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Ontology based multi agent system for improved procurement process: Application for the handicraft domain

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Abstract

Suitable suppliers' recommendation forms the basis for a successful procurement process. An automated personalization of procurement opportunities relies on the buyer and the seller profiles consistency. However, dealing with their profiles matching is not a trivial task. In fact, each contextual detail may play a crucial role in the decision making procedure especially when final users express very specific and variable needs in a heterogeneous and inconstant environment. In this paper, we designed and developed a multi agent system (MAS) for the supply chain automatization. It includes two supplier selection levels followed by a negotiation module relying on the handicraft woman online situation. Several handicraft business ontologies in addition to multi-side profile ontology are developed in order to drive the agent communication with the internal and external environment.

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Keywords: Multi agent system; supply chain; supplier selection; recommender system; personalization; buyer profile; seller profile; profile ontology; business ontology; handicraft domain

1. Introduction

The procurement process is widely important for the producer survival. It involves several steps¹⁷ beginning with the required good specification, the suitable supplier selection⁵, the price negotiation until the payment approval. The automatization of the supply chain is discussed recently in different research works. Indeed, this processing facilitates the task for the final users and suggests moreover trustworthy procurement opportunities.

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In this current paper, we aim to assist handicraft women (HDWs) from developing countries through the procurement opportunities recommendation. However, HDWs are situated in a heterogeneous and dynamic business environment affected by internal and external factors. While internal factors consider the HDW profile and needs, the external ones are focusing on the price variability, new suppliers' emergency, supply (a raw material or a tool) availability etc. That is why we are motivated to adopt the multi agent architecture. Nevertheless, in order to ensure the procurement chain communication system using intelligent agents, we need the integration of domain ontology. In fact, this latter helps agents in representing domain knowledge¹⁸, enables their interoperability, coordination¹⁶ and reinforces the merchant and customer confidence¹². Thus, we developed several business ontologies that are specific to particular handicraft fields. This enables a better understanding of the HDWs issues, needs and expectations. A multi-side profile ontology is also proposed which describes the HDW and the supplier profiles from different perspectives. Besides, this ontology is more informative than a standard user profile and is updated dynamically. Several matching rules are established so to check the supplier and the HDW profile suitability. Later, the most appropriate suppliers list is recommended online to the HDW and thus the negotiation phase takes place.

The remainder of this paper is organized as follows: Section 2 presents related works. Then, section 3 introduces the handicraft domain modeling including the business and profile ontologies. In section 4, we describe our model for the proposed recommender system agentification. A case study is then undertaken in order to validate our proposal in section 5. Finally, we conclude this paper in Section 6.

2. Related works

In the field of recommender systems, different scientific papers are focusing on the suggestion of commerce opportunities. Maamar et al in⁸, for instance, propose to set up a framework inspired by social habits which aims at promoting m-commerce activities. The developed system is designed to support stakeholders (consumers, providers, brokers) interactions during commercial activities through mobile. Stakeholders' communications are mapped onto social relationships. Hence, a consumers' social network for collaboration and referral are proposed. Likewise, a providers' social network for competition, collaboration is settled up. Moreover, Seungsup et al¹⁴ implement a recommender system which targets to select a suitable but also trustworthy seller among the huge number of available ones. They use the decision tree technique for suppliers' classification (trustworthy one or not). In order to find the top list of suppliers, they developed a recommender system based on a content-based filtering method.

In many research works, the MAS architecture is undertaken when dealing with the e-procurement process. In¹³ for instance, the authors designed and developed a dynamic framework for supply chain management and coordination based on the multi-agent architecture. It targets to identify business opportunities and to exploit the power of capacity scheduling functionality across the supply chain. Giovannucci et al. in¹ proposed the iBundler" agent-aware service which aims to assist the buyers when trying to determine the best set of the providing agents' bids taking into account their business rules. In⁶, the authors proposed an e-procurement process based on multi agent paradigm. The system targets to look for potential suppliers, facilitate the buyer and seller negotiations and finally to evaluate the performance of the suppliers relying on specific selection parameters. In⁷ the authors proposed an agent-based price negotiation system for on-line auctions. Mainly, three agents are used in the study: a seller agent, a buyer agent, and a mediator agent. In¹⁷, authors propose a multi-agent architecture for e-procurement exception management. The conceptual framework targets to reduce the complexity, uncertainty and risks in business transactions such as inventory failure, sharp increased demand, and delivery delay.

