A Model for Agent Communication Based on Imprecise Information Using Synonyms

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Abstract. This paper describes the development of an model in area of communication between agents. This study involves the concepts of agents and communication issues in their interactions. Using the ontology as a technique of classification of knowledge, the model includes an approach to build an intermediate software component between agents and ontological knowledge base, using fuzzy application in treatment of inaccuracy information based in synonymous. Protégé editor is chosen to develop the ontology in OWL. The software component uses Jena and SPARQL for manipulation of the ontology. To validation, the case study used is the model of the multi-agent system that represents the urban vegetable garden of Parque São Jerônimo (Spain).

Keywords: Communication, Fuzzy, Jena, Multi-agent System, Ontology, Protégé.

1 Introduction

In the continuous development of the information technology area, one of the strands in the classification of knowledge that has received attention is the area of ontologies. The ontology has resorted to computer science, developing studies in the treatment of classified information about an environment of interest, shaping the connections between data, obtaining a reference to knowledge.

There are some works related with information and knowledge components, combining with ontologies and agents. The architecture developed in [1] is an implementation that focuses on agents oriented paradigm in systems of knowledge management. Another relevant work is the proposal of a web service in communicating agents using middleware as an ontological agent [2] for the mediation of the information.

Some papers on fuzzy ontologies approach bring the notion of imprecise concepts. This is the case of Fuzzy OntoMethodology [3], where the work initially points to other studies, discussing the application of fuzzy ontological models but it is not clear with the concepts of fuzzy sets or determines any changes in existing ontological structure. Later, they present a more refined model of a framework to ontologists involving the same ontological construction aspects of a traditional formal ontology (crisp ontology) and fuzzy ontology (the ontology formalization of sets with membership functions). In [4] are commented the negative aspects of open the ontological structure to insert fuzzy constructors, altering languages for ontology that are already standardized. Other models show how classify, at fuzzy, pairs of concepts between two ontologies, computing the values of relationships to find possible combinations [5].

The purpose of this study is the development of a software component that can enable interoperability of communication to agents without the use of an ontological agent. Also it includes a proposal on the application the fuzzy logic, manipulating imprecise concepts, basing in synonymous. The study in this area of communication is an approximation to the reality of individuals, in their communication and their information exchange with imprecise interpretation.

The paper is structured as follows: Section 2 describes the techniques or concepts used, such as Ontology, Fuzzy and standards of communication between agents. In section 2.4 an analysis of related works in Fuzzy Ontologies is described. Section 3 is divided into three subsections. Initially describe the concepts of multi-agent systems, the urban vegetable garden of which is the focus of the application of this study. In further sub-sections, presents the proposed model of interoperability with details about technology. Section 4 discusses the conclusions and further works.

2 Techniques Used

2.1 Ontology

The first insights into ontology areas date back to ancient Greek philosophy, where the term derives from *ontos* which means *to be* and *logos* which means *word* [6]. The artificial intelligence area has adopted this thought in the development of semantic structures a certain time. One of the most widely accepted concepts in the ontological engineering [7] is defined in [8] where the ontology is described as a specification of conceptualization, the conceptual specification of a particular domain of interest.

This specification is structured between a set of objects, relationships and instances. The objects, or classes, describe the existing concepts, while the relationships suggest and formalize the inter-relationships between concepts. There are properties that can be types of relationships between concepts or, in the case of concepts, internal features (object properties). Instances, or also called as individuals, are the elements of each class.

Therefore, the ontology can sort and organize the existing knowledge about a given area in a structure that can be readable both by machines and by people. The ontology composes a glossary and it operated by several software devices in order to recognize the desired environment.

2.2 Agents and Communication

An agent can be understood as a software entity that has autonomous action, should be located in a particular environment where they can and realize it, but also cooperating with other agents to achieve its goal [9] [10]. These agents have implementations of mental notions or perceptions such as humans with beliefs and intentions [11].

To achieve their objectives, the agents may cooperate or compete in an environment and deliberately they will interact at some time talking with each other [12]. Because of this, the communication between agents can be considered an important factor for the achievement of their purpose. Thus, some protocols or languages have been developed that implement the technologies for communication between agents or perform standardization for better interoperability, as FIPA, KIF and KQML.

