Towards the definition of an Agent-supported intelligent collaboration system to represent a scientific network

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Abstract

The study of collaborative networks has an impact when it comes to analyzing environments where participants interact forming teams with common interest. The complexity of these emerging interactions becomes more difficult to analyze and the results reflect a greater or lesser degree the level of success. On the other hand the power to track the performance, optimize the capabilities of the team in order to get better results is a difficult goal is achieved when it is required to start a new project or is faced with a different environment. This research work is focused on the application of intelligent collaborative systems supported by two strong pillars, Collaborative System Design and the design of systems supported by the paradigm of artificial intelligence, specifically the branch of multiagent systems. These paradigms have been focused on two main objectives: the optimization of resource uses and achievement of results that implies a complex environment, which provide solid information for decision-making and improve creation of collaborative research networks.

Keywords: *Collaborative systems, Multiagent Systems, Artificial systems, Scientific Network.*

1. Introduction

Currently it is possible to observe how organizations have achieved goals based on Teamwork. Teamwork is seen only as a group with a common goal where different disciplines interact, as an organization in which all participants collaborate from the beginning in the analysis of an environment to identify areas of opportunity and develop solutions together.

On the other hand, it is possible to observe that economic advances made recently at different countries are closely linked to innovation processes and knowledge transference. Thus, generation of new knowledge, technological progress and innovation have been become key elements for economy growing. De Solla [9], posed that the collaboration among researchers as a central part of its activities.

This allows that exponential growth at scientific collaboration rates is anticipated as a consequence of professional research communities. Therefore, scientific collaboration can be viewed as fundamental to the science progress, due to it allow to study complex problems, complete gaps and enables the critical mass is reached for the advancement of knowledge.

However, this new paradigm of collaboration has led to an increase in the complexity of the interactions, the volume of information that is managed, filtering and analysing of the same and a limited global vision for all participants by the large number of interactions that are present.

The aim of this work is the proposal of a new paradigm that offer an agent-supported tool that allows to represent a scientific teamwork that helps in the search for solutions to new opportunities based on the recovery of the prior experience.

2. Theoretical Framework

Teams are formed by the need to incorporate individuals with different perspectives, skills and resources. Creativity is harnessed when the innovations that have been implemented in a specific environment are introduced into a new domain to solve old problems and inspire fresh ideas. Then, collaboration between individuals becomes more important during the analysis and development of new proposals for improvement. Some researchers have developed works based on the hypothesis that a creative environment is supported by a network of collaborators who inspire, provide support and assess their work [13],[31],[7].

According to Powel and Dimaggio[29], knowledge has become as the most valuable asset at organizations. Then, replication of knowledge requires, socialization, economic conditions and an appropriated language that allows interaction among more people [28]. People acquire and develop knowledge along their lives, it is refined belong activities, relations, experience and observation [11]. At the “knowledge society”, scientific and technological knowledge production is generated at autonomous way. The learning process is interactive, where groups develop system processes to acquire, use and communicate knowledge at the society. Moreover, the knowledge transfer describes activities focused on take knowledge, abilities and intellectual property from universities to enterprises [4]. Universities execute transfer knowledge activities based on their experience get from education and research, to contribute to economic development. by the transfer of academic knowledge to society. Finally, studies related to knowledge transfer are focused on the intra-organizational transmission applying formal methods. These studies analyze efficiency during knowledge transference based on actor (emissary and receptor) properties, and how the actor position at a network influences.

The study of complex systems has been focused on the seeking of new ways to represent such systems, including networks [15]. Actually it is possible to observe how many systems can be effectively modeled by networks in which the components of such systems are modeled as vertices, and the interactions between them are modeled as lines between vertices. The identification of these networks (linked through their interactions) to measure the degree of connection, determines the evolution of the same and the results obtained from these developments [1], [24].

Such interactions are also observed in the studies on Social Collaboration Networks [13], which are defined in terms of a group of entities (called actors in social literature), and a group of acts of collaboration. The actors relate to each other by taking part in an act of mutual collaboration. Under this scenario it is possible to observe as collaboration networks can be represented as bipartite graphs with two types of vertices, one representing a type of actor, while the other vertex represents acts of collaboration where interactions become more complex.

