Ontology-Based Fragmented Company Knowledge Integration: Possible Approaches

Alexander Smirnov[1] and Nikolay Shilov[2](✉)

[1] ITMO University, St. Petersburg, Russia
smir@iias.spb.su
[2] SPIIRAS, St. Petersburg, Russia
nick@iias.spb.su

Abstract. Companies have multiple business process, some of which are supported by knowledge described via ontologies. However, due to their nature, the processes use different knowledge notation what causes a problem of integrating such fragmented heterogeneous knowledge. The paper investigates the problem of developing a single multi-domain ontology for integrating company knowledge taking into account differences between terminologies and formalisms used in various business processes. Different options of designing ontologies covering multiple domains are considered. Three of them: (i) ontology localization/multilingual ontologies, (ii) granular ontologies, and (iii) ontologies with temporal logics are considered in details and analyzed.

Keywords: Knowledge management · Interoperability
Multi-domain ontology

1 Introduction

Development of knowledge management technologies enables companies to apply new technologies, workflows, and software tools. This, in turn, usually speeds up business processes and increases their flexibility and efficiency. However, different workflows often rely on different AI mechanisms caused by their nature. For example, product classification and feature definition can be done by using some general ontology model, and more specific domains, such as configuration models can be derived by inheriting or subclassing the ontologies within the general model. Rule-based language SWRL can be used for description of constraints. It is based on OWL and the resulting ontology can be an extension of OWL ontology. Configuration system in turn can be implemented using JESS what would require mapping of OWL-based configuration knowledge and SWRL-based constraints into Jess facts and Jess, respectively [1].

Thus, the variety of the elements of the resulting eco-system of information and knowledge representation can become really high. A possible scale of the problem was identified in [2] and presented in Fig. 1.

It is obvious that the problem of interoperability and integrity of fragmented company knowledge related to different workflows arises. The paper is aimed at investigating the possible problem of integrating fragmented company knowledge representing via ontologies. Various possibilities of developing ontologies to describe

W. Abramowicz and A. Paschke (Eds.): BIS 2018 Workshops, LNBIP 339, pp. 30–37, 2019.
https://doi.org/10.1007/978-3-030-04849-5_3

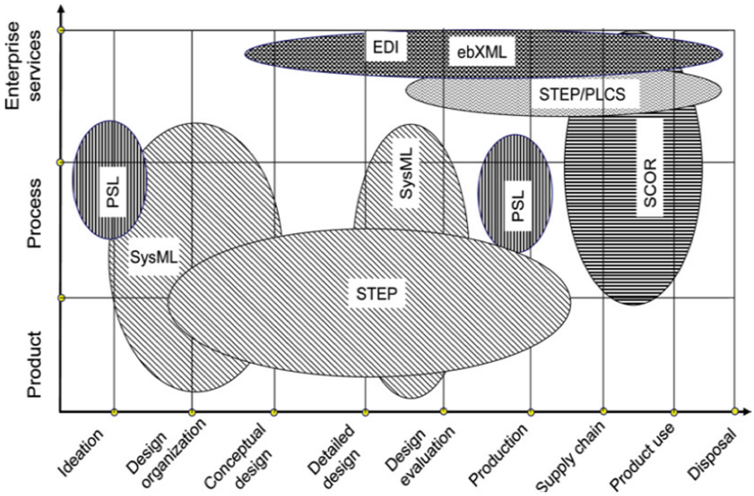

Fig. 1. Usage of different languages for information description [2].

several domains are considered. The most suitable ones are considered in detail and analysed. The research develops the earlier obtained results [3, 4] aimed at development of knowledge-based solutions for various company workflows. Though the carried out projects have led to substantial results in the areas complex product and system information management and configuration, it is still visible that the developed and existing knowledge management systems are separated. An important task would be to develop a way to integrate existing knowledge so that it could be freely used in different processes.

2 Ontologies for Multi-domain Knowledge Description

Ontologies are aimed at describing knowledge related to a certain domain in a machine-readable way. Ontologies make it possible to obtain, exchange and process information and knowledge taking into account their semantics and not just syntax. Ontology is a formal conceptualisation of a particular domain of interest shared among heterogeneous applications [5, 6]. An ontology usually includes concepts existing in the domain, relationships between them and axioms. Ontologies are thought to be a well-proven tool for solving the problem of interoperability. However, there still exist the problem of using different ontologies with different terminology and notation in applications addressing different tasks even within one company that has to be solved. E.g., the authors of [7] propose a model-driven interoperability framework for technical support of co-evolution strategy of products and manufacturing systems. They address connecting possible modules to all possible production capabilities managed on different software tools through establishing “connector framework” matching used ontologies.

