# A University Knowledge Management Tool for Academic Research Activity Evaluation

Mihaela OPREA
University Petroleum-Gas of Ploiesti, Department of Informatics, Romania
mihaela@upg-ploiesti.ro

*The implementation of an efficient university knowledge management system involves the development of several software tools that assist the decision making process for the three main activities of a university: teaching, research, and management. Artificial intelligence provides a variety of techniques that can be used by such tools: machine learning, data mining, text mining, knowledge based systems, expert systems, case-based reasoning, decision support systems, intelligent agents etc. In this paper it is proposed a generic structure of a university knowledge management system, and it is presented an expert system, ACDI_UPG, developed for academic research activity evaluation, that can be used as a decision support tool by the university knowledge management system for planning future research activities according to the main objectives of the university and of the national / international academic research funding organizations.*

***Keywords:*** *University Knowledge Management, Research Activity Evaluation, Artificial Intelligence, Expert Systems, Decision Support System*

## 1 Introduction

In the last decade, many universities have started the development of their own knowledge management system in order to increase their performances (e.g. better decision making, reduced costs, improved academic services etc). University knowledge management (KM) comprises a set of strategies, methods, practices and tools for the identification, creation, sharing and applying knowledge to better achieve the objectives of the university. An efficient university KM system requires the use of intelligent software tools, based on artificial intelligence techniques [8]. Such tools can improve the performances of the university KM system by taking into account, for example, the current trends of the jobs market, and/or of the economy at a local or global level, the experiences accumulated by the university itself or the good practices of the best universities. The university KM system can provide a decision support system for all the activities of the university, teaching, research and university management.

The paper presents an expert system, ACDI_UPG, that was developed for the evaluation of the academic research activity, at different levels, individual level (in the sense of individual knowledge researcher performance [19]), by a (researcher or professor (to evaluate her/his own performances), department level (to evaluate the whole department research activity), faculty level (to evaluate the research activity for different programs of studies) or university level (to evaluate the whole university research activity for university classification). The ACDI_UPG system can be used as a decision support tool by the university knowledge management system for planning future research activities. It integrates knowledge modeling by using a specific ontology, a knowledge base that uses the knowledge representation under the form of production rules with some of the rules generated by inductive learning, and an inference engine that allow automated reasoning when a specific evaluation is required.

The paper is organized as follows. In section 2 it is described a generic university knowledge management system with the main components related to three activities of a university, teaching, research and management, and some research work reported in the literature are briefly described. The academic research activity evaluation is discussed in section 3, pointing out the potential use of some artificial intelligence techniques. Section 4 presents the ACDI_UPG expert system that was developed as a university KM tool for academic research activity evaluation. The architecture of the system, as well as details about the ontology, the knowledge base, and some case studies of system run are also given. The last section concludes the paper.

## 2 University knowledge management

Knowledge sharing is the most important characteristic of a university as one of its main missions is knowledge transfer from teachers to students and from researchers to the academic community. We have to strengthen that the university research activity creates itself new knowledge that is shared with the whole academic community (researchers, professors, students). Thus, the implementation of a university knowledge management system can be done in a natural way.

*The structure of a generic university KM system*

A university KM system incorporates three modules for the main activities performed by a university: teaching, research and university management (i.e. institutional management) [1]. In Figure 1 it is shown the structure of a generic university KM system. In this structure, we can identify the three modules: the Teaching KM module (TKM), the Research KM module (RKM), the University Management module (UKM), and some support modules: the IT infrastructure (e.g. intranet), and a university portal which offers the interface with potential users: students (undergraduate, MSc, PhD, PostDoc, postgraduate), academic personnel, potential students, and other persons interested by the activities of the university.