Environments where it has been possible to observe how the study of collaborative networks has a significant impact on the behavior and development are in the field of science. It is possible to observe that the application of scientific collaboration networks has resulted in increased scientific capacity, particularly in emerging nations have contributed to the growth of international collaboration [18],[37]. Beaver and Rosen [5], suggest that collaboration became professionalized science that has been taking place in institutions with devoted areas to science. These studies show that collaboration becomes a mechanism both to gain and maintain access to professional recognition in the community. Collaboration is an intrinsic advantage for scientists, particularly when it occurs between a "master" and "apprentice".

The research of the application of collaborative networks has been studied from diverse approaches including psychology, marketing, sociology, and artificial intelligence. Artificial intelligence approach has recovered concepts from other approaches focused on human behavior replication, by offering alternatives for environments representing individuals with complex interactions [32], [27].

3. Justification

A network implies a set of relationships that connect different actors (individuals, group of individuals) that cooperate to acquire resources that cannot get by them-selves. Thus a cooperation network can be defined as associations of individuals whom goal is get jointly agreed results obtained through participation and collaboration. At this kind of network there are common well-defined goals and a plan that includes an active participation of all members [35]. There are four criteria used to create a collaboration network:

•¿Who are associated? It can be individuals or groups.
•¿What they are associated for? It implies the goal of the association; there are different types of networks: Network of information and communication, Academic, Thematic, Research, Innovation and Technological services.
•¿Which is the association scope? This issue is related to the geographical scope of the network, it can be national, international or regional.
•¿Which is the association nature? Networks can be created as formal or informal structure.

This work is focused on two specific types of networks:

Academic Networks: These usually are present at Superior Education, they tend to involve mobility and interchange of students and professors. Also, they are promoted at posgraduate studies to interchange experience and university management models. Their motivation is based on internationalization among Universities around the World.
Research Networks: These are called no-wall laboratories. These are associations focused on the development of research and technological activities by joint projects. At this kind of networks there are common research projects, then each node at the network (a research group is a node) provides specific knowledge and product to meet common goals. These networks are based on the premise that each node is a complement that provides capabilities and strength to the network.

Science has left to be an individual effort to become a collective enterprise. Currently, science cannot exist and grow in isolation; it requires cooperation, interchange of knowledge, and the possibility of scientists criticize and interpret work of other. The collaboration of each of the members of an organization is the key in the analysis and development of new improvement proposals. In this way, the organization grows, adapts and evolves optimizing their resources [22]. Thus, the structure of a scientific collaboration network has been studied from different perspectives.

On one hand, the collaboration graphs have been made using databases and specialized software able to connect authors and coauthors in a collaboration scientific network [23]. The collaboration is feature of science evolution. The organizations responsible of scientific policies promote collaboration by initiatives to joint development of research projects and creation of cooperative research structures. However, this implies the emergence of complex problems that include, use of interdisciplinary approaches, increase at specialization, finance policies to promote work teams creation, establishment of cooperation agreements, use of information technologies to facilitate remote working and science globalization.

Besides, scientific collaboration is a highlighted phenomenon that has contributed to science transformation from three centuries ago [9]. Actually, it is observed an increment of scientific collaboration, especially at disciplines identified as basic science [3. Beyond their source, scientific collaboration has reached a great importance at current science. Then the formalization of scientific collaboration improves both transference and diffusion of results. The Organization for Economic and Cooperation Development (OECD) made a declaration that contemplates that cooperation at science and technology, both national and international cooperation are considered extremely important for facilitate sustainable development, improve researcher mobility, and increase cultural and scientific heritage of the participants. These are essential conditions for achieving socioeconomic independence of developing countries [25].

The causes that lead scientists to work together are related to the subject specialization and the need to address increasingly complex problems that require the involvement of multidisciplinary teams. In general, cooperation depends on how open or closed it is the scientific community to participate in research projects with colleagues from the same or different country and with other specialties.

The international scientific and technological cooperation is now an intrinsic activity in the generation and transfer of knowledge and technologies, regardless of the level of development of countries and institutions. This scenario raises the need to analyze the specific characteristics of scientific and technological cooperation in the context of development cooperation. Features not lie both in the nature of the processes and modalities of cooperation, but their motivations, the emphasis of the objectives and approaches, outcomes and impacts.