Ontology matching [8] seems to be one of the solutions to this problem. But in reality, automatic ontology matching is still not reliable enough while manual ontology matching takes too much efforts and time. There exist some works aimed at the improvement of ontology matching through enriching ontologies with additional information (e.g., extension of DAML+OIL for description of configuration problems [9], introduction of semantic annotations [10], etc.), but they are not enough to solve the problem of integrating heterogeneous information and knowledge described in different ontologies.

As a result, it can be seen that maintaining several ontologies is not an efficient way since it requires continuous translation of information and knowledge between them.

The authors of [11] suggested a solution based on semantically annotated multi-faceted ontology for a family of products that can automatically identify semantically-related annotations. A fragment of the solution is shown in Fig. 2. This work has helped to identify the further direction of research aimed at integration of fragmented heterogeneous knowledge through developing a single complex multi-domain ontology. There are a number of works in this area and after an extensive study of the domain, we have defined three main and most promising approaches discussed further in the paper.

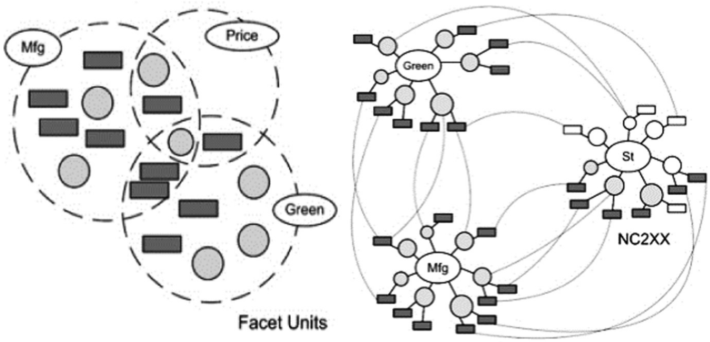

Fig. 2. A multi-faceted ontology for a family of products (adapted from [11]).

3 Approaches to Building a Multi-domain Ontology

3.1 Multilingual Ontology

The goal of multilingual ontologies is to resolve terminological issues that arise due to usage of different languages. Among the terminological issues the following can be selected [12]:

1. Existence of an exact equivalent. This is the easiest case when two terms have completely the same meaning. In real life (when talking of regular languages such as English or German) this is a rear situation, however in a company most of terminology would be the case. For example, "product" would mean the same both during the design stage and the production stage, or in the case reported earlier [3], "feature" during the design stage means the same as "characteristic" during the production stage.

2. Existence of several context-dependent equivalents. This case assumes that one can choose the right translation (the right equivalent) based on the situation. An example could be the term "modular product" that can stand for both product consisting of several modules or product with some variable characteristics. Treating such ambiguity for a person could be relatively simple but for a machine it can cause significant difficulties.
3. Existence of a conceptualization mismatch. This is an important issue for regular languages, standing for a lack of semantic equivalent for a given term. In case of ontologies used in business processes this is a much less common issue since the lack of a certain term in a business process usually would mean that it is just not used (not needed) in this process.

Such ontologies are built as an ontology with language-specific fragments with relationships between terms and it might be a straightforward enough solution for multi- domain ontology. This would really help to overcome the terminological issues, as well as to solve the problem of heterogeneity of information and knowledge between different business processes.

However, a multilingual ontology is formulated in a single formalism and collecting together, for example, procurement and configuration knowledge would not be possible without losing certain semantics. As a result, this approach can not solve the problem formulated. Multilingual support can be of high importance for global companies that have employees speaking in different languages but this is out of the scope of the presented here research.

3.2 Granular Ontology

Granular ontologies are based on the integration of ontology-based knowledge representation with the concept of granular computing. Granular computing is based around the notion of granule that links together similar regarding to a chosen criteria objects or entities ("drawn together by indistinguishability, similarity, proximity or functionality" [13]). The granules can also be linked together into bigger granules forming multiple levels of granularity.

From the knowledge representation point of view, a granule can be considered as a chunk of knowledge made about a certain object, set of objects or sub-domain [14]. A level is a collection of granules of similar nature. When speaking about corporate knowledge, lower-level granules can be related to particular business processes, and higher-level granules can combine knowledge related to macro-processes. The hierarchy of granules then would form a hierarchy of business processes of the company.

