An Agent-Based Knowledge Management System for University Research Activity Monitoring

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Academic research activity monitoring and evaluation are major tasks of a university knowledge management system in the context of the university activity assessments for various national and international classifications. The paper proposes the architecture of a multi-agent system developed for university research activity monitoring as a knowledge management tool. Preliminary results of a prototype system run are briefly discussed.
Keywords: *University Knowledge Management, Academic Research Activity Monitoring, Artificial Intelligence, Multi-Agent Systems*

1 Introduction

Knowledge management (KM) is a key issue in the development of a modern university, competitive at national and international level. As universities are periodically (e.g. annually, biannually, at five years) evaluated by external evaluation commissions their management teams must adopt efficient management strategies that should be adapted each year to the current realities of their specific academic activity, with the main goal of improving the whole university performances. Under the framework of universities national and international classifications, new efficient and effective knowledge management tools are needed in order to assist the university management team. Artificial intelligence can offer a variety of approaches and technologies, such as knowledge based systems, intelligent agents and multi-agent systems, machine learning and computational intelligence approaches and so on, for the development of specific KM tools. Multi-agent systems provide a proper technology for distributed systems modeling, and can be applied with success for the implementation of monitoring systems in various domains, not only on technical ones [20]. In particular, as the structure of a university management system is organized hierarchically, on different levels, starting with the rector and vice-rectors, deans and vice-deans of faculties and heads of departments, each level can be modeled as an intelligent agent or a smaller multi-agent system (especially, at the level of a faculty or department) that are parts of a larger multi-agent system covering the whole university. In the case of academic research activity monitoring, a multi-agent system could be a valuable tool for the university management team when adjusting annually their research management strategy for the current year or for a specific short or medium future period.

The paper proposes the architecture of a multi-agent system, Research-UKM, that was developed for monitoring the research activity done in a university during an academic year or a specific period of time, depending on the research evaluation purposes.

The paper is organized as follows. In section 2 it is briefly discussed the university research activity knowledge management system and some current solutions proposed in the literature. The architecture of the Research-UKM multi-agent system developed for academic research activity monitoring is proposed in section 3. Some details about the ontology, the agents and their specific tasks, as well as the description of a case study of system use are also given. Section 4 describes a prototype multi-agent system, Research-UKM-1, that was implemented in Zeus, a Java-based intelligent agents development tool. Some preliminary results of system run are presented. The last section concludes the paper.

2 University Research Activity Knowledge Management

A university has three main activities, didactical activity (e.g. teaching, students evaluation), research activity (e.g. activity done under research projects), and institutional management (i.e. university management) [1]. All these activities are evaluated periodically by internal and external commissions. Among them, the research activity has a higher importance in the university ranking in national and international classifications. The continuous improvement of this activity should be the goal of a university research knowledge management system. We have proposed in a previous work [15] a modeling framework for university knowledge management system with specific details about the didactical and research activities. In the vision of the research work presented in this paper, the university research activity knowledge management system is hierarchically structured on the following layers: the university management layer, the faculty layer, the department layer, and the academic staff layer. In case research centers and research laboratories are running under a specific department, another layer will be included for these specific research entities. Figure 1 presents the hierarchically structure of a university research activity knowledge management system.

