KISF: An interactive Ontology Framework

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Abstract. *Nowadays information circulates quickly in a human organization, what generates an internal difficulty in preserving inside the organization essential information to support decision-making. Decision Support Systems (DSS) aiding organizational decision-making, had, up to now, rigid inferences machines restricted to the organization area. These factors do not totally satisfy an integrated strategic decision-making process within a holistic view, an imposition of the current Information Age. So, the need of developing a DSS with inference capacity to relate the knowledge spread in the organizational structure became clear. To attain such result, the DSS must be associated with other methodologies and/or technologies, such as Artificial Intelligence, like Computational Agents and Ontology.*

This article intends to present the "KISF" (Knowledge Integration & Sharing Framework), which is an interactive framework using ontology, based on autonomous agents, for the knowledge integration and sharing and support strategic decision-making. The "KISF" provides the ontology construction and evolution throughout the individual and group agent actions when it comes to happen on the phenomenon perception. The framework developed aimed to formally represent the operation of an organization through ontology, and also map the abilities and competences of its members by creating Users' Profiles. After representing the organizational structure, a society of computational agents was established with the intent of performing computational reasoning within the information formalized by the organization, emphasizing Ontology, Profiles and Phenomena. Rules, priming on representing ways of extracting and formalizing knowledge in organizations, were elaborated. The attained results were shown to managers in the organization so as to undergo importance analysis. These were then incorporated to the Ontology of the organization, allowing its constant learning.

Key Words*: Agent, Ontology, SMA, Artificial Intelligence.*

1. Introduction

The application of knowledge, while distinguishing evolutionary, is a characteristic of several areas of human being's performance. The representation of this knowledge, built through cognitive and motor capacities, can be observed in the diverse phases of the human being evolution, starting from the primitive representations, passing by the language and, recently, culminating with the representation of cognitive structures through the technology of the information (image, sound, odor, palate and tactile perception).

Searching the surrounding world interpretation and the establishment of new states of the real world, man represents the surrounding world in order to formalize nexuses between the symbolic world, the one created through the application of cognitive processes, and the individualized perception of the immanent world. When dealing with world entities, there appears the necessity of the representation protocol in order to allow the knowledge transference and, in last analysis, the communication between beings. Moreover, representing the experience is distinguishing competitive towards allowing the oncoming generations to learn how to know, without, necessarily, going through all the phases that have characterized the discovery process.

The representation of knowledge, while protocol structure of communication of experiences and formalization of symbolic knowing, passes, undeniably, by the subjectivity and, as such, it must provide structures aiming to allow sharing and successive refinement, through the performance of a society with interests in common.

In this direction, the representation of knowledge through ontology of domain provides the necessary formalism for the characteristic normalizations of the scientific process, due to the explicit specification of the concepts related in the considered domain [GRU93]. The present article aims to present the “KISF” (Knowledge Integration & Sharing Framework), which is a framework based in computational agents for the sharing and representation of knowledge through ontology, allowing the extraction of knowledge from different multi-ways and providing updating mechanisms based on phenomenological proponents.

2. Methodology for representation of based on ontology knowledge

In an interdisciplinary conception, the multiple actions domains of the human activity many times confront, approach and establish connection with one another. These dynamic relations not only happen in the theorization and intellectuality field, but also strongly act in the domain of the actions, in the transforming intervention of the reality.

“Component and protagonist of a natural world and creator of an artificial world, the human being, during its period of life, is constantly modifying the state of the real world” [SHM99] and, consequently, the knowledge that emerges from the relations of him/herself with the reality. The knowledge representation must consider this dynamics and continued elaboration of itself, the relations between learned concepts and, in a computational domain, the diversity of sources that represent the noticeable world, beyond the impossibility of world representation as it is presented, or part of it, with all the details [GUI02].

The observation of new phenomena implies the reevaluation of historic/scientific knowing, aiming to adjust it to reality. Such scene, applied to the knowledge representation, must be faced in two fronts: technological and epistemological ones. From the technological point of view, the phenomenological observation undertakes matters as: storage, formalism of access, availability, among others. In the epistemological scene it is necessary to consider in which way an observed fact modifies the effective beliefs. [GUI02] highlights that “to represent a phenomenon or part of the world, which we call a domain, it is necessary to focus on a limited number of concepts that are sufficient and relevant to create an abstraction of the phenomenon at hand”, for so he uses an ontology that “is a formal explicit description of concepts in a domain of discourse (classes -sometimes called concepts), properties of each concept describing various features and attributes of the concept (slots - sometimes called roles or properties), and restrictions on slots (facets - sometimes called role restrictions)” [NoyMcG01].

