Engineering a BDI Agent-based Semantic e-Barter System

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***Abstract*—Barter system is an alternative commerce approach where customers meet at a marketplace in order to exchange their goods or services without currency. E-barter systems, also gain attention with the rise of e-commerce. Barterers search databases for goods and services they need. In this paper, the integration of ontology and agent systems is proposed as a solution for searching in diverse barter databases semantically and bargaining on behalf of the customers. Systematic design of the semantic e-barter system based on the Belief-Desire-Intention (BDI) agents is performed with using Prometheus methodology. The system is implemented on JACK intelligent agent platform. The implemented system is benefited from matchmaking reasoning by employing ontologies.**

Keywords—e-barter system; software agent; multi-agent system; ontology; JACK Intelligent Agents; Prometheus Methodology

I. INTRODUCTION

Barter system is an alternative commerce approach where customers meet at a marketplace to exchange their goods or services without currency [1]. Recently barter systems have been used widely, since trading in a barter system is considered a marketing tool. Companies usually trade unsold goods or underused services in barter markets. E-barter systems, also gain attention with the rise of e-commerce. Barterers of the companies are searching databases for offered and requested goods and services.

Searching in diverse databases may be a cumbersome activity especially when the items are rare and specific. Same type of goods and services may be referred different in multiple databases. The user of a barter system must choose the right concept which is named differently in diverse databases. This brings a huge problem which is called "concept problem", because alternative names of the same concept must be searched. On the other hand, many barterers tend to search same items several times when they could not find a proper barter. This repeated search of diverse databases is also a challenging issue which is called "iteration problem". Besides, barterers tend to bargain because of the nature of the barter system. Since it is hard to determine the value of the goods between each other, many users are willing to exchange in different amount ratios rather than a fixed ratio of items. This requires a bargaining state when two barterers come together. It may also hard to find the two sides of bartering at the same time on the barter system. Because of above mentioned "bargain problem", the bartering process may take too long time.

In this study, use of ontology is proposed as a solution for aforementioned concept problem. Iteration problem and bargaining problem are solved via autonomous agents in a semantic e-barter system. The agents of the system conform to belief-desire-intention (BDI) architecture and they search proper barter offers and bargain several times on behalf of their barterers until the exchange is accomplished. During analysis and design of the agent system, we benefit from Prometheus methodology [2]. Customer Agent and Matchmaker Agent in our system work simultaneous while adding and closing a barter offer into Semantic e-Barter System. The main goal of Matchmaker Agent is to find a proper barter offer to its client Customer Agent which searches the ontologies.

Rest of the paper is organized as follows: Related work is given in Section 2. Section 3 discusses requirement analysis and design of software agents for constructing the proposed BDI agent-based semantic e-barter system, using Prometheus Methodology. Agents with their behavioral model and agent interactions are discussed in Section 4. Section 5 covers the implementation of the system with JACK Intelligent Agents. Section 6 discusses the semantic approach followed and finally Section 7 concludes the paper with including an assessment of the system.

II. RELATED WORK

In [3], customers of e-barter system are first grouped into local markets, according mainly to their localities. Next, a higher order construction allows composing markets, so that a global market takes a tree-like shape. Another work [4] aims to ensure the integrity between formal specification and a suitable design for an e-barter system. There are also some other works about generation of automated test scenarios for e-barter systems [5, 6].

Núñez et al. [7] provided a formal language, based on classical process algebra for specifying and analyzing e-barter systems. They showed that the final distribution of goods in a hierarchical e-barter system is a Pareto optimum.

In [4], the design of e-barter systems, whose structure is based on a tree of markets, was defined by means of web services using BPEL4WS. It is related to our work since our work uses linked data platform services similar to the BPEL4WS services used in [4].

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Demirkol et al. [1] discussed design and implementation of a multi-agent e-barter system which utilizes ontology-based comparison for bid matching.

Abdalla et al [8] introduced an agent-based service application for users of pocket computing devices (BarterCell). Proposed software agents of BarterCell can operate in wireless networks on behalf of nomadic users, cooperate to resolve complex tasks and negotiate to reach mutually beneficial bartering agreements. A recommender system which assists handicraft women during the procurement process of the required e-bartering is proposed by Dhaouadi et al [9].

Since [1] is a proposal of an ontology based e-barter system, our study and [1] have a similar design approach. However, our study promotes this approach by implementing ontologies and semantic e-barter relations and developing the required BDI agent based Semantic e-Barter System with applying an agent-oriented methodology which are all missing in [1].