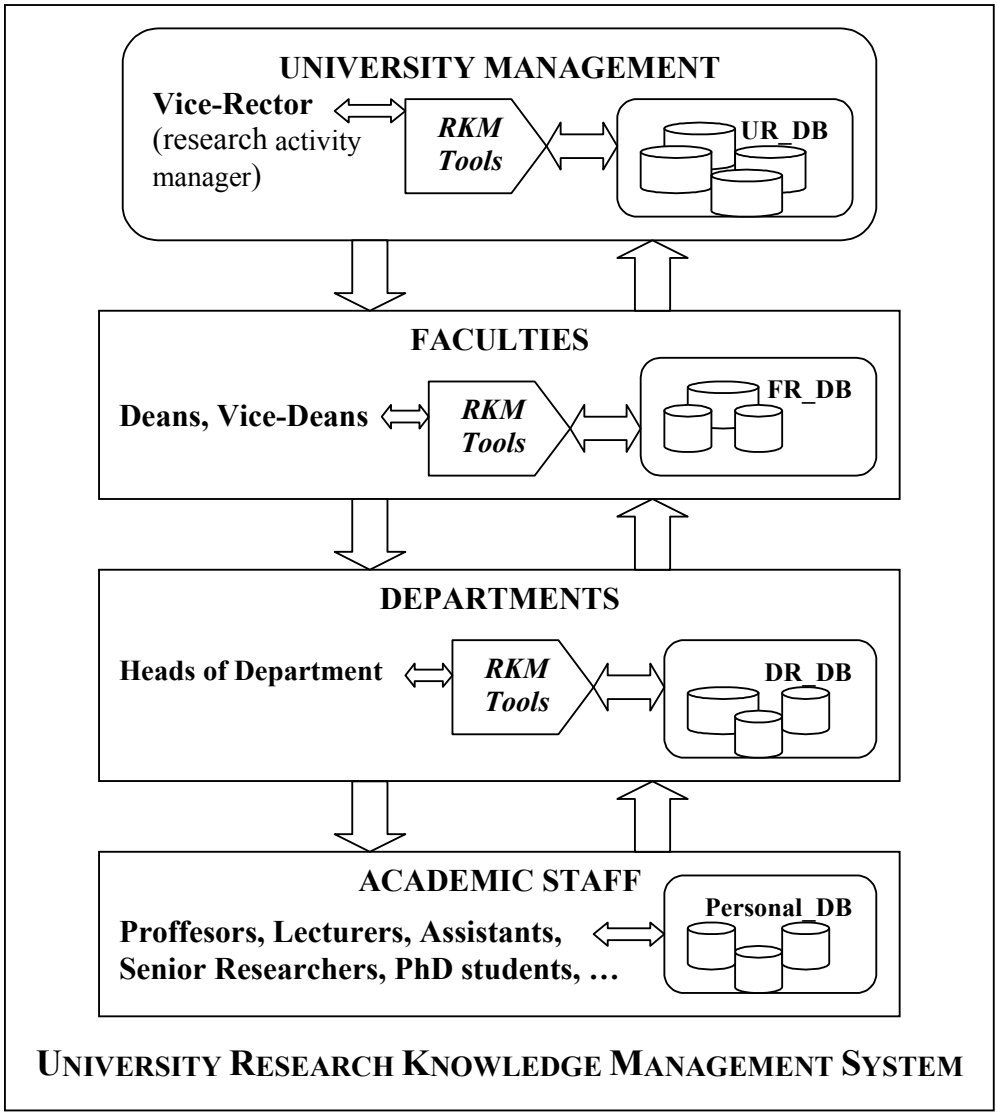

Fig. 1. The hierarchically structure of a University Research Knowledge Management System

The first layer of the system is the university management layer represented by the vice-rector responsible with the university research activity management. The second layer is the faculty layer that includes all faculties of the university, each faculty being represented by its dean and the vice-dean responsible with the faculty research activity. The third layer is the department layer that includes all departments of each faculty. A department is represented by its head of department. The last layer is the academic staff layer which provides the personal research activity information asked by the first three layers [21]. At each layer there are databases with the specific research activity information, personal research activity databases (Personal_DB) at the academic staff layer, departments research activity databases (DR_DB) at the department layer, faculties research activity databases (FR_DB) at the faculty layer, and university research activity databases (UR_DB) at the university management layer. The research activity is divided in general research domains (e.g. informatics, mathematics, computer science, physics, chemistry, social sciences, philology, electrical engineering, electronics and telecommunications, arts) and under each domain in specific research dissemination activities (elaboration of patents, innovations; publication of articles, books etc.). The university knowledge management system has at each level some knowledge management tools (KM Tools such as expert systems, case based reasoning, data mining etc.) as decision making support.

Several university knowledge management systems that include support for the research activity management were proposed so far (see e.g. [2], [5], [7], [9], [10], [11], [15], [18]). Some of the systems that were reported in the literature are using artificial intelligence-based KM tools for academic research knowledge management. The most used artificial intelligence techniques and approaches are knowledge based systems and experts system ([4], [10], [13], [15]), case based reasoning ([19]), computational intelligence and machine learning techniques ([3], [14]), knowledge modeling and ontologies ([6], [12]). The intelligent agents and multiagent systems technology was proposed for the knowledge management system of an organization, usually a company (see e.g. [8], [22]). Also, the importance of the collective intelligence in knowledge management systems was emphasized in [3].

The academic research activity evaluation is done by external institutions such as the Educational and Research Ministry or other institutions that make periodical evaluations or that fund the university. Such evaluations provides the basis of universities classifications according to specific indicators [17]. The most used research evaluation indicators are those applied by the Thomson Reuters classifications (high impact papers, InCites, Institutional Citation Report, Journal Analysis Database, Journal Performance Reports, National Citation Report, Journal Performance Indicators and others [24]). The majority of the countries have their national institutions that evaluate periodically the academic activity of their universities. For example, in Australia there is a Centre for Policy Innovation (CPI) [26], that makes systematic evaluation and mapping of research across all fields of scholarship. In Japan there is the National Institution for Academic Degree and University Evaluation, NIAD-UE [27], that realizes a performance-based evaluation of national university corporations and inter-university research institute corporations, using specific plans and objectives for education, research and management. The academic activity evaluation is made in Romania by the Ministry of Education, Research, Youth and Sports, and by UEFISCDI [25]. These external evaluations performs a bibliometric analysis of the scientific research production (e.g. research publications) made under the framework of publicly funded institutions (e.g. in Romania, ANCS and CNCS). The academic research activity evaluation is done according to specific research evaluation indicators and to the updated bibliometric databases that contain information about all the scientific research production disseminated in a certain period of time. The

databases contain information about each publication (article, book etc): the title of the publication, the authors names, the ISI publication code (DOI), the name of the journal, the publication year, the tape year (the year when the publication entered into the ISI Web of Knowledge database), the number of authors, the number of pages, the publication type (article, review), the ISI index in which the publication is found, the citations of the publication, the impact factor, the relative impact factor, the influenced relative score etc. The major domains that are analyzed are: science, social sciences, humanist sciences. For each domain there are specific research evaluation indicators.