One identified difficulty to characterize scientific and technological development cooperation lies in the different level of maturity of the scientific-technical systems and even countries in the heterogeneity that may exist between scientific and technological fields and economic sectors in each country.

The knowledge that currently is distributed among a network of collaborators implies the emergence of complex interactions that are difficult to replicate using traditional techniques. However, optimizing the use of such knowledge, in identifying the team of collaborators with the capabilities more suitable to be involved in the resolution of specific problems, is an opportunity area that can bring benefits both individual and global organization. The collaboration cannot be unrelated to the goal of strengthening the scientific culture as en elemental development.

3.1 Scientific Collaboration Models and Agents Paradigm

There are different proposals about models to regulate behavior of scientific networks. COST is a successful model applied at Europe, it allows that researches of any place can collaborate; their management structures are flexible and agile. It promotes coordinated networks for national research projects among five countries. Links among different group of scientists from the same field or from similar scope are established, their activities, publications, training, and short-term interchanges of researchers are financed. Another model is the Research at Network, it is based on strategic collaborations forms a long-term among excellence centers. It takes advantage of knowledge, scientific and technical infrastructure that provide this kind of centers around the world.

Based on this premise, this work is aimed at the definition of a tool that helps to those groups in these processes of continuous improvement. For this, the work is based on the application of an artificial intelligence paradigm, the Multiagent Systems, which have given excellent results in the field of human behavior replication [25], [20],[21].

The paradigm of agents and multi-agent systems [20], [36] is currently an area of increasing interest in artificial intelligence, among other reasons, to be applicable to solving complex problems unresolved satisfactory using classical techniques [17],[33],[34]. Many applications based on this new paradigm are being used in a wide range of areas [16], such as process control, production processes, air traffic control, commercial applications, information management, electronic commerce, psychology, among others. Also, it has been widely used since the representation of complex systems to the integration of intelligence in electronic devices [16]. These devices work independently, autonomously and proactively together simulating a collaboration network [2], [8], [14] which also have the feature of being able to interact with the physical environment, acting as a collaborator who interact with humans within intelligent collaborative network where knowledge is distributed among all stakeholders [26],.

This work proposes the Multi-Agent Systems paradigm included at Artificial Intelligence, as a viable paradigm that based on its properties (such as autonomy, proactivity, cooperation, distributed knowledge) allows the simulation of complex systems (that requires the collection of large amount of information that is found on a network in a distributed and held by different actors with different skills) that can get the optimization of the usage of information and increased network capabilities for collaboration at scientific environment.

4. Metamodel of intelligent collaboration system

Based on the review and analysis of the literature of the different areas presented at sections 2 and 3, it was possible to integrate and define the basis of the proposed design and the contributions that it offers as part of the definition of an Intelligent Collaboration Network. Thus, applying criteria presented at section 3, a scientific collaboration network can be created answer them as follows:

¿Who are associated? The network includes professors, researchers, and students, who can be grouped at research groups.

¿What they are associated? (Goal).The scientific collaboration network initially will be created as an Information and Communication network that will evolve to an academic and thematical network and then to a research network until it can turns into an innovation network.

¿Which is the association scope? This work initially represents a regional network, that can evolve to be international network.

¿Which is the association nature? This work is based on the creation of a network viewed as an informal structure, where individuals collaborate voluntarily.

It is possible to observe that professors, researchers and students have different level of experience and knowledge. Then, it is required to identify how knowledge can be transmitted, trough learning techniques. Lebert [19] proposes learning levels as follows:

Learning Level 0: It is a specific response (good/bad) faced to a scenario without correction action.
Learning Level I: Generates an action to reduce the difference between answer and expected value, it does not take into account other possibilities.
Learning Level II: Promotes change at level I of learning process. The learning takes into account the context (Level I is present) but it allows correction.
Learning Level III: It promotes changes at Learning Level II. It is possible due to integration at a high level of context learning.
Learning Level IV: It implies changes at Learning Level III. It allows reversible processes at the thought under different conditions at different in either order.

This category allows identifying which of them will be applied to represent the knowledge that individuals will share among them at a scientific network. Some Researchers and professors can apply level III and IV, while students usually will apply Level 0 and I when participates at a collaboration network.