FIPA (Foundation for Intelligent Physical Agents) was established in 1995 as an effort among several organizations to produce specifications for open interfaces agents [13]. The interfaces describe four major areas of technological specifications. The first is the Agent Communication, where language FIPA-ACL is contained; the second is the Managing Agents; the third is the integration between Agent and Software; and the last is the integration between agent and people.

The KIF (Knowledge Interchange Format) is a formal language for exchange of knowledge among software entities [14]. Not intended to be a primary language for interaction with people or an internal representation of knowledge. However, it has characteristics such as clarity in the semantics and the construction of knowledge representation, which can be used for these purposes too.

The KQML (Knowledge Query and Manipulation Language) is also a language (and protocol) to exchange information and knowledge among agents, but it emphasizes the pragmatism of the conversation than the semantics [15]. In a first level, the specifications seek to know who is the receiver of the conversation or where the same can be found and then, how to start and to maintain the information exchange. The second level develops the protocol primitives to maintain and to reuse of knowledge bases, involving communication between agents with one or more ontologies.

There is a number of technologies for the development of communications architectures and in most languages are a growing concern with the sharing content and the content of information bases. Remembering that without an information or knowledge recorded in their databases, the only world that agents have to share is a world full of bits and bytes [12]. For it, is required higher level of information and representations of reality for these entities, to find and to know more concepts (about the environment, other agents, objects and relationships).

Furthermore, some agents may use a word or phrase that considers something while another agent may use the same word for something else [16]. For communication, the ontologies can be considered a central structure and that can reduce some conceptual confusion (due to the high level of formalization) and it may be useful to share information with people (or agents) from different points of view [17].

2.3 Fuzzy Logic

Fuzzy logic, originates from the mathematics area that describes imprecise phenomena in the real world. They are sets or classes that define objects that do not have the usual mathematical descriptive sense (accuracy) [18]. The classical numerical sets describe categories where an object belongs or does not belong to a definition (0 or 1). However, the most categories have a sense of belonging in their cataloging and logic fuzzy provides their operators to deal with this.

The membership function allows to use the concept of classic numerical sets, admitting intermediate values (between 0 and 1, or between non-owned and belongs), providing an richer interpretation in the description set in the real world which boundary conditions are not well defined [19]. This imprecision is important in human thinking, in the information communication [18], as well as the ability to represent vague concepts expressed in natural language, "while partially blind", for example [20].

This method joins the components of fuzzification, rule base and defuzzification. Initially, fuzzification joins the modeling of the sets and their domains, according to the inputs of the system [21]. Then, it composes the basis of rules in linguistic propositions that is defined by the expert's domain on the system, and the membership functions are cataloged. The component which depends on the rule base is the fuzzy inference, where it performs the propositions developed in mathematical form (may be used fuzzy logic techniques as t-norms, t-conorms or fuzzy implications). At the end of fuzzy method, the output (defuzzification) performs calculations (centroid, the maximum center or maximum average) to understand a fuzzy set for a real number.

Another important component are the linguistic variables, which values are words rather than numbers [22] it is an extension of logic fuzzy. These variables can describe linguistic characteristics of systems basing in human behavior, and they are less specific than numbers. They are useful to handle definitions that there are not accurate to describe numerically. A variable defines a set of linguistic terms. The terms are word sets associated with them, which have fuzzy restrictions values. Each term has a degree of compatibility between 0 and 1 that defines the degree of term relevance in the set.

2.4 Analysis of Fuzzy Ontologies

The concepts described in previous sections are important for the design of models or components that can handle the imprecision of knowledge. Fuzzy techniques and Fuzzy Ontology in information management are very important. There are some models that treat Ontology with Fuzzy, extending the recognition of information, either within the ontology, or external queries to this. These are called Fuzzy Ontologies.

In [23] are presented some works on Fuzzy Ontologies that incorporate concepts in the ontology. As the use of fuzzy relation in the class descriptor, which are encoded the degrees of the properties of some set of relevanceThe authors developed a fuzzy model that focuses on not only in use the inclusion of ordinary fuzzy sets in the ontology, but also in the semantic relationships between concepts, providing difficulties for mapping ontology. It develops a model based on the logic of intuitionistic fuzzy sets, which represents a greater description and vagueness about an object than the classic set, combined with a specific model for linguistic variable ontology.

