CONCEPTUAL MODEL FOR THE INTEGRATION OF PRONTO WITH ISO STANDARD 15926

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ABSTRACT: In this paper a conceptual model based on the ISO 15926 standard is proposed in order to extend and make explicit the representation of product variants given by PRONTO. This extension will allow introducing the product model in a collaborative environment where information systems are able to exchange information with other products systems. Interoperability of systems tends to increase the consistency of models, due to they may have several interpretations. Therefore, the proposal defines new elements and adapts these to the data model of the standard, for a complete concept mapping of PRONTO. Furthermore, changes in the product information are represented in time, through 4D approach.

Keywords: Interoperability. ISO 15926 Standard. Products Family. PRONTO. Semantic Web.

1   INTRODUCTION

The increase in demand for new products, the customer needs for a wider variety of items, the globalization of markets, the reduction of products lifecycle time, the need of increasing flexibility, the ability to response to the market changes, and the information technology improvement are the main challenges of companies that are involved in the product development process. The success of global manufacturing companies depends on the integration of their product development process and their manufacturing operations, which

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are geographically distributed. This integration can be achieved by means of a manufacturing collaborative environment (VALILAI; HOUSHMAND, 2013).

In manufacturing collaborative environments, the PLM (Product Lifecycle Management) systems are considered as information backbone of companies. PLM is the global term representing the management of product information throughout its life cycle (GOPSILL; MCAPLINE; HICKS, 2011). The various actors, consumers and/or producers of data from these systems require different views of the information because the type of information and the level of detail that is required by these actors are different. Thus, to achieve the implementation of these manufacturing environments, the corporate knowledge of different actors and several heterogeneous sources has to be unified (GRAUBE et al., 2011).

This unification requires a common model that enables the interoperability between different information systems involved during the product lifecycle management. This model, unlike the existing product models, hast to take into account the existence of multiple variants and versions for efficient product information management to enable rapid response to market changes.

In this sense, there are several proposals for representing and exchanging product data among different systems. The ISO 10303 (STEP - Standard for Exchange of Product model data) standard (STEP, 1991) is one of the most widely used. However, the application of this standard has encountered several difficulties (VALILAI; HOUSHMAND, 2013; LEE; EASTMAN; SACKS, 2007; BALL; DING; PATEL, 2008; GIELINGH, 2008). STEP represents product variants as different products with the consequent data duplication. On the other hand, it captures the information of products as a snapshot in time and lacks the ability to represent the products evolution over time.

These problems of STEP influenced the motivation for defining the ISO 15926 Part 2 standard. This standard describes a generic data model which allows the representation of product information at different abstraction levels. Moreover, it enables the representation of both the functional (abstract) and physical aspects of products.

Even though ISO 15926 has been defined for gas and oil production plants, due to its generality and extensibility capacity it has become a widely accepted standard in different industrial domains. It was designed keeping in mind a 4-dimensional vision of the data (4D approach). This approach allows representing product data evolution over time. However, this standard does not explicit how the product variants are specified.

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This paper proposes extend the ISO 15926 standard in order to make explicit the representation of product variants through the concepts proposed by PRONTO (PRoduct ONTOlogy) (VEGETTI; LEONE; HENNING, 2011). The mentioned ontology modifies the two-level product family concept (Family – Product) by the addition of a new level between them. This three level family concept (Family – VariantSet – Product) allows representing product information at different abstraction levels and it enables the definition of processes of information aggregation and disaggregation between them, This feature is important for production planning activities at different levels (strategic, tactical and operational).

This article is organized as follows. Section 2 introduces briefly the fundamental concepts of ISO 15926 standard and PRONTO ontology. The details of the proposed mapping are presented in Section 3 and its application into a case study is illustrated in Section 4. Finally, the conclusions and future work are drawn in Section 5.

2   RELATED WORK

Having in mind that the adoption of a neutral model contributes to the exchange of data in industrial plants, several standards focused on product data representation were proposed. One of these standards is ISO 15926 standard, which is widely accepted due to its generic data model. This generic data model is capable of representing product information in different domains. These specific product domain models are then implemented through repository-based web services and Semantic web technologies. Likewise, PRONTO is selected due to its capability of representing product variant in a consistently way. Both proposals are briefly introduced in this section.