There is a rising interest regarding the integration of the ontology concept into MASs so to facilitate the interoperability between intelligent agents. In¹⁸, the authors propose a multi-agent system platform for individual companies in order to establish an ecological virtual enterprise. That is why, the ontology based

framework aims to select the suitable collaborators (in the generalized case suppliers). However suppliers are selected relying on several criteria such as price, quantity, quality, lead time but also environmental factors like environmental management, green image, green product and pollution control.

3. Handicraft environment modeling

The handicraft domain includes different business fields such as ceramic, tapestry, traditional pastry, embroidery etc. Each one has its specific particularities namely the business actors, the business tasks, the producing techniques, the required raw material and tools etc. In order to deal with the handicraft communities' needs, we had first to define their business environment. This latter encompasses both the business and contextual knowledge. This leads us to develop a business ontology for each handicraft field in addition to a generic profile ontology specifying the different business actors. In the following subsections, we will introduce a generic model for the whole handicraft business activities, specific business ontologies and finally a multi-side profile ontology.

3.1. The Generic business ontology model

The specification of the handicraft domain provides several advantages such as satisfying and understanding the handicraft woman needs, affording to her precise, precious and practical advices and finally skipping ambiguity issues related to handicraft knowledge details. Thus, we developed an ontology model specifying the handicraft domain. This model is common and takes into account the handicraft fields generalities. The ontology concept² is defined as the formal, explicit specification of a shared conceptualization. Besides, it is considered as part of the real-world knowledge representation³. Generally, it defines taxonomic and semantic relationships among particular domain concepts. Our proposed ontology highlights three business processes as mentioned in Fig. 1:

- **The Procurement process** which underlines the purchase steps of necessary raw materials and tools.
- **The Producing process** which clarifies the different phases of any artisanal product realization.
- **The Commercialization process** which emphasizes where, how and for whom selling final products.

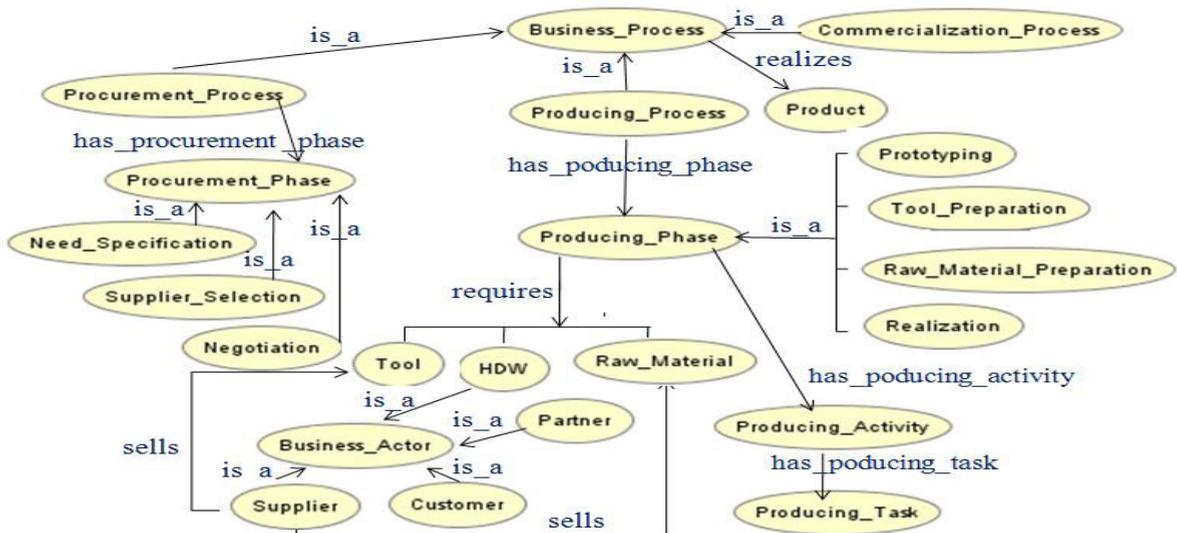


Fig. 1. the generic business ontology overview

Each business process includes several phases. Producing process, for instance, includes four producing phases, namely raw material preparation, tool preparation, prototyping and realization. Likewise, it realizes a product as output. Generally, a producing phase requires the implication of 1) one or more handicraft women and/or partner as business actors, 2) an eventual tool, 3) an eventual raw material etc. Furthermore, it includes different producing activities. However, a complicated producing activity could be subdivided into multiple producing tasks. These tasks contribute together to the achievement of a specific producing target. Moreover, the producing activity and producing task individuals may inherit the mentioned properties qualifying a producing phase. More specific knowledge is modeled in the next subsection. In fact, this business ontology model can be extended in order to define a specific handicraft area.

