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ABSTRACT

Product ontologies in B2B relationships establish a shared and common understanding of a product domain by building hierarchies of product classes enriched by attributes. This is especially true for standardized product ontologies which enable efficient catalog navigation and product search as well as product comparison across suppliers. While much research work has been carried out on the classification process, business practice has to cope with heterogeneities regarding data exchange, formal specifications and semantic richness that hinder the proliferation of product ontologies. One solution may be the standard ISO 13584, routed in product data management. This paper aims at analyzing the potential of ISO 13584 as a reference model for product ontologies. The paper will assess its capabilities by deriving requirements. This will be complemented by an empirical analysis of a selected product ontology in order to determine both the current relevance of ISO 13584 and needs for enhancements or modifications.

Keywords

B2B, e-commerce, ontologies, standardization, XML

INTRODUCTION

Product classification in B2B e-commerce has the task to assign each product of an electronic product catalog to a class of a given product ontology. All products belonging to the same class fulfill a similar function and/or have similar attributes, thus they are similar or equivalent to each other. Classification and classified product data are a success factor in web-based procurement such as desktop purchasing systems and electronic marketplaces. Moreover, standardized product ontologies (e.g., UNSPSC, eCl@ss, EGAS, NCS, and RNTD) enable efficient catalog navigation and product search as well as qualified product comparison across suppliers, since their class definitions, hierarchies and sets of attributes are supplier-independent (Fensel, Ding, Omelayenko, Schulten, Botquin, Brown and Flett, 2001).

Classifying product data is a time-consuming and error-prone effort which requires extensive knowledge of the respective product domain. This process can be automated by adopting algorithms and tools for classification in general. The most prominent approach is the Vector Space Model (VSM) as a classic method of information retrieval (IR). Other methods are Bayesian and K-Nearest Classification. These IR methods have in common that they determine similarities between a search query – here product data – and a set of documents – here a set of classes building a hierarchy. A fundamentally different approach is schema integration which takes two product ontologies, O1 and O2, as two (database) schemas which have to be integrated by determining mappings between classes. If a product belongs to class N of ontology O1 and this class is mapped to class M of Ontology O2, then the product belongs to class M, too; thus the classification process can be automated.

While automated product classification is quite good described in theory, there are some significant problems caused by basic conditions of product data management and obstacles in exchanging product ontologies. These include different concepts for building product ontologies, a low semantic level of information describing classes and their relationships, and different vocabularies for supplier-drenched product data vs. supplier-independent class hierarchies. The last two aspects reduce the success rate of automated product classification, since information retrieval as well as schema integration are mainly based on terminological similarities rather than formalized semantics. Instead of working on better and more domain-situated classification algorithms, this paper takes a closer look at product ontologies, their structure, semantic richness and degree of standardization. The reason is that harmonized product ontologies address the data exchange issues, and more important, are able to increase the success of automated product classification.

This paper aims at analyzing the potential of ISO 13584 as a reference model for product ontologies. To do so, the paper will assess its capabilities by deriving basic requirements. This will be complemented by an empirical analysis of the structural characteristics of a selected product ontology in order to determine both the current relevance of ISO 13584 and needs for enhancements or modifications. We then go on to describe the impact of ISO 13584 and related standards on the product classification process. Finally, we will discuss related and further work.

REQUIREMENTS ON PRODUCT ONTOLOGIES

In this section we describe requirements for product ontologies, that is, their basic components, formal specifications and data exchange issues. For terminology reasons we first must distinguish the following terms:

- A *standard product ontology* is developed by an organization for a specific domain or across branches of industry. In this case, the term standard relates to the content of the ontology, meaning the hierarchy of classes and attached attributes.
- A *standardized specification* is a specification of a product ontology that adheres to a specification standard. This standard may cover the conceptual level and/or the exchange format level.
- A *standard exchange format* is a format for exchanging product ontologies and is developed by a standardization organization (consortia, associations, companies, or standardization bodies).