III. Analysis and Design of Semantic E-Barter System

We used the Prometheus Methodology [2] during analysis and design of the BDI agent based Semantic e-Barter System. Also, Prometheus Design Tool (PDT) was employed in order to design and implement the multi-agent system (MAS) on Eclipse platform. Prometheus methodology consists of three phases: System Specification, Architectural Design and Detailed Design. Following subsections discuss how the proposed MAS is developed within these phases and inner stages of these phases.

A. System Specification

1) Analysis Overview

Conforming to the Prometheus methodology, we first define main system goals, scenarios and actors in analysis overview. We also describe the interaction between agent system and the environment (percepts, actions and data sets). Actors in our system are Customer Actor and Matchmaker Actor while Bargaining Scenario, Customer and Matchmaker Scenario and Barter Information System Scenario are defined as the scenarios. Main goals of the system are determined as “Make Bargain”, “Create Barter Request”, “Send Next Barter Match”, “Save Own Barter to Environment” and “Close Barter Information Request”. Finally, initial percepts are “Barter Request Info” and “Find Match Request”. Customer Actor makes bargain with other customer actors in order to achieve bargaining scenario. Customer Actor creates the barter request. Matchmaker Actor tries to find best matches for any barter request. Also, if Customer Actors could not exchange goods or services in bargaining circumstances, Matchmaker Actor will send next best match to Customer Actor. So, Customer Actor and Matchmaker Actor achieve “Customer and Matchmaker Scenario”. Plus, Matchmaker Actor can save barter request to ontology or close barter request in order to achieve Barter Information System Scenario.

Simple Knowledge Organization System (SKOS) schema [10] is used for item definitions to be bartered in the system. SKOS is an area of work developing specifications and standards to support the use of knowledge organization systems (KOS) such as thesauri, classification schemes, subject heading systems and taxonomies within the framework of the Semantic Web. The SKOS Specifications are currently published as W3C Recommendations, which means that they are in stable state.

There is no overview about scenarios in PDT. Hence, we define 3 major scenarios for our e-barter system in analysis overview. One of them is Bargaining Scenario. This scenario is needed to achieve exchanging their goods or services in more suitable way for customers. Second scenario is Customer and Matchmaker Scenario which provides creating barter request for customer and sending next suitable match for customers by Matchmakers. Third scenario is Barter Information System Scenario.

2) Goal Overview

The process for capturing the goals of the system begins by capturing an initial set of goals from the high-level system description. These initial goals are then developed into a more complete set of goals by considering each goal and asking how that goal could be achieved. This identifies additional sub-goals. Conforming to the PDT, the goals are represented using a goal diagram. E-barter system has four main goals as briefly discussed below:

- Manage Barter Info: Barter information should be kept inside an ontology in our system. So this information needs to be managed.
- Bargain: Customers need to bargain to exchange items in the most beneficial way for itself.
- Create Barter Info: To exchange specific items, they need to be defined accurately.
- Match Making: They provide some mechanism that matches customer’s barter requests.

B. Architectural Design

1) System Role Overview

Four roles in our e-Barter MAS are defined as follows

- Barter Information System Interface Role: This role is responsible for managing the database of e-barter system.
- Barter Optimization Role: This role is responsible for optimizing the barter in favor of customer. Optimization may vary according to the choices the customer makes when s/he defines the barter request.
- Identifying Barter Request Role: This role is responsible for identifying barter request role in a proper format which can be inserted into e-barter system.
- Match Making Role: This role is responsible for querying barter requests on the web and brings the agents address to the customer agent of its own.

2) Agent Role Grouping Overview

Decisions regarding grouping of roles into agents are captured in the “Agent-Role Grouping Overview”. One of the