The evaluation of the research activity done in a university involves the analysis of the research dissemination activity (published books, scientific papers published in ISI Web of Knowledge journals or ISI proceedings), the research activity done under the framework of national and international research projects (e.g. FP7, Eureka, COST) or research collaborations (Networks of Excellence in Research, for example), awards, inventions, patents, the involvement of the academic staff in the organization of international conferences (indexed in the Web of Knowledge), the involvement of the academic staff in the editorial board of ISI Web of Knowledge journals, the international mobility of the academic staff, and other activities. Among these activities the most important percentages in the research evaluation criteria are provided by: the university research activity dissemination in ISI journals (with impact factor and influenced relative score), and the elaboration of patents and innovations. As a consequence it is desirable to have a careful monitoring of these activities in order to increase the university total research score. In the next section it is presented the architecture of a multi-agent system, Research_UKM, developed for the academic research activity monitoring.

3 The Architecture of the Research-UKM Multi-Agent System

We are proposing the architecture of a multi-agent system for academic research activity monitoring. The Research-UKM system can be used as a monitoring support tool in the university research KM system, introduced in section 2 (and presented in Figure 1). The main purpose of the multi-agent system is to provide real information about the current state of the university research activity for the dynamic adaptation of the research knowledge management strategy in order to improve the university ranking position. Figure 2 shows an example of a university research KM multi-agent system with eight agents associated with the research vice-rector, the vice-dean of one faculty, the head of one department in the faculty, and five academic staff (AS) in the department.

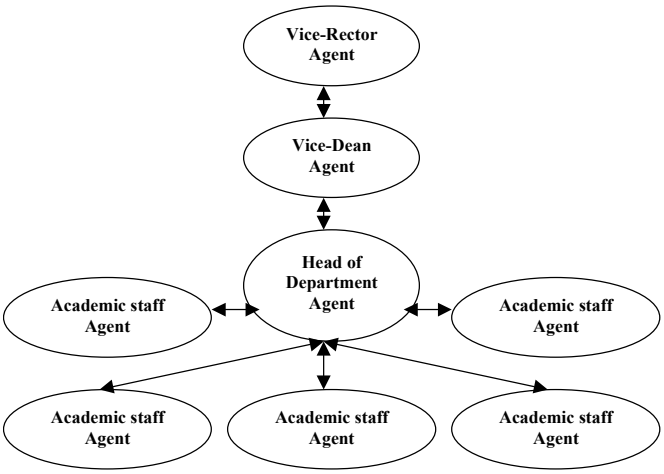

Fig. 2. Example of university research KM multi-agent system architecture

The general architecture of the Research-UKM multi-agent system is detailed in Figure 3. We have considered that the university has n faculties, each faculty has a number of m_i departments (i=1, …, n), and each department has a number of t_j academic staff (j=1, …, m_i).

