A first approximation of an Ontological Model for Manufactured Physical Artifacts

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Abstract. Enterprises that provide configuration service of artifacts in a given environment in addition to its sale are distribution intermediaries in the midst of customer and suppliers. Distribution intermediates play an important role in the distribution chain of physical artifacts in the industry. The increase of new lines of technological physical artifacts dramatically evolve. In this paper, we present a new *Bill of Materials (BOM)* proposal for an ontological model for this industry. Our model proposes an adaptation of the BOM to the needs of this enterprise type that are dedicated not only to the sale of physical artifacts but also to their correct configuration. Any technological artifact that can be sold is considered a *product*. Finally, a first approximation of the ontological model is presented.

1 Motivation and Related Work

On enterprises that are distribution intermediaries, the responses towards clients have become slower due to the big data corpora of products available for configuring and installing technological artifacts more complexes. Any technological artifact that can be sold is considered a product. The time to mine these product databases is unacceptable as customers not only need a precise answer (that means, a technological artifact satisfying their requirements) but also a fast answer. As consequence, workers in charge to provide the answer to customers don't explore all the available products and restrict their-selves to recommender artifacts considering only few products. Thus, these types of intermediary companies have had to modify their forms of organization and to do business to adapt to new needs as custom configuration of artifacts, control of artifact variants, cost and quality control. Hence, these industrial companies need to have a model that allows them to speed up the information retrieval on the artifacts with that works the company. This model is the basis to construct an agile decision support system to help intermediary companies and service providers in configuration efficient artifacts in the industry of technological artifacts. In this sense, the use of metadata and ontologies represents a solution [1].

In the last few years, many software solutions[2], [3], [4], [5], [6] have been developed based on ontologies as a retrieval and classification model of information about catalogs of product-service. These models allow to categorize the information in business sceneries by the meaning of words related to the sector in question. Applications can retrieve data according to the knowledge stored in these models. With respect to this topic, four research trends have been identified [6].

First, development of ontologies as business models for *Product-Service Systems (PSS)*. Model that is used to define both the product offers and the implementation of marketing strategies related to transform company resources in *Value*. In this line, some interesting proposals of ontologies as a basis for PSS business models have been devised [7], [8], [9].

Second, design of models based on international standards. Many isolated solutions have been developed to enhance the information retrieval and search relating to an specific product-service (for example UNSPSC[4] or the RosettaNet standard[5]).

Third, consider taxonomies as ontologies and define the meaning of terms related to a certain industry domain. Taxonomy is based on the need of managers to organize their contracts, invoices, reports and other documents, which should have a coherent organization for their further search. The development of systems to ease the delivery of product-service started in 90s. Wemmerlöv [10] emphasizes that one of the main problems of service delivery systems is their taxonomic nature. In 1998 an specific methodology of Domain Analysis is presented by [11]. A taxonomy simply requires its components to be organized in order to carry out a successful classification. However, the interpretation of the taxonomic relationship is an important modeled decision.

Four, development of ontological representations oriented to product description according to its form or composition. An efficient information retrieval with regard to a particular product through suppliers, commercial partners and customers is allowed in business scenarios if and only a well-defined conceptual design is available. Ontologies and metadata have been considered an optimal solution for a conceptual design of tools as basis of product-service description between a company and its partners. The corresponding ontological models is associated to a formal language allowing the retrieve information in an automated way (see PCS2OWL[6] tool, *GoodRelations* [3] vocabulary for e-commerce or *schema.org*[7].) In addition, it is possible to represent the knowledge from a par-

[4] United Nations Standard Products and Services Code(UNSPSC). https://www.unspsc.org/

[5] A consortium of major Computer and Consumer Electronics, Electronic Components, Semiconductor Manufacturing, Telecommunications and Logistics companies working to create and implement industry-wide, open e-business process standards. https://supplier.intel.com/static/B2Bi/RosettaNet.htm