PRONTO allows representing product data at different levels of abstraction. It defines two hierarchies, an abstraction (AH) and a structural (SH) ones. The first hierarchy allows the representation of non-structural product information at different abstraction levels as well as the definition of aggregation and disaggregation processes between these levels. The SH allows representing the information of products and the components required to manufacture them. PRONTO formalizes a knowledge representation that integrates the SH and AH hierarchies, emphasizing the treatment of structural information. As it is shown in Figure 1, the AH contains 3 levels:

- Family: Highest level of abstraction that represents a set of similar products that share one or more common structures.

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- VariantSet: Intermediate level that represents a subset of family members, which share the same structure. These members may include changes on the structure of the family from which they belong.

- Product: Lower level of abstraction to represents individual items, which are members of a set of variants. They have a structure and represent products whit real existence.

Figure 1 – PRONTO main concepts
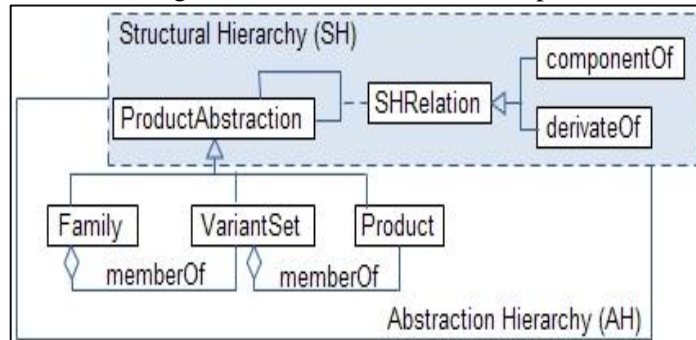
The *memberOf* association links these three levels and represents the membership relation between individuals that are defined at a lower level with an individual at the immediate upper level. The SH considers two types of structural relationship which are specialized as *componentOf* and *derivateOf*. The first one is used for structures that relate a product with the parts required to manufacture it. The second association links a product with the parts that are obtained from it by a disaggregation process. So, an entity may be related to other entities (components or derivatives) at the same level of abstraction. The SH relations allow the definition of different types of bills of materials (BOMs) for products that are made by assembling their component parts as well as by the disaggregation of non-atomic raw materials. In order to have an easier understanding of the proposal and narrow the scope of this article, it focuses only on the *componentOf* relationship.

In order to exemplify the two PRONTO hierarchies, a simple case study related with the assembly of DELL computer parts is considered. At the highest level of the AH the *DELL Laptop Family* is defined. This family has the following variant sets as members: *DELL Inspiron 14z*, *Dell Inspiron 1545* and *DELL Inspiron M5030*. For space reasons, this example is focused only on the first variant set. *DELL Inspiron 14z* has concrete products as members, like *DELL Inspiron 14z 2100-SLV*.

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As it is previously mentioned, the SH of a specific product specifies the components part required to manufacture it and it is defined at each level of the AH. At the highest AH level, the SH of *DELL Laptop Family* involves the mentioned family and its component: Memory, Hard Drive and Processor families. At the middle level, the *DELL Inspiron 14z* variant set is composed of *DDR3*, *SATA HD* and *Dual Core* variant sets, which are members of Memory, Hard Drive and Processor families respectively. In turn, the SH corresponding to *DELL Inspiron 14z 2100SLV* product is conform by *6 Gb DDR3 1600MHz*, *500GB SATA HD*, and *Intel Core i3 1.9GHz*, products which are members of the mentioned variant sets. More details about the mentioned example could be found in Section 4.

In turn, the ISO 15926 standard provides a neutral format to unify independent data formats for information systems interoperability in industries. It is organized into several parts, many of which are still under evaluation. This work pays special attention to the data model included in ISO 15926 Part 2. This data model will be extended in order to represent the AH and SH hierarchies aforementioned. ISO 15926 Part 4 creates a reference data library (RDL-Reference Data Library) from Part 2 data model. This library organizes all the elements defined in tabular form with a unique identification number, a name in English or Russian, a brief description, the entity type from which the element is instance of, and some additional data (ISO/TS 15926-4, 2012).