For the methodological definition for ontology construction in the present work, the works of Grundstein and Barthès [GruBar96] - that verse about knowledge capitalization - and the methodologies proposed in the works TOVE [FoxGru98] and ENTERPRISE [UscKin95] have been considered. It is concluded, however, that the cited works represent contextualized readings of the scientific elaboration method that, in its basic structure, searches for the systematic observation of reality for the elaboration of models (that in the current context identifies the created ontology) that reproduce it, identifying cause-and-effect relations and interpret the most varied events and its unfolding.

In this scene, the scientific elaboration methodology for its universal applicability in the diverse areas of the human knowledge was selected. Thus, the construction of an ontology, preliminarily, passes by descriptive processes that lead to the recognition of reality and, subsequently, by two distinct methodological approaches, though they are complementary: the inductive and the deductive ones, composing a cycle to confront the model with the noticeable reality.

In synthesis [DEM80]:

- **The recognition:** It consists in the systemized observation of reality. Once it is defined the specific inquiry field of an aspect of reality, it is observed, classified and described the categories of this same reality that are pertinent to the intended inquiry. The recognition involves, thus, the ample observation of the real world, from which phenomena, data and relations are selected, that may be able to its understanding or interpretation. Normally, this stage is characterized by the continued performance of the Knowledge Engineer, being initiated in the construction of the taxonomy and, later, in the involved conceptual relations;

- **The Induction:** The gathering of information, resulting from systemized processes of recognition, pertaining or not to ontology, may lead to the formularization of explicit principles/models of the observed reality, allowing the temporal evaluation of the observed facts and the detention of impacts in the ontological structure in the considered instant **t**. It is distinguished that the transposition of the recognition process of reality for its systemized theoretical approach is what characterizes the inductive method.

- **The Deduction:** The deductive approach results from aprioristic processes, in which it is raised hypotheses about not investigated realities through systemized surveys, due to either the nature of the involved questions, or its complexity. The formulated hypotheses are object of theoretical development, whose factibility is not subjected, however, to the conventional measuring, but to typification of facts or behaviors deduced from abstractions on the concrete reality.

3. "KISF"

Recent works that deal with application or definition of ontology ([UscKin95], [FoxGru98], [NoyMcG01], [GUI02], [GRU93] and [ELE01]) discourse on ontological structures that, carried through the recognition process, do not suffer alteration due to new observed phenomena.

For Canguilhem, cited in [JAP82], knowledge is a historical reality, originated in the "interior of the temporality", developing itself in, and in it producing results. In this context, ontology, while explicit representation of a knowledge domain, is also affected by the temporality, characterized by the phenomenological observation and the resultant epistemological consequences resulted from observation.

In this direction, ontology, in the context of the present work, is a result of processes application about the conceptual model of application.

By conceptual model it is understood as "an actual implementation of an ontology that has to satisfy the engineering trade-offs of a running application, while the design of an ontology is independent from run-time considerations, and its only goal is to specify the conceptualization of the world underlying such application" [WEL01].

Considering that many are the phenomenological proponents, the "KISF" is a multi-agent environment, aiming to allow the distribution of tasks and cooperation between diverse computational agents, that, as [RUS95] "agent is an entity that can perceive its environment through sensors and act on this environment through actuators".

In a general way, the multi-agent systems term has been applied to any system composed of actuator agents [DUR94]. Currently, a multi-agent system is a system composed of:

- an *Am* environment,
- an *Ag* set of agents, and
- an *Ob* set of objects not agents.

An *Am* environment is a dynamic space, endowed with a set of rules that make possible the agents to perceive, locate and act over objects. A set of agents *Ag* is a set that presents a structure of organization, society, group or micro, homogeneous or heterogeneous agents, which act/react in the *Am* environment before the elements of the *Ob* set or due to the elements of the *Ag* set, through **behaviors**. An *Ob* set of objects is a set of entities, not-agents, present in the *Am* environment that suffer manipulations by the elements from the *Ag* set.