3.2. The specific business ontologies

We developed several business ontologies which each is specific to a particular handicraft field. These ontologies take into account the relevant business entities and the semantic links between them. This enables us later to increase the number of HDWs as final users of the established recommender system.

Due to space limitations, we propose a short overview only on two specific business ontologies dealing respectively with the ceramic production (Fig. 2) and the candle designing fields (Fig.3). Note that in the following figures, the “io” relationship means “instance-of”. As seen in the first figure, “modeling” which is a producing activity includes several producing tasks such as “potter wheel mounting”, “surface smoothing” and “product drying”. Each producing task requires particular resources. The “putting in oven” task for example requires an “oven” which is provided by the supplier “Ali”.

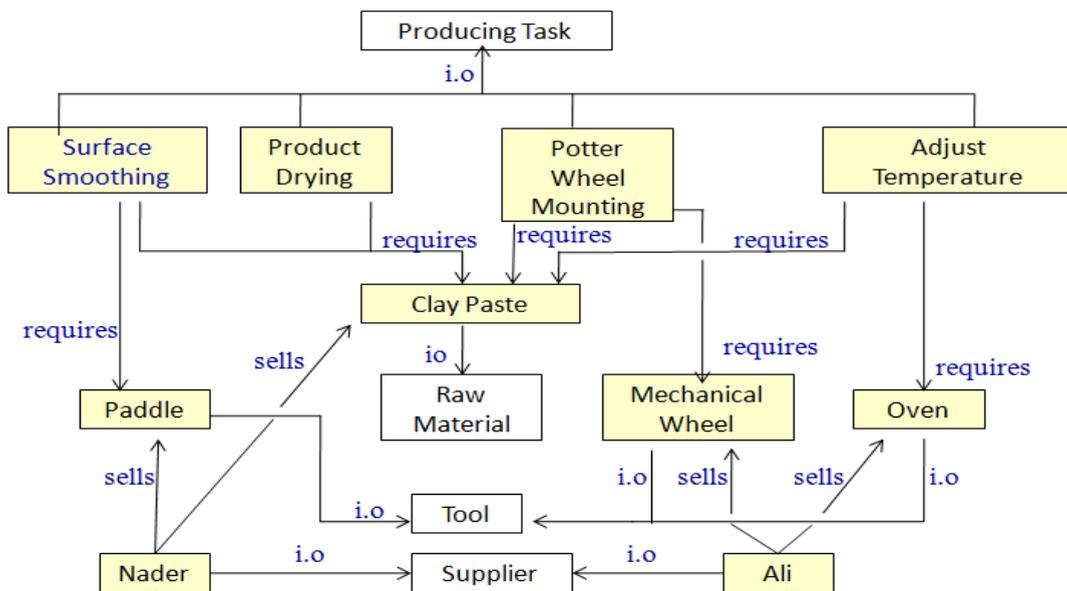


Fig. 2. the specific ontology for the ceramic production

In the second figure, several producing tasks are highlighted such as “Melt Wax”, “Add Colorant”, “Shape Candle” etc. We remark that the “Colorant”, which is a raw material instance, is required during the “Add Colorant” producing task. It is provided also by the supplier “Rayan”.