Table 1 – Main entities types of the data model of ISO 15926 standard

Thing: It is anything that is or may be thought about or perceived, including material and non-material objects, ideas, and actions.	**functional_physical_object**: it is a *physical_object* that has functional, rather than material, continuity as its basis for identity.
class_of_class_of_individual: It is a class_of_class whose members are instance of *class_of_individual*.	**physical_object:** It is a *possible_individual* that is a distribution of matter, energy or both.
class_of_class_of_composition: it indicates that its members are instance of *class_of_composition_of_ individual*.	**materialized_physical_object:** it is a *physical_object* that has matter and/or energy continuity as it bases for identify.
Beginning / ending: It is a *temporal_bounding* that marks the temporal start/end of a *possible_individual*	**class_of_relationship**: it is a class_of_abstract_object whose members are members of *relationship*.
class_of_composition_of_individual: It is a class_of_relationship whose members are instance of *composition_of_individual*.	**event:** it is a *possible_individual* that indicate a temporal boundary between one or two possi*ble _individual*.
possible_individual: It is a *thing* that exists in space and time.	**temporal_bounding**: It indicates that an *event* is a temporal bound.
composition_of_individual: it indicates that a *possible_individual* is part of *possible_individual*.	**class_of_individual**: It is a class whose members are instance of *possible_individual*

There are diverse RDLs that cover different areas of definition. Due to their size have been increased over time causing difficulties to read the tables, a set of templates have been

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developed in Part 7 of the standard. These templates have the aim of creating a common neutral framework for exchange information among systems. Thus, using these templates, information from different sources is mapped to this common structure to reach interoperability.

The use of templates ensures that the entities and relationships used in the RDL have a precise meaning, which facilitates the reusability and interoperability among information systems (JOHAN; KLÜWER; SKJÆVELAND, 2008). Templates are required for the implementation of Part 8 of the standard, which allows mapping the content of templates into OWL (Ontology Web Language) statements. Currently there are about 240 templates defined and categorized (LIST OF TEMPLATES, 2013), many of which are being evaluated. Some basics concepts were shown and briefly described in Table 1. These concepts are also presented in Figure 2 and they are mentioned in the following sections.

Figure 2 – Representation of abstraction levels whit ISO 15926 Parte 2
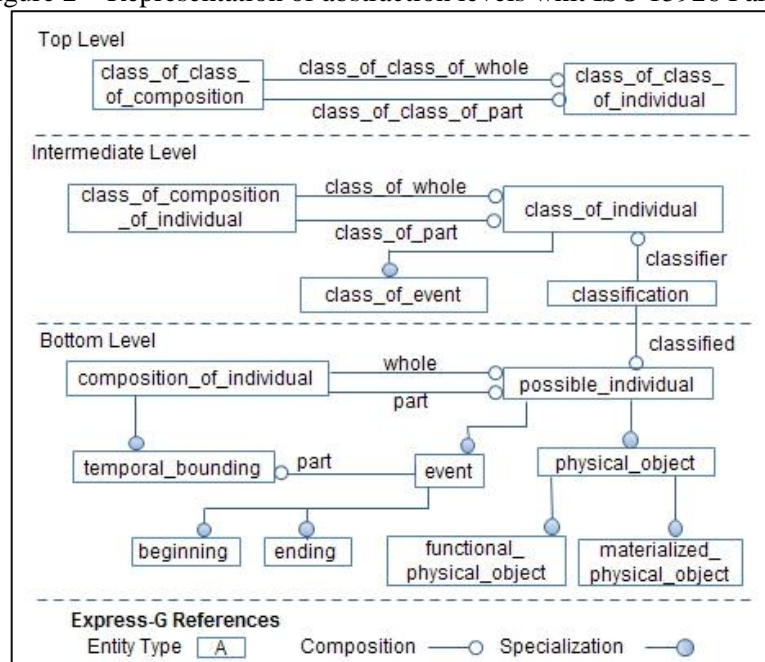
The proposed concepts in the ISO 15926 data model allow defining 3 information abstraction levels: Top, Bottom, and Intermediate. The highest level ("Top Level"), which is represented by *class_of_class_of_individuals* entity type, relates to other entities in the same level through the composition relationship called *class_of_class_of_composition*. In this relation, an entity plays the role of compound object or container (*class_of_class_of_whole*) and the other entity plays the role of a component or part (*class_of_class_of_part*).