Aiming to consider the temporality and the observation of new facts as proponent elements of ontological updating, the framework is composed by the components as presented in Figure 1.

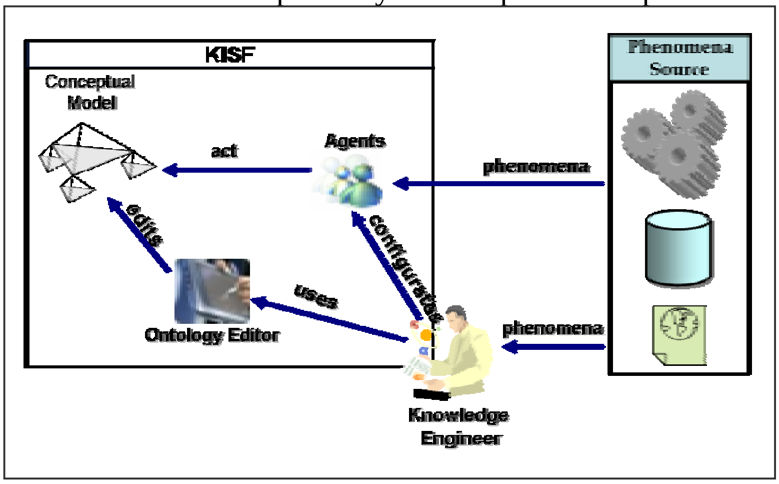

Figure 1 - KISF Architecture

The Knowledge Engineer (human agent) acts in the elaboration and critics. Elaboration, in the sense of configuring the society of agents through an environment of critics and assay in the scope of direct performance - in the creation and configuration of the conceptual structure -, or indirect - aiming to approve (or not) the results generated by the computational **agents** (actions carried through the computational device called **Ontology Editor**).

By **Source of Phenomena** it is understood [AUR03] "something that originates or produces happenings" - in short: all phenomenon that, through a distal stimulation (objects and real events of the observed environment), generates a proximal stimulation (an image in the retina, for instance). The phenomenological observation allows the epistemological performance, characteristic of the individual performance of the agents as configuration of the Knowledge Engineer.

Mainly the Knowledge Engineer carries through the recognition process. However - in an auxiliary way – it may be carried through by computational agents. The performances of the agents are computational representations of the induction and deduction methodologies in the individual or social scope. In this context, the commanded pair is defined by the "KISF" system to the most abstract level:

> (***Ont, Ls***) where:
>
> i) ***Ont*** is the ontology,
>
> ii) ***Ls*** is an involving agent [SHM95] responsible for the delimitation of the internal world of the society of configured agents (represented by the set, void or not, of {Agt}) and is the thrower of the society.

Ontology (***Ont***) is the explicit representation of domain knowledge, structuralized in the modules: Conceptual Layer, Properties, Sensible Layer and Profile.

Presently, the representation of Ontology is carried through representation plans [LasSwi99], due to different natures of the represented entities. In the Concepts Plan, or **Conceptual Layer**, the explicit representation of the Metaphysical plan is carried out - the one of the symbolization, in which is identified the concepts that shape the analyzed domain.

In the Sensorial Plan, or **Sensible Layer**, the instances are represented observed in the concrete world, caused by the projection of the knowledge represented in the Conceptual Layer and observed through the senses.

The nexuses are explicited through associations that are configured through accomplishment of Properties. The associations occur between concepts, instances or instances and concepts, as presented in Figure 2.

