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A Semantic-checking based Model-driven Approach to Serve Multi-organization Collaboration

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Abstract

Multi-organization collaboration, which allows partners focus on their core business, is becoming a trend. Besides the interoperability of each partner, the mechanism of selecting qualified and suitable partners is another key issue to guarantee the success of collaboration. Based on our previous work, this paper aims to provide a model-driven approach to solve the partners selecting problem in building collaboration. In this approach, a meta-model is defined to describe the context of collaboration. All the potential partners' inputs shall be conformed to this meta-model. In order to select the required partners automatically, semantic checks are combined.

Keywords: Multi-organization collaboration; Partners selecting; Model-driven approach; Semantic checks

1. Introduction

As stated in[1], since the 70's, "Collaborative Networks of Organizations" (CNO) have evolved from intra-collaborations of single workshops to inter-organizational collaborations. To strengthen competitiveness, more and more organizations (enterprises) focus on their core business and choose to cooperate with other organizations. To achieve some common objectives (e.g., maximize profit, environmental protection), organizations with specific advantages and skills have to work together. So, multi-organization collaboration becomes a trend.

Comparing with the traditional collaborative situations, current collaborations own new characteristics[2,3], such as the dynamic combination of partners (enter and exit the partnership at any time), short duration collaboration and more international and diversified partners. To effectively and quickly build collaboration among heterogeneous partners becomes a tough problem. To solve this problem, three main issues have to be addressed: 1) how to select qualified and suitable partners based on a specific collaboration objective, 2) how to improve partners' interoperability[4,5], and 3) how to manage collaboration process. This paper focuses particularly on the first issue (the other two issues are beyond the scope of this paper).

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Before, the establishment of cross-organizational collaborations relied mainly on empirical abilities, informally held by specific people in the enterprise. As a result, the scope of potential partners remains narrow. To build better collaboration, more suitable and competitive partners shall be chosen from a bigger scope. In our previous work[6], we proposed a social platform serving to deduce inter-enterprise collaboration by gathering and exploiting knowledge. As an extension to that work, this paper proposes a **model-driven approach** "APS-M" to describe collaboration objectives, potential partners' capability, etc in a unified way. By applying **semantic checks** between the potential relevant terms, the suitable partners of a specific collaboration can be selected automatically. Fig. 1 shows a general idea of APS-M.

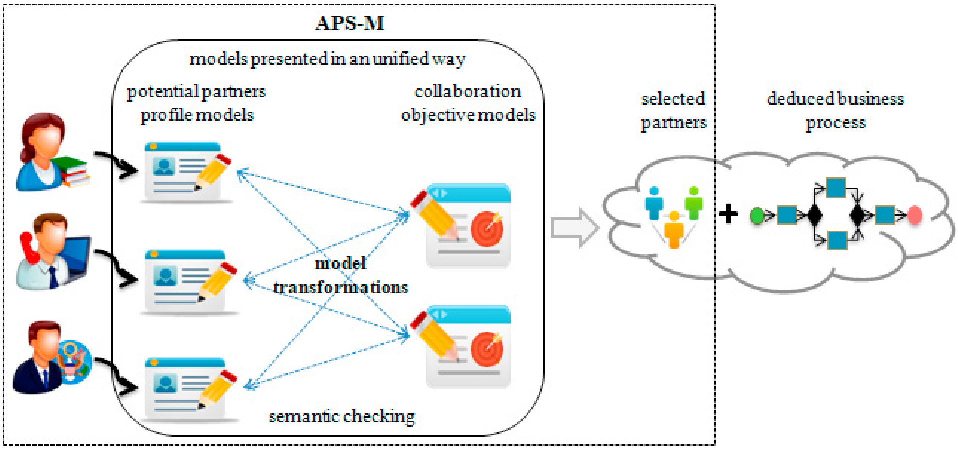

Fig. 1. A general illustration of APS-M.