Data Exchange

To be able to classify a product, companies need to know the product ontology; thus the data describing the ontology must be imported into an information system, e.g., catalog management system. This role is fulfilled by the formal specification, which is a set of structured data that describes and defines the content of the product ontology. Importing a formal specification requires that this data can be exchanged between participating companies. This data exchange can be seen as part of the general catalog data exchange, but we must keep in mind that product ontology data can be exchanged independently from a specific catalog. The results of our analysis of the exchange relationships between different organizations are summarized in Figure 1, illustrating nine types of relationships.

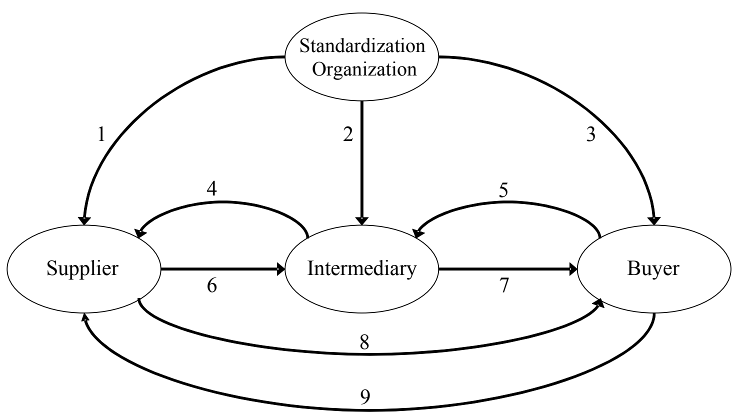

Figure 1. Exchange of Product Ontologies

We distinguish standardization organizations (provide standard product ontologies), suppliers, intermediaries, and buyers. Standardization organizations do not maintain product catalogs but develop neutral, standard product ontologies. They provide formal specifications. Companies that apply such an ontology require the specification (R1-R3). A similar picture is drawn by company-specific product ontologies, which are used by suppliers (R6 and R8) or intermediaries (R7) in their respective product catalogs. In the opposite direction, it is possible that a catalog-receiving company prescribes that all catalogs must adhere to a given product ontology, e.g., in R4 the intermediary demands that all suppliers follow the marketplace product ontology; in R5 and R9 the purchasing company makes this type of restriction on catalogs coming from intermediaries and suppliers.

The analysis shows that product ontologies and their formal specifications are subject of all organizations participating in catalog-based transactions; they are a part of product catalogs, or the exchange process is separated from catalogs. Especially in the case of standard product ontologies it is important that all market partners are able to access and process the formal specifications. From the view of organizations that develop standard product ontologies, it must be guaranteed that suppliers, intermediaries and buying companies are supplied with the specifications in a given exchange format, thus the data exchange is limited to R1-R3. In this regard, one could think that the complexity of data exchange and the number of exchange formats are already reduced by using standard product ontologies. However, business practice does not prove this.

In general, each standard product ontology uses a different exchange format. The import of these definitions calls for flexible tools for mapping data elements of the exchange format to the schema of the importing information system. Heterogeneity is not limited to the general format type such as comma separated values (CSV), Microsoft Excel spreadsheets (XLS) and Microsoft Access database files (MDB) but includes the number of data elements, their naming and relationships. Thus the schemas of product ontologies are different and must be integrated or mapped to a common schema.

Standardization in this area is two-fold: on one hand, several XML-based standard exchange formats for product catalogs are available, and some of these formats also cover the exchange of product ontologies. Catalog formats such as BMEcat (Schmitz and Kelkar and Pastoors, 2002), cXML (Ariba, 2004), OAGIS (Open Applications Group, 2002) and xCBL (CommerceOne, 2002) have to be mentioned. However, the analysis in (Leukel, Schmitz and Dorloff, 2002) has shown that their suitability for transferring standard product ontologies is very limited, because relevant information losses occur, especially regarding attribute definitions. In face of these limitations, it is necessary that the mentioned standard exchange formats will improve their capabilities.