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To represent an intermediate level of abstraction ("*Intermediate Level*") the data model provides the *class_of_individual* entity type. This type relates to others entities at the same level using the *class_of_composition_of_individual* composition relationship in which the participants play the role of *class_of_part* and *class_of_whole* respectively. The lowest abstraction level ("Bottom Level") is represented by the *possible_individual* entity type which can represents both physical objects (*physical_object*) as well as events (*event)*. The composition association at this level is defined by *composition_of_individual* entity type. The entity types that participate in this relation play the roles of whole and part, respectively.

As it is shown in Figure 2, the *classification* entity type allows connecting a *possible_individual* at the lowest level with its class (*class_of_individual*) at the intermediate level. In this relationship the mentioned entities types play the roles of classified and classifier, respectively.

In addition, the standard introduces the 4D spatial-temporal approach for the definition of physical objects. According to this approach, each *physical_object* has two parts, one temporal and one spatial. For the representation of these parts, the approach introduces two entity types: *functional_physical_object* and *materialized_physical_object*. The first entity type expresses the function that a physical object has to execute. The second one indicates that the physical object is playing some specific role in a given period. The length of this period is defined by the occurrence of events that indicate the beginning ("beginning") or the end ("ending") of the object on the temporal path.
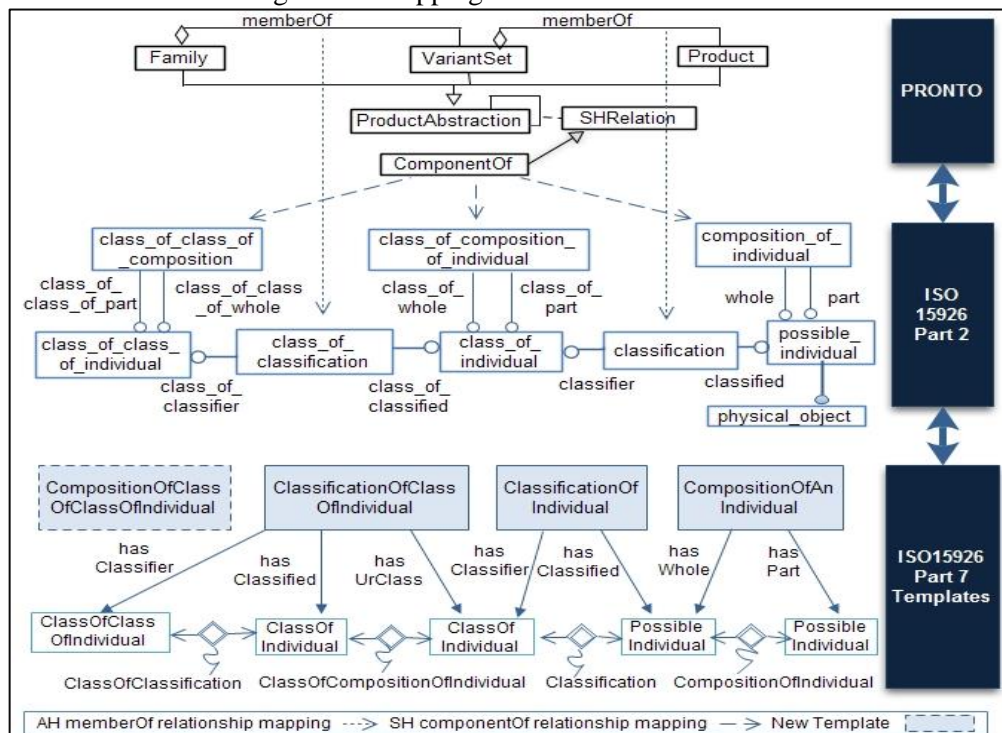
3   MAPPING PRONTO TO ISO 15926 STANDARD

The three levels of product definition given by PRONTO were represented using different levels of abstraction available in the standard data model. The type of *class_of_class_of_individual* entity, which is defined at the highest level of abstraction in the ISO 15926 standard, represents the concept of family as is specified in the ontology. Similarly, *class_of_individual* and *physical_object* represents Variant Set and Product concepts, respectively. The composition relations between entities of the same level, which are called *class_of_class_of_composition*, *class_of_composition_of_individual*, and *composition_of_individual* allow representing the SH *componentOf* association in each level of PRONTO abstraction hierarchy.