At the first stage of this work, the collaboration network will be based on reproduce an Information and Communication network, where the individuals interchange information and data, the collaboration network will allow maintain updated information, knowledge and results viewed as papers. Then, it is necessary to include different kinds of individuals like students and professors with different levels of experience to represent an Academic Network whom main purpose is the generation of new knowledge that promotes innovation. Knowledge Sharing arise because of the individuals‟ effort to transfer knowledge to others in the organization. Knowledge sharing is an activity that is common to discuss in knowledge management. Knowledge sharing is also an important part in knowledge management. Knowledge innovation, is the goal from the knowledge management but the knowledge innovation unable to work without the knowledge. Here, sharing and using the information will speed up the innovation process and improve the quality of innovation [30].

It is considered that when this network evolves, each individual is specialized at a specific theme. Thus, these elements will allow establishing basis for a Research network where research groups made activities focused on research and development (R&D) by working at a joint project.

As a result of this research stage, the results have been incorporated using the design methodology ANEMONA [12]. ANEMONA is a Multi-agent Methodology for Holonic Manufacturing Systems, which lays the foundation for the development of a multi-agent system to a system considered as a whole in which the sum of its parts, where all agents collaborate under specific scenarios. In such scenarios, are established the interactions among entities (actors), the flow of information and algorithms of data processing for obtaining results as a basis for decision-making.

In this paper, in the first phase are modeled intelligent collaborative network in which nodes are more than a hub of information, an active member in the network that provides information and collaborate with others to achieve a goal. The ANEMONA methodology that was applied in the design of Multi-Agent System includes the following set of activities: Identification of Main system processes and Environment or scenarios, Definition of Basic Entities, Metamodel for Agents, Tasks and Objectives of agents, Agent Interaction, and Definition of Organization.

4.1 Main System processes

The first step is the definition of the main processes of the network (Fig.1), this processes include main activities that entities (agents) performance as part of their own behavior.

4.2 Environment Definition

At this step, the environment can be viewed as scenario set where the entities participate during the system processes. Figure 2 presents the main scenarios that compose the environment.

At the Researcher Registration Scenario **(1)**, the Researchers register their data in order to identify their skills, list of knowledge area, expertise level, degree, adscription, and personal data. This data are useful at Search Researcher Scenario**(7)** when a collaboration network is created based on a selected knowledge area and skills required to create a new collaboration network for a execute a Research process Scenario **(2)** or participate at a project at Project Execution Scenario**(4)**.

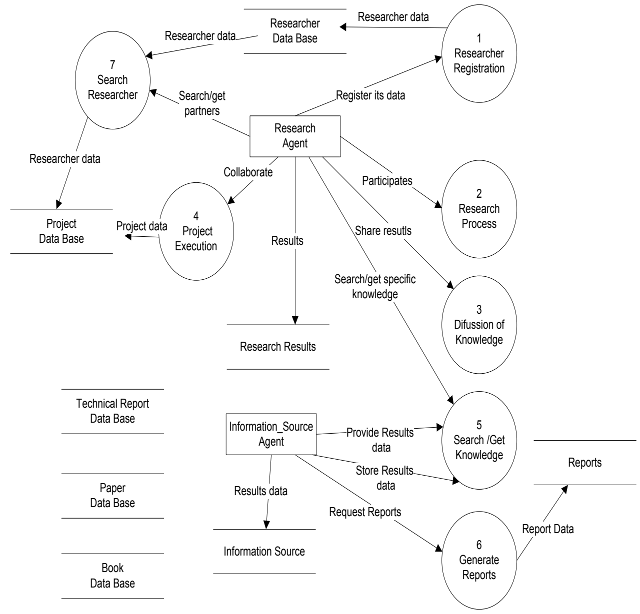

Fig. 1 Main System Processes.

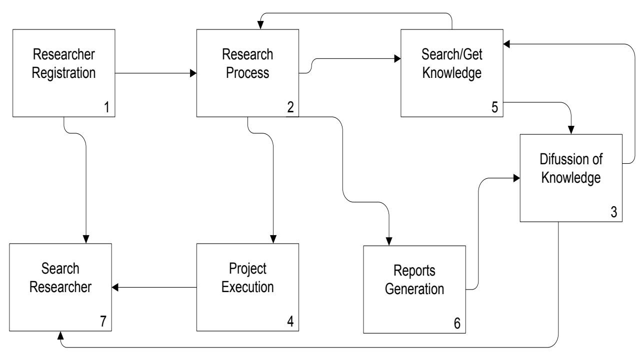

Fig. 2 Main Interaction Scenarios of System.