Model-driven approaches take models and model transformations as two pillars. Models[7,8] are built to present real systems (highlight special sets of characteristics). A set of models can be built to present one single system from different point of views. Model transformations[9,10], which are used to build connections between different models, can simulate the interactions between modelled systems. The main purpose of applying model-driven approaches is to abstract complex system, to break down complex issues layer by layer.

Semantic checks are built on the basis of semantic checking technologies. While, semantic checking technologies shall be implemented on the basis of some specific semantic thesaurus. In APS-M, a specific semantic thesaurus is developed, and the semantic checking measurements are implemented with the help of this thesaurus. By applying semantic checks, model transformation rules can be defined automatically and then the suitable partners (being modelled) can be selected.

This paper is structured as follows. The second section presents the related work of model-driven approaches used for building multi-organization collaboration, and semantic checking technologies and approaches. The third section shows an overview of APS-M and the semantic checking measurements being used. A use case with its evaluation is illustrated in the fourth section. Finally, the fifth section draws a conclusion.

2. Related work

2.1 Model-driven approaches used in collaboration management

Many research works adopted model-driven approaches to manage collaboration, such as "Enterprise Interoperability Framework (EIF)[11]", "CIM Open System Architecture (CIMOSA)[12]" and "Mediation Information System Engineering (MISE)[13]".

EIF aims to define the research scope of enterprise interoperability and help to identify and structure the knowledge of this domain. It employs models to represent enterprises' architectures. As shown in the part (a) of Fig. 2, EIF defines four main concerns and three kinds of barriers of enterprise interoperability. Furthermore, three approaches: "integrated", "Unified" and "Federated" are provided in EIF.

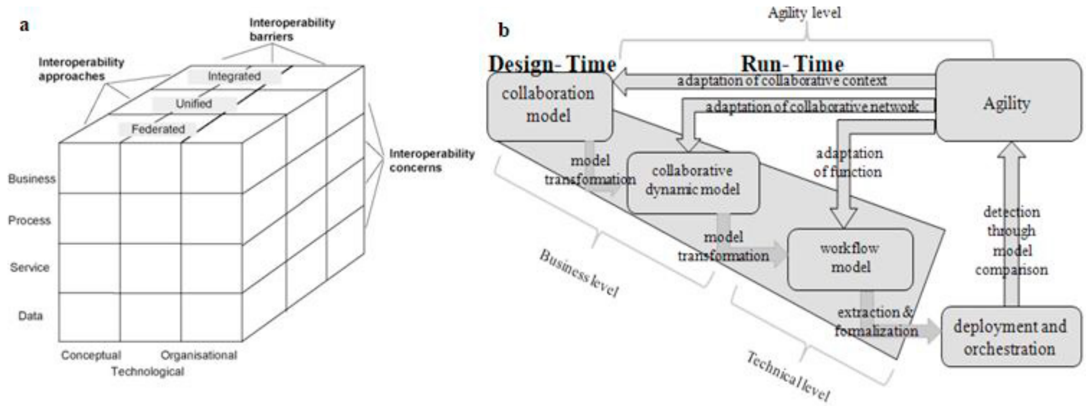

Fig. 2. Enterprise interoperability framework[11] and the structure of MISE[13].

CIMOSA aims at building and maintaining the enterprise knowledge base and enabling its efficient use for decision support in enterprise engineering. While, enterprise modeling plays a key role in building this kind of knowledge base and in using it for enterprise integration and operational decision support. As stated in[12], CIMOSA provides a process oriented modeling concept and supports evolutionary enterprise modeling. It separates functionality and behavior (following an enterprise engineering concept).

MISE aims to automatically set up a "mediation information system[14]" to fit specific needs of collaboration. It employs model-driven approaches and presents a knowledge-based system. As shown in the part (b) of Fig. 2, this system can be decomposed into four processes: 1) gather collaborative knowledge via business-oriented models, 2) elaborate a suitable collaborative business process to reach the latter gathered collaborative objectives, 3) turn the collaborative business process into a technical workflow, and 4) orchestrate the workflow.