[6] http://www.ebusiness-unibw.org/ontologies/pcs2owl/

[7] http://schema.org/Product

ticular application domain, which goes beyond research-development projects because the handled ontological representations provide relevant information about product-service in a given area of the industry ([5], [12]). Finally, the proposal more interesting for this research, in this trend is a proposed ontological model with a consistent semantic representation for product known with the named of PRONTO[5]. This ontology allows the representation of data for products at different levels of abstraction. They define an *Abstraction Hierarchy* and an *Structural Hierarchy*, each one with a different role in the ontological model. On the one hand, *Abstraction Hierarchy* allows unstructured representation of information products at different levels of abstraction, and aggregated representation and disaggregation of information among these abstraction levels. On the other hand, *Structural Hierarchy* contains information about the products and components involved in product manufacture. The model handles relations among product structures, but only through *componentOf* and *derivateOf* relations. One of the main advantages of this proposal is that it defines a representation for a *Bill of Materials (BOM)* of products that are semi-manufactured by assembly of component parts, given its level of abstract hierarchy. In contrast to this proposal, we design a new knowledge representation based on an ontology to describe technological artifacts based on a new BOM. However, an ontological model satisfying all needs for physical technological artifacts information retrieval in the industry is not easy to obtain. To the best of our knowledge, this work is a first attempt to propose an ontological model on the basis of a new BOM focused in a *Bill of Parts (BOP)* from a new part concept abstraction for technological products manufactured.

This model proposes an adaptation of the BOM to the needs of this enterprise type in the industry of technological artifacts. Therefore, this work is organized as follows. Section 2 describes a new adaptation of BOM with the name of *Bill of Parts* (BOP) to satisfy the needs of intermediary companies in the the industry of technological artifacts. Section 3 introduce a first approximation of the ontological model. Finally, Section 4 shows conclusions and future work.

2 *Bill of Parts* (BOP) from *Bill of Materials* (BOM)

Our proposal has as main need to identify the parts that make up a configuration sequence of a certain artifact and the relations that are established between them. Here is where BOM models play an important role given that a model of this type is defined as *an structured list of the parts used to obtain a product*[13]. The rise of new technologies lead to new approaches of BOMs such as those proposed by [14], [15], [16] among others, which present models to adapt the BOM to the different needs. In this sense, we define our BOM model as *an structured list of the parts (physical artifacts) used to configure a technological artifact determined.* Thus, our materials are parts too but that have been previously manufactured. Hence we will refer to "*Bill of Parts (BOP)*" instead of BOM form now on. BOP is a generative BOM[14], [15], [16]. Generative BOMs do not store the structural configuration of each technological artifact in the representation model. In contrast, this structure is generated from a basic structure previously defined.

The structure of BOP is made up of previously manufactured physical artifacts, which are bought to suppliers of this type of business. A BOP of previously manufactured physical artifacts is composed of the parts shown in Figure 1, which are described below.

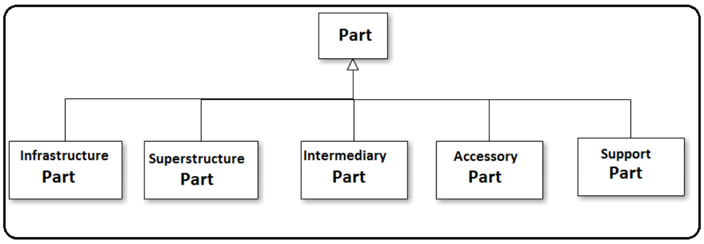

Fig. 1. Our new BOM proposal: named "*Bill of Parts (BOP)*"

- **Infrastructure pats** are the parts used as a basis for assisting the corresponding artifact (as a *Whole*) and that interact with other similar parts.
- **Superstructure parts** are parts employed as an interaction layer between external agents and infrastructure parts. Each artifact must contain at least one of each kind of these artifacts. For example, given an artifact that is a video-door entry system (see Figure 2), intercom phones are a type of superstructure physical artifact, because at least one of them is required for the system to be functional.
- **Intermediate parts** are those parts that connects other two parts of the artifact to configure. An important observation is that this type of part can be also an infrastructure or superstructure part.
- **Accessory parts** are those parts used as a complement or ornament. These parts are not necessary for the correct performance of the artifact to configure. Besides, these parts are in physical contact with some of the other parts of the system.
- **Support parts** are those parts that serve as support (or support the remaining parts of the artifact). Physical contact is established with all the parts that are held in it.