Thus, a Research Process can be part of a Project. Then, research results are integrated at papers, technical reports and thesis at Report Generation Scenario **(6)**, which are diffused and shared with the scientific community (attending Conferences, sending results to magazines, editorials, etc.) at Diffusion of Knowledge Scenario**(3)**.

Finally, during the Research Process the knowledge can be searched and get using information sources that act like an information manager, which can search specific knowledge at papers, technical reports, thesis, books, etc, at the Search/Get Knowledge Scenario**(5)**.

4.3 Definition of Basic Entities

At this step, the entities are those participants engaged in activities that provide key information for the operation of the system are defined. The main entities that were identified at a scientific environment include:

Senior Researcher: Is an entity that has a high-level of knowledge of a specific area, which has a wide-range of specific skills and high-level experience. This entity is considered as a "master".

Junior Researcher: Is an entity that has a low-level of knowledge of a specific area, which has a low-range of specific skills and low-level experience. This entity is considered as an "apprentice".

Information Source: Is an entity that provides specific information of a specific area, which has a specific range of reliability related to the information that diffuses.

It is possible to observe that the Researcher entity viewed as a holon is an entity with specialization where the expertise level is property that defines when it is a "Senior" or "Junior" researcher. Thus, Figure 3 presents the main relations identified among the entities.

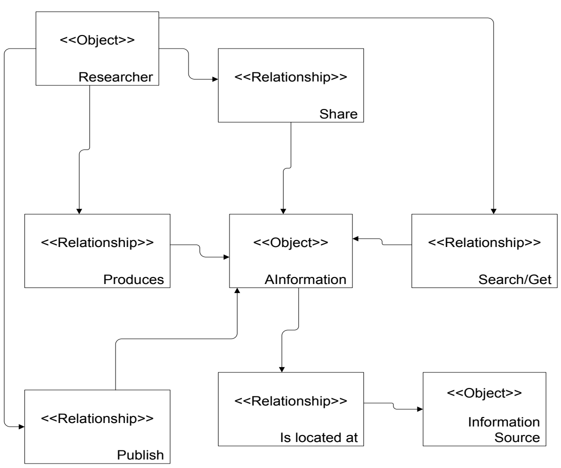

Fig. 3 Main Interaction Scenarios of System.

4.4 Definition of a Metamodel for Agents

This step involves the definition of the capabilities of each of the entities, their way of communicating with others and how agent receive and process the information.

The main characteristics related to the Researcher holon takes into account the main concepts that are required to identify and show the main interactions with other holons.

These concepts are related to the generated products by Researcher such as papers (identified as AInformation holon) that are published at many information sources (identified as Source_Informationholon). Holons have linked both properties and objects that describe their main functions.

These issues have been defined based on the requirements related to their internal relationships and their relations with other holons. Figure 4 presents the relationships among entities viewed as a metamodel of holons.

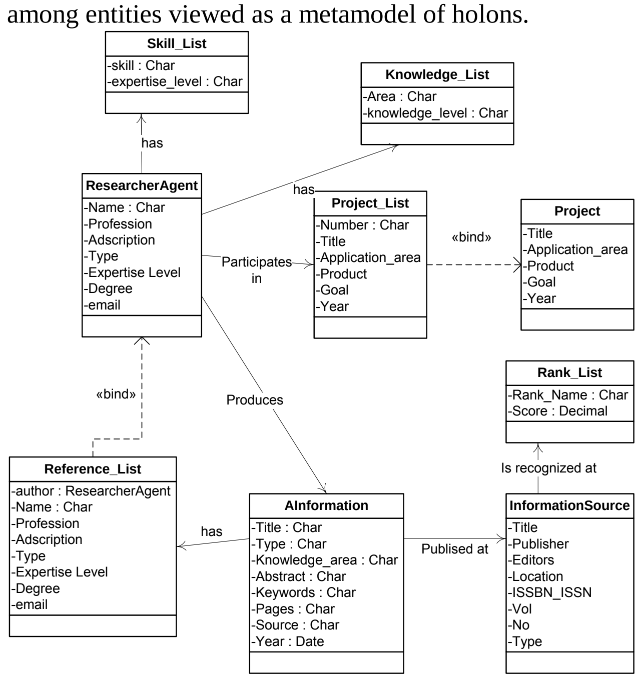

Fig. 4 Metamodel of Collaboration Network.