2.2 Semantic checking approaches

As stated in[15], semantic checks deal with the meaning behind an element or a diagram. Semantic checks can be used to detect the semantic relations between certain objects or concepts. Since this technology can achieve the efficient (automatic) purpose, certain domains such as "database system management" and "knowledge engineering", have adopted it. Table 1 lists three research works that used semantic checks.

Table 1. Research works employing semantic checking.

Research work	Domain	Purpose	Note
Reference[16]	model transformation	integrating modeling languages	integration of modeling languages via their meta-models
Reference[17]	database management	matching data schemes	categorized schema-based matching techniques
Reference[18]	knowledge engineering	matching ontologies	matching ontologies by using concrete semantic thesaurus

Syntactic checking, which focuses on the rules and principles of governing the structure of sentences and words can be used to enhance the performance of semantic checking. In some terms, syntactic checking may disclose some potential semantic relations with less resource consuming. A typical technology of doing syntactic checking is to use string metrics, and a survey of this kind of technologies is given in[19]. Syntactic checking measurements have been employed in certain fields, such as statistics, database and artificial intelligence, to match automatically entity names.

Generally, both semantic and syntactic checking technologies are used between pairs of words (concepts) to detect the similarity (on semantic and syntax aspects). Both the diversity of the conveyed technologies (e.g., ontologies, database schemes and concept models) and the difference of the organization (and meanings) of concepts in different domains, affect the selection of semantic thesaurus and the way of designing semantic (and syntactic) checking approaches. In simple words, different semantic checking approaches, which are built on the basis of general semantic checking technologies, are developed to serve diverse purposes. In APS-M, considering both the users' inputs and the structures (organization of concepts) of the ontologies being used, a new detecting process is designed and implemented.

2.3 Short conclusion

Our previous work[6] aims at selecting partners and deducing collaborative process by gathering and exploiting knowledge. It is part of the MISE project. This paper focuses particularly on the partners selecting issue and details the theories and technologies of modelling and the semantic checking measurements being employed.

Considering the three issues: selecting partners, partners' interoperability and (deduce) collaboration process, table 2 summarizes the aims of the three approaches illustrated in the former subsection.

Table 2. Research works employing semantic checking.

	Selecting partners	Partners' interoperability	Collaboration process
EIF	-	Yes	-
CIMOSA	-	Yes	Yes
MISE	-	-	Yes
Reference[6]	Yes	-	Yes

Many research works focus on enterprise collaboration and pay particular attention to enterprise interoperability (e.g., EIF and CIMOSA). Some of the research works address the deducing collaboration process issue (e.g., CIMOSA and MISE). Very few research works focus on selecting suitable partners of collaboration.

3. APS-M overview

Potential partners' selection shall be based on two factors: collaborative objectives and organizations' capabilities. As stated in[6], both of the information can be collected from partners (by fulfilling the modelers), and then be linked with an ontology-based system. As explained in[6], this ontology-based system contains two ontologies named: the collaborative ontology (CO) and the business field ontology (BFO), respectively. A detailed illustration about the two ontologies can be consulted in[20].

CO is built up on MIT process handbook[21]. It is a decomposition of objectives and capabilities, where objectives can be decomposed into sub-objectives and linked to a set of capabilities. To realize an objective, all the capabilities linked to it have to be obtained. Since the objectives maintained in CO are generic, BFO is developed based on wide ISIC Classification[22]. BFO maintains the decomposition of business fields and sub-business fields. Fig. 3 shows an overall view of the linkage between the collaborative objectives and capabilities that captured from partners with the two ontologies (also, the structures of them are presented).