The study in [3] performs an initial search with related work similar to those found in [23]. However, some projects implements fuzzy logic concepts directly in ontology source code. This is due to the fact that ontologies are encoded in languages that have become standards, such as OWL, without these mechanisms, while the fuzzy ontology, there is no standardization. Changing the structure of ontology can be critical to technologies that perform inference or rationalization over that structure. In this way, the authors developed OnthoMethodoloy, which is both a model and methodology. In the model, a fuzzy ontology can be developed, detailing and implementing all the fuzzy logic of descriptions in the ontology. In part of the methodology, methods and practices from Ontology Engineering can be done, to qualify and align common activities in the development of the ontologists.

Another methodology to develop ontologies is OWL 2 [24]. The method involves the extension of the annotation properties of ontology language OWL 2 to insert the specific fuzzy modifiers into the structure. Even though the OWL 2 may have different syntaxes, the authors show how to write the note for each one. This can be useful, because the ontology cannot encode fuzzy properties, it is used to note the structures that exist for receiving these modifiers. A fuzzy modifier can be used to define a class in its annotation property. The method also creates data types in the ontology that can treat fuzzy values.

Other applications focus on the level of relationships between concepts. Alignment algorithms between two ontologies can be applied fuzzy to find common parts through a series of calculations and combinations, by arcs between the concepts [5]. These arcs have a fuzzy weight that are assigned a value depending on the proximity of meaning with its superior concept the values are between generalizations (hypernym) and specialization (hyponyms). Another study that also involves similar technique is the H-Match algorithm for combining terms of ontologies in the context of distributed networks (peer-to-peer) [25]. It uses fuzzy weights in the arcs of relationships between concepts. To determine these values, it is considered the amount of use or manipulation of the arc, interpreting the relationship between language and context. The weights will vary depending on the type of the relationship in the ontology, i.e., under the point of semantics view. In linguistic interpretation, the weights are distributed among the arcs that can mean synonyms, hyponym/hyperonym or related terms (receiving, respectively, values 1.0, 0.8 and 0.5).

On the model proposed in [26], ontology is structured in two layers. The first layer consists of category names and the second contains words related to these categories. These relationships have a degree of association. The model is applied in association and queries electronic documents. In the query, the association algorithms use fuzzy max-min to match the request with categories or words and it calculates the relevance of documents for required information. Despite the architecture has relations with fuzzy theory, the model does not detail the implementation of these issues directly in the ontology structure, although the model based on fuzzy ontologies also determine weights to the arcs of relationships between concepts (words).

In our researches, we can observe that there are some levels of applications involving ontologies and fuzzy. Some implementations treat fuzzy theory incorporated or integrated with ontologies (or not changing the existing structure), creating models of fuzzy ontology. These models formalize and develop detailed components within the fuzzy logic and ontology itself. Generally they are methods for the construction of a complete or fuzzy ontology for evaluations in semantic relationships between concepts, i.e., fuzzy weights in the relationships of words, in consideration with the meaning of these. These types of techniques generally apply fuzzy weights between the arcs of various specialized concepts with general concept, or vice versa.

The present study does not develop a fuzzy ontology from the beginning. The idea is to treat existing imprecise information. This imprecision has been caused by the requisition or question that an agent can perform to the ontology. The ontology is defined as a network of concepts, but these concepts are words that could have interpretations. One word can means other thing depending on the subject matter, but in the ontology, the relationships for a given concept may not achieve all these meanings.

3 Urban Vegetable Gardens and Multi-Agent Systems

The area of social systems joins a structure that provides supplements to observe the various societies, organizations and interactions, not just in their basic levels, but higher levels of analysis [27]. An urban social system has individuals interacting to achieve its goals in an environment, that provides rules or definitions of they need to know or believe. Thinking computationally, in an artificial social system is possible to define as a set of conventions and rules that restrict the behavior of agents, where one of the main components is how conflicts are handled when they occur [28].