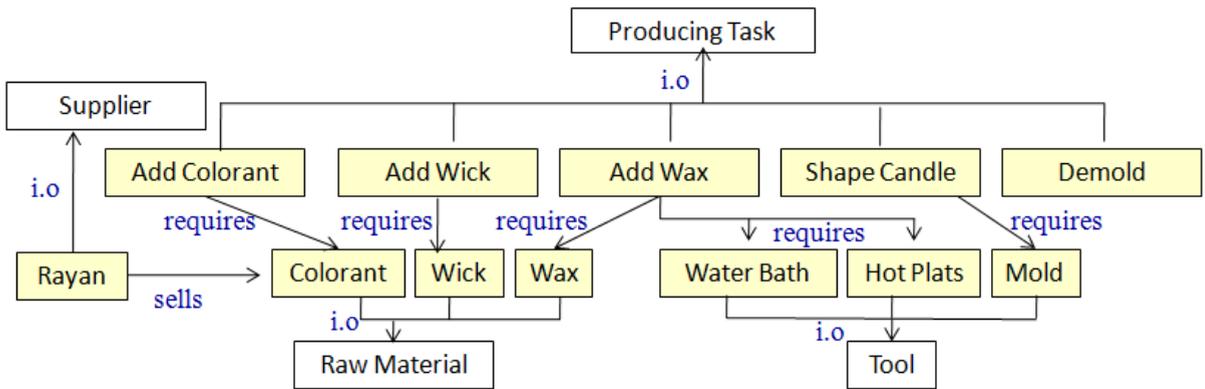


Fig. 3. the specific ontology for the perfumed candle designing

In order to control the flow of activities e.g. a task must be done before another, we propose to assign a numeric attribute to each producing concept within the specific business ontologies. This attribute mentions the task order during the producing stage. Indeed, this information could be useful to guide the recommendation process within its different stages.

3.3. The proposed profile ontology

According to⁴, “Personalization is the ability to provide content and services that are tailored to individuals based on knowledge about their preferences and behaviors”. Very often, personalization relies on the user profile definition. Besides, a user profile “contains mostly static data, like personal information, work history, links to contacts and services”¹⁵.

Our goal is to provide personalized assistance to HDWs from different contexts and diversified fields via the recommendation of several procurement opportunities. To this end, our recommender system has to define both the HDW and the supplier profiles. Indeed, the system suggests the most suitable providers considering the HDW and supplier profiles consistency. We move hence to the presentation of the developed profile ontology which details the profile parameters of the involved business actors namely the HDW and the supplier.

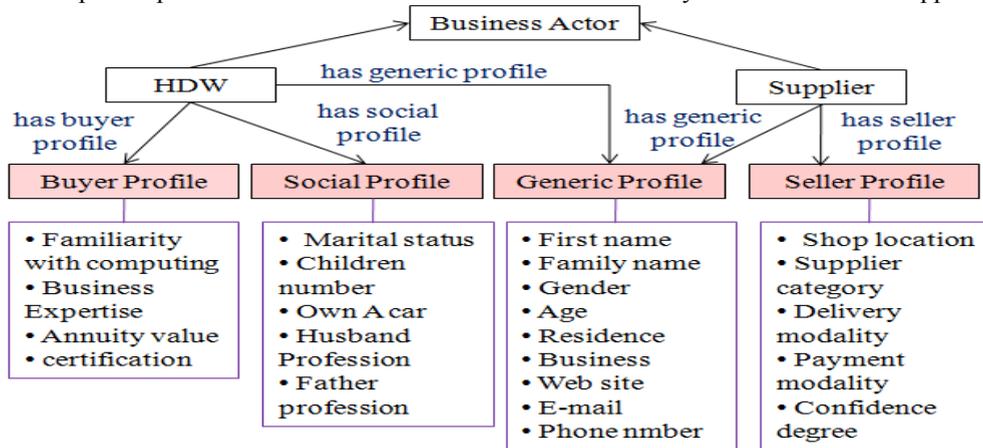


Fig. 4. the Multi-side profile ontology

As seen in the Fig. 4, the HDW and the supplier both are characterized by a “Generic Profile” representing personal information such as “First Name”, “Family Name”, “Gender”, “Age”, “Residence”, and contact details such as, “Phone Number”, “E-Mail”, “Business”, “Web Site”. A professional actor, the supplier has a seller profile (“Shop Location”, “Supplier Category”, “Payment Modality”, “Delivery Modality”, “Confidence Degree”) while the HDW has a buyer profile (“Expertise Degree”, “Familiarity with computing”, “Certification”, “Annuity Value”). Moreover, the HDW has a social profile including: “Marital Status”, “Children Number”, “Own a Car”, “Husband Profession”, “Father profession”, “Mother profession”. The social profile may affect dramatically the system recommendations in spite of the other profiles’ parameters.