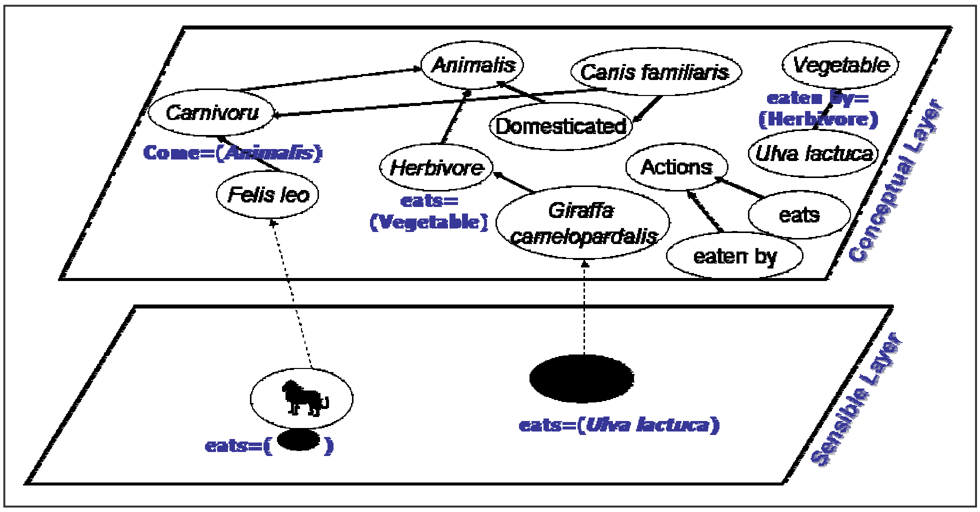

Figure 2 - Ontology Example [FEN01]

In the Figure 2, the concepts are represented through an identificator and delimited by an ellipse; the relation "It's one", used for taxonomic representation is delimited through an arrow, pointing to the originator concept. The associations are delimited through the property identificator that defines the semantics of the association, and the associated concept/instance, being represented through the commanded pair: (Property, Associated Concepts/Instances). The instances, represented in the Sensible Layer, are characterized by a Sign (text, number, image, color...) and connected to the concept origin through a dotted arrow.

Considering that the human symbolization process, while methodology for representation of knowledge, is, also, limitant factor for reality understanding due to the "production" of "versions" of it, in this context, searching for the production of a significant ontology for different groups that compose a same domain, it was applied the profiles concept, allowing the epistemological personalization of the ontology, making possible the framing of the conceptual structure in scenes that include differences in language, levels of formalization and/or associative framing between ontological beings.

Figure 3 illustrates the devices used for the configuration of the ontology by the Knowledge Engineer. In **A** and **B** structures of conceptual configuration are presented, in **C** the configuration of properties is presented, and in **D** the of instances insertion (sensible layer).

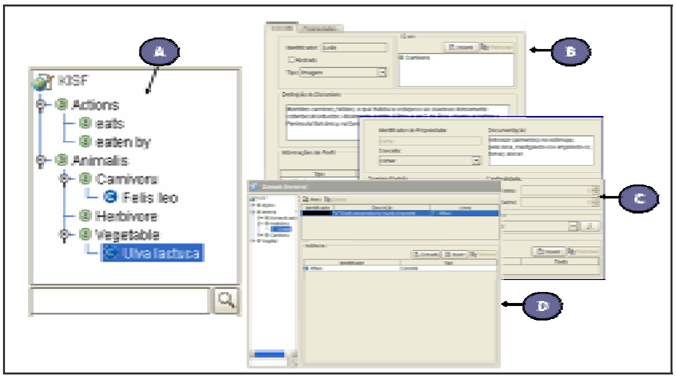

Figure 3 – Configuration devices of the elements that compose the ontology

3.1. Construction and evolution of ontologies

The performance in the conceptual model, decurrently from the phenomenological observation, is divided into two levels (epistemic and credible):

i. In the **epistemic level,** a new observation, when of the application of the resultant processes set of the performance of the agents' society, allows the identification and the creation of concepts or associations in the existing ontological structure (being fit in the process of scientific methodology, in the stage of Recognition). Exemplifying: an agent whose ability is related in the domain of a forest, for the search of new species.

ii. In the **credible level**, a new observation can generate the strengthening or the weakness of a determined belief in an association. Exemplifying: "an association: lion **eats** vegetable, is not credible", such assertive is possible in function of a set of phenomenological observations that had proven it. In this direction, the environment of the "KISF" allows the specification of associations that can, due to the set of observed phenomena, to be credible or not. It is distinguished that only credible associations are shown in the ontology visualization and, methodologically, this performance is based in the methodology of Reinforcement Learning [RUS95], being necessary to the explicitation of a minimum level of reinforcement for the determination if such association is, or not, credible.