During the research process the object **Researcher** acquire knowledge about different areas and improve their skills to solve specific problems. On the other hand, this knowledge and skills, improve the knowledge level and expertise of a Researcher who can become an expert when it has to propose solutions to a specific problem at that area. Moreover, a Researcher shares this knowledge by diffusing it on papers, technical reports, projects (identified as an **Ainformation** holon) and face to face with another researcher with less level-experience at such area. Therefore, Researcher search and get knowledge from another researchers by consulting papers, books and reports.

Although, this knowledge and skills allows Researcher to participate at project oriented to application areas that require experienced people with certain skills. On this way, a Researcher acquires more experience and improves their skills at each project where he participates.

Thus, an **Ainformation** holon includes the results obtained as part of a previous research process. This holon has a list of authors who have participate during the research process and the main area where the proposal could be applied and the year when the analysis and results have been presented. It has a title which describes the main idea of it; its type allows identifying kind of information that contains.

A technical report will show the technical aspects and results of that analysis, a conference paper presents results that have been reviewed for an expert panel previously their publication and presented at specific forum, a book presents a wide volume of information that includes a framework, the development of a specific problem, results viewed as a whole environment with problems, proposals and solutions that have been published by an editorial that has distributed and promoted widely the product.

Finally, an **Information Source holon** is a place where a Researcher can search on papers, technical reports, projects (**Ainformation** holon). This entities group **Ainformation** holons of specific types, and are ranked based on number of cites linked to their papers, authors reputation, web page usage, the publisher and editors reputation. An **Ainformation** holon has detailed data about the authors, an abstract, year, knowledge area, keywords that allows identifying if it is useful for a researcher. Thus, the author list linked to an **Ainformation**holon and the project data allows building a collaboration network. Figure 5 shows main processes that are executed by these main entities of this network.

4.5 Definition of Tasks and Objectives of Agents

This step refers to the establishment of the tasks that are required for the purpose of achieving specific objectives. The goals of the collaboration network include:

- Create a Researcher Database
- Create a Project Database
- Create a Information Database
- Manage a Database of Information related to specific knowledge area
- Create possible collaboration network composed by researchers with specific experience and skills
- Collaborate during a research project
- Search and get information about a specific knowledge area
- Participate at collaboration network

On this hand, it is possible to identify tasks that agents must execute in order to achieve the goals. Figure 6 presents the tasks that affect specific goals and tasks or goals that depend among them. Figure 7 shows which Agents are focused on achieving specific goals and collaborate or participate to get them. Thereby, at Figure 8 it is possible to observe a task set that help agents meet those goals.

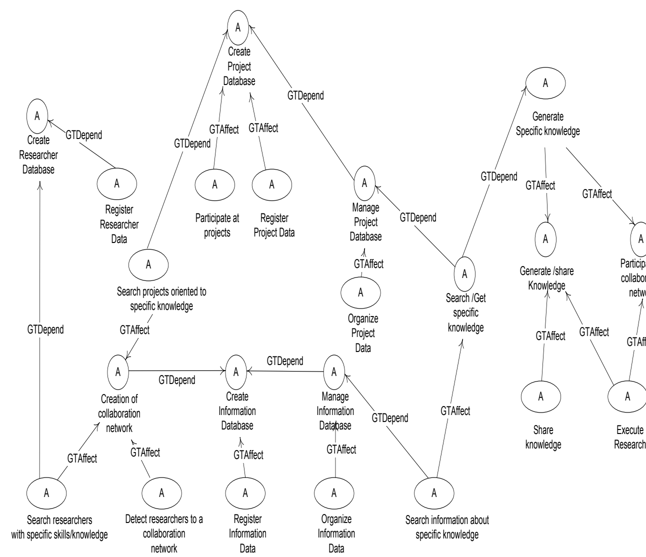

Fig. 5 System Goals and Tasks of Agents.