Several business rules are formulated in order to check the consistency of the HDW and the provider profiles and will be presented in a next part. In the current paper, the different profile parameters are only deduced statically. However, on most cases the information about the user preference is learnt dynamically^{9,10} e.g. learn that a particular woman likes using a certain type of colorant, so that the system recommends suppliers that provide that kind of colorant. That is why this issue will be the subject of a future work.

4. Multi agent system conception for the handicraft supply chain

Our recommender system is situated within a relatively dynamic environment (see Fig. 5). In fact, exterior exchanges may provoke internal impacts. This leads us to adopt multi agent architecture. The multi-agent systems (MASs) are convenient technologies for the automated coordination between the supply chain agents. In fact, it highlights several aspects like distribution, collaboration, autonomy, and intelligence¹¹. Moreover, the global system behavior is conditioned by its local agent interactions. In the next sections, we will reveal the implicated agents and then identify their eventual interactions.

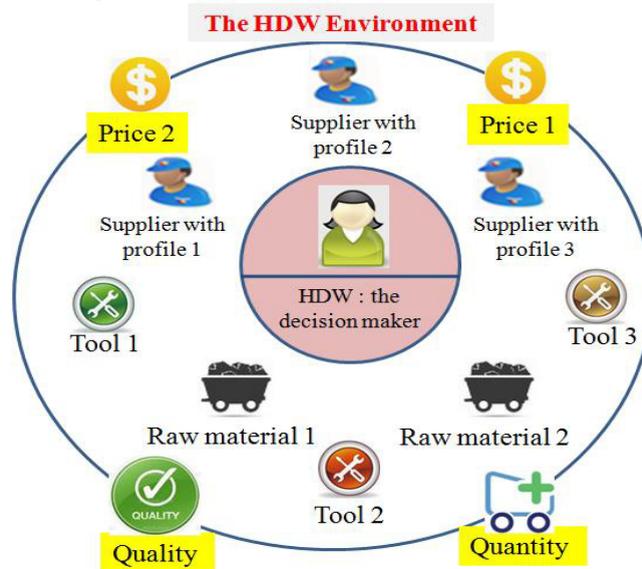


Fig. 5. the handicraft woman environment

4.1. Agent identification

Our proposed procurement chain includes two modules namely supply selection and negotiation. Each module underlines particular agents in order to meet its goals. These agents are able to deduce and incorporate

relevant information from external environment relying on their roles. Hence, the proposed multi agent framework is appropriate for both the business and profile ontologies survival. It monitors likewise the communication between the actors within the procurement chain. Let's discover more about each agent details in the following table. The agents are categorized into different classes depending on their scope.

Table 1. The procurement agents' details

Category	Agent	Scope	Number
Knowledge management	Business Knowledge Manager	He is designed to deduce new relevant business knowledge not yet capitalized from diverse sources such as social web. In fact, he is able to capture new instances of raw material or tools related to a specific handicraft domain. Then, he owes to put them within the appropriate business knowledge at the right position. These instances will be finally linked to the suitable producing tasks according to the business logics.	One by business ontology
	HDW Profile Manager	He is interested in the profile ontology enrichment. He is able to add new handicraft woman instance when she is logged in the system. Its correspondent features' values could be stored systematically. Indeed, the HDW should provide some contextual information while other profile parameters may be discovered or updated dynamically.	One agent
	Supplier Profile Manager	From semantic web and related data bases, this agent extracts new supplier profiles. He stored them as supplier concept individuals within the profile ontology. This agent follows their features evolution.	One agent
Business transactions	HDW Agent	He has the same features like the buyer profile. Besides, he delegates his demands for the intermediate agent who aims to recommend suitable suppliers according to the HDW agent attributes	One by an identified HDW
	Supplier Agent	He has the same features like the seller profile. Furthermore, he communicates his state in order to be elected by the Intermediate agent. Supplier agents coexist in a competitive relationship. Every supplier agent would like to be selected.	One by an identified supplier
Inference	Intermediate Agent	He plays the role of the intermediate between the logged HDW agent and the available supplier agents. He transfers the HDW agent needs to the supplier agents' population. He disposes of a matching rules bank which helps him to better identify the suitable suppliers. The selected providers list will be then sent to the HDW agent. He insures also the negotiation communication between the business actors.	One agent