To allow the performance of the agents' society in a distributed system, it was selected the technology *aglets* acting on the *Tahiti* platform [OSL98], *pattern Design By Contract* [MEY92], that defines a contractual formalism between the parts when executioning an activity, and the methodology defined for the architecture "ARCHON" [WIT92]. Aiming to encapsulate the presented structures it was implemented architecture of independent computational agents, presented in Figure 4.

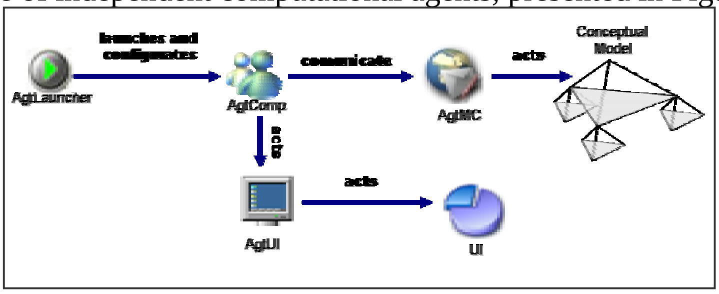

Figure 4 - Functional Diagram of the agents' society

The **AgtLauncher (*Ls*)** is an involving agent [SHM95], responsible for the launching of the society and the internal delimitation of the agents **AgtComp** (independent and mobile), that present a set of abilities that qualify them to, in an individual or collective way, act in the Conceptual Model, performance carried through the **AgtMC** (specified aiming to congregate the action of the mobile agents, carrying through the consistency of the requests, guaranteeing that unbalanced visions of the world, when of the action of an agent, do not produce inconsistent results).

The **AgtUI** receives information from **AgtComp** agents and shows them in proper device, allowing the following up of the actions of the respective agents.

The abilities of the **AgtComp** agents can enclose, in agreed or individualized way:

i. the **Phenomenological Perception**, which encloses the observation of phenomena from the sensible world with the application of an specific technology (as the access to databases or Web Services),

ii. the **epistemic and/or credible performance**, that makes possible the agent to act in the ontological structure aiming to create new associations or concepts and to carry through the strengthening or weakness of existing associations, and

iii. the **Phenomenological Transformation**, that allows the procedural transformation of a phenomenon in another relevant phenomenon for the world, through the application of equated, deductive or inductive structures. The configuration of the society of AgtComp agents is carried through by intermediary of the Engineer of Knowledge with intention to get new knowledge that can be used in the Conceptual Model. The implementation of such society, presented in Figure 5, was based on the work of [VAS02].

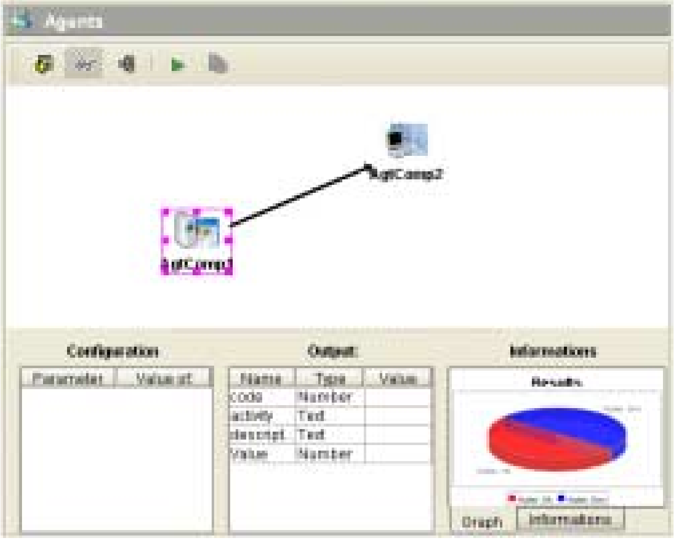

Figure 5 – AgtComp configuration environment

Description of the elements detached in Figure 5:

i. identificator of the agent (image and name),

ii. personalization of the level of knowledge between the agents, allowing the performance in society,

iii. explicitation of the phenomenological flow, and

iv. device brought up to date by AgtUI with information on the performance of the selected agent.