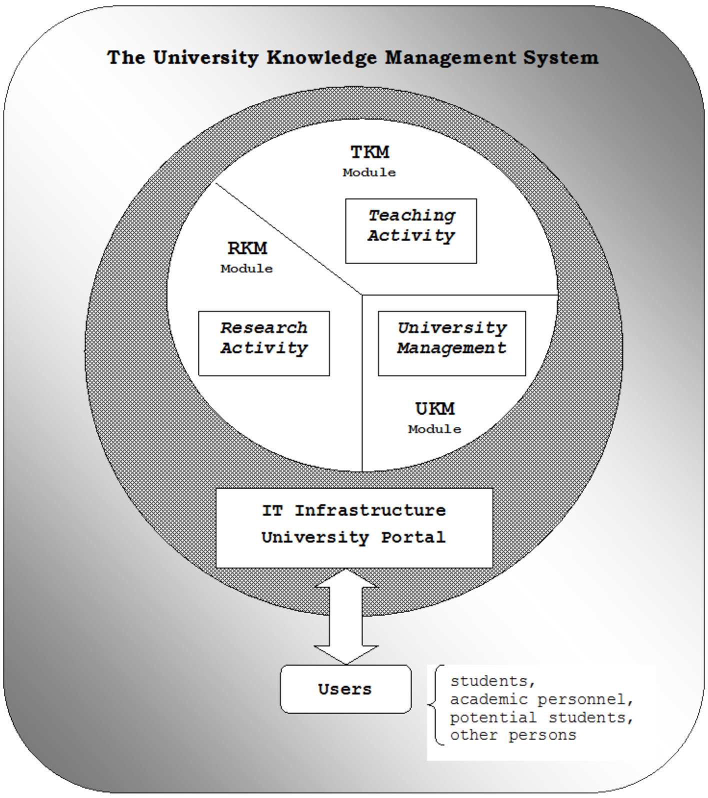


**Fig. 1.** The structure of a generic University Knowledge Management system

The TKM module manages the whole knowledge regarding the teaching activity done under different programs of study, bachelor, master, doctoral, postgraduate, post-doctoral, for different domains of study. Figure 2 shows an overview of a generic TKM module structure. The structure takes into account the two organizational levels of a university, department and faculty, and the didactical activity management done by a vice-rector.

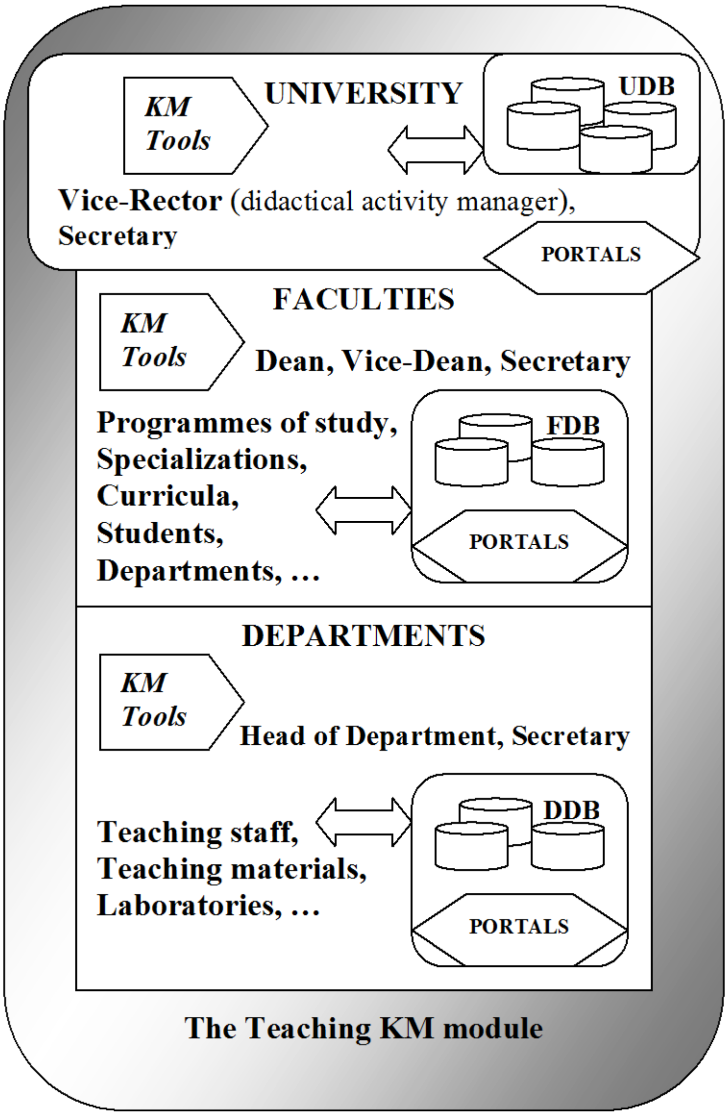


**Fig. 2.** An overview of a generic TKM module structure

Each faculty of a university has one or more departments, and has a number of program studies they manage, for all levels of study. A faculty manages the databases FDB (Faculty DataBases) with data about the enrolled students, programs of study, alumni etc. Each department has to manage the activity of its teaching staff, and all its physical and virtual resources (laboratories, equipments, pedagogical resources such as teaching materials: books, tutorials, software, documents, presentations, demos). A department manages local databases DDB (Department of Databases), with data about its teaching staff, about the programs of study it manages etc. As a department, it can manage one or more programs of study that involves apart from the teaching activity, a research activity (e.g. master, doctoral, postdoctoral programs), some of the databases will be shared with the RKM module. Each organizational level uses KM tools. All data are centralized at the university level and are directly managed by a vice-rector through a decision support system. An example of activity that can be done by the TKM module is the management of the curriculum development process. This complex activity involves the development of portals and repositories for information related to the teaching and learning technology,

to pedagogy and assessment techniques, students' evaluations, updated materials, and others.
The RKM module manages the whole activity related to the research activity done in the university in different departments. Figure 3 shows an overview of a generic RKM module. The structure takes into account the two organizational levels of a university, department and faculty, and the research activity management done by a vice-rector.