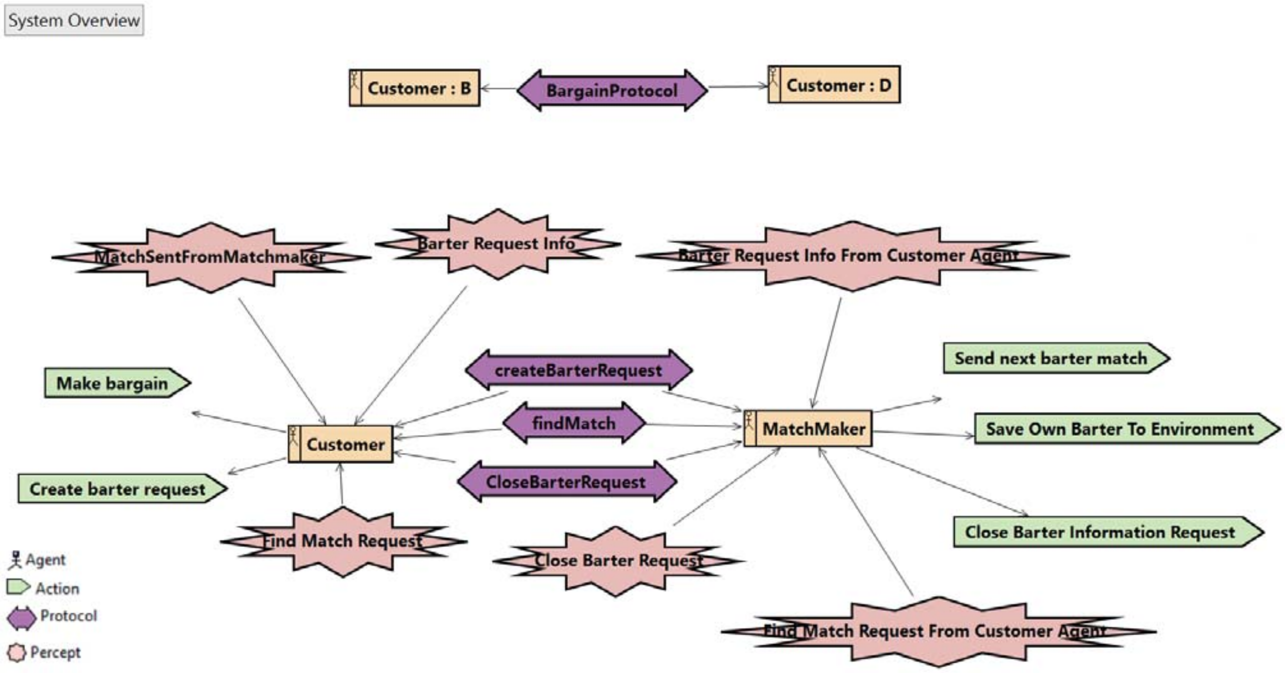

Figure 1 System Overview

agent types is Matchmaker with playing roles named 'Match Making' and 'Barter Information System Interface'. Other agent type is 'Customer' who plays 'Barter Optimization' and 'Identify Barter Request' roles.

3) System Overview

Overall system overview, which portrays agents, their interactions and played roles, is illustrated in Figure 1.

There are two main messaging couples. One is between two customers, another one is between a Customer and a Matchmaker Agent. Customers communicate to bargain while Customer and Matchmaker communicate to deliver the customers' barter request into the system, find a proper match to bargain and close the request when the barter is completed.

C. Detailed Design

1) Agent Overview

a) Matchmaker Agent Overview

Taking into consideration the Matchmaker agent, three capabilities are defined as follows

- Finding Match**:** In this capability, Matchmaker agent finds another barter request that satisfies the current barter request which is sent from its own customer.
- Creating Barter Request in Ontology**:** This capability is responsible for creating barter request in ontology.
- Closing Barter Request in Ontology**:** In this capability, the barter request is closed so finished requests will not be in the search results anymore.

b) Customer Agent Overview

A customer agent has four capabilities in the proposed MAS as discussed below:

- Creating Barter Request **:** In this capability, 'Barter Request Info' percept from customer actor is taken and 'barterRequest' message is sent to Matchmaker Agent. The returned barter request id is saved in customer agent.
- Request a Match: This capability is responsible from creating a match request from related barter requests. Barter request is referenced by the barter request id. A customer agent sends 'findMatchById' message and manages 'findMatch' transaction protocol.
- Closing Barter Request: In closing barter request capability, the customer agent sends 'CloseBarterReq' message to Matchmaker agent.
- Bargaining: In this capability, the bargaining process manages the bargain in the favor of its customer agent where 'BargainProtocol' is used.

2) Capability Overview

a) Finding Match Capability

This capability is about finding next match. Customers want to trade with two different scenarios. One of these is barter with bargaining and the other one is barter without bargaining. Starting from this approach, our system should have 2 different plans for matching.