The following abilities of agents have been implemented, being available for use in the environment:

i. **Perception of the Inner**: performance of phenomenological perception, it presents the capacity of observation of the world *inner* [Shm9] (conceptual structure), detecting the creation of new instances or concepts, as well as the alteration of the same ones,

ii. **Search for Definition**: performance at epistemic level, aims the search for definition of a concept in multi-ways,

iii. **Creation of concepts**: performance at epistemic level, acts in the creation of concepts from received phenomena,

iv. **Creation of instances**: performance at epistemic level, acts in the creation of instances from received phenomena,

v. **Actuation in Profile**: performance at epistemic level, presents abilities aiming to act, automatically, in the personalization of Profiles in concepts,

vi. **Search for based on Dictionary definition**: performance of phenomenological perception, carries through the search of the meaning of a concept in an online dictionary, based on the *XPath* technology,

vii. **Phenomenological transformation through Translation**: performance of phenomenological perception, carries through the translation of terms in several languages (it accesses the *Babylon online* through SOAP protocol),

viii. **Credible performance through Trees of Decision**: with performance at credible level, aims the strengthening or weakness of associations based on received phenomena,

ix. **Phenomenological transformation through Bayesian Nets**: performance of phenomenological transformation, calculates probabilities considering entrance phenomena applying the theory of Bayes,

x. **Phenomenological Transformation through Statistics**: performance of phenomenological transformation, totalizes statistical values based on logical functions configured by the Knowledge Engineer,

xi. **Phenomenological perception through Data base**: performance of phenomenological perception, recoups phenomena from a DB,

xii. **Phenomenological perception through Web Services**: performance of phenomenological perception, recoups phenomena from Web Services, established in the WSDL structure for consultation the structure of data of it,

xiii. **Sources Selection**: performance of phenomenological perception, recoups documents of a set of configured multi-ways,

xiv. **Phenomenological perception through Document Processing**: performance of phenomenological perception, from a set of documents carries through the extraction and counting of significant words in the, excluding words of linking semantics (called *stop-words*) and considering the syntactic root of it (stemming process), and

xv. **Credible Performance through established Rules:** with performance at credible level, acts aiming to consider direct consequences in the ontological structure. The performance of this agent aims the dealing of exceptions of the type: in case X phenomenon is observed, then association "Concept A associated with Concept B" it is (not) visible, regardless of previous evidences.

xvi. **Association by Hypothetical Syllogism**: The objective of the agent is to search new associations, starting from already existing associations between concepts in the Conceptual Layer. To carry through this task, it is used the principle of the Hypothetical Syllogism [REI99].

xvii. **Association by Concepts**: The objective of the present rule is to focus in the externalization of the knowledge [NON95], formalizing the knowledge that is find expressed in the organization, through the intermediation of the abilities of the members of its structure.

xviii. **Association by Instances**: A set of Phenomena (part) may generate an alteration in the organizational representation (all) through ontology. This rule intends to identify a pattern of relation between Phenomena and concepts that allows an association in the Conceptual Layer between the related concepts.

xix. **Association between Profiles**: The agent uses the information contained in the users profiles and searches other users who possess characteristics in common, searching associations between them.

xx. **Association by Candidate Key-Word**: A Phenomenon possesses identified its more frequent words, called key-words candidates, used to represent it. The entailing of these words to the Phenomena is an artifice used to identify to new associations between an already existing concept in ontology and a new concept that will be added to the same one, proceeding from a key-word candidate.

xxi. **Association by Conceptual Composition**: It is suggested creation of new associations, from an association with semantic is-part-of between two concepts

xxii. **Results Exhibition**: agent that is responsible for the exhibition of the results gotten by means of the agents of the architecture.

Other agents may be added to the environment in a dynamic way, being enough the implementation based on the *AgentComp* class.

With the aim to assist the ontology construction process, two assistants are available: **Extraction of ontology from documents** and **Extraction of ontology from Relationary Bases**. In the **extraction based on documents** the Knowledge Engineer, through an interactive process, selects a set of documents and, after executed the process of recovery defined for the ***AgtComp* - Phenomenological Perception through the Document Processing**, applies the terms recouped in the ontology, either in the form of new concepts or synonymous. In the **extraction of relationary bases** the Knowledge Engineer selects a set of entities in a diagram of relations, extracted through automatized way, and the assistant creates the concepts (from the table structures) and instances (available registers), besides configuring the society of agents (through the agents: Creation of concepts, Creation of instances and Phenomenological Perception through Data base) for the recovery of new phenomena of the considered base.