Granular ontologies seem to be a suitable solution to support multiple domains: they enable splitting the domain in smaller areas with consistent terminology and formalisms. The possibility to form a hierarchy (generalisation) is also beneficial due to the possibility to define generic concepts and relationships at higher levels.

However, business processes usually overlap in terms of used information and knowledge (Fig. 3). This means that there exist multiple processes that assume collaboration and usage of the same information and knowledge. Pure granular ontologies cannot solve the problem of terms having different meaning in different processes or different company departments. There are multiple efforts in the area of rough granular computing [15–17], however, they are not directly related to ontology design. As a result, additional research in this area is required. Another possibility is to extend a granular ontology with a concept that would enable certain “roughness” of it, and the following section proposes such a possibility.

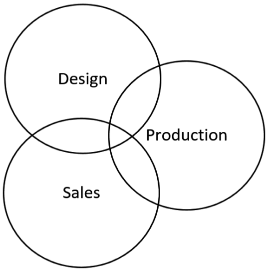

Fig. 3. Example of overlapping business processes.

3.3 Temporal Logics-Based Ontology

The authors of [18] propose to address the problem of terms having different meaning in different business processes or different company departments through usage of temporal logics.

The approach presented in [18] is based on the fuzzy extension of temporal logics to enable links and overlapping between different business processes. The metaphor used in the approach is based on the idea of different business processes as time intervals with fuzzy duration.

The ontology (ONT_{LC}) is described by the following formula:

$$ONT_{LC} = \langle C_{LC}, R_{LC}, O_{LC}, T_{LC} \rangle, \text{ where}$$

C_{LC} is the set of concepts (all the concepts of the ontology used in all business processes),

R_{LC} is the set of relations between the concepts,

O_{LC} is the set of operations over concepts and/or relations,

T_{LC} is the set of temporal characteristics.

Since the ontology is aimed at separation of concepts between business processes, the systemic kernel is represented as the following triple:

$$ONT_S = \langle S, R_S, O_S \rangle, \text{ where}$$

S is the set of business processes under consideration,

R_S is the set of relations between the processes,

O_S is the set of operations used on the processes.

As it was mentioned the different business processes are considered as time intervals $s = [t^{-}, t^{+}]$, with starting and ending time points t^{-} and t^{+} respectively. However, in order to indicate the overlapping of processes, the intervals are considered to be fuzzy.

Though the usage of granular ontology with temporal logic as a notation for multi-domain knowledge representation looks complex, it can solve the heterogeneity problem arising from different mental models in different business processes. Besides, the "complexity" of this approach makes it possible to include different representations related to different processes preserving the expressiveness of the representations and languages used unlike multilingual ontologies. As a result, it was concluded that in the considered case the semantic interoperability support for fragmented company knowledge based on a multi-domain ontology should be implemented via the notation of granular ontology with temporal logic.

4 Conclusion and Future Work

The paper represents an analysis of the possible notations for building a multi-domain ontology supporting semantic interoperability.

Building a multi-domain segmented ontology basically consisting of a number of ontologies (sub-ontologies) can be based on using unchanged source ontologies and the overall structure of such an ontology would be simple and easy to process. However, this would lead to the necessity of continuous translation of information and knowledge between different representations and standards, which is not an easy task. The dynamic structure of the terminology would make this issue even more complex for solving. As a result, this solution was not accepted.

Multilingual ontologies can solve the problem of heterogeneity of information and knowledge but lack the possibility to support multiple problem-specific formalisms. This solution was not accepted wither but it was noted that multilingual support could be useful for global companies, which have employees speaking in different languages.

It was identified that the semantic interoperability for fragmented company knowledge should be based on granular multi-domain ontology extended with temporal logics elements. The pilot efforts related to building smaller ontologies with the purpose of validation of this approach proved its viability and potential efficiency. The future research is aimed at building a larger-scale ontology including real company data.

Acknowledgements. The paper is partially due to collaboration between SPIIRAS and Festo AG & Co KG, State Research # 0073-2018-0002, projects funded by grants ## 18-07-01201, 18-07-01272 of the Russian Foundation for Basic Research. The work has been also partially financially supported by the Government of Russian Federation, Grant 08-08.