On the other hand, we have to consider the ISO 13584 standard which aims at serving as a reference model for part libraries, product classification systems, and in our terminology, product ontologies (ISO, 1998). ISO 13584 originates in the product data management area and is therefore focused on engineering, construction and production of technical goods and related data exchange issues regarding product data, especially libraries describing these products. A common abbreviation for ISO 13584 is PLIB - product libraries. PLIB provides a conceptual data model, specified formally in the EXPRESS language of STEP (standard for the exchange of product model data).

In general, we can say that PLIB does not address web-based procurement systems and marketplaces. On the technical side, PLIB is not based on XML, because XML was not available in the mid-1990s when PLIB development began. While the current version stems from 1998, some projects (e.g., Pierra, Potier and Sardet, 2000) intended to add an XML-based exchange format, but these developments have not been included in the standard itself.

Contrary to its aim, the adoption of PLIB is quite low, especially in e-procurement. If we look at relevant standard product ontologies, we see that no standardization organization provides PLIB compliant formal specifications. The reasons are the complexity of the PLIB model and documentation, its outdated technological basis, and several limitations to fulfill new requirements of product ontologies in business-to-business e-commerce. In contrast to these limitations, PLIB requires a lot of supplementing information. For instance, each class definition must have an identifier, preferred name, short name, definition, date of the original definition, date of the current definition, and version number plus revision number. So far, no standard product ontology provides all this data.

Complexity of Formal Specifications

The basic components of product ontologies are classes and attributes assigned to classes. While keeping this in mind, one could assume that such a formal specification is only complex in terms of its number of classes and attributes, but the specification itself would be rather simple. For instance, a class definition would consist of identification, class name, long description and a reference to the super class. An attribute definition would contain identification, attribute name and description plus data type and domain of values. Mappings between classes and attributes would be the third component. Yet this simple model does not match the actual complexity. There are many further concepts that require both additional specification elements and relationships as well.

Such extended or complex specifications, as they are introduced by standard product ontologies, are driven by new requirements arising from web-based procurement and sales systems. These requirements can be grouped as follows:

- The formal specification has to go beyond classes and provide detailed information about class-specific attributes, because sets of attributes are a cornerstone of aligned product descriptions and efficient product comparisons. Therefore, modeling of attributes is essential in many standard product ontologies. The attribute specification is not only important for suppliers who have to describe products according to these specifications, but also delivers information for the suitable representation in web-based application systems, e.g., defined sequences of attributes instead of alphanumerical listings, semantic grouping of attributes (i.e., identification, dimensions, material, shape, business attributes), and mandatory vs. optional attributes.
- The formal specification also must include definitions of synonyms, units and values as additional components. For instance, class synonyms could be defined separately from the classes. Each class synonym is defined by its identifier,

name, textual definition, version information etc. Modeling of units of measurement is a new concept contrary to giving references to units already defined in the Système International d'Unités (standardized in ISO 10303-41). Modeling of attribute values is especially useful for customized enumerations.

- The formal specification has to provide meta information about the product ontology, its structure and basic concepts. One argument for providing this meta information is to enable software systems to build the class hierarchy correctly and efficiently. This would require that there are data elements that say, for instance, "Number of Levels=4"; "Balanced tree=yes" meaning that all sub-trees have the same number of levels, e.g., any class on the third level has at least one sub-class, fourth level. Poly-hierarchies would allow that a class has two or more father classes. Additional meta information may be helpful to describe the intended usage of the given product ontology by suppliers etc., thus it describes requirements on the classification process. For instance, "mapping level=leaf only" would say that if you use this product ontology, then you have to assign products to classes on the leaf level only; "cardinality=multiple" would allow that a product can be assigned to more than one class (contrary to "single").

Semantics

A complex formal specification provides more semantics than a less complex one. This semantics describes classes and attributes in more detail, hence companies that create catalogs and classify products according to a given standard product ontology can use these semantics in order to classify product more correctly. From this view, a complex specification helps to understand the structure and content of product ontologies. Contrary to the more detailed class definitions, the relationships between classes are less specified: All relationships between classes are "is_part_of" relationships. This is sufficient to build a hierarchy of classes, but it does not provide additional semantics, especially no information about the scope of sub and super classes. In addition, there is no formal description of the rational to build a specific hierarchy. For instance, what are the requirements for a product and its attributes if it belongs to a given class? This information is expressed by textual definitions only, but not formally.