For this project, the model of Multi-Agent System (MAS) was chosen which represents the urban vegetable gardens, specifically São Jerônimo Park, located in Seville, Spain. Since this is an initiative of the NGO Ecologists in Acción, which encourages the practice of organic agriculture and social participation of individuals which the objective it environmental education [29]. It is composed of a cultivated park with 42 plots (plot is a dimensioned land to allow individuals to grow food), where they receive technical support to assist in production.

The NGO has regulations on the participation and behavior, so the project for the modeling of the system to social simulation started in [30] which currently continue with efforts in the development of multi-agent system. Thus, this project aims to develop a communication component applied to these individuals on some aspects of their own organization, containing features such as: rules, restrictions and other settings on this urban social system.

3.1 The Proposed Model

The proposed model aims to be an option as a component of software for interoperability of information between agents and ontology. Providing an access bridge between the MAS and knowledge base ontological, in a simplified way. Also considering the treatment of inaccuracy of the information.

Figure 1 shows the integration between the MAS and the proposed ontology. The MAS that represents the agents of urban vegetable garden environment described in section 3 is in development by research group in [29] and [30]. To integrate the ontology, a mediating layer (or driver) will be built in Java, containing primitives of the Jena library (more details in the following sections). Between these two layers will be implemented the exchange of messages through a protocol to be chosen (KIF, KQML, FIPA-ACL), which accept the use of ontologies. The mediator layer will receive query messages of communication protocol from the MAS and performs the manipulation and research in the ontology using SPARQL. After, the driver will make the opposite way, i.e., it will delivers the message in an understandable way to MAS.

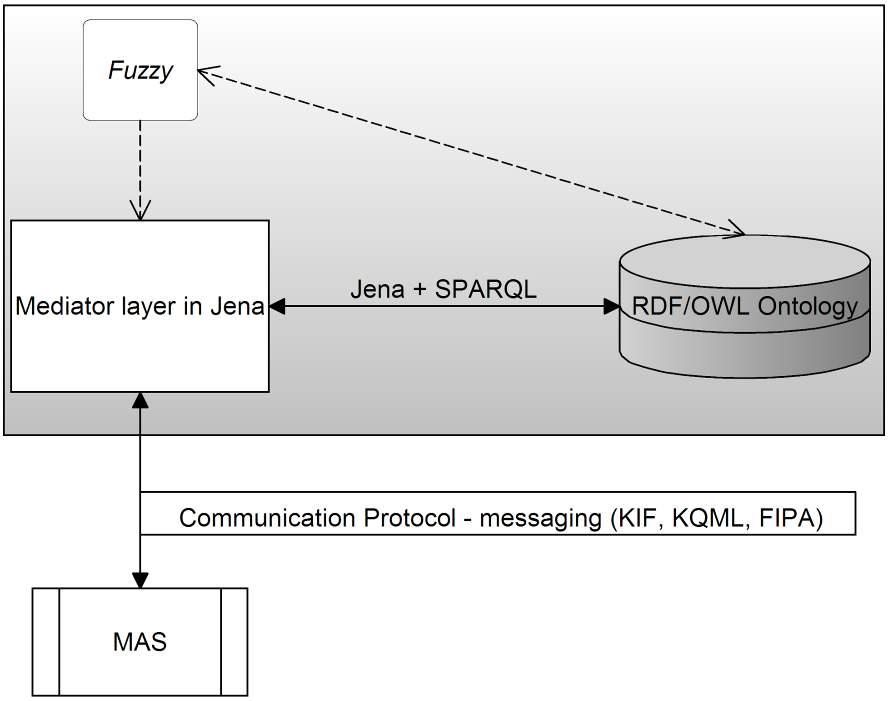

Fig. 1. Application Model.

Due to the imprecision of the information, the mediator layer contains a component that applies fuzzy concepts. The synonyms, with their degrees of relevance, were inserted in some concepts of the ontology and they are recovered for the treated component. If the mediator layer does not successful research requested information by agents, it triggers the device to find synonyms, which occurs through four primitives: (1) SPARQL query to determine the existence of synonyms between concepts, (2) combination via SPARQL, with the individual of the concept that has a synonym, to see if the word searched is synonymous, (3) extraction of synonyms with filtering which excludes possible encoded text format errors, (4) formalization, by programming the set of fuzzy linguistic variables, for the concept approved by the previous steps. Although the items 1 and 2 can be unified in coding, they were divided to decrease processing time of the driver.