4. Experiment

The accomplishment of experiments allows the ascertainment of the scientific viability of a research work. From a developed prototype, an experiment in an organization was effectuated. The results have been presented to the organization managers, which have evaluated the relevance of the suggested results.

The accomplishment of the experiment was divided in three stages:

(i) Ontology;
(ii) Profiles;
(iii) Agents.

In the first stage, the ontology of the domain of the experiment is elaborated. After that, in the stage of Profiles referring information are added to the users that compose the organization in analysis. Finally, the stage of Agents allows the configuration of the multiagent system structure that carries through the computational reasoning.

The carried through experiment has done the analysis of a recognized national organization that produces perfumes, being composed by five sectors: Human Resources, Financial, Marketing, Production and Commercial.

The perfume manufacturing is composed from four supplied things: imported raw material (essence), national raw material (chemical components, formed by distilled water and alcohol), bottle and external packing.

In the topics that follow it is presented the stages and the results of the carried through experiment.

4.1. Ontology

The construction of the organizational ontology was made through interviews and observations *in loco*, with the direct application of the scientific method.

4.1.1. Ontology Implementation

After the construction of ontology, its implementation is done in the prototype. Initially, the concepts in the ontology are created. Next, the properties are created, which are used as semantics of the associations between concepts. In the sequence, the associations between the concepts are established. Such associations use the properties to indicate its semantics. The experiment presents an organization manufacturer and perfume dealer, whose ontological representation possesses 125 generated concepts.

4.2. Profiles

4.2.1. Implementation of the Profiles

The implementation of the profiles in the architecture of the prototype requires the fulfilling of some requirements. Thus, the computational configuration of a profile needs:

(i) creation of an identification of the Profile;
(ii) association of concepts to the areas of interests of each Profile;
(iii) addition of the Profiles associated.

The Profile identificator is represented by the name of the employee, for identification, and by its e-mail address, for contact. The second configuration item is the employee’s areas of interest. These, relate the concepts with which the user possesses affinities, in such a way professional as well as personally. Such information assists the socialization process among the employees of the organization. Concerned to the experiment, eight Profiles have been created. The *Antonio* Profile is the Marketing manager, whose attribution is the creation of the referring strategies for the product spreading. The *Carla* Profile is in charge of the Human resources area, carrying through frequent contacts with the employees. The Financial manager is the Profile *Fernando*, whose attribution is to calculate the selling price of the product and to analyze the financial reports. The Profile *Luiz* is responsible for the Production area, whose main activity is the management of the company's volume of production. The Profiles *João, Marcelo* and *Marta* are the laborers of the company and work in the production of the perfume. Finally, to the *Roberta* Profile it is attributed the Commercial area, that carries through the market follow up.

4.3. Agents

In Table 1, it is presented the entrance and exit information of each one of the agents used in this experiment.

Table 1 – Agents Information

Agent	Ability	Input	Output
AgSources	Selection of Sources	Sources of information	Documents of the sources
AgPhenomena	Phenomenological Perception through the Document Processing	Documents	Relevant Documents
AgRSilogism	Association by Hypothetical Syllogism	New concepts	Results
AgRConcepts	Association by Concepts	New concepts + Profiles	Results
AgRInstances	Association by Instances	Relevant Documents	Results
AgRProfiles	Association between Profiles	New concepts + Profiles	Results
AgRKeyWord	Association by Candidate Key-word	Relevant Documents	Results
AgResults	Results Exhibition	Results	Results Exhibition

The implemented multiagent system for this experiment, as well as its relations between the agents, are represented in Figure 6.