We can provide two reasons for this lack of semantics concerning class relationships. First, the formal specification languages for standard product ontologies used today are not able to express these semantics. This is especially true for file formats based on CSV, XLS or MDB. The use of XML, and even more RDF (resource description framework) would enhance the semantic richness of standard product ontologies (Brickley and Guha, 2004). Contrary to the capabilities of RDF, no standard product ontology provides specifications based on this language. Second, and this reason is critical, we can assume that organizations that develop and maintain product ontology do not follow strict rationales when building class hierarchies, since hierarchies and sets of classes are the result of standardization processes and require consensus between involved parties. Therefore, standard product ontologies concentrate on building *accepted* hierarchies rather than on defining exactly why a class hierarchy is structured as it is.

STANDARD PRODUCT ONTOLOGY: ECL@SS 5.0

If we look at standard product ontologies, we have to state that the complexity of formal specifications results in complex data models and exchange formats as well. An analysis of the newest version 5.0 of eCl@ss underlines this (eCl@ss e.V. 2003). eCl@ss is a horizontal product ontology being developed by a consortium of mainly German companies since the late 1990s. It has gained a significant relevance for e-procurement in many European countries. eCl@ss provides more than 24,000 classes, 33,450 class synonyms, and 3,667 attributes. The eCl@ss data model includes specifications of classes (16 data elements), synonyms (8 data elements), attributes (23 data elements), values (11 data elements) and relationships between classes/attributes and attributes/values. Table 1 lists the data elements for class specifications and maps them to ISO 13584, if possible:

- Four of six data elements introduced in version 5.0 were directly adopted from ISO 13584.
- The data element "coded name" is not covered by ISO 13584 at all. The reason for this element is that the class identifier itself says nothing about the position of the class in the hierarchy, while the coded name is derived from the hierarchy (for instance: 03-12-23; first level 03, second level 12, third level 23). The identifier does not change over time, even when the class is moved in the hierarchy. The coded name can be used for presentation purposes, since it is self describing.
- Four data elements transfer redundant information that can be derived from the other data. For instance, two flags indicate if there are synonyms and attributes for this class.

	Data Element	Description	Remark

	idcl	Primary key	
	identifier	Identifier	
	version number	eCl@ss release number	
NEW in 5.0	publication date	Publication date of version	Adopted from ISO 13584
	revision number	Revision number	
	coded name	eCl@ss number	Not covered by ISO 13584
	preferred name	Preferred name	
NEW in 5.0	definition	Definition of class	Adopted from ISO 13584
NEW in 5.0	iso language code	ISO-language code	For multi-linguality
NEW in 5.0	iso country code	ISO-country code	For country-specific classes
NEW in 5.0	note	Note on definition	Adopted from ISO 13584
NEW in 5.0	remark	Remark for usage	Adopted from ISO 13584
	level	Hierarchical level	Redundant information
	mksubclass	Flag subgroup 0=no/1=yes	Redundant information
	mksynonym	Flag key words s=yes	Redundant information
	mkbsa	Flag standard set of attributes	Redundant information

Table 1. Class Specification in eCl@ss 5.0

The specification of attributes in eCl@ss 5.0 reveals a similar picture (see Table 2):

- Five data elements were adopted from ISO 13584.
- The number of data elements has increased from 12 to 23.
- One element transfers redundant information; the flag "attribute type" indicates whether the attribute domain is an enumeration of allowed values.
- Three data elements are not covered by ISO 13584; "valency" is a flag for multivalent attributes, while "category" and "definition class" serve for mapping eCl@ss attributes to other classifications (IEC 61360 and International Classification of Standards). The two latter elements are part of eCl@ss 5.0, but not used yet.