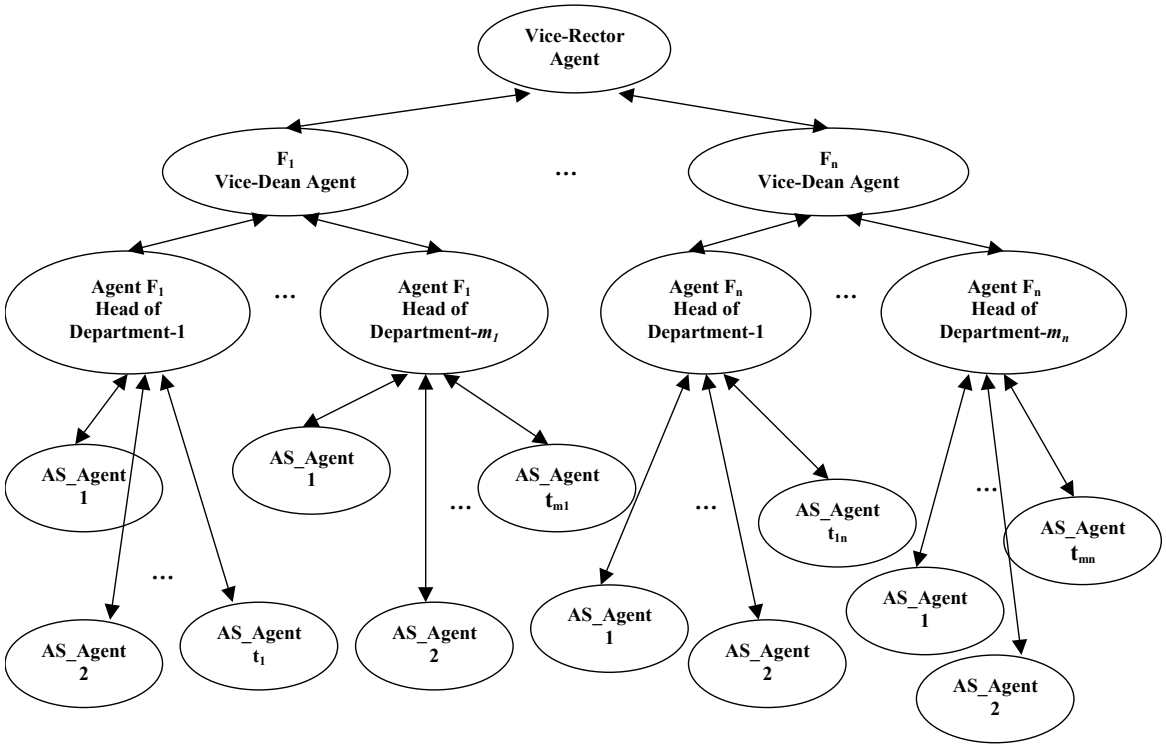

Fig. 3. The architecture of the Research-UKM multi-agent system

The agents that are included in the Research_UKM multi-agent system are communicating via the hierarchical communication channel the research activity dissemination results that are centralized stage by stage at the department level, at the faculty level (F_i), and finally, at the university level. The main advantages of using an agent-based approach are given by the proactivity characteristic of each agent as well as by the autonomy ability and social characteristic. The agents are using a common ontology in order to be capable to communicate between them. We have developed a specific ontology, Onto_ResearchKM, with terms that are used for the university research activity evaluation. A part of the ontology hierarchy is presented in Figure 4, while in Figure 5 it is given a screenshot from the ontology hierarchy implemented in Protégé [16], a Java-based ontology editor.

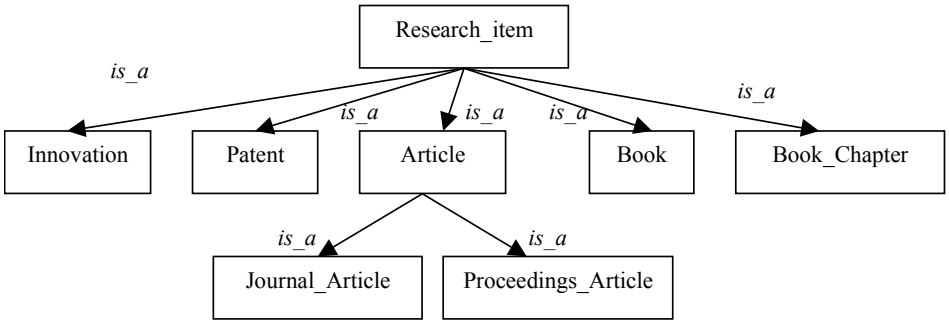

Fig. 4. The Onto_ResearchKM ontology hierarchy (selection)