The mediator layer gathers a set of procedures to recognize a query request through the interface with the MAS. Then it performs conversions, applying rules, in order to request the information which the agent wants from the Ontology. It's performs the queries in the ontology with the fuzzy component support. Finally, it converts the response into an acceptable format to the agent, in its communication protocol (to be chosen) and delivery to the MAS.

3.2 The Ontology

In the development of applications that directly manipulate documents such as semantic ontology, it is necessary to use or develop a tool that understands the concepts and relationships in these documents. For this project, the Jena library is used, developed by HP Labs [31]. This tool is developed in Java and it helps many activities for programmers that use models and languages of the semantic web.

The library includes a set of packages to handle with semantic files, as RDF or OWL. The facility exists in the form that the ontology is considered in the programming language. Jena employs the use of object orientation in the manipulation of the ontology. Therefore, the concepts, individuals, relationships are understood as objects, instances and properties, respectively.

Another technology to operate with ontologies is SPARQL, which is a language and a protocol, for perform queries and treatment results in semantic documents [32]. These documents not necessarily are ontologies. Many file formats can be used as database-level knowledge. Despite the semantic differences, the original idea is to have a SQL language of relational databases to semantic and for this purpose, SPARQL has contributed to the ontologists.

In order to accomplish the modeling of knowledge about urban vegetable garden we chose to develop an ontology based on the concept map [29] and constantly consult to experts from the case study. The map represents the major structures within the São Jerônimo Park.

To develop it, we used the Protégé tool. In this project, the editor used is based on frames, i.e., the development ontology is a concept hierarchy form, where each term is a class, where we have: classes, instances and relationships between these objects. As shown in Figure 2, each class modeled is seen as a semantic network. All the ontology concepts and their relationships, present in tables and figures, are in Brazilian Portuguese, because this is the natural language of the application[1].

Fig. 2. Protégé view of the model concepts.

Each network node is a concept. These nodes are related with each other through arcs that describe their meanings (predicates, which compose the semantics). These arcs are called technically as "object properties". The relationships have been implemented as shown in Figure 3 and they are formalized as follows:

```
<baseConcept1, baseConceptN...> predicate <targetCon-
cept1, targetConceptN...>
```

[1] The figures are generated by the ontology editor.