In summary, we observe that eCl@ss seems to be aware of ISO 13584 and adopts it in part. However, some important eCl@ss concepts are not compliant with ISO 13584 (e.g., coded names, separate definitions of synonyms and values).

IMPACT OF ISO 13584 AND RELATED STANDARDS ON AUTOMATED CLASSIFICATION

Our analysis of ISO 13584 and the need for standardized specifications, data models and exchange formats has identified several benefits of standardization and obstacles of current standards. Moreover, we stressed that heterogeneity is still evident.

Exchange formats and formal specifications play an important role for automating product classification. All IR based classifiers implement a wrapper to be able to import different product ontologies. The reason is that a common data model for product ontologies is still lacking; at least the standard product ontologies do not adopt ISO 13584 fully, and use custom and therefore proprietary exchange formats. If standard product ontologies would agree on a common data model and use the same exchange format, then the wrappers would become obsolete. Importing standard product ontologies would benefit from this standardization. Implementing IR based classifiers could concentrate on IR algorithms and on integrating domain specific requirements.

Complex formal specifications of product ontologies result in more complex schema and therefore in new vector attributes (attributes in terms of classification according to the VSM, not product attributes) that have to be considered by classification algorithms. This development is two-fold: on one hand, the number of attributes is rising as standard product ontologies add new data elements. For instance, the textual definition of a class in eCl@ss is distributed on four data elements: preferred name, definition, note, and remark. Each data element may contain relevant attributes, thus new terms must be extracted from these fields. On the other hand, the more complex attribute space delivers additional information about classes. This information contributes to the classification process and could result in greater classification successes.

	Data Element	Description	Remark
	idatt	Primary key	
	identifier	Identifier	
	version number	Attribute release number	
NEW in 5.0	publication date	Publication date of version	Adopted from ISO 13584
	revision number	Revision number	
	preferred name	Preferred name	
	short name	Short name	
	definition	Definition	
NEW in 5.0	note	Note on definition	Adopted from ISO 13584
NEW in 5.0	remark	Remark for usage	Adopted from ISO 13584
	alias name 1	Alias name 1	
	alias name 2	Alias name 2	
	formular symbol	Preferred formular symbol	
	format	Number of characters + Field type	
	unit of measure	Unit of the appropriate value	
NEW in 5.0	unit of measure code	UN/CEFACT coded of the Unit of measure	
NEW in 5.0	iso language code	ISO-language code	For multi-linguality
NEW in 5.0	iso country code	ISO-country code	For country-specific attributes
NEW in 5.0	category	IEC 61360 category of attribute	Not covered by ISO 13584
NEW in 5.0	attribute type	Set of values mark	Redundant information
NEW in 5.0	valency	Multivalent mark	Not covered by ISO 13584
NEW in 5.0	reference	Reference of definition	Adopted from ISO 13584
NEW in 5.0	definition class	ICS-class	Not covered by ISO 13584

Table 2. Attribute Specification in eCl@ss 5.0

The next steps to semantic richness are relationships between classes. We have seen that the degree of semantics concerning class relationships and the class hierarchy itself is very low. Additional semantics would allow improved or new classification approaches based on this formal semantic. However, this is beyond the scope of classic IR (for ontology-based integration, e.g., Corcho and Gómez-Pérez, 2001).

Similar to IR approaches, schema integration has to deal with the formal specification of two or more product ontologies that must be integrated. A common instrument to overcome schema heterogeneity is to map the given product ontology specification to an internal schema. Therefore, when integrating two product ontologies the first step is to import the specifications. The benefit of standardization of data models and exchange formats is obvious: if standard product ontologies provide their specifications based on the same data model and use the same exchange format, then importing product ontologies is a rather simple task. In addition, this kind of reference data model can also build the foundation for the internal schema of the integration tool. Our conclusion is that designing a tool for product ontology integration is very similar to the development of a reference model describing the structure of product ontologies. ISO 13584 can serve as a starting point for such a reference model, and for the internal schema of the integration tool as well. If standard product ontologies adopt ISO 13584 partially or completely, product ontology integration is also facilitated.