4.2. Agent communication for improved procurement process

As said in a previous section, we have implemented a business ontology model. This model is expected to be populated by eventual specific instances in order to define specific business ontologies. Hence, we obtain specific business ontology by a handicraft area. The Business Knowledge Manager (see Fig. 6) is responsible for the extraction of new business instances e.g. raw materials, tools, techniques (1). These instances are obtained from sharing sites within the web based on RDF crawlers. The Business Knowledge Manager must then add them within the appropriate business ontology at the right position (2). The integration depends on the established business rules. Likewise, we dispose of a profile ontology which defines the procurement process actors namely HDWs and suppliers. The supplier profile manager and the HDW profile manager are the responsible for the deduction of new instances of procurement process actors (3). They owe also filling in their missed features (4). The deduction of new actors together with their missed parameters relies on the social and/or professional online networks analysis. In fact social media translates actually the professional from the handicraft domain as well as their interactions. The previously mentioned agents are classified as the knowledge Managers. They communicate online with external environment in order to capture relevant information (1) (3). Hence the developed business and profile ontologies are updated (2) (4). It is essential because it represents the input of the procurement opportunities recommendation.

If a particular HDW is logged, her correspondent agent will be activated (5). This latter has the right to access to the HDW profile parameters within the profile ontology (6), the same thing for the supplier agent (7). The HDW agent tells the intermediate agent about his profession (8). The intermediate agent has to search for producing tasks within the right business ontology (9). The tasks list will be communicated to the HDW agent interface (10). From the listed producing tasks within her interface, the HDW should choose its current situation. The intermediate agent visits the appropriate business ontology searching for the required raw materials and tools. When the HDW validate her final choice, the HDW agent memorizes the chosen article to purchase. Later, he tells the intermediate agent, who handles the communication between the HDW and supplier agents, about it (11). The intermediate agent sends a message to the supplier agent community asking for ones selling the required good (12). Every supplier agent checks his current state (his features) (13). Later, he sends a confirmation or invalidation response to the intermediate agent (14). This latter categorizes the received responses: this is the first stage of selection. Regarding the matching rules, he defines the convenient profile type for the HDW agent in question (15). Then, he sends a message for the recently retained supplier agents asking for those characterized by the requested profile (16). The preselected supplier agents check their states (17) and inform the intermediate agent (18). Only the affirmative responses are retained for the negotiation phase: this is the second stage of selection. Now, the intermediate agent tells the HDW agent about the group of supplier agents corresponding to his expectations (19). In order to drive the negotiation procedure, the HDW agent requires the article quantity and quality (20) (21). So, the promoted supplier agents who meet the previous requirement communicate their bids concerning the price, the delivery delay and costs (22). An ordered list of supplier agents will be finally proposed to HDW agent who is expected to validate his final decision.