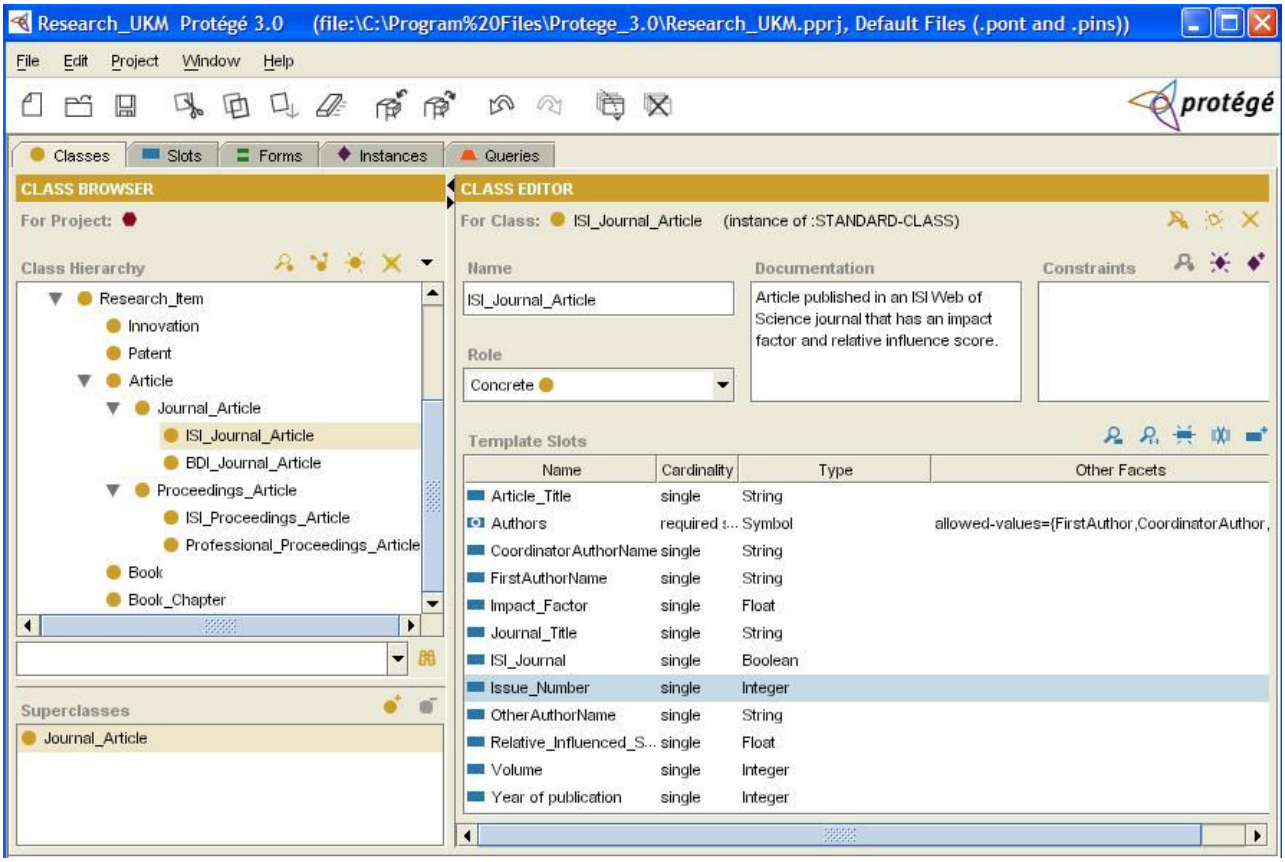

Fig. 5. A screenshot from the Onto_ResearchKM ontology in Protégé 3.0

The Research-UKM multi-agent system include four types of agents: Vice-rector Agent, Vice-dean Agent, Head of department Agent, and Academic staff Agent. The goal of the first three types of agents is to monitor the research activity of the agents that are under their direct supervision. Each agent has a number of tasks to perform. Table 1 summarizes the tasks associated with the agents of the Research-UKM multi-agent system.

Table 1. The tasks associated with the agents of the Research-UKM multi-agent system

Agent	**Tasks**
Vice-rector Agent	*University Research Activity Monitoring* *University Research Analysis Report*
Vice-dean Agent	*Faculty Research Activity Monitoring* *Faculty Research Analysis Report*
Head of department Agent	*Department Research Activity Monitoring* *Department Research Analysis Report*
Academic staff Agent	*Research Activity Analysis Report*

The Vice-rector Agent performs two tasks: *University Research Activity Monitoring* and *University Research Analysis Report*. The Vice-dean Agent performs two tasks: *Faculty Research Activity Monitoring* and *Faculty Research Analysis Report*. The Head of department Agent performs two tasks: *Department Research Activity Monitoring*, *Department Research Analysis Report*. Finally, the Academic staff Agent is doing *Research Activity Analysis Report*. The Vice-rector will ask periodically, during the current academic

year, various Research Activity Reports in order to identify the weak points of the current research activity in certain domains of research and to improve the research activity dissemination by some management measures (e.g. increase of the academic staff salary, prizes, paper registration fees payment, conference travel payment, improving the university research facilities, identification or improvement of the international academic collaborations etc.). As we are using intelligent agents, the research activity reports will be asked autonomously, as programmed by the university Vice-Rector with certain deadlines that will be automatically launched by the internal clock of the system. The basic research activity information are provided by the Academic staff agents under numerical form for each research item (e.g. number of articles published in ISI journals with impact factor and relative influenced score), and as a descriptive text with all known details about the corresponding research item (with pre-defined description slots), at the scheduled monitoring time. Figure 6 shows an example of information that are included in the academic staff research activity report as asked by the university Vice-rector.

I. Articles published in ISI Thomson - Reuters (Web of Science) international journals

Authors	Paper Title	Journal Name	Vol. No	Pag.	Publisher	Impact Factor	Relative Influence Score

II. Articles published in international journals (indexed in international data bases)

Authors	Paper Title	Journal Name	Vol. No	Pag.	Publisher	International Data Bases (Scopus, IEEExplore, ACM, …)

III. Innovations and Patents

Authors	Innovation / Patent	Title	National / International

Fig. 6. Example of information that is included in a research activity report

Figure 7 shows the agents interaction diagram for a scenario of the Research_UKM multi-agent system run when the Vice-rector Agent is asking a Research Activity Report regarding the current state of the articles publication in ISI journals with impact factor and relative influenced score. We have considered a simple version of the Research_UKM system with the structure provided in Figure 2.