- WithoutBarganing Plan: If this plan is chosen from the customer actor, only exact matches are considered. This plan is also activated, even if this plan is not chosen. If no exact match can be found, 'WithBargaining' plan is executed afterwards.
- WithBarganing Plan: Customer actor defines lower limit ratio of amounts of the items. Matchmaker agent

tries to find offers that suitable for bargaining with this ratio. Minimum and maximum item numbers to be exchanged for both customers are also considered as well.

b) Bargaining Capability

Bargaining capability is the customer agent's capability and has 2 different plans. These plans about bargaining types are:

- FixedItemToGive Plan: This plan does not let changing the amount of the given item. Consequently, customer agent makes bargain without changing the amount of item to be taken.
- FixedItemToGet Plan: This plan is "FixedItemToGive" plan's opposite. Customer agent wants to change the amount of the given item.

IV. Implementation of the Semantic E-Barter System

The multi-agent semantic e-barter system, proposed in this paper, has been implemented by using the JACK Intelligent Agents framework [11]. JACK is a mature, cross-platform environment for building, running and integrating commercial-grade MASs. It is built on a sound logical foundation: BDI. BDI is an intuitive and powerful abstraction that allows developers to manage the complexity of the problem.

Barter items are mainly in two types. One is goods and the other is services. The ontology "goods and services" is used to perform semantic matchmaking according to the goals of agents. Figure 2 shows part of this ontology. When a barter request is issued, it is matched in two levels using this ontology. Those are exact matching and semantic matching. The Semantic E-Barter system first tries to apply the exact matching for the barter transaction. This matching uses the traditional search method without looking for any proximity relation. However, in this case, there is a possibility that the matching does not happen. If the matching does not happen, the second matchmaking approach, semantic matching, is used. In this case, it is tried to perform matching using proximity relations. For example, when looking for an apple has no result in the system, other fruits may be offered to the user with the affinity relationship. The ontology required for the Semantic E-Barter system was implemented in Marmotta Platform [12].

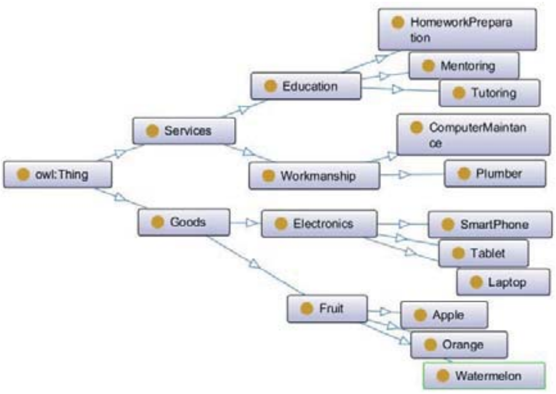

Figure 2: Goods and Services Ontology

The Matchmaker agent is the most important agent in our e-barter system. It is created when any customer agent made a barter request. So, it is created dynamically. Main duty of the Matchmaker agent is querying link data platform to get best suitable matches for the requestor's offer. If customer, who requests barter, fails to agree with matches, Matchmaker agent will save customer's offer to the link data platform. On the other hand, if customer that requests barter succeeds on bargaining, the Matchmaker agent will close suggested offer.

The customer agent is another important agent in our system. There are two plans for exchanging goods and services. One of the plans is "without bargaining" plan. This plan is executed when customers' ratios are suitable for each other. Also, customer agent has "with bargaining plan" that is executed when their ratios are not suitable. Customer agents negotiate through this plan about offer conditions. If the bargaining plan fails, customer that requests barter will add the opponent customer to the banned list to prevent same pair's negotiation.

In our study, there are 3 types of ratio; minimum ratio, actual ratio and actual reverse ratio. Ratio is determined by dividing the offered amounts of item into the given amounts of item. Minimum ratio represents a lower limit for our ratio and it is checked for every negotiation. Our system contains two types of amount information about goods and services. The initial amount indicates the first bid offered before the bargain. The dynamic amount refers to the current offer amount during negotiations. Actual ratio and actual reverse ratio are calculated with this variable and they change in every offer. Actual ratio refers to the ratio of the offer concerned and actual reverse ratio is the inverse of this ratio. Thus, during the evaluation of each offer, an agent uses his own actual ratio and opponent's actual reverse ratio. The logic of bargaining is shown in Figure 3.

Additionally, other important parameters are lower and upper limits for the amount of items. All offers are created according to these parameters. Lower and upper limits are checked by customer agents to understand offer's profit for themselves.