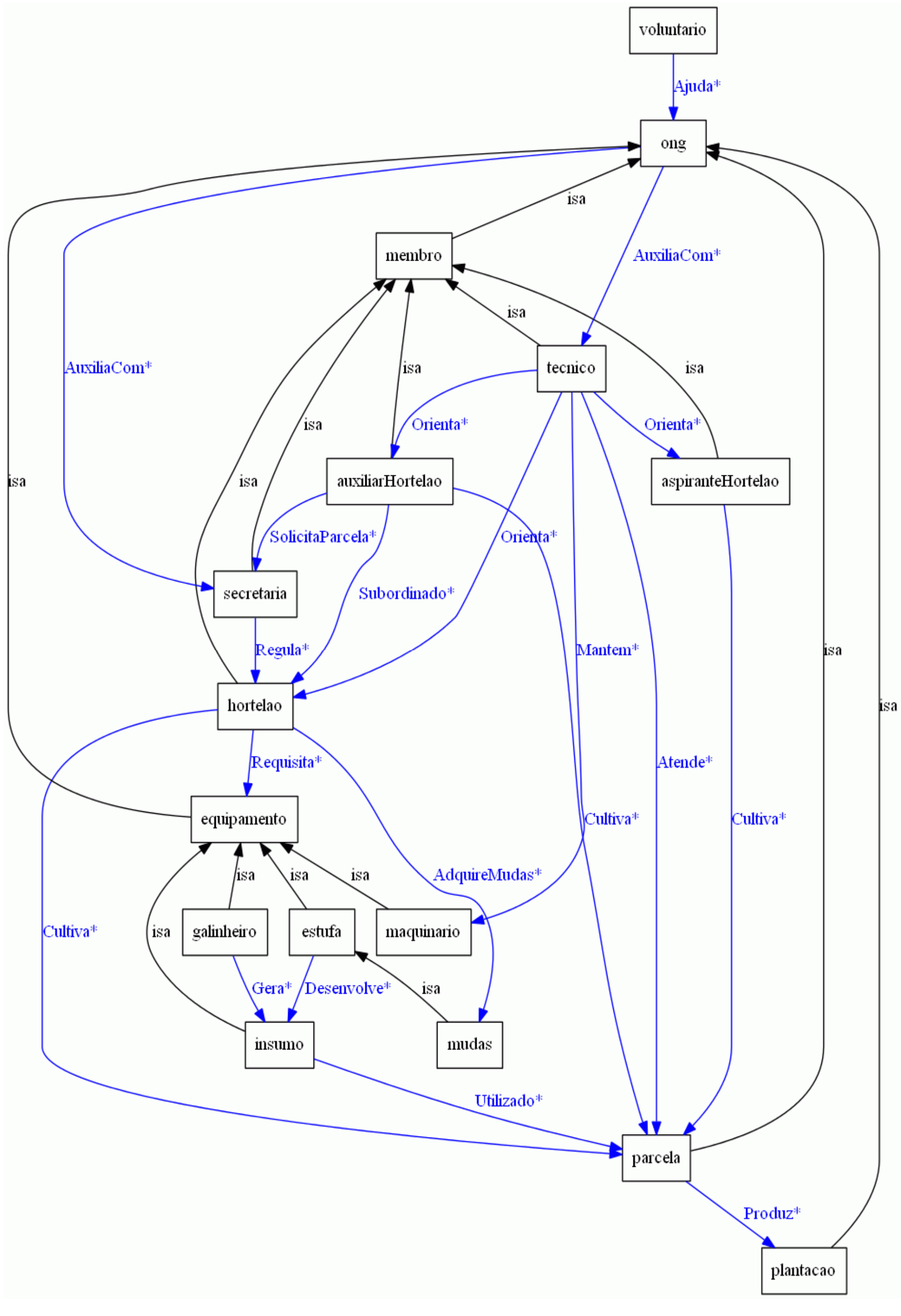

Fig. 3. Visualization of the ontology with relationships between concepts ("is-a" relationship is only to describe links between concepts that do not have a formalized property).

So, for the ontology proposed we have:

```
<hortelao> AdquireMudas <mudas>
<voluntario> Ajuda <ong>
<tecnico> Atende <parcela>
<ong> AuxiliaCom <tecnico, secretaria>
<hortelao, aspiranteHortelao, auxiliarHortelao> Cultiva
<parcela>
<estufa> Desenvolve <insumo>
<galinheiro> Gera <insumo>
<tecnico> Mantem <maquinario>
<tecnico> Orienta <hortelao, aspiranteHortelao, auxiliar-
Hortelao>
<parcela> Produz <plantacao>
<secretaria> Regula <hortelao>
<hortelao> Requisita <equipamento>
<auxiliarHortelao> SolicitaParcela <secretaria>
<auxiliarHortelao> Subordinado <hortelao>
<insumo> Utilizado <parcela>
```

From the editing tool of Ontology, this ontology is generated in a file. This file is used as a knowledge base, where domain information can be queried. Further details will not be displayed on this ontology construction. It is an important side of which will operate the proposed model and it ontological knowledge base is available to the MAS research group. In the next section will be presented and discussed of Fuzzy mechanism to treat imprecise concepts.

3.3 Fuzzy in our Ontology

An ontology has been formalized in a set of concepts and relationships on the universe of those field agents. Agents can communicate with each other or to request information available in a knowledge base. However some agents may refer to a particular concept without being specific on this.

The ontology has a level of rigidity in its structure of formal concepts. It is not bad, because it is a specification of conceptualization in a particular domain of knowledge. It is for this issue (among others), many applications have been developed to address the inaccuracy of information (described in section 2.4).

In this case, during the analysis and construct of the ontology, we found that some concepts had more than one interpretation or name. To increase understanding of the area, synonyms are named in each concept, as listed in Table 1.

Table 1. Concepts synonym in ontology.

Concept (class) in Ontology	Synonyms
Membro	Sócio, Funcionário.
Hortelão	Horticultor, Agricultor.
Técnico	Especialista, Acadêmico.
Parcela	Lote, Porção, Quinhão.
Plantação	Lavoura, Cultura.