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For the representation of the AH *memberOf* relationship the proposal suggests to use the *classification* entity type that links the product level playing the role of *classified*, with Variant Set level having the *classifier* role. The standard does not include an entity type that links the upper level, which represents the family, with the intermediate level representing the variant set concept. This is because generally, in other proposals for implementing the product family concept only two levels (the family and its members) are considers, unlike PRONTO which establishes 3 abstraction levels. In order to represent the *memberOf* relationship between the two upper levels, the definition of a new entity type called *class_of_classification* is proposed.

The entity type *class_of_classification* is subclass of *class_of_relationship* and superclass of *classification* (see Figure 3). Both *class_of_relationship* and *classification* are basic entities types of the ISO 15926-2 data model (see Table 1). The entity type *class_of_classification* sets that *class_of_individual,* with *class_of_classified* role, is a member of *class_of_class_of_individual* having the *class_of_classifier* role. Thus, the *VariantSet* level is linked to the Family one reaching the binding of the 3 levels proposed by PRONTO. Therefore, a complete representation of PRONTO AH and SH hierarchies is achieved. Figure 3 shows the proposed new elements and the corresponding mapping between PRONTO model and the data model of Part 2 of the standard.

Figure 3 – Mapping PRONTO to ISO 15926

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To simplify the understanding of the mapped data model three templates, which are defined in Part 7 of the standard, are considered. These templates allow representing the product information as shown in Figure 3. Each template has a name, a specification in first-order logic and the URI (Unified Resource Identifier) of each element that composes it. The template *CompositionOfAnIndividual* allows representing *componetOf* relationship at Product level. In turn, the template *ClassificationOf-ClassOfIndividual* is proposed to represent the same relation at the Variant Set level and *memberOf* relationship between this intermediate level and the Family level.

ClassificationOfIndividual template enables the representation of *memberOf* association between the lowest and intermediate levels. Finally, to complete the representation of the relationships of both PRONTO hierarchies, the definition of a new template is proposed with the name *CompositionOfClassOfClassOfIndividual* to specify the *componentOf* relation at the highest level. The definition of this new template has been necessary to maintain the representation of the three different levels. In Table 2 the relevant aspects of the specification of the template are shown using the format published in the web site POSC Caesar Association (BATRES et al., 2007) for templates specification.

Table 2 – *CompositionOfClassOfClassOfIndividual* template specification

TEMPLATES NAME
CompositionOfClassOfClassOfIndividual
DESCRIPTION
Composition Relationship of Class_Of_Class_Of_Individual
LIFTED AND LOWERED GRAPH
SPECIFICATION IN FIRST-ORDER LOGIC
CompositionOfClassOfClassOfIndividual(x1,x2)<--> ClassOfClassOfIndividual(x1)& ClassOfClassOfIndividual(x2)

At Product level, objects can have functional continuity rather than material one, and their components can be replaceable parts (*materialized_physical_object*) without affecting the function of the whole object (*functional_physical_object*). This situation may be represented by the 4D approach proposed by ISO 15926. The 4D approach applies only at the

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lowest level of definition of information products, because of their physical existence. However, in section 4 the mentioned approach will be adapted to be used at the higher abstract levels. The modification proposed in the mentioned section suggests the use of overlapping layers reflecting product versions at different levels. The representation of versions may affect the consistency of PRONTO model. Therefore, it is necessary the definition of a mechanism for version traceability that manages versions and product history. However, for space limitation this aspect is not considered in the present work.
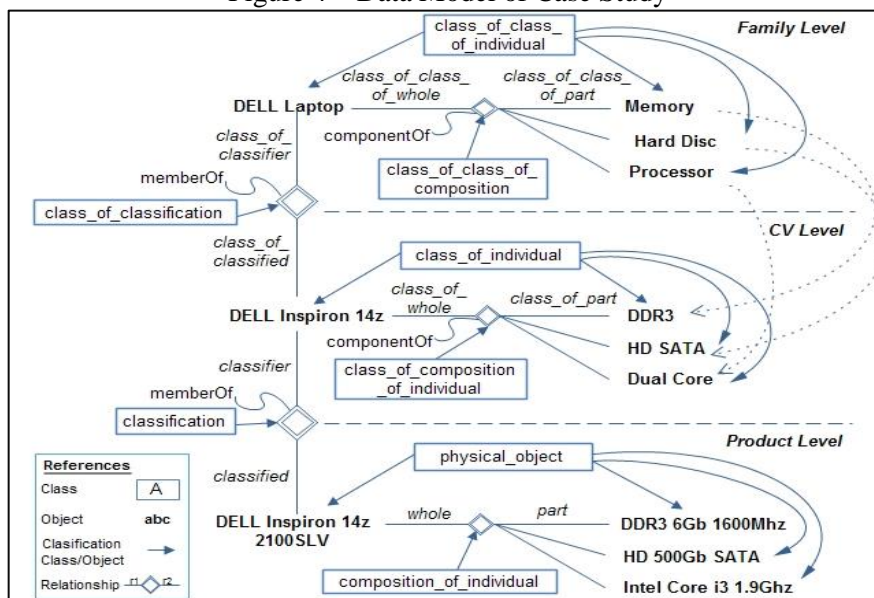
4   CASE STUDY