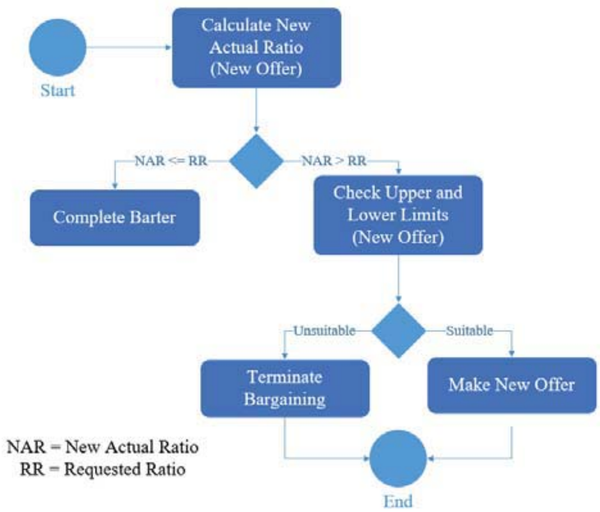

Figure 3: Logic of Bargaining

V. Case Study: Example of a Bargaining Scenario

Bargaining process is one of the most important parts of the exchanging goods and services. In our study, customer agents have ability to bargain. The main purpose of bargaining scenario is performing the most profitable exchange for the user. The following case study shows a sample bargain scenario.

Firstly, in our scenario, CUSTOMER 1 agent would like to barter with someone who offers a suitable bidder. To achieve this, CUSTOMER 1 creates a barter request. This barter request has some properties about offer. When we look closely in Figure 4, there are 2 items in the offer. These items represent barter items. CUSTOMER 1 wants to give 4 kg. of banana and in return wants to get 20-hour Computer Maintenance. In addition, other features -like minimum and maximum- are important features in the decision process.

```
CUSTOMER 1 Barter Request
Item to Give :   4.0 kg banana
                 Min: 1.0          Max: 10.0
                 Change Frequency: 1.0
Item to Get :    20.0 hour computer maintance
                 Min: 1.0          Max: 100.0
                 Change Frequency: 1.0
Ratio Infos :    Acceptable Min Ratio : 3.0
                 Actual Ratio: 5.0
                 Actual Reverse Ratio: 0.2
```

Figure 4: Barter Request

After the request is given, the Matchmaker agent is created automatically (Matchmaker 1). Referring to Figure 5, Matchmaker agent finds suitable matches for CUSTOMER 1's offer in the system. For this scenario, the suitable offer is CUSTOMER 2's offer. CUSTOMER 2 wants to give 16-hour Computer Maintenance and in return wants to get 4 kg. of banana.

```
MatchMaker 1@%portal found CUSTOMER 2 suitable.
MatchMaker 1@%portal recommended its to CUSTOMER 1 for bargain.

CUSTOMER 2 Barter Request
Item to Give :   16.0 hour computer maintance
                 Min: 4.0          Max: 20.0
                 Change Frequency: 1.0
Item to Get :    4.0 kg banana
                 Min: 1.0          Max: 10.0
                 Change Frequency: 1.0
Ratio Infos :    Acceptable Min Ratio : 0.2
                 Actual Ratio: 0.25
                 Actual Reverse Ratio: 4.0
```

Figure 5: Finding Match

When matching is completed, Matchmaker 1 agent notifies the CUSTOMER 1 agent. After this stage, the bargain begins. The bargaining conforms to the logic as previously shown in Figure 2. Motivating from this logic, CUSTOMER 1 constructs a new request for his own profit and compares ratios. (New Actual Ratio vs. Requested Ratio). After that, if the new request is more profitable then the opponent offer, Customer makes new offer. In the first step of our scenario, CUSTOMER 1 agent's new offer is more profitable than CUSTOMER 2's default offer. So, CUSTOMER 1 makes new offer in Figure 6.

```
               CUSTOMER 1 Evaluation
GAINLESS-      Next Actual Ratio: 4.75 vs 4.0 : Requested Ratio
SUITABLE+      Next ItemToGive Amount: 4.0 vs 10.0 : Upper Limit
SUITABLE+      Next ItemToGet Amount: 19.0 vs 1.0 : Lower Limit

               New Barter Request: CUSTOMER 1 > CUSTOMER 2
               Item to Get : 19.0 hour computer maintance
               Item to Give  : 4.0 kg banana
```

Figure 6: Evaluation (Customer 1)

Figure 7 and Figure 8 show the next steps of the bargain process. Agreement cannot be achieved at these steps.

```
               CUSTOMER 2 Evaluation
GAINLESS-      Next Actual Ratio: 0.23 vs 0.21 : Requested Ratio
SUITABLE+      Next ItemToGive Amount: 17.0 vs 20.0 : Upper Limit
SUITABLE+      Next ItemToGet Amount: 4.0 vs 1.0 : Lower Limit

               New Barter Request: CUSTOMER 2 > CUSTOMER 1
               Item to Get : 4.0 kg banana
               Item to Give  : 17.0 hour computer maintance
```