Figures 2 and 3 illustrates two examples of different technological artifacts where the parts that conform to it are identified: Figure 2 presents the part concept abstraction in a switch artifact for difficult environments and, Figure 3 shows the part concept abstraction in an Hydraulics Mini-stations.

Note that the definitions shown in Figure 1 and describe previously are classified according to the role they play within the artifact to configure. A technological artifact could not have within its compositional structure all the abstractions

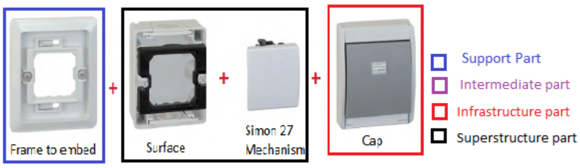

Fig. 2. Examples of technological artifacts: the part concept abstraction in a switch artifact for difficult environments.

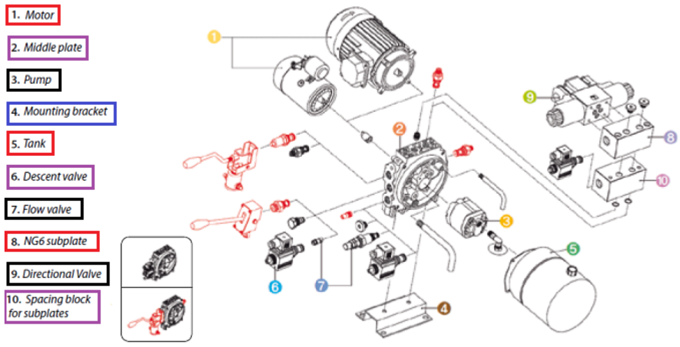

Fig. 3. Examples of technological artifacts: the part concept abstraction in an Hydraulics Mini-stations.

of the concept defined above, it can include from a single type to all abstraction types. For example if it has a part of each type of the abstraction concepts specified then the remaining parts will be placed on the support part. Further, the superstructure part is to be connected to the infrastructure parts through the intermediate parts. In addition both superstructure and intermediate parts as well as the superstructure parts may have associated accessory parts. Also the superstructure part is where external agents, human beings, another devices (such as any physical artifact) or the environment interact.

2.1 BOP types according to their structure

Each type of artifact to be configured will generate a BOP specific according to its compositional structure. Also the parts that make up an artifact will have implicit a BOP representation which is not of interest of this work since the companies by which is being developed the research do not manufacture these parts but rather buy these parts previously manufactured through their different suppliers. The BOPs generated by our model describe two types of different compositional structures, which are defined below:

- **Atomic structure:** a BOP of atomic structure is a BOP which is composed of a unique part which cannot be broken down in other parts, or also It may

be an artifact that although its structure is composed of different parts, the case study that concerns us treats the artifact as an atomic product because it is not of interest of this research to decompose it into its constituent parts (since just as it is formed, it is susceptible to be sold), ie the artifact as a whole is part of the configuration of another more complex artifact. Some examples of this type of artifacts are a *thermostat*, a *CPG-215M Saivod Split Wall Heater*. A BOP of atomic structure can only be:
  - *Homogeneous:* a BOP of homogeneous structure describes the same type of part based on one dimension. The parts that make up this structure type are obtained by applying a quantitative measure.
- **Non-atomic structure:** a BOP of non-atomic structure is a composed BOP of at least two different parts related to each other to form its structure. These parts are those described above which abstracts the "**part**" concept (see figure 1). Non-atomic structure BOPs can be:
  - *Heterogeneous:* a BOP of heterogeneous structure describes an artifact composed of different class or nature parts, ie these parts are different from each other both by the classes that define them and by the role for which these have been created within the artifact that make up.
  - *Uniform:* a BOP of uniform structure describes an artifact composed of parts that can be classified under an unique condition, either a property, an attribute, etc.