In this section, is describing the product representation of an organization responsible for the assembly of computer parts. Figure 4 shows part of the family DELL Laptop abstract hierarchy. This hierarchy binds through the *memberOf* relation the mentioned family with its DELL Inspiron 14z Variants Set (CV). DELL Inspiron 14z Variants Set has a DELL Inspiron 14z 2100SLV Product as its member. The *componentOf* relationship states that the DELL Laptop family structure includes Memory, Hard Drive and Processor families. Similarly, the SH of DELL Inspiron 14z CV contains others variants sets as: DDR3, SATA HD and Dual Core.

Each CV is linked with a family at top level and with at least one product at lower level, conforming the AH (show in Figure 4 by the dotted arrows). The hierarchy abstraction relationships with the lower level are not shown to maintain the clarity of Figure 4, but these relationships are similar to the top level explained. The Level Product (see Fig. 4) shows the SH of DELL Inspiron 14z 2100sLV product is shown.

Each element mentioned in the previous paragraphs are instances of entity types of the data model proposed in the ISO 15926 (ISO 15926, 2013; TEMPLATE SPECIFICATION, 2013) Part 2 standard. Thus, each family is instance of the *class_of_class_of_individual* entity type and can have a structure composed by other families or not (i.e. *Dell Laptop*).

In the first case, a composition structure has the *class_of_class_of_composition* relationship to link the *DELL Laptop* family, which is instance of *class_of_class_of_whole,* with its parts that are instances of *class_of_class_of_part.* Each family has a CV associated by *memberOf* relationship, which is an instance of the *class_of_classification* entity type proposed in the previous section. In this relationship, the family *DELL Laptop* plays the role of *class_of_classifier* and *DELL Inspiron 14z* CV plays the role of *class_of_classified*.

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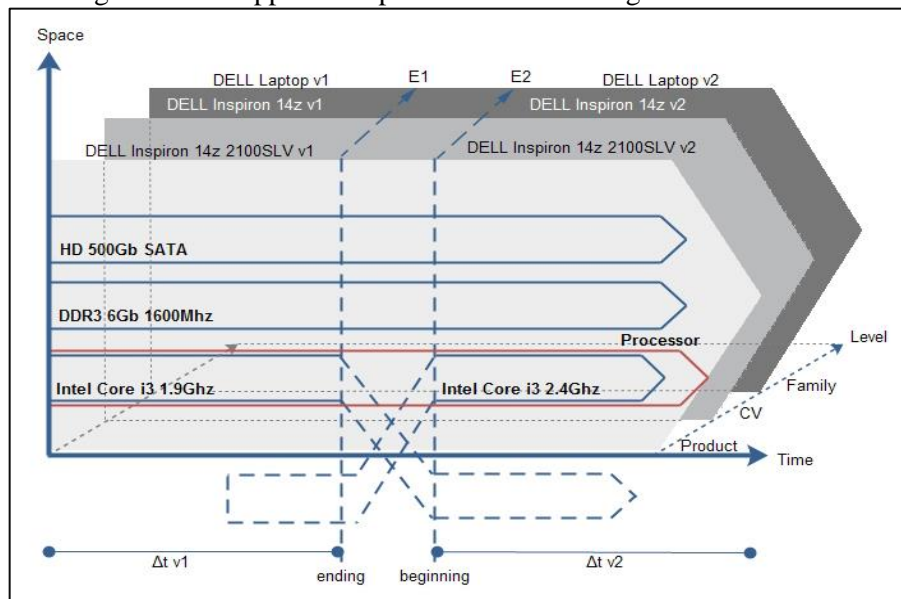
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Figure 4 – Data Model of Case Study