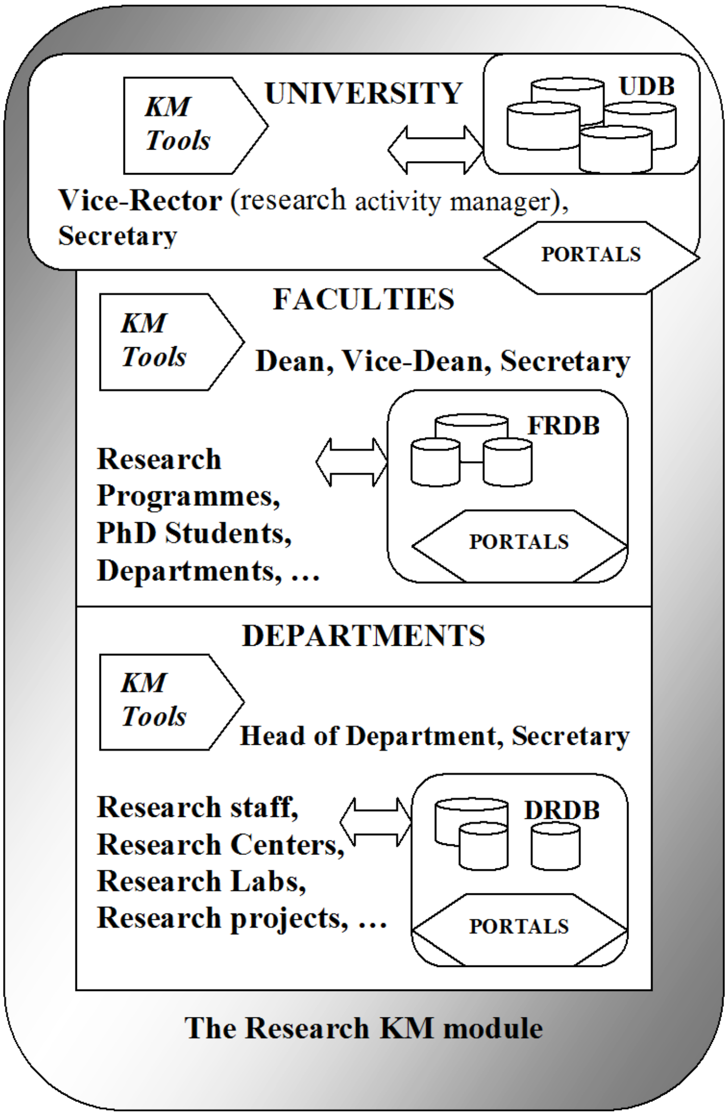


**Fig. 3.** An overview of a generic RKM module structure

Each faculty centralizes the research activity of its departments in the faculty research activity databases, FRDB, and sends reports to the upper level, i.e. the university, which centralizes all the reports in its databases, UDB. From these databases, the university sends reports to the ministry or other research funding/evaluating organizations that can ask them periodically. The research activity takes place at the level of a department, in a research center, or a research laboratory. The research activity is usually performed under the framework of international, national or regional research projects. A department manages the whole research activity done under its supervision, and stores all data in its databases (Department Research Databases, DRDB). Examples of activities that can be done by the RKM module are: finding funding opportunities (e.g. national and international research funding competitions, industrial partners), reports on the research activity, searching commercial opportunities for the implementation of the research results etc. The RKM module makes use of some KM tools, and maintains different portals as communication support tools.

The UKM module manages the whole administrative activity done in a university, such as strategic planning, and the activity of the administrative services (human resources, accounting, investment etc). This module makes use of specific KM tools and maintains different portals as communication support tools (as for example, a public auctions portal).

Starting from the generic structure of the university KM system, that is proposed in this paper, with the two overviews of the TKM module, and of the RKM module, we have started to implement some artificial intelligence based tools that can assist different KM activities for teaching and research. We shall continue the discussion in the next sections, focusing on the research activity evaluation. Next, there are briefly presented some university KM systems, that were reported in the literature, and it is shortly discussed the current and/or potential use of some artificial intelligence in KM systems, in general, and in university KM systems, in particular.

*University KM systems reported in the literature*

The use of KM in universities was recently introduced and the first studies and experiments of applying KM in universities were reported in the literature in the period 1997-2000, while in the last decade many universities had started the implementation of a university KM system, the majority of them being based on advanced Web technologies.

In [10] it is presented the project of management decision support through knowledge management developed at the University of Hradec Králové (Czech Republic), Faculty of Management and Information Technology. Some results of implementing the faculty teaching activities scheduling are also discussed. General and specific issues of implementing a knowledge management system in a university are detailed in [7]. Also, it is highlighted the idea that universities must deliver integrated services by using web-based portals. In [11] it is described a web-based architecture, GCC, that enables knowledge management in scientific environments, and increases collaborations between researchers. GCC was developed to be used by research centers and universities. There are some other applications of KM to research activities, such as those presented in [5], for research commercialization, and [17], for university software research and development groups. In [9] it is analyzed the use of three statistical software instruments (SAS, SPSS, Weka) for higher education quality analysis. An expert system for university research quality assessment is described in [13].

*Artificial intelligence used in KM systems*

Several artificial intelligence techniques can be applied to university knowledge management: machine learning (e.g. inductive learning, artificial neural networks), data mining, text mining, knowledge based systems, expert systems, case-based reasoning, intelligent agents and others. At