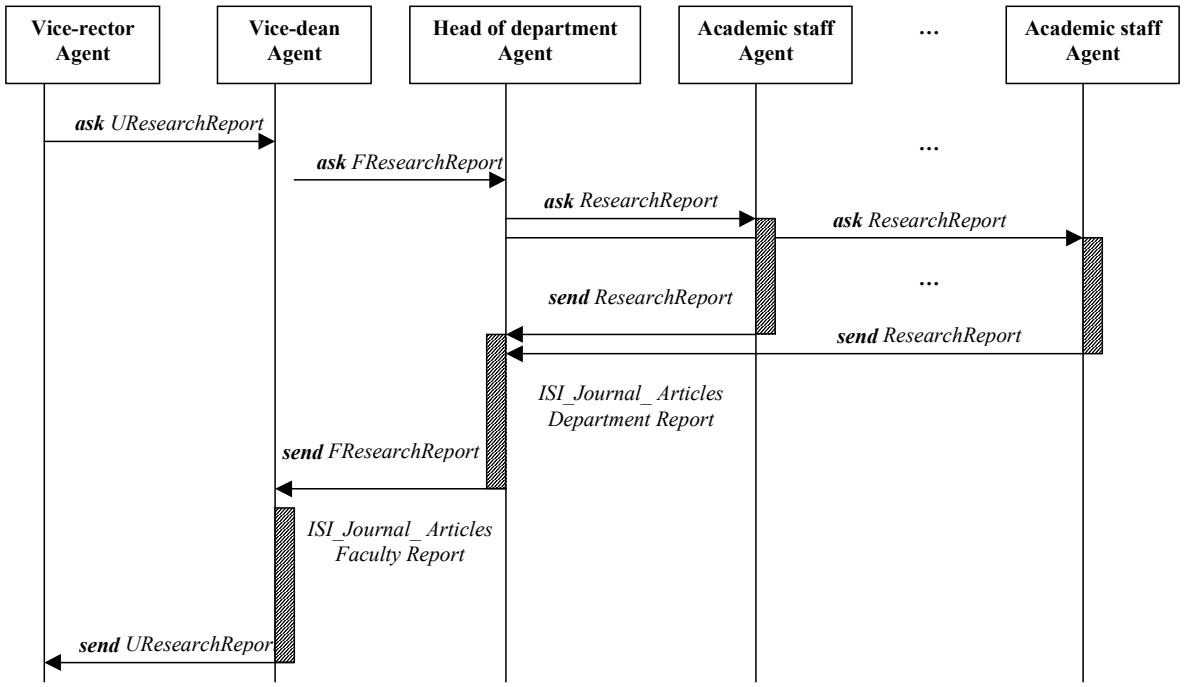

Fig. 7. Agents interaction diagram for a scenario of the Research_UKM system run

4 Implementation of the Prototype System

We have developed a prototype multi-agent system, Research_UKM-1, by implementing in Zeus toolkit [23] the simple version of the multi-agent system proposed in Figure 2. Figure 8 shows a screenshot from the Zeus Agent Generator with the Research_UKM-1 project.

Fig. 8. Screenshot of the Zeus Agent Generator with the Research_UKM-1 project

The Research_UKM-1 prototype multi-agent system uses the Onto_ResearchKM ontology that was briefly described in section 3, and initially, implemented in Protégé in order to check the ontology consistency. Figure 9 shows a screenshot with selected terms from the ontology of the Research_UKM-1 system. In Zeus the ontology (the Research_UKM-1.ont file) is stored under the form of a facts hierarchy, where each term has associated a fact that can be of type abstract or entity, and is characterized by a set of attributes, in a similar way with the slots of a class in Protégé.