The complexity of formal specifications also must be considered in schema integration approaches. Two product ontologies may cover these extensions differently, but all specifications serve as input data for the integration problem and go into the mapping process. We can assume that a specification of high complexity provides more semantics about classes and attributes, hence this information is able to make the mapping process easier, or more successful. Since attribute usage thrives (Ondracek and Sander, 2003), mapping of different attributes will become more important; thus the formal specification of attributes is also important for the integration task.

A richer specification of relationships between classes using relationships types, formally expressed rationales, and class-specific requirements for attribute values also can be seen as additional input to the integration problem. Moreover, mappings between two product ontologies already provided by standardization organizations fulfill a similar role. For instance, eOTD aims at defining a set of classes and attributes suitable for eCl@ss, UNSPSC and other product ontologies (ECCMA, 2003). Thus eOTD maps its own classes and attributes to similar classes and attributes of other product ontologies. These mappings are part of the eOTD formal specification. If this data is freely available, then product ontology integration could benefit and automated re-classifications based on this data would be enabled. However, a standard specification or reference model for these mappings is still lacking; ISO 13584 does not address the mapping problem.

RELATED AND FURTHER WORK

In this paper we have analyzed the potential of ISO 13584 as a reference model for product ontologies and evaluated its capabilities by referring to requirements from literature and business practice. We showed that the product classification problem has to cope with heterogeneity in data models, exchange formats, granularity of formal specification and semantic richness. Standardization addresses the need for a set of basic concepts accepted by organizations that develop and maintain product ontologies. A starting point for such a standard may be ISO 13584, but it does not fulfill all requirements so far, and its usage is still low. Yet we have seen that eCl@ss 5.0 - as one of the important horizontal product ontologies - has adopted some concepts of ISO 13584 recently.

Much work has been carried out in applying, evaluating and improving classification tools for this specific domain, product data in B2B e-commerce. The Vector Space Model for product classification is implemented in GoldenBullet (Ding, Korotkiy, Omelayenko, Kartseva, Zykov, Klein, Schulten and Fensel, 2002). A wrapper imports the formal specification of product ontologies; it is limited to UNSPSC and class definitions, however. Contrary to the high complexity of formal specifications (see eCl@ss for instance), the classification process is based on class names only. The problem of different data models and extended specification is not described.

An implementation of the schema integration approach is the MOMIS system (Bergamaschi, Guerra and Vincini, 2002). MOMIS allows defining relationships by (1) comparing class names and relating them to terms of the WordNet ontology, (2) building relationships manually by domain experts, and (3) deriving additional relationships through inference algorithms. The problem of heterogeneity in data models as described in our paper is handled by a flexible wrapper, thus MOMIS does not concentrate on a common structural model (no specification of attributes, no mappings between classes).

Similar to our approach, (Leukel et al., 2002) describes structural aspects of product ontologies. However, its aim is to develop a universal, XML-based exchange format. It derives requirements from an analysis of four standard product ontologies (eCl@ss, EGAS, RNTD, and UNSPSC) and three exchange formats (BMEcat, OAGIS, and xCBL). There are two limitations: ISO 13584 is not mentioned at all, and the impact of standardization on automating product classification is neglected.

The results of our analysis back up recent initiatives by standardization bodies and organizations that develop product ontologies. On one hand, CEN/ISSS as a standardization body in Europe (European Committee for Standardization / Information Society Standardization System) has started a project on harmonizing different data models and exchange formats for product ontologies (CEN/ISSS, 2004). On the other hand, many standard product ontologies have agreed to align basic concepts and terminology, and are aware of the future role of ISO 13584 or its successors. For instance, the Open and Interoperable Domain Dictionary Initiative (OIDDI, 2003) has organized workshops on this issue since 2001 and recommends the reuse of existing standards. However, new requirements from business-to-business e-commerce as well as countless initiatives to develop and improve standard product ontologies for different branches of industry and different markets worldwide call for independent, medium-term research and standardization work in the future.

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