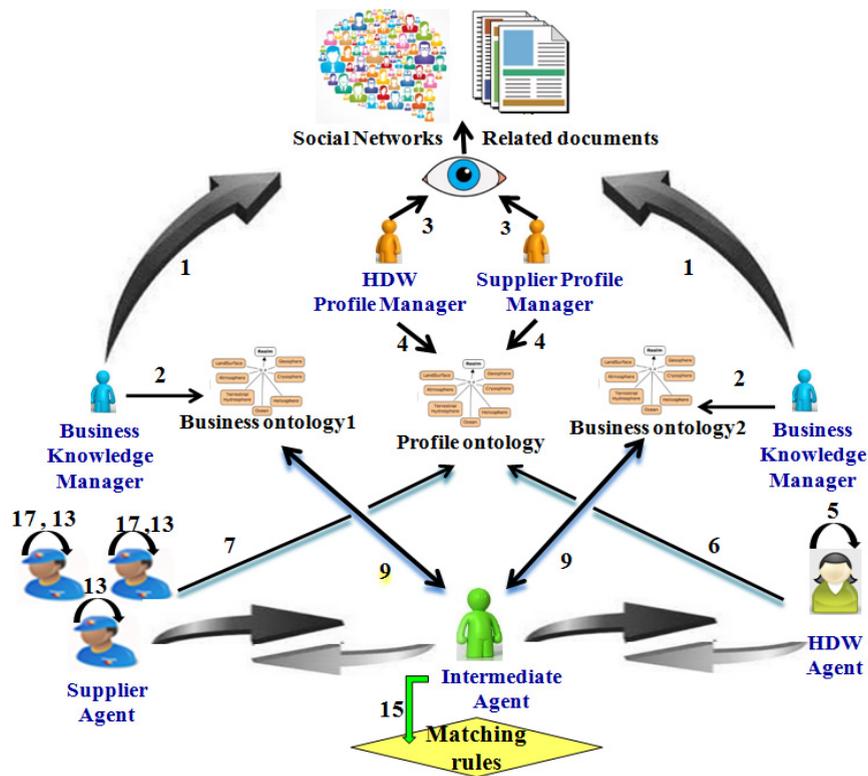


Fig. 6. the multi agent system interactions

4.3. Business rules

In order to recommend suitable suppliers to a particular HDW depending on her current occupation, several matching rules are underlined. These rules compute the compatibility degree between the buyer and the seller profiles. These rules are mainly inspired from the HDW answers when they are interviewed. Indeed, we conducted significant number of interviews in order to gather among other relevant business knowledge related to procurement procedure. From the analysis of the HDW answers, we deduced the major supplier selection criteria. Through the proposed rules we tried to specify accommodate recommendations across the supply chain so to meet the HDW expectations. In the next table, we expose several business rules. Let **TA_k**: a task instance, **Ta**: a tool instance, **Rb**: a raw material instance, **H_j**: a handicraft woman instance, **Si**: a supplier instance.

Table 2. Business rules specification

Selection level	Rule N°	Rule definition
Level 1	N°1	If TA _k requires R _b AND S _i sells R _b OR TA _k requires T _a AND S _i sells T _a THEN select S _i
Level 2	N°1	If the residence of H _j = the shop Location of S _i THEN select S _i
	N°2	If the residence of H _j ≠ the shop Location of S _i AND H _j owns a car THEN select S _i
	N°3	IF the residence of H _j ≠ the shop Location of S _i AND H _j is familiar with computing AND S _i provide an online payment modality AND at home delivery modality THEN select S _i
	N°4	IF H _j is a beginner HDW AND S _i is a wholesaler supplier THEN select S _i

5. Validation

In order to validate our proposal and illustrate our framework, we simulate here a recommendation scenario. “Samira”, which is a particular HDW, logged to the system. Her appropriate agent is then activated and he acquired her profile parameters among other her profession. In fact, she is a *beginner candle designer*. She *has not a car* and she is *unfamiliar with computing* so not able to buy via internet. The intermediate agent conscious of her situation, proposes a list of tasks related to the candle producing phase (extracted from the specific business ontology related to the perfumed candle designing). Later, “Samira” selects the “Add_Colorant” task and asks the recommender system for the most convenient suppliers selling the required colorants. The intermediate agent will operate internally at two levels. Among available suppliers, he firstly, retains only those providing the colorants as raw material. Secondly, he defines the probably convenient supplier profile according to “Samira” situation based on the below discussed matching rules. Actually, the suppliers expected to be suggested have to satisfy a number of criteria such as: to be a *retailer*, to have a *shop* settled in the *same location* as “Samira”. Our recommender system infers “Ali” and “Rayan” as suitable suppliers among available ones. Right now, a negotiation phase begins. “Ali” and “Rayan” offer both the required quality and quantity of colorants. However, “Ali” who proposes an interesting price is hence finally selected. At the same time and dynamically, the knowledge manager agents are looking for new updates according the business and/or profile information.

6. Conclusion

In this paper, we propose a framework for the supply chain agentification. The system is designed to automatically recommend suitable suppliers for the HDWs’ communities during their business activities. The recommendation procedure is based on two supplier selection levels followed by a negotiation phase. The first

level consists in selecting only providers selling the required articles. The second level consists in selecting only those having a seller profile successfully matched with the HDW one. During the negotiation phase, the implicated business actors discuss the required good quantity, quality, costs and delivery delay. The originality of this research paper consists in defining a recommender system operating under a heterogeneous environment from business and social perspectives. It underlines the presence of buyers and sellers from very different contexts. However, our work needs further perfections in terms of real case application. Moreover, several issues can be discussed and improved in future works such as the dynamic HDW preferences learning, the business tasks flow management, the new business and actor instances extraction from the web.

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