In addition, both atomic and non-atomic structures can describe:

- A *composition structure* obtains the necessary information about which are the parts that make up a technological artifact, and releases a model that will lead us to the most accurate way of representing the knowledge about its compositional structure.
- A *modular structure* describes the maximum number of connections that the part or artifact supports (this can be a part type or the artifact as a whole). For example: If an artifact of server system type has: 1) two power supplies (ie, two wires to plug into the mains); 2) four network cards (ie four ports to connect to the network) and 3) a wifi connector, then it supports a maximum of seven connections (i.e. seven modules where only two modules are for power supplies, four modules are for connection to the wired network and a module is for connection to the wifi network).
- An *hybrid structure* combines the above structures (all at once or in pairs).

3 A first approximation of the Ontological Model

The final goal is the development of an ontological model that allows the derivation of BOP structures that comply with the features described in the previous section. This paper describes a research project under development. So some of the requirements are already covered in the current model, while others are being analyzed to incorporate them to the final ontological model With the aim to cover each one of the needs of this type of intermediary companies in the technological artifacts industry.

Like the ontology PRONTO[5] introduced in the related work's section, our ontological model will describe an *Abstraction Model (AM)* and an *Structural Model (SM)*, each one with a different role. On the one hand, our AM will allows information unstructured representation about artifacts at different levels of abstraction. An approximation of these levels is defined as follows:

1. **Configuration Area:** represents the fifth and highest level of specification and defines the artifact set that respond to the same general functionality but with different behaviors. This level consists of at least one artifact family.
2. **Artifact Family:** Represents the fourth level and defines the artifact set that have similar functionalities and behaviors but that belong to different commercial brands.
3. **Commercial Brand:** is the third level and defines the name or label that is assigned to a artifact set to distinguish it, or to denote quality or membership of a particular supplier.
4. **Variant Set:** represents the second level and defines the artifacts of the same brand with similar functionalities and behaviors but with at least one characteristic that distinguishes them from the rest of artifacts of a same family.
5. **Artifact:** is the lowest level and represents individual items that are members of a particular variant set, so it has the structure associated with that set. Structure that is constituted by other artifacts or physical parts.

....*belongingTo* relationship

On the other hand, our SM contains information about the parts (or components) involved in artifact configuration sequence. This is generated from the BOP in correspondence with the level of abstraction that is being referenced. One of the main advantages of our proposal is that it defines a SM representation for any BOP of built artifacts given its level of AM. Each level of abstraction has one SM associated, ie each AM has one SM associated. In our case, the SM associated with the lowest level of abstraction (Artifact) is described in a more specific way because each SM of the remaining abstraction levels inherits the SM of the artifacts which belong to that level of abstraction.

Finally, given that part types that make up the SM establish relations between them, whether of connection or of another nature. Definitions and axioms of the Part-Whole relationships allowed by SM are studied. These relationships are know in the literature as mereotopological primitives[17], [18] which are defined by a predicate logic primitive $R(x, y)$ that describes a particular relation between two classes. These primitives are an important element of our ontological model and are under research.

4 Conclusions and Future Works

This paper describes a new BOM for an ontological model of the industry of manufactured physical artifacts. It is shown as an adaptation of the BOM according to the parts that make up a technological artifact (BOP). This BOM defines a new part concept abstraction based on structural composition of technological artifact in this industry. The proposed model is a tool to represent the structure (SM) of a technological artifact according to its structure.

As future work, we plan to work on an ontological model on the basis of the new BOM (BOP) described in this work. Besides, we are studing and analyzing a significant sample of mereotopological theories with the aim to identify what relationships of parthood and connectedness types are possible between the parts that make up each one of the structures that describe the BOP. Furthermore, an analysis of the overall relationships by artifacts structure based on their type might help us predict possibles new structures depending on what type of artifact is in correspondence with BOP.

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