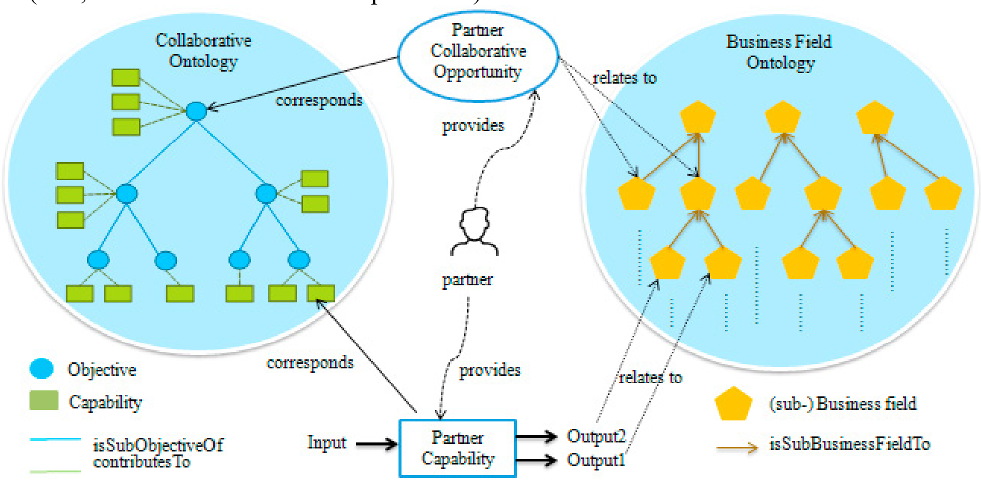

Fig. 3. The link between partners' inputs to the two ontologies.

3.1 The theory of APS-M

As can be seen from Fig. 3, in order to make use of partners' inputs (be readable by IT systems), some potential links (i.e., "corresponds" and "relates to") have to be built. APS-M aims to build these links automatically by applying semantic checks.

APS-M is designed as a model-driven approach. The partners' inputs (i.e. collaborative objectives and partners' capabilities) shall be expressed in models. As stated in[6], we provide two modelers (as services) to allow partners to fulfill their information. Models shall be built based on some predefined rules, which are described in meta-models. As defined in[8], a meta-model is a model that makes statements about what can be expressed in valid models. To regulate partners' inputs and also define semantic checking mechanism, a meta-model is developed in APS-M.

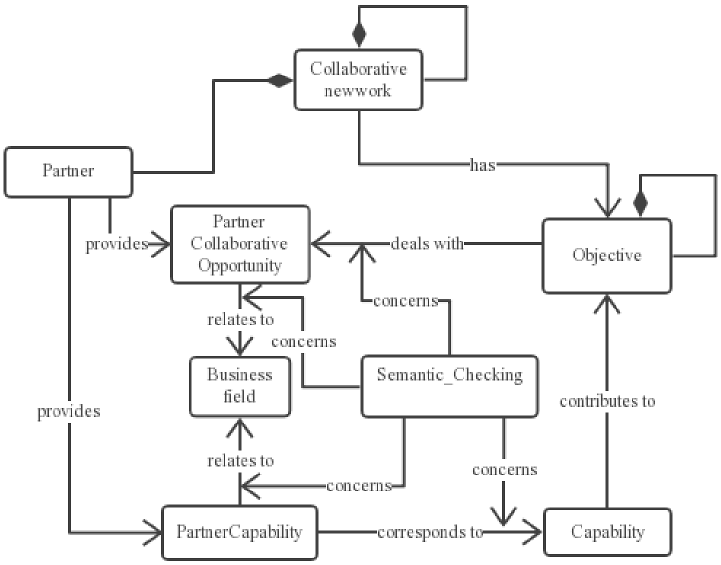

Fig. 4. The meta-model defined in APS-M.

As shown in Fig. 4, there are eight core elements contained in this meta-model. "Collaborative network" is self-contained and consists of a set of "partners". Each "Partner" provides its "capabilities" and "collaborative opportunities" to this network. A collaborative network has a specific "objective", which shall be located in the CO and also self-contained (objective – sub-objectives). This "Objective" can only be achieved by executing a set of "capabilities" (maintained in CO) contributing to it. An "Objective" deals with the partners' "collaborative opportunities" and "Partners' Capability" corresponds to the "Capability" maintained in CO. To specify the collaborative objectives and partners capabilities, all of them shall be linked with the terms (i.e. business field) defined in BFO.

On the basis of general semantic checking technologies, semantic checking approaches are defined to build the links between relevant terms (e.g., partners' capability to capability, partners' capability to business field) in APS-M.

3.2 Adapted Semantic Checking Measurements

To enhance the semantic checking performance, syntactic checking, which may disclose some potential semantic relations, is combined as a part of semantic checking measurements in APS-M. Fig.5 details the mechanism of doing semantic checks.

Semantic checking measurements (semantic checks) are applied between partners' terms and ontologies' terms (e.g., partners' capabilities – capabilities maintained in CO, partners' collaborative objectives – business fields maintained in BCO). The output is the comparing value between a pair of terms, which measures the similarity degree between them. Two steps: **syntactic checking** and **semantic checking** are performed.

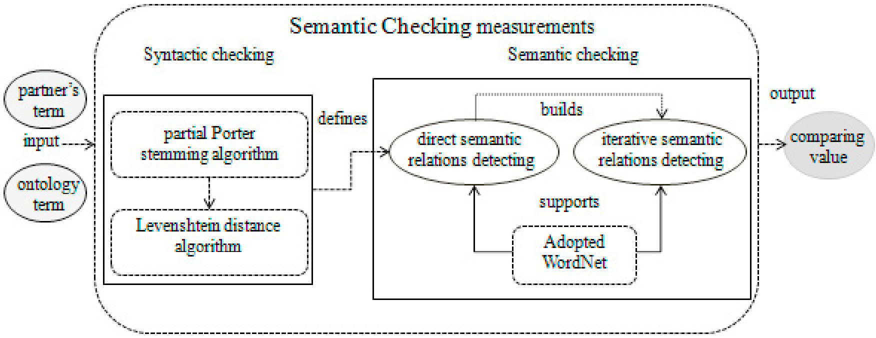

Fig. 5. An overview of the semantic checking mechanism used in APS-M.

The first step "syntactic checking" contains two phases: applying partial "Porter stemming" algorithm[23] and applying "Levenshtein distance" algorithm[24]. The purpose of applying "Porter stemming" algorithm is to discover certain special direct semantic relations (e.g., synonym: teacher-teachers, city-cities) between a pair of comparing terms. Informally, the "Levenshtein distance" between two words is the minimum number of single-character edits (i.e. insertions, deletions or substitutions), which stands by Lev(a, b), required to change one word (a) into the other word (b). With the help of Lev(a, b), Equation (1) is defined to calculate the syntactic similarity between a pair of words (a) and (b), where |a| and |b| stands for the lengths of them.

$$SyV = 1 - Lev(a, b) / \max(|a|, |b|) \quad (1)$$

The rules of calculating Lev(a, b) can be consulted in[25]. "SyV" stands for the syntactic similarity value, which is in the range of 0 to 1. The higher of this value means the higher syntactic similarity between two comparing terms. If two terms own a high syntactic similarity, they may convey a same (or similar) semantic meaning.

The second step "semantic checking" adopts WordNet[26] as the semantic thesaurus (implemented using neo4j and named as APS_ST). It consists three kinds of items: words (with quantity: 147,306), word senses (with quantity: 206,941), and synsets (a synset is a group of word senses owning synonym meanings, with quantity: 114,038). Semantic relations are defined and maintained between different synsets.

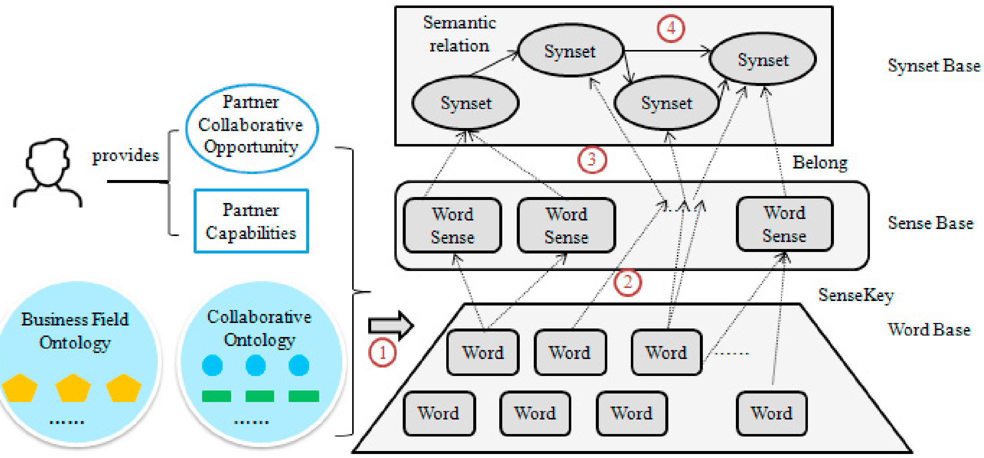

Fig. 6. An illustration about the APS_ST used in APS-M.

As shown in Fig. 6, all the comparing terms coming from CO, BFO and partners inputs can be regarded as words (concepts) and shall be located in WordNet. The comparing process follows four steps. Firstly, locate the two comparing words in WordNet. Secondly, search all the senses of the comparing words and form two groups respectively. Thirdly, trace the synsets that those senses belonging to and compose two groups (A and B) of synsets. Finally, detecting the semantic relations maintained between each pair of synsets (one from group A and the other from group B). All the semantic relations defined and maintained in WordNet have been inherited in APS_ST.

As shown in table 3, only parts of the semantic relations are being detected in APS-M. There are two kinds of semantic relations: direct semantic relations (e.g., alsosee and similarto) and iterative semantic relations (e.g., hypernym, hyponym), are being detected between a pair of comparing terms. Direct semantic relation means the shortest path between two synsets is one (or zero: belonging to the same synset). If there is one (or several) path(s) between two synsets, and the shortest one is n (n>1), there is a n-iterative semantic relation between the two synsets.

Table 3. The semantic relations being detected in APS-M.

Category	Semantic relation	SeV	Example
Direct semantic relation	alsosee	0.9	good - better
	similarto	0.85	good - goodish
	hypernym	0.9	creator-person
	hyponym	0.7	person-creator
	word	0.95	telephone & phone
Iterative semantic relation	iterative hypernym	0.9^n	maker-creator-person (n equals 2)
	iterative hyponym	0.7^n	person-creator-maker (n equals 2)
	hyponym & word	0.7*0.95	phoneme - telephone
	……	……	……

Considering the context of selecting partners for collaboration, five direct semantic relations are being detected. The iterative semantic relations being detected are kinds of combination of these direct semantic relations.

The “SeV”, which stands for semantic similarity value, is a value assigned (to direct semantic relation) or calculated (for iterative semantic relations) as the similarity on semantic aspect between a pair of comparing terms. The higher this value is, the closer the two comparing terms are.

These SeVs are assigned in a relative way. The intuitive idea is: a semantic relation that implies a high possibility of transformation owns a relatively big SeV. For example, between a pair of words “person” and “creator”, “person” is a hypernym of “creator” and “creator” is a hyponym of “person”. The possibility of transforming “creator” to “person” is higher than the one of transforming “person” to “creator”, so the value ‘0.9’ is assigned to the hypernym relation as the SeV and ‘0.7’ is assigned to the hyponym relation as its SeV.

Based on the “Semantic relation - SeV value” pairs, a concrete value may be calculated between every pair of comparing terms. Considering both the SyV and SeV, Equation (2) is defined.

$$SC\_V = \begin{cases} 1 & \text{if: same terms determined by syntactic checking} \\ SeV & \text{else if: a semantic relation is found by semantic checking or by syntactic checking} \\ SyV & \text{else if: words can not be located in WordNet} \\ 0 & \text{else} \end{cases} \quad (2)$$

“SC_V” is short for “Semantic Checking Value”. It ranges between “0” and “1”. The syntactic checking will be executed first, if it determines two comparing terms are the same or a direct semantic relation (stemming issue) exists between them, then SC_V equals to “1” or a specific “SeV”. When two terms have a very high syntactic similarity, they are assumed to convey the same semantic meaning (SC_V between them is 1). When syntactic checking cannot determine the SC_V, semantic checking will be executed. If certain of semantic relations are detected, then a SC_V (equals to SeV) can be calculated. If one (or both) of the two comparing words cannot be located in WordNet, the SC_V between them equals to the SyV that is calculated only considering their syntactic similarity. Otherwise, SC_V equals “0”. Between a pair of comparing terms, the higher “SC_V” means a stronger link (transformation possibility) between them.

Since there may exist several semantic relations between a pair of comparing words (concerning their different meanings), several SC_Vs may be calculated. In the context of APS-M, the maximum SC_V will always be selected as the potential matching possibility between any pair of comparing words.

4. Use case

4.1Use case illustration

To explain clearly the mechanism of doing semantic checks in APS-M, a simple use case is given. As shown in Fig. 7, this use case simulates the scenario of selecting partners based on their (input) capabilities.

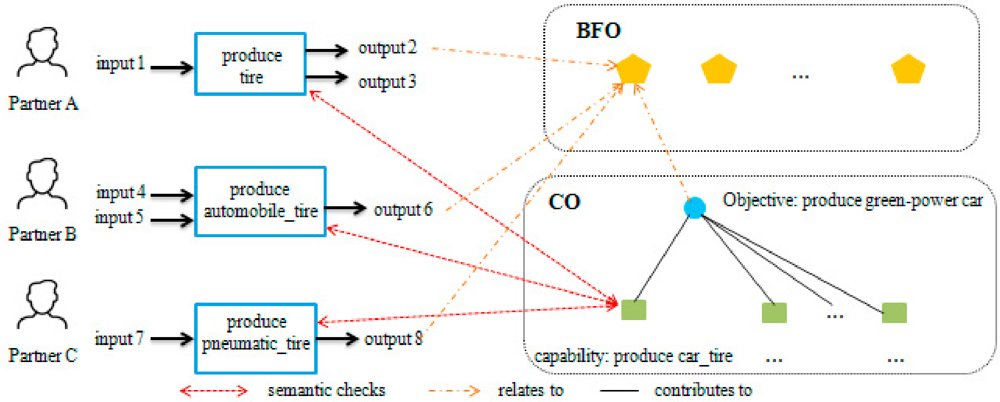

Fig. 7. A general overview of the use case.

In this use case, two hypotheses are made: 1) selecting partners for a specific collaborative objective, which corresponds to the one "produce green-power car" in CO and relates to one business field in BFO, 2) based on this business field, three partners are selected (concerning their outputs).

To achieve this specific collaborative objective, one of the three partners (i.e., A, B, C) will be selected to contribute his capability that relates to the one "produce car_tire". Semantic checks shall be used between partners' (input) capabilities and the capability "produce car_tire".

4.2 Testing process and results

The syntactic checking process will be firstly executed between three pairs of words: tire – car_tire, automobile_tire – car_tire and pneumatic_tire – car_tire. Since there is no stemming issues can be found (by executing the partial potter stemming algorithms defined in APS-M), equation (1) is applied. The SyVs calculated for these comparing pairs are: 0.5, 0.333 and 0.429. If any of these words cannot be located in WorldNet, the corresponding SyV(s) will be used as the final SC_V(s).

Then, semantic checks are executed between these three pairs of words and the comparing result is shown in Fig. 8, which consists of three screenshots.

Fig. 8. The testing result of this use case.

The semantic relation between "tire" and "car_tire" is "hyponym", so the SC_V between them equals to the SeV '0.7' (defined in table 3). The semantic relation between "automobile_tire" and "car_tire" is "word", so the SC_V between them equals to the SeV ‘0.95’. The semantic relation between “pneumatic_tire” and “car_tire” is iterative “hypernym-hyponym”, so the SC_V between them equals to ‘0.63’ (0.7*0.9). According to the three SC_Vs, partner B will be selected (considering only the capability) to join this collaboration.

4.3 Evaluation

The performance evaluation focuses on the time consuming issue and has been performed on a personal computer of 2.4 GHz, i5-6200U CPU and 8 G RAM (with Windows 10 OS and Java 9 JDK). APS_ST is stored in a neo4j database (which has been created on a local power server).

The evaluation is carried out by comparing three pairs of words: tire – car_tire (with a direct semantic relation), pneumatic_tire – car_tire (with an iterative semantic relation), and plane – car_tire (no semantic relation exists between them). The evaluation process is: from employing only direct semantic relations (from one to five) detecting to employing iterative semantic relations (combination of two direct semantic relations) detecting. Fig. 9 shows the evaluation result.

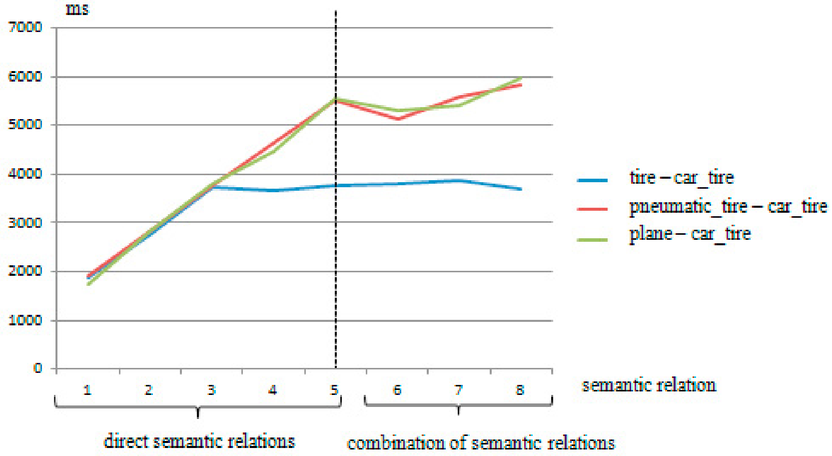

Fig. 9. The evaluation result on time-consuming issue.

The time of doing direct semantic relations detecting increases at a fixed ratio. One more direct semantic relation detecting consumes around one more thousand milliseconds (until one relation detected). For doing combination iterative semantic relations (ignore the quantity) detecting, the time consumed stays almost the same. So, it seems the calculating time concerns mainly on the quantity of direct semantic relations being detected.

More relevant relations may be disclosed while more semantic relations (both direct and iterative) are being detected. Meanwhile, more unexpected terms (words) may be linked by those semantic relations.

5. Conclusion

Selecting suitable partners is a tough task in current collaboration. Few research works have been carried out on this topic. Based on our previous work[6], this paper proposes a model-driven approach “APS-M” to address this task. To improve the efficiency, semantic checking measurements have been employed in APS-M.

Comparing with the work[6], this paper focuses particularly on partners’ selection issue (the deducing collaborative process issue is also presented in[6]). This paper details the semantic checking measurements used in APS-M, and especially explain the way of combining these measurements into the partners’ selection process. Comparing with other semantic checking approaches, the comparing pairs of terms are particular and the semantic relations being detected in APS-M are special. A meta-model is defined and used as the fundamental theory of APS-M. Also, a graph database is developed as the semantic thesaurus to support the semantic checking measurements. Furthermore, a use case with its evaluation is presented.

At this moment, APS-M only pays attention to partners' capabilities and collaborative objectives while selecting suitable partners. There are also some other important aspects that should be taken into consideration, such as the collaborative constraint (e.g., cost, time and quality). Some of these aspects have already been addressed in our other research works.

As future work, there are some potential extensions to this research work, such as: 1) the meta-model defined in the third section have to be improved with more detail (more aspects shall be taken into account while selecting partners), 2) more suitable iterative semantic relations shall be added and to be detected, and 3) the mechanism of doing automatic verification of the selecting results have to be addressed.

Acknowledgements

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