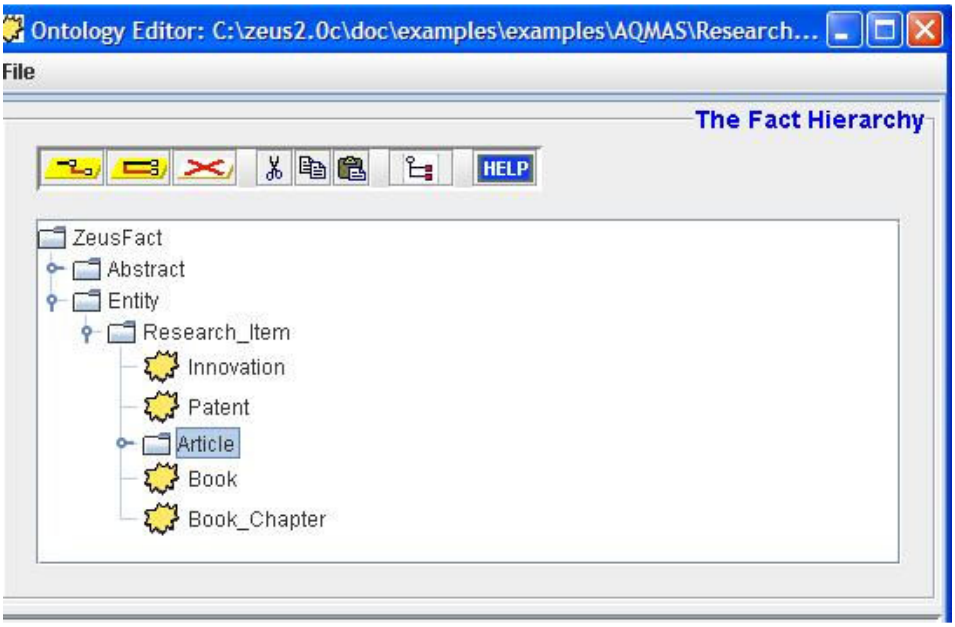

Fig. 9. Screenshot with selected terms from the ontology of the Research_UKM-1 system

All the agents of the multiagent system have associated primitive tasks, with preconditions and postconditions specific to each task. For example, the *Faculty Research Analysis Report* task has as precondition the **DepartmentResearchAnalysisReport** fact received from the Head of department Agent of each department that is member of the faculty. In our case study, we have considered one faculty. Figure 10 shows the block schema of the *Faculty Research Analysis Report* primitive task.

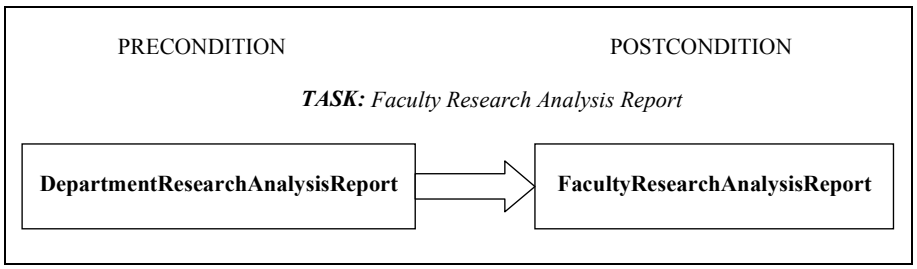

Fig. 10. Example of primitive task – *Faculty Research Analysis Report*

The organizational relations between the agents of the Research_UKM-1 multiagent system are of type superior, subordinate and co-worker. For example the relation between the Vice-rector Agent and the Vice-dean Agent is superior, and between the Academic staff Agent and the Head of department Agent is subordinate, while the relation between two Academic staff Agents is co-worker. Table 2 summarizes the relationships between the agents that compose the Re-

search_UKM-1 multiagent system, considered in the order column → row.

Table 2. The organizational relations between the agents of the Research-UKM-1 multi-agent system

Organizational Relation	*Vice-rector Agent*	*Vice-dean Agent*	*Head of department Agent*	*Academic staff Agent*
Vice-rector Agent	co-worker	subordinate	subordinate	subordinate
Vice-dean Agent	superior	co-worker	subordinate	subordinate
Head of department Agent	superior	superior	co-worker	subordinate
Academic staff Agent	superior	superior	superior	co-worker

In Figure 11 it is presented a screenshot with the coordination mechanism of the Head of department Agent. Two coordination protocols can be used by this agent, the Fipa-Contract-Net-Manager and the Fipa-Contract-Net-Contractor. The agent has the initiator role under the Fipa-Contract-Net-Manager coordination protocol that can be used in relation with the Academic staff Agent, while under the Fipa-Contract-Net-Contractor can have the respondent role in relation with the Vice-dean Agent.