References

1. Yang, D., Miao, R., Wu, H., Zhou, Y.: Product configuration knowledge modeling using ontology web language. Expert Syst. Appl. **36**, 4399–4411 (2009). https://doi.org/10.1016/j.eswa.2008.05.026
2. Rachuri, S., Subrahmanian, E., Bouras, A., et al.: Information sharing and exchange in the context of product lifecycle management: role of standards. Comput. Des. **40**, 789–800 (2008). https://doi.org/10.1016/j.cad.2007.06.012
3. Smirnov, A.V., Shilov, N., Oroszi, A., et al.: Changing information management for product-service system engineering: customer-oriented strategies and lessons learned. Int. J. Prod. Lifecycle Manag. **11**(1), 1–18 (2018). https://doi.org/10.1504/IJPLM.2018.091647
4. Oroszi, A., Jung, T., Smirnov, A., et al.: Ontology-driven codification for discrete and modular products. Int. J. Prod. Dev. **8**, 162–177 (2009). https://doi.org/10.1504/IJPD.2009.024186
5. Gruber, T.R.: A translation approach to portable ontology specifications. Knowl. Acquisition **5**, 199–220 (1993). https://doi.org/10.1006/knac.1993.1008
6. Staab, S., Studer, R.: Handbook on Ontologies. Springer, Heidelberg (2009). https://doi.org/10.1007/978-3-540-92673-3
7. Lafleur, M., Terkaj, W., Belkadi, F., Urgo, M., Bernard, A., Colledani, M.: An onto-based interoperability framework for the connection of PLM and production capability tools. In: Harik, R., Rivest, L., Bernard, A., Eynard, B., Bouras, A. (eds.) PLM 2016. IAICT, vol. 492, pp. 134–145. Springer, Cham (2016). https://doi.org/10.1007/978-3-319-54660-5_13
8. Smirnov, A., Shilov, N.: Ontology matching in collaborative recommendation system for PLM. Int. J. Prod. Lifecycle Manag. **6**, 322–338 (2013). https://doi.org/10.1504/IJPLM.2013.063210
9. Felfernig, A., Friedrich, G., Jannach, D., et al.: Configuration knowledge representations for semantic web applications. Artif. Intell. Eng. Des. Anal. Manuf. **17**, 31–50 (2003). https://doi.org/10.1017/S0890060403171041
10. Liao, Y., Lezoche, M., Panetto, H., Boudjlida, N.: Semantic annotations for semantic interoperability in a product lifecycle management context. Int. J. Prod. Res. **54**, 5534–5553 (2016). https://doi.org/10.1080/00207543.2016.1165875
11. Lim, S.C.J., Liu, Y., Lee, W.B.: A methodology for building a semantically annotated multi-faceted ontology for product family modelling. Adv. Eng. Inform. **25**, 147–161 (2011). https://doi.org/10.1016/j.aei.2010.07.005
12. Espinoza, M., Montiel-Ponsoda, E., Gómez-Pérez, A.: Ontology localization. In: Proceedings of the Fifth International Conference on Knowledge Capture - K-CAP 2009, New York, New York, USA, pp. 33–40. ACM Press (2009)
13. Zadeh, L.A.: Is there a need for fuzzy logic? Inf. Sci. (Ny) **178**, 2751–2779 (2008). https://doi.org/10.1016/j.ins.2008.02.012
14. Calegari, S., Ciucci, D.: Granular computing applied to ontologies. Int. J. Approximate Reasoning **51**, 391–409 (2010). https://doi.org/10.1016/j.ijar.2009.11.006
15. Jankowski, A., Skowron, A.: Toward rough-granular computing. In: An, A., Stefanowski, J., Ramanna, S., Butz, C.J., Pedrycz, W., Wang, G. (eds.) RSFDGrC 2007. LNCS (LNAI), vol. 4482, pp. 1–12. Springer, Heidelberg (2007). https://doi.org/10.1007/978-3-540-72530-5_1
16. Inuiguchi, M., Hirano, S., Tsumoto, S.: Rough Set Theory and Granular Computing. Springer, Heidelberg (2003). https://doi.org/10.1007/978-3-540-36473-3

17. Polkowski, L., Skowron, A.: Rough mereological calculi of granules: a rough set approach to computation. Comput. Intell. **17**, 472–492 (2001). https://doi.org/10.1111/0824-7935.00159
18. Tarassov, V., Fedotova, A., Stark, R., Karabekov, B.: Granular meta-ontology and extended allen's logic: some theoretical background and application to intelligent product lifecycle management systems valery. In: Schwab, I., van Moergestel, L., Gonçalves, G. (eds) The Fourth International Conference on Intelligent Systems and Applications, INTELLI 2015, St. Julians, Malta, pp. 86–93 (2015)