At the CV level, each CV is represented as instances of *class_of_individual* and the composition relationships between entities at this level as instances of *class_of_composition_of_individual*. In this relationship the *Dell Inspiron 14z* plays the role of *class_of_whole* and the other sets shown (DDR3, SATA HD Driver and Core) play the role of *class_of_part*.

At the Product level, the products are represented as instances of *physical_object*, a *possible_individual* subclass. Each product is relates with a CV through the instantiation of the *classification* entity type, where the CV plays the role of the *classifier* and the product of *classified*. The SH relationship at Product level corresponds to an instance of the *composition_of_individual* entity type.

4D approach representation considers the occurrence of an event indicating a change in the structure information of a product. For example, the event could be an inconvenience with the import process of *Processor* component, which implies the need to replace it with another compatible model and identify the product version to facilitate the information traceability.

In Figure 5, the replacement of the 1.9 Ghz Intel Core i3 product by the 2.4Ghz Intel Core i3 product is shown. As mentioned above, the 4D approach applies to products with physical existence, represented at the Product level. However, in Figure 5 the three abstraction levels are represented by the superposition of layers incorporating an additional axis on the traditional graphic representation of the standard.

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Figure 5 – 4D approach representation including abstraction levels

During the change of products in Figure 5, the functional continuity Processor (*functional_physical_object*) is not affected, because both products develop the same function and are fully replaceable. The event E1, besides indicating the end (*ending*) of 1.9 Ghz Intel Core i3 product, shows that the product information has undergone a change ending the version 1, where Δt v1 shows its trajectory over time. The event E2 indicates the starting point (*beginning*) of the materializing (*materialized_physical_object*) of the processor function with a new product version, Intel Core i3 2.4 Ghz.

Dotted areas in Figure 5 represent the physical continuity of the product. This implies that, despite replacing the 1.9Ghz Intel Core i3 product which materializes *Processor* function in a product of Dell Laptop family, this object (Intel Core i3 1.9Ghz) can materialize the function in another products family dissimilar to this case study. This analysis can be applied on the CV level and Family level. However, the replacement of any component affects the lower-level level. This means, if the HP Dual Core CV component is replaced by another HP Quad Core CV, the Intel Core i3 1.9Ghz component, which belongs to the product level (the lowest level), will be affected due to the consistency in the AH relationship of PRONTO.

5   CONCLUSIONS AND FUTURE WORK

These days, industries recognize the importance of the integration of different information systems as a key to be inserted and compete in the global market with increasing consumer demands. Integration requires a neutral data model capable of supporting different

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data formats, specific to each industry, to achieve interoperability of their information systems. Therefore this proposal presents a mapping between the concepts of standard ISO 15926 and ontology PRONTO. This strategy seeks to integrate, through the ISO 15926 standard, the ontology PRONTO with other ontologies to facilitate information systems interoperability. The standard provides a user-oriented language to represent, assess and improve operations, but it lack of tools to represents domain models.

Moreover, the ISO 15926 standard, unlike STEP, has the advantage of having a low coupling extensible information model. The data model described in Part 2 is quite robust and allows us to represent most of the product information introduced by the ontology PRONTO. To complete this representation, it was necessary to define a new entity type and a template for the complete mapping of the two proposals (PRONTO and standard ISO 15926), because the levels of abstraction of the ontology were not fully represented in the standard.

Currently, Part 7 of ISO 15926 standard is under development and many of the proposed templates are still being evaluated. The advantage of having defined templates (in Part 8 of the standard) is that they can be transformed into statements in OWL language, with the aim of carrying out an implementation based on Semantic Web technologies.

As future work, a model to represent versions of the product information, maintaining consistency with the different levels of definition will be developed. In addition, we will work on the specification of a single template applied to a particular domain, to simplify the mapping between PRONTO and ISO15926 standard.

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