Each synonym can have a degree of interpretation on the meaning of the term used in the ontology. Through this imprecision, fuzzy logic could be used, in this work, as a mechanism of interpretation and computational support in the use of synonyms. As mentioned, there are several models described in section 2.4, but those models have an increased need for building ontological understanding and greater computational requirements. The focus of this study is a model that facilitates the use of ontology, with imprecision concepts.

This study proposes the application of fuzzy to organize and add these synonyms in a simpler format and it can be used by those who use the ontology. As example, consider the concept of *Hortelão* proposing that the concept is a linguistic variable, where the elements are the synonyms listed in Table 1. Setting a list of pairs as:

```
Hortelão = 0.9/horticultor + 0.3/agricultor
```

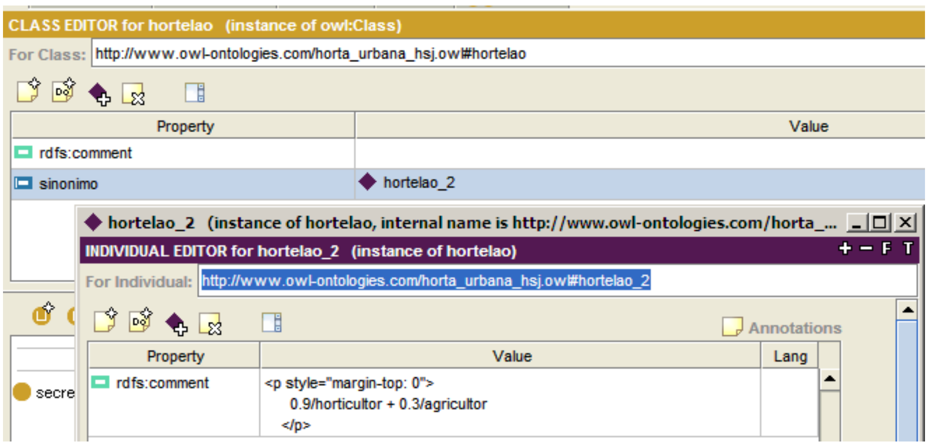

Fig. 4. Insertion of synonyms.

Due to the nature of the application domain, it is not possible to determine values through a well-defined function of compatibility between the elements and the linguistic variable. The criteria used in determining the degrees between 0 and 1 are the compatibility semantics. This degree was chosen by experts in the area.

The synonymous was included in classes through an annotation property of the object (class) called "synonymous". By including the property to the concept, a markup, comment type of the ontology language, is added. This marking an individual needs to instantiate the class, to explicit the information, which thereafter is useful in the manipulation of the ontology. There are individuals that contain textual information of the synonyms, according to Figure 4. Each synonym has a degree of compatibility with the semantic concept belongs.

To check whether a particular synonym is in a class, a survey is conducted with a related term desired. This term is combined with each concept that has set, i.e., is combined with each linguistic variable. This occurs through a query on ontology, using the following SPARQL query:

```
SELECT ?ind ?sinonimo WHERE {
        ?ind rdf:type <URIofIndividual>.
        ?ind rdfs:comment ?sinonimo.
        FILTER (regex(?sinonimo, "relatedTerm" , "i"))
}
```

Where *?sinonimo* parameter is the identifier of the annotation class and the filter function is used to research fragments, i.e., it is not necessary to have the full term to compare with the synonyms. A fragment of the term (or a corrupted word) can be found.

4 Conclusion

This paper presents the development of an application for communication between agents. The ontology that deals with imprecision information was defined and a part of the driver Jena/SPARQL was implemented (Fuzzy component). However, the application must have constant changes, evolving their functionalities, basing in constant experimentation in the MAS and expert evaluations (evolutionary development by increasing the maturity of the application).

Preliminary results show good design features in order to develop semantic applications and, applying it specifically in communication between agents. The next step is to implement a communication protocol interface between the agents and the driver. Next, will complete the integration between modules.

After the complete implementation of the proposed model, the study case chosen will be subject to tests, in order to check the treatment of the resulting data communication. It is necessary to validate the consistency of the manipulated data. Moreover, the proposed model should be aligned to become useful to any MAS and Ontology, among some embodiments, to be developed.

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