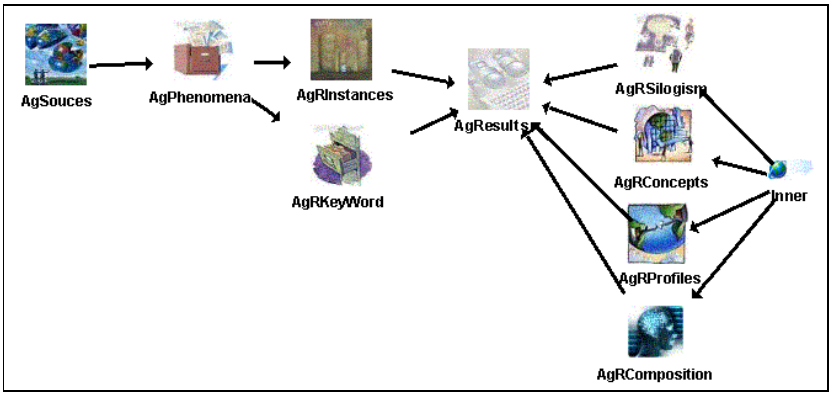

Figure 6 – Architecture of the multiagent system used in the experiment

This way, the present experiment contains the following agents:

(i) **AgSources**: Responsible by the indication and the storage of the information sources that will be used by the system;

(ii) **AgPhenomena**: Responsible for the document management of the system.

(iii) **AgReasoner**: Composed by the AgRSilogism, AgRConcepts, AgRInstances, AgRProfiles and AgRKeyWord, represents the reasonings to be carried through in the ontology of the organization.

(iv) **AgResults**: Exhibition of the gotten results.

(v) ***Inner* Agent**: its objective is to inform the agents related to it the existence of a new concept added to the ontology.

After the construction and the establishment of the relations of the multiagent system, it is done the configuration of its component agents.

4.4. Experiment Results:

The results approved by the manager are incorporated to the ontology and transferred from the list of obtained results to the carried through actions description list. The experiment have been generated 108 results. The amount of generated results per each of the reasoning agents is described in Figure 7.

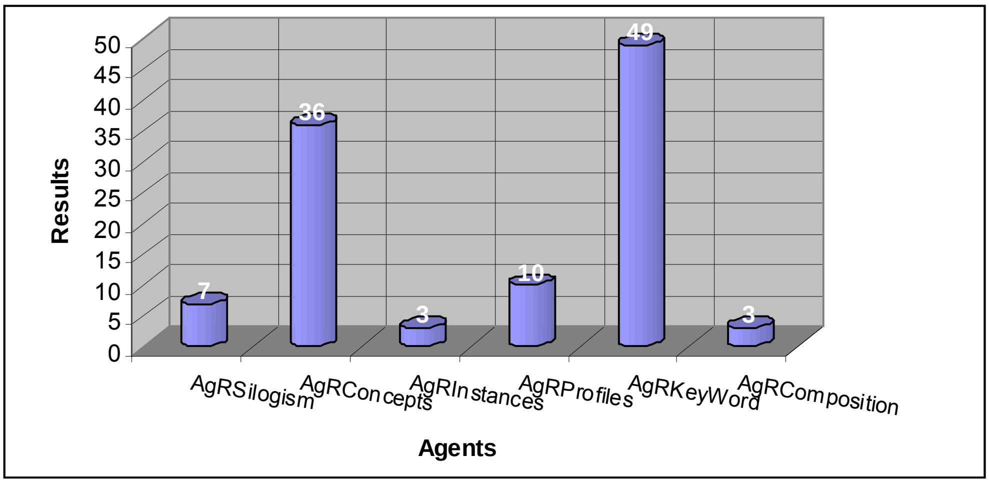

Figure 7 – Results from each reasoning agent

The results generated by the system have been presented to the organization manager that considered 56% of the relevant results for the organization’s strategical planning. The relevant results have been divided into two classification categories, whether it may be implicit and explicit knowledge. The implicit knowledge is found in associations that represent an important knowledge for the organization, and that would not be observed by the manager without the use of the prototype. About the explicit knowledge, it is determined by associations that simulate an important knowledge for the organization, but that have already been observed by the manager without the necessity of prototype use. For the first experiment, the manager found out 73% of the relevant results has determined explicit knowledge and 27% has originated implicit knowledge.

5. Final Considerations

The epistemological update of the ontology, from observed phenomena, allows the creation of a dynamic structure aiming to guarantee the synchronization between the model and the noticeable reality.

A set of experiments is being developed on the proposed framework, aiming to identify new interest abilities for the agents’ society. Among the experiments it is cited: the organizational modeling of companies of the software sector based on the model of [FoxGru98] and the representation of ontology of legacy systems, with the aim to allow the tracking between the COBOL code and the organization’s conceptual structure.

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