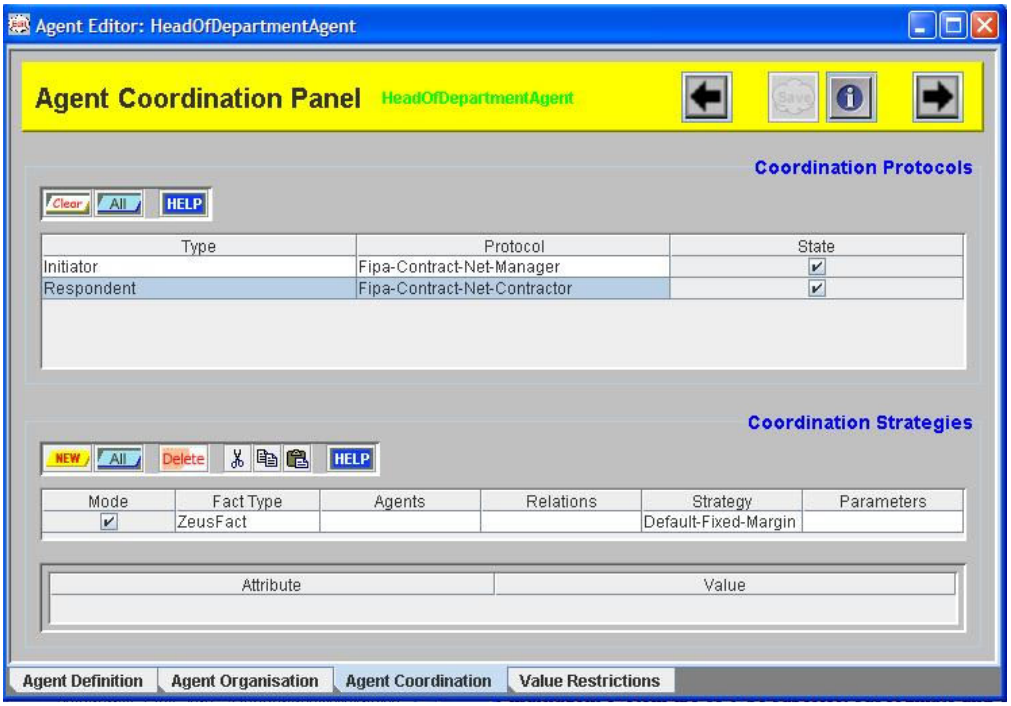

Fig. 11. Screenshot of the coordination mechanism of the Head of department Agent

An example of the prototype system run for the scenario described in the previous section (and illustrated in Figure 7) is presented in Figure 12. The Research_UKM-1 system provides the total number of ISI journal articles that were published in the period October 2011-March 2012 in the domain of Computer Science. The information is collected from the Academic Staff agents of the Computer Science Department and are sent to the upper levels of the multi-agent system, i.e. to the Vice-dean agent associated with the Automatic and Computer Science Faculty, and finally, to the agent associated with the university research management Vice-rector.

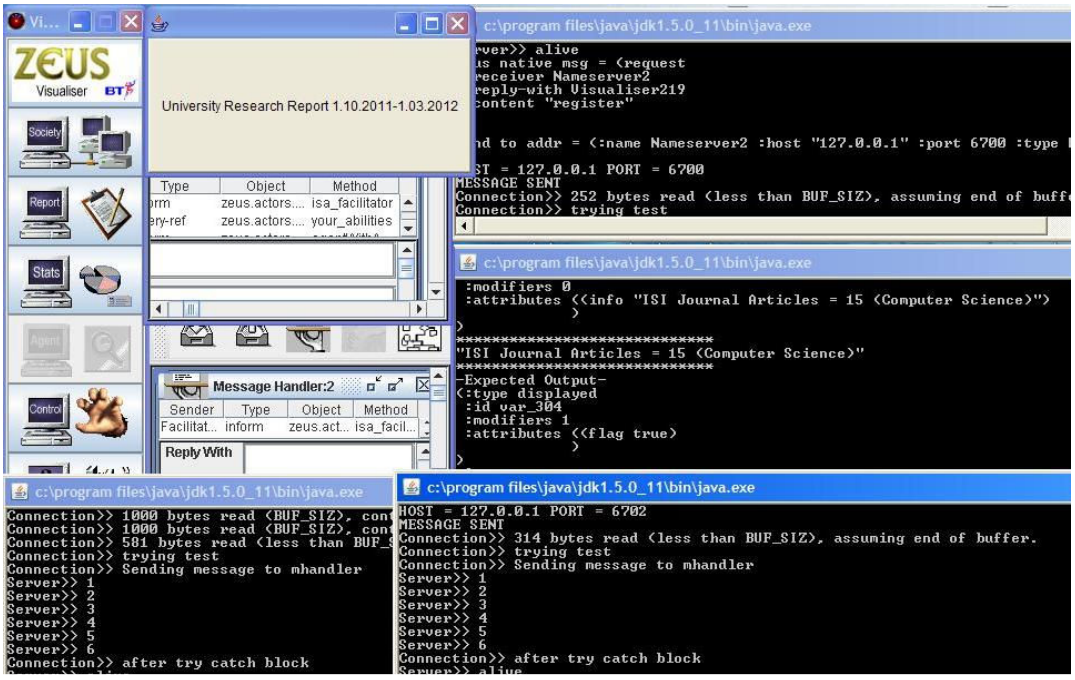

Fig. 12. Screenshot of the Research_UKM-1 prototype multi-agent system run in Zeus

5 Conclusion

The continuous improvement of an university management system can be supported by intelligent systems as decision making assistants and/or advisors for the selection of efficient and more effective university management strategies that have as main purpose the university ranking position increasing in national and international universities classifications, as well as the university adaptation to the current economic realities on the jobs markets. In the context of university activity periodically evaluation, the academic research activity assessment has a higher importance, especially the research dissemination activity.

The paper proposed the architecture of a multi-agent system, Research-UKM for university research activity monitoring. The system can be integrated in the university knowledge management system, and can be used as a decision support tool for the adoption of new strategies for the research activity improvement, as the system provides the weak and strong points of the research activity done in a certain period of time.

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