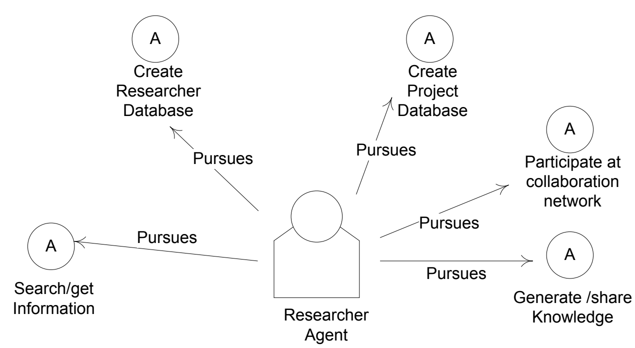

Fig. 6 SomeGoals of Researcher Agent

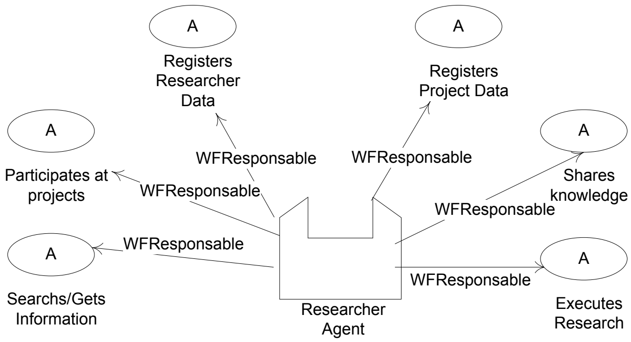

Fig. 7 Agent Task oriented to goals of a Researcher Agent

4.6 Definition of Agent interaction

This step allows defining the interactions that occur between entities under a specific scenario, the information that flows between them for the fulfillment of tasks aimed at achieving goals. Figure 8 presents the main agent interactions that agents execute in order to achieve their goals.

Finally, the overall performance of the organization, integrating the objectives, tasks, entities and interactions between them are defined.

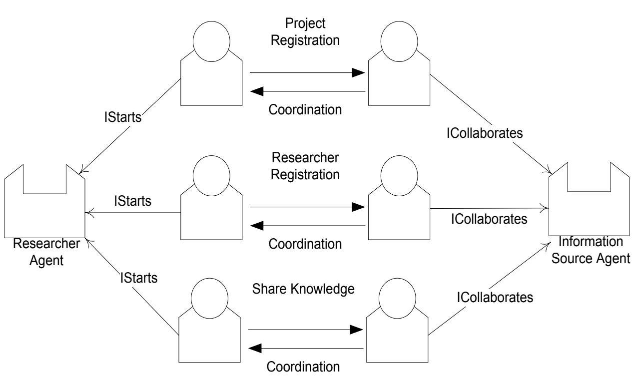

Fig. 8 Main Agent interactions of Researcher Agent

5. Conclusions and Future work

The analysis of specialized literature allows the identification of the main elements and their behavior that participate at collaborative networks at scientific environments. As a result, it was possible to design an initial metamodel for an agent-supported Collaboration System to represent complex interactions that are present during collaboration processes at scientific environments using a ANEMONA which is a Multi-agent Methodology for Holonic Manufacturing Systems, which lays the foundation for the development of a multi-agent system to a system considered as a whole in which the sum of its parts where all agents collaborate under specific scenarios.

Next steps include implementation of the designed metamodel as a multiagent system in the selected platform. The technology used for the implementation of the prototype includes:

- JAVA (6.x), a standard programming language-e
-JADE (ver3.4), as a development platform based on JAVA, which provides basic schemata for defining agents and communication protocols
-ECLIPSE (See 4.5), development as an interface for managing JADE [Ec-lipse05].
-MYSQL (Ver5.0) that provides a database server SQL (STRUCTURED QUERY LANGUAGE), multi-threaded, multi-user and robust, which is used as a manager for a database which can be accessed by drivers JAVA jdbc.

Also, in order to validate its feasibility in a real environment, working as part of the a collaboration with another researches form other areas, this project will provide a tool to other project which is oriented to the analysis and definition of a scientific collaboration network at the Autonomous University of Hidalgo State, Mexico. Furthermore, in the same phase will be designed and implemented a basic platform for implementing a collaborative network supported by sensors for obtaining environmental data that can be applied in an industrial environment.

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