Figure 4: Evaluation (Customer 2)

```
               CUSTOMER 1 Evaluation
GAINLESS-      Next Actual Ratio: 4.5 vs 4.25 : Requested Ratio
SUITABLE+      Next ItemToGive Amount: 4.0 vs 10.0 : Upper Limit
SUITABLE+      Next ItemToGet Amount: 18.0 vs 1.0 : Lower Limit

               New Barter Request: CUSTOMER 1 > CUSTOMER 2
               Item to Get : 18.0 hour computer maintance
               Item to Give  : 4.0 kg banana
```

Figure 8: Evaluation (Customer 1)

Final stage is shown in Figure 8. CUSTOMER 2 evaluates CUSTOMER 1's offer (4 kg Banana – 18 hour Computer Maintenance). Actual ratio of CUSTOMER 2's next offer is 0.22 and current CUSTOMER 1's offer ratio is 0.22. Therefore, this offer is profitable and suitable for CUSTOMER 2. Thus, bilateral agreement is now made and barter transaction is completed.

```
               CUSTOMER 2 Evaluation
PROFITABLE+    Actual Ratio: 0.22 vs 0.22 : Requested Ratio
SUITABLE+      Next ItemToGive Amount: 18.0 vs 20.0 : Upper Limit
SUITABLE+      Next ItemToGet Amount: 4.0 vs 1.0 : Lower Limit

CUSTOMER 2 accepted the offer.
Bilateral agreement has been made.
CUSTOMER 2 (>>> 4.0 kg banana >>>) - (<<< 18.0 hour computer maintance <<<) CUSTOMER 1
Barter transaction was completed.
```

Figure 9: Evaluation (Customer 2)

VI. DISCUSSION

In the traditional electronic bartering systems, matching is done by searching the exact word. Due to the lack of a semantic approach, the search results contain a restricted subset of the solution space. In conclusion, the majority of the trials for matching will be unsuccessful. In our study, a semantic approach is used in the matching for bartering. Thus, semantic proximity ensures that successful matching is achieved, if there is any close item to our bartering item.

On the other hand, as a result of using the semantic approach, the number of bartering items which will be scanned in the system to find the desired one is limited. In other words, instead of searching the whole domain space for an item, the proposed system searches a sub category of the items based on the ontology result. This improves the efficiency of the system.

VII. CONCLUSION

The design and implementation of a semantic e-barter system based on BDI agents is discussed in this paper. From early requirements to the concrete implementation, all of the phases of the system development are elaborated. Each participant in the system is designed as BDI agents with their beliefs, goals, and plans and then BDI reasoning and behavioral structure of the designed agents are implemented.

Moreover, use of the Semantic Web and Linked Data meet the requirements of the e-barter MAS. There may be several linked data platforms using the same barter ontologies. The Matchmaker agents search for the desired barter offers in these linked data platforms in a weekly or daily manner if the customer sets matchmaker agents in that way. Although periodic searches were not implemented in this study, it is considered that it is a trivial work.

Using ontologies provides us to define item types unambiguously in our study. Related DBpedia sources also are definitive to human participants of the barter system. They can clearly understand what the term of item is offered by the other barterers via DBpedia definitions. In this study, ontological inferences are not used extensively but it has been considered that if a Matchmaker agent cannot find an exact match of an item, let us say banana, it may find avocado which is in the same skos:ConceptScheme with banana like tropical fruits scheme and asks its user if s/he wants to exchange with avocado. If the user accepts the exchange, s/he will need to define the amount of items in barter, since values of banana and avocado will probably be different.

It is also worth indicating that we benefited from Prometheus agent development methodology during the development of the required MAS. We experienced that the step by step and top down approach followed with Prometheus facilitates the tracking both the analysis and the design of system agents. Furthermore, the specialized design tool of Prometheus, PDT, also simplified the MAS engineering process. By the help of the PDT tool, we were able to select appropriate terms i.e. roles, activities, plans which are initially defined in the previous stages of the methodology.

Our future work consists of developing mobile versions of the implemented agents to use the system in various mobile devices. Moreover, implementing semantic relations over SKOS ontological components and realizing the periodic searches are also considered as the future work. By the help of such inferences, we believe that the capability of Matchmaker agents will be improved in the way of suggesting more proper items.

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