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A Social Platform for Knowledge Gathering and Exploitation, Towards the Deduction of Inter-enterprise Collaborations

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Abstract

Several standards have been defined for enhancing the efficiency of B2B web-supported collaboration. However, they suffer from the lack of a general semantic representation, which leaves aside the promise of deducing automatically the inter-enterprise business processes. To achieve the automatic deduction, this paper presents a social platform, which aims at acquiring knowledge from users and linking the acquired knowledge with the one maintained on the platform. Based on this linkage, this platform aims at deducing automatically cross-organizational business processes (i.e. selection of partners and sequencing of their activities) to fulfill any opportunity of collaboration.

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Keywords: Cross-organization collaborative platform; Inter-organizational business process deduction; Semantic web-based system; Ontology alignment.

1. Introduction

Since the 70's, "Collaborative Networks of Organizations" (CNO) have evolved from intra-collaborations of single workshops to inter-organizational collaborations [1]. With the appearance of these new kinds of collaborations, a key problematic is put forward: how to design and run collaborations of heterogeneous organizations? We address this problematic by a two-level response. First level, from a functional point of view, collaborations should be supported by interoperable IT systems with efficient functions; second level, from a technical point of view, the interoperable IT systems should be able to deal with heterogeneous data coming from all users.

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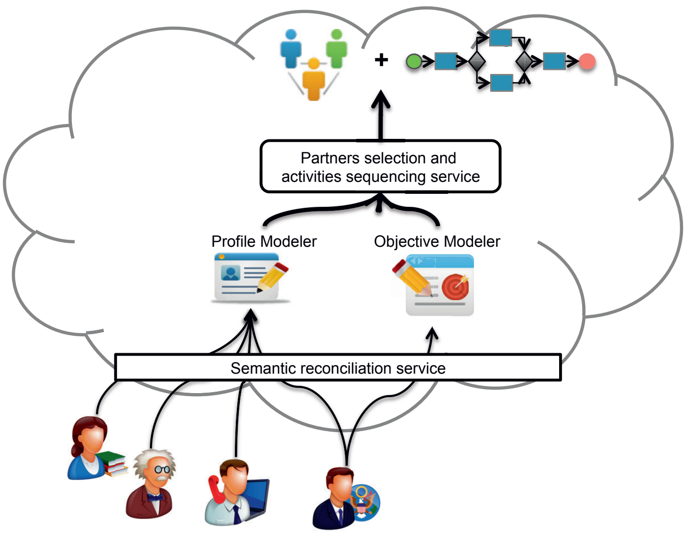

Fig. 1 Users' interactions with the information system.

For organizations involved in collaborations, the ability of cooperating with different partners is crucial. "Interoperability" might be used to describe this ability. Two definitions are listed here: "the ability of a system or a product to work with other systems or products without special effort from the user" by Konstantas [2] and "a measure of the degree to which diverse systems, organizations, and/or individual are able to work together to achieve a common goal. For computer systems, interoperability is typically defined in terms of syntactic interoperability and semantic interoperability" by Ide and Pustejovsky [3].

Many standards have been set up to enable enterprises to work together by using standardized exchange protocols and data formats. Two examples of these standards are RosettaNet [4] and ebXML [5]. However, these standards are difficult to implement because of (i) the cost of making them effective (especially for SMEs) and (ii) the lack of "agility" (i.e. the processes have to be established upstream and are not intended to be "deduced" on-the-fly), as expressed by Ko et al.[6].

According to Chen et al. [7], enterprise interoperability could be fulfilled by three approaches: *integration* (i.e. all the partners of the CNO use the same data format), *unification* (i.e. a common metal-level is used by all the partners and semantic links to "translate" a format into another one are provided) and *federation* (i.e. matching data on-the-fly). This paper deals especially with the establishment of an inter-organization collaborative platform using a Federation approach, which enables on-the-fly data matching, and the building of very lose collaborations. Consequently, this platform could provide cheaper and reactive solutions to support collaborations.

This collaborative platform can be divided into two parts, which address two main levels:

- **The technical level**. (cf Fig. 1 "Semantic reconciliation service") This part concerns a semantic-based reconciliation system, which merges the data coming from users with the collaborative knowledge base (gathered in the next functional level). This semantic-based reconciliation system indeed focuses on the step of knowledge acquisition to analyze and to "understand" the users' needs (i.e. during their interaction with the Profile and the Objective modelers), and enables the further exploitation in order to deduce on-the-fly inter-organizational processes.

- **The functional level**. (cf Fig. 1 "Partners selection and activities sequencing service") This part deals with the exploitation of users' data and collaborative knowledge. The goal of this part is, from collaboration knowledge gathering (i.e. objective and context of collaboration) to deduce inter-enterprises collaborative processes (i.e. partners, tasks and execution sequence). This function is implemented by a two-modelers interface: (i) a "Profile

Modeler" lets the users describe functionally their business services (also called capabilities) and thus gathers knowledge on "who is able to do what?" (ii) An "Objective Modeler", to describe also the goals and the context of the collaboration. Finally, deducing mechanisms are implemented to exploit the collaborative knowledge in order to build on-the-fly process.

This paper is divided into five sections. The second section presents a state of the art on the existing solutions, and then Section 3 is oriented towards a solution to knowledge acquisition; as the technical level, this section illustrates the semantic and syntactic checking measurements. Section 4 deals with the functional level solution : the exploitation of collaborative knowledge towards the deduction of collaborative processes in the third section. Finally, a conclusion is given in the fifth section.

2. State of the art

2.1. Semantic-based reconciliation system

2.1.1. Syntactic checking mechanism

Syntactic checking is used to calculate the *syntactic similarity* between two words. There exist several syntactic checking methods; most of them use classic similarity metrics to calculate the syntactic relations. As stated in [8], such methods are: "edit-distance metrics", "fast heuristic string comparators", "token-based distance metrics" and hybrid methods. Also in [8], several existing string matrix matching (syntactic checking) methods have been presented and compared with each other. For example: string-edit distances, TFIDF distance metric.

The purpose of applying syntactic checking between two words could be: names-matching or records-matching. One of the typical usages of this technology is "to serve database management (data integration)".

2.1.2. Semantic checking mechanism

Semantic checking is used as an artificial intelligent approach; it replaces the human efforts involved in some engineering processes. However, most of the semantic checking measurements are implemented within specific domains, and focus on specific problematic. Two examples are stated in [9] and [10].

Semantic checking measurements rely on huge semantic thesauruses. Such semantic thesauruses contain large amount of words, words' semantic meanings and semantic relations among these words. Semantic checking measurements for specific usages could be built upon domain specific ontology (e.g. MIT Process Handbook [11] on industrial processes), which works as a semantic thesaurus. For general usage purpose, a more general semantic thesaurus is needed. "WordNet" [12] is one of such kind semantic thesaurus. One example of using "WordNet" as semantic thesaurus is stated in [13].

2.2. Collaborative systems and deduction of inter-organizational processes

On the one hand, the creation of IT systems for facilitating collaborations has become an important research topic in recent years, and numerous models and system implementations have been explored. On the other hand, only some works focus especially on the on-the-fly deduction of process. This part of the state of the art focuses on these two aspects.

2.2.1 Supporting inter-organizational collaborations

Camarinha-Matos [14] describes Virtual Organizations (VOs) as democratic collaborations between organizations that need to share their skills to reach collaborative goals. The modeling of business processes comes along with the VO concept, since it easily helps to model the interaction and the information exchange between the partners of the VO, and schematically, illustrates the question of "*Who* needs to execute *which activities*, and *when*?". As previously cited works RosettaNet [4] and ebXML [5], several standards have been set up to support inter-organizational collaborations. In parallel, the new XaaS (Everything as a Service) technologies allow now to support collaborations with a more federative approach since the users do not need anymore to adapt to the standards formats. Accorsi [15] introduces BPaaS (Business Process as a Service) softwares as solutions for organizations to work together, from the design-time to the run-time of a process, and as underlined by Sun et al., the muti-tenancy is an intrinsic property of this kind of collaborative platform. Some industrial products like ARIS [16] or SAP Netwaeaver [17] also provide IT collaborative supports that enable organizations to share processes, workflows and exchange data. The main limitation of these works relies on the fact that the design-time remains mostly a human task (i.e. not automated).

2.2.2 Deducing inter-organizational collaborative processes

The automation of the design-time of inter-organizational collaborations has become a key factor to implement more efficient and reactive collaborative platforms. Many research works address this problematic via two different approaches: (i) either the actors are already known and their activities should be ordered, or (ii) the main steps of the process are already established, and the partners have to be selected. Mu[18] has implemented a collaborative tool that allows from a collaborative opportunity and a coalition of partners to define the corresponding business process. This IT system relies on the exploitation of a collaborative ontology based on the MIT Process Handbook[11]. The web service composition problematic is also very close to the composition of business services here. In [19], Wang et al. made a survey on the bio-inspired algorithm used for web service composition. According to them, such algorithms are widely used because of the non-functional dimension of workflows or processes: it is not sufficient to find partners able to execute each service and there is now a need to find the best partners (e.g. on time delivery or cost dimensions). These types of algorithms are used to resolve global optimization issues on service composition: the selection of all "atomic" best partners for each service is indeed not sufficient anymore because of time optimization (i.e. the whole time of execution of the workflow can only be assessed when all the partners are known since their services could be parallelized for example). Both types of work have their limitations that our deduction service aims at addressing: it is a perspective of the research works of Mu, on which the coalition of partners was already known, and also an extension of the works realized on service composition, because it is not only about the selection of partners but also on the deduction the workflow.

A first version of this deduction service has been presented in [20], by providing a basic process deduction mechanism based on two ontologies (a generic collaborative ontology and a specific business field ontology). However, the approach described at this time suffers from two main inconveniences. First, the user needs to directly link its capabilities and collaborative objectives to those stored in the ontologies. That means that, the semantic acquisition of knowledge remains human and assumes that the user is able to adapt to the exact semantic of the ontologies. Second, the algorithm described to select partners and sequence their activities only enables to provide a "feasible" process that fulfills the collaborative opportunity: thus, it could provide a very bad solution considering non-functional criteria such as cost, delivery time or quality (which is not realistic in a competitive context in which several companies could provide the same capabilities). The further Section 3 and 4 actually address these two issues.

3. Knowledge acquisition, semantic reconciliation of enterprises' knowledge bases

Based on the requirement of deducing collaborative business process, a semantic reconciliation system is needed to fulfill the gap between the users' terms used to define their profiles and their collaborative objectives (cf. Profile Modeler and Objective Modeler in Fig. 1), and what the IT system can understand (i.e. the terms contained in its collaborative knowledge also called collaborative ontologies, as explained in Section 4). Hence, it is required to consider the semantic meanings of the items (i.e. collaborative objectives and capabilities) to match it to knowledge contained in the collaborative ontologies. So, our semantic reconciliation system focuses on comparing automatically semantic relations between two words. As an adjunct to semantic detecting, syntactic detecting is also involved in this semantic reconciliation system. Formula (1) shows the rules of calculating the relation between two words.

$$S\_SSV = sem\_weight*S\_SeV + syn\_weight*S\_SyV \quad (1)$$

In (1), "S_SSV" stands for "semantic and syntactic value between two words". "sem_weight" and "syn_weight" are two impact factors for semantic value and syntactic value between two words. The sum of them is 1. "S_SeV" stands for the semantic value between two words, while "S_SyV" stands for the syntactic value. The details of calculating "S_SyV" and "S_SeV" are illustrated in the following two subsections, respectively.

3.1. Syntactic checking measurement

Syntactic checking measurement is used to calculate the syntactic similarity between two words. The syntactic checking measurement involved in our semantic reconciliation system is divided into two phases:

- Pretreatment: focuses on finding if two words that in different forms (e.g. tense, morphology) stand for a same word.

For pretreatment, Table 1 shows several pairs of the situation: two words that in different forms (e.g. tense, morphology) stand for the same word.

Table 1. Syntactic Pretreatment Situations

Case	Word 1	Word 2	Example
1		word 1 + 's' at end	son & sons
2	Ends with 's' "sh", "ch", 'x'	word 1 + "es" at end	match & matches
3		word 1 + "ing" at the end	do & doing
4	Ends with 'y'	change 'y' to 'i' + "es"	city & cities
5	……	……	……

The pretreatment phase does not consider some specific cases that do not follow general transformation rules (e.g. man and men).

- "Levenshtein Distances" algorithm [21].

If two words do not satisfy the conditions defined in the pretreatment, "Levenshtein Distances" algorithm is applied between them. This algorithm calculates the syntactic similarity between two words; it is based on the occurrences of the letters that involved in two words.

"Levenshtein distance" is equal to the number of operations needed to transform one word into another. There are three kinds of operations: insertions, deletions and substitutions. During the calculation process, a two-dimensional table is created to store the transformation information. The basic theory and concrete executing process of this algorithm is stated in [21].

Equation (2) shows the calculation rules of syntactic relation between two words: word1 and word2, which based on "Levenshtein distances".

$$S\_SyV = 1 - LD \, / \, Max\,(word1.length, word2.length) \qquad (2)$$

In (2), "S_SyV" stands for the syntactic similarity value between word1 and word2; "LD" means the "Levenshtein distances" between them. The value of "S_SyV" is between 0 and 1; the higher of this value means the higher syntactic similarity. The word's length (i.e. word1.length and word2.length) is also taken into account in (2), in order not to favorite short words.

3.2. Semantic checking measurement

Different to syntactic checking measurement (relies just on the two comparing words); semantic checking measurement relies upon a huge semantic thesaurus which contains large amount of words, their semantic meanings and semantic relations among these words. A huge semantic thesaurus has been created for serving to this semantic reconciliation system. We created a specific semantic thesaurus, which uses "WordNet" as data basis; the semantic-based reconciliation system is built upon this specific semantic thesaurus. Fig. 2 shows the structure of this semantic thesaurus.

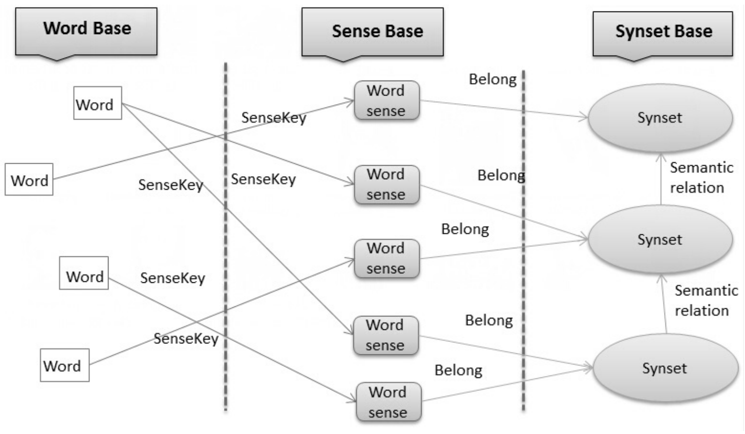

Fig. 2 Structure of the Semantic Thesaurus

As shown in Fig. 2, there are three kinds of items in this semantic thesaurus, they are listed as following:

- Word base: contains normal English words (nouns, verbs and adjectives).
- Sense base: contains all the word senses; a word could have “one or several” senses. For example: word “star”: it has six senses; as noun, it has four senses; as verb, it has another two senses. However, one word sense only concerns one word.
- “Synset” base: a group of word senses that own synonym meanings; semantic relations are built among different synsets.

Based on the context of deducing collaborative business process (matching objectives and capabilities), seven kinds of semantic relations are defined and maintained among synsets: “synonym”, “hypernym”, “hyponym”, “coordinate terms”, “holonym”, “meronym” and “similar-to”. For each of the semantic relations, a specific value (between 0 and 1) is assigned to it. Table 2 shows these semantic relations and their values pairs.

Table 2. Semantic Relations and Values in Semantic Thesaurus An example of a table.

Semantic relation	S_SeV	Remark	Example
synonym	0.9	words from the same synset	shut & close
hypernym	0.6	Y is a hypernym of X if every X is a (kind of) Y	person-to-maker
hyponym	0.8	Y is a hyponym of X if every Y is a (kind of) X	creator-to-person
coordinate terms	0.7	Y is a coordinate term of X if X and Y share a hypernym	maker & artist
holonym	0.65	Y is a holonym of X if X is a part of Y	building-to-door
meronym	0.75	Y is a meronym of X if Y is a part of X	door-to-building
similar-to	0.85	iterative hyponym relation	good & bad

The “S_SeV” values shown in table II could be used by (1), and with the help of (2), the relation between any pair of words could be defined (by a value between 0 and 1). The semantic checking measurements (search and retrieve words and the semantic relation between them) are supported by algorithms.

One issue to be mentioned: to improve the semantic checking measurement, the iterative situations for “hypernym”, “hyponym”, “holonym”, “meronym” semantic relations, should be considered. Fig. 3 illustrates this issue, which takes “iterative hypernym” semantic relation as example.

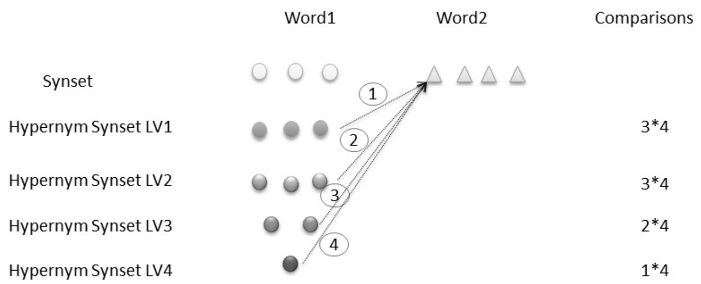

Fig. 3 Structure of the Semantic Thesaurus

The basic idea of this detecting process is: locating the synsets that have "hypernym relation" with word1's synsets iteratively and comparing with word2's synsets, in order to find two same synsets.

With the huge content stored in this semantic thesaurus (147306 words, 206941 word-senses and 114038 synsets), it is possible to do the semantic checking for deducing automatically collaborative business process explained in the further section.

4. Knowledge exploitation, towards the deduction of inter-organizational processes

We propose a business process deduction from: (i) collaborative objectives and (ii) a repository of business capabilities that organizations have proposed in their profile. Thus, the knowledge exploitation can be divided into two parts: the first deals with modelers (Profile and Objective Modelers), and the second focuses on the algorithm used to exploit the knowledge gathered by the modelers, in order to find the partners of the collaboration (Who?), their activities to set up (What?) and the sequencing of these activities (How?).

4.1. Collaborative ontologies

The modelers aim at providing interfaces, so that the users can describe the collaborative context. Actually, they rely on an ontology-based system that consists of two ontologies. These ontologies have been described in [20], however, in an effort to facilitate the comprehension of the further deduction process, it is important to clarify here their structure and how they have been built and populated.

- **The Collaborative Ontology** (CO) is a generic and structured knowledge base that has been built according to a top-down approach. Hence, it contains generic *objectives* that are themselves decomposed into *sub-objectives*. Each of them is linked to a set of *capabilities* that need to be executed in order to fulfill the parent *objective*. The CO is based on easy transformation from the OWL version of the MIT Process Handbook [i] into the adapted *objectives*/*capabilities* decomposition. Since the CO is very generic in its concepts (e.g. *objective* "Buy" does not allow the difference between "buying a car" and "buying chocolate"), another ontology has been implemented, which is oriented towards business activities.
- **The Business Field Ontology** (BFO), only consists on the decomposition of *business fields*, into *sub-business fields*, and is based on a transformation of the wide ISIC Classification [22] into an exploitable OWL file. These ontologies are illustrated in the right part of the Fig. 4.

4.2. Profile and Objective modelers

Two modelers have been implemented as human interfaces and relies on the use of the two previous ontologies CO and BFO, as a way for the IT system to understand the organizations' profiles and needs. In the next paragraphs, the linkage between users' terms and the ontologies are actually done via the previous syntaxo-semantic reconciliation service, as described in Fig. 1.

- **The Profile Modeler** has been implemented so that organizations could easily describe their capabilities (also called business services). Thus, it proposes to the users to describe their capabilities, based on the IDEF0 standard[23], with a central capability linked to a *capability* of the CO, and its input and output. The goal of the input and output, here, is to specialize the prerequisites and the results of the capability. Consequently they are linked with one or more *business field(s)* of the BFO. For example, the Fig. 4 illustrates the description of the capability « Place order », with « Office administrative service » as input business field and « Manufacture of chocolate » as the business field concerned by the result. It means that the user can order chocolate with industries of chocolate, and the capability concerns an administrative service.

- **The Objective Modeler** proposes to the users to describe the collaboration they need to design. As such, the objective of the collaboration is the central part, and is linked with an *objective* of the CO. Then, following the same logic as the Profile Modeler, this objective deals with specific business fields (as many as needed). For example, the Fig. 4 illustrates the description of the objective « Buy », which is sepcified by two business fields « Manufacture of chocolate » and «Freight transport by road ». This objective model means that the user needs to establish a collaboration that would him to buy chocolate products, and also that he cannot take care of the transport which would therefore be supported by the final collaboration.

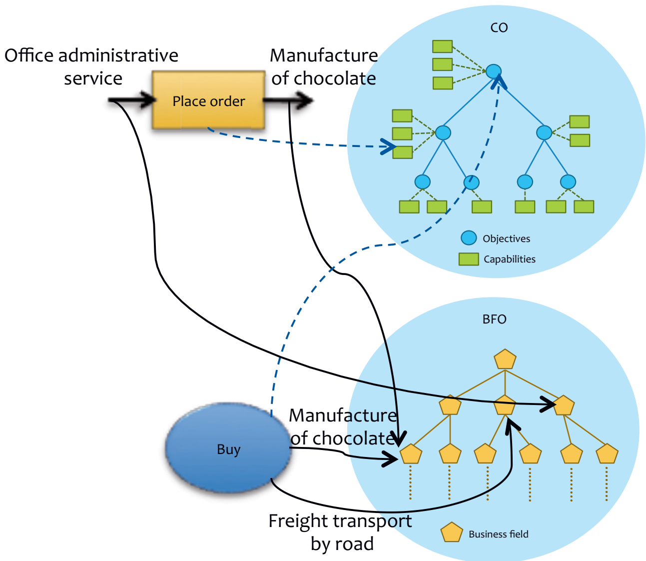

Fig. 4 Profile and objective modelers and their link to the CO and the BFO.

4.3. Process deduction

The deduction of a collaboration process consists on three phases : (i) finding the capabilities required to fulfill an objective, (ii) selecting the proper partners to execute these capabilities (optimized selection on delivery time, cost and quality criteria) and (iii) creating the corresponding process.

The choice of a Ant Colony Optimization algorithm was made so that these three steps could lead to an « optimal » process. Indeed, for each capability to execute, many organizations are expected to offer it. Thus, the goal here is to set up a coalition of most relevant partners.

Schematically, the Ant Colony Optimization (ACO) has been initially proposed by Dorigo[24] and is based on the biologic behavior of ants when they are searching for food. When exploring, an ant digs tunnels and if it discovers a source of food, it deposits pheromone on the path, so that the further ants could follow and also exploit this food.

The Fig. 5 provides an illustration of the comparison between the tunnels and the paths of the deduction algorithm : the links within the CO (from *Objectives* to their *sub-objectives*, and from *objective* to their required *capabilities*), and the links created by the users with the modelers (from an collaborative objective to the corresponding *objective*, and from the organization capability to the corresponding *capability*. Each ant explores the CO's paths with the following possibilities: (i) decomposition of the objective into sub-objectives, the ant is duplicated as many time as there are sub-objectives; (ii) decomposition of the objectives into required capabilities, the ant is duplicated as many time as there are required capabilities and (iii) links from CO's capabilities to organizations' capabilities, the ant choses a path according to the amount of pheromone already deposited by previous ants.

Finally, a set of organizations' capabilities is obtained: a process can be built and its feasability checked. If it is feasible and if the deduced process is convincing enough according to the non-functional criteria, pheromones are deposited in the path between the required capabilities and the corresponding organizations' capabilities.

Moreover, the construction of a process is a right-to-left matching: the output's business field(s) of the last capability must match the objective's business fields. Then a matching is done between intput and output so that the input of a capability matches the output of the previous one.

On a specific number of cycles, several ants deposit such pheromones, so that at the end, all the ants converge towards a « quasi-optimal » process.

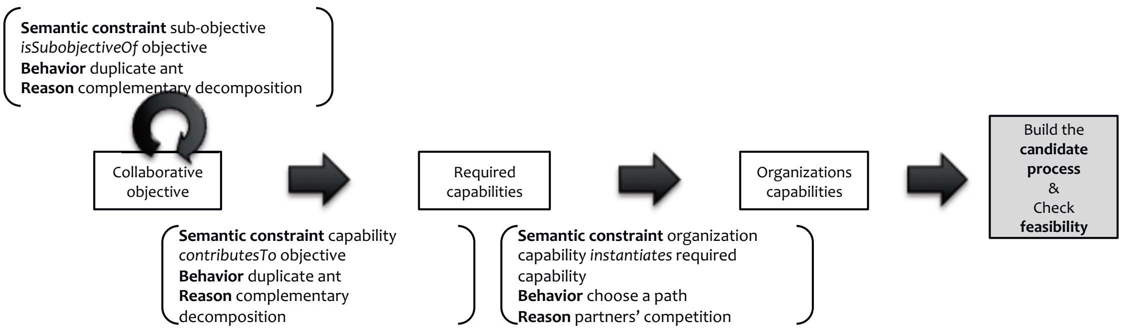

Fig. 5 Ant behavior during one cycle of the ACO.

5. Conclusion

This paper presents an innovative collaborative platform that allows deducing and supporting inter-organizational processes through two main parts: (i) the gathering of minimal collaborative knowledge and (ii) the deduction of quasi-optimal processes. In the first part, the knowledge gathering deals with the linkage between users's term on their capabilities and their collaborative needs. This gap between human thinking and IT knowledge is based on a syntactico-semantic reconciliation that provides the links between the terms of the users and the terms embedded in two ontologies: the generic Collaborative Ontology and the specified Business Field Ontology. This acquired knowledge allows generating a repository of profiles of organizations (i.e. a repository of all capabilities that the organizations are able to offer), and then define objectives of collaboration. Based on these two types of knowledge, a process deduction service based on an Ant Colony Optimization algorithm, is able to answer the objectives by (i) finding the required capabilities, (ii) finding the best partners (in terms of delivery time, cost and quality) able to provide these capabilities and (iii) order these capabilities in a collaborative business process.

The whole deduction system relies entirely on the relevance of the two ontologies. Thus, an "update service" of these ontologies could be a great benefit to make the system evolve and able to "understand" and support new types of collaborations. Basically, the syntactico-semantic reconciliation can be applied to merge ontologies, so that the organizations could provide their own ontologies and merge it with the already existing CO.

Another perspective of this system could also be the automated emergence of organizations' profiles and collaborative opportunities. Nowadays, this approach is indeed facilitated by the high mount of data gathered inside the organizations but also on social networks. On the one hand, for example, process mining [25] allows to analyze files with high amount of data from organizations, in order to deduce the corresponding and effective processes. This approach is usually used so that the organizations could have a "real" vision of their processes and enhance it. To the authors thoughts, by linking it to the syntactico-semantic reconciliation, it could also leads to the automated emergence of organizations' profiles. On the other hand, a similar analysis of various news feed could enable the emergence of new collaborative opportunities, by finding ideal contexts of collaborations.

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