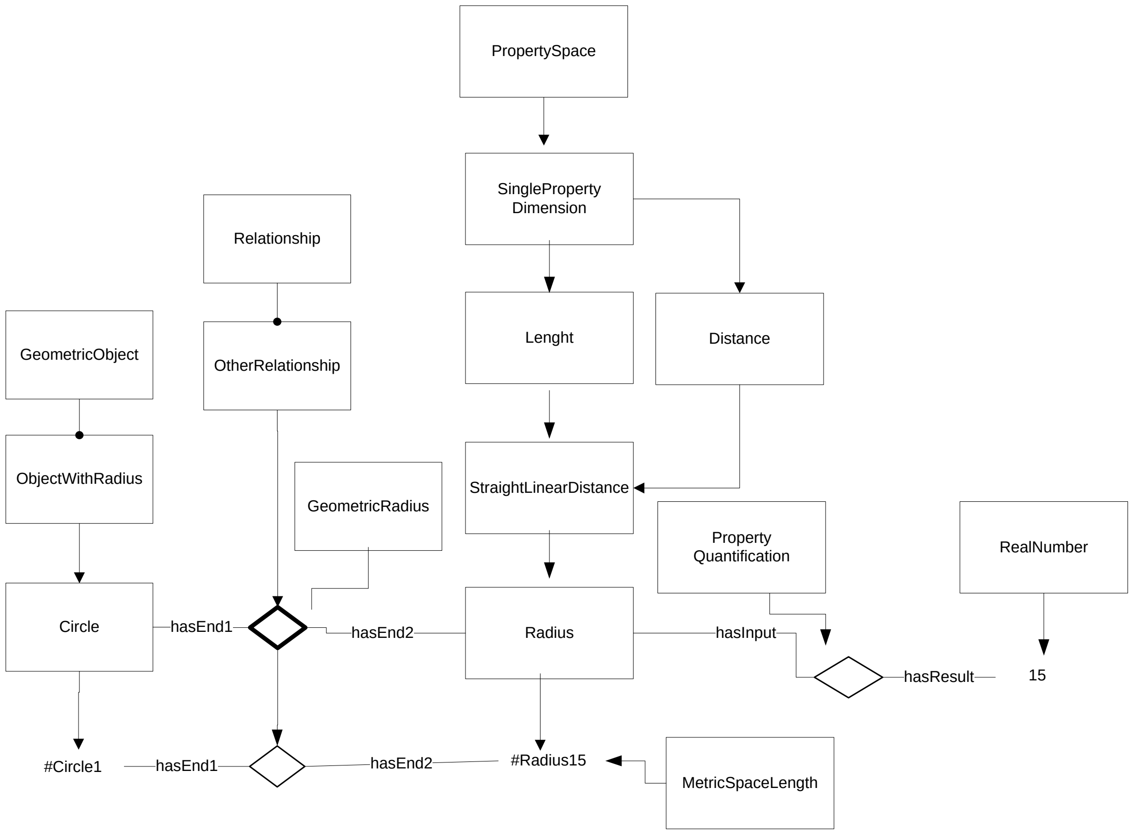

Figure5. Model of the template Radius to the circle

To model the template **ReferencePointAndDirection,** it's roles must also be modelled. Since the modeling process of the *MetricSpacePoint* role is similar to the role *Direction*, Figure 6 and 7 shows the an incomplete model the template **ReferencePointAndDirection** containing only the modeling of the *Direction* role.

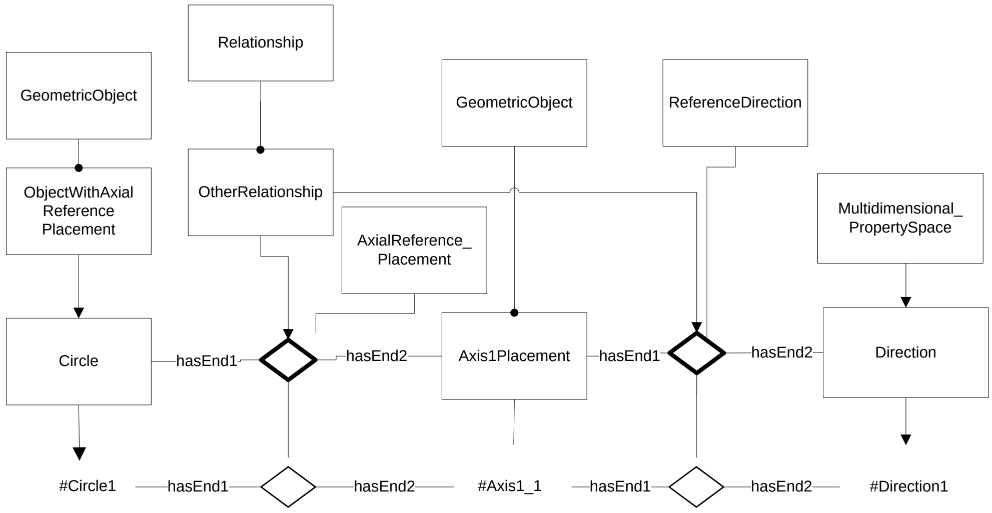

Figure 6. Model of part of the template ReferencePointAndDirection- Part 1

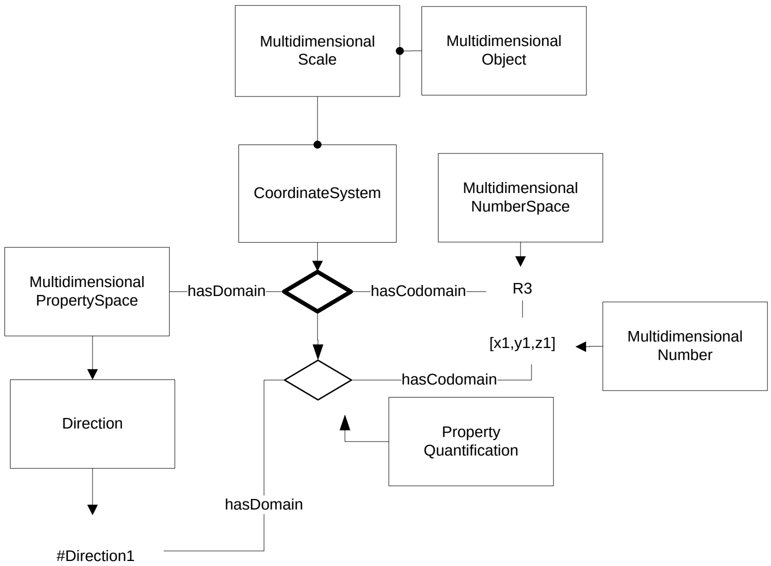

Figure 7. Model of part of the template ReferencePointAndDirection- Part2(The connection with the Figure 6 is done through the entity **direction**)

4. CONCLUSION

The ISO 15926 proposes a standard for integration and interoperability of data between computer systems. The effort in the development and application of the ISO15926 standard contributed to create a new paradigm of information management at the Oil e Gas industry, that will reduce the costs in this area[Gallaher, M.P. et al (2004)]. It is the first step toward a new paradigm that will expand to other industries such as automotive, aerospace, naval etc. For the development of computer systems that are compliant with the standard across the industry, it shall know how to define, to manage, to extend the information models to store the data in a neutral format.

There are many documents about the ISO 15926 standard, but is difficult to organize the knowledge and to understand how to model the concepts without a methodology. This creates barriers for the deployment of the standard. Collaborating on this challenge, this work defines a methodology to model concepts of the standard ISO15926 – Part 3 [ISO 15926-3:2007] from the template signature. With the methodology proposed here, the relations between the roles of the template signature can be understood. It is the first step for the construction of a tool that, from the template signatures, will be able to suggest a model using to ISO15926 – Part 2 as well as other templates.

In future works, the main objective is to develop the standard researching subjects as:

- Implementation of tools to help domain experts use the ISO15926 standard, i.e. software to model and verify ISO15926 templates, as well as an environment to create and to manage distributed data bases built upon the ISO15926 proposed paradigm, building on the accumulated experience of the iRING User Group, etc.

- Implementation of the models using Web Ontology Language using the ISO15926 - Part 8, envolving studies correlated with present day ontology challenges such as: how to store the ontology, how to manage the RDF triple store, how to make an efficient query across distributed RDF databases on the web.

- Design of an architecture to support format neutral exchange of 2D and 3D documents, based on SPARQL Endpoints providing federated management of process plant item symbology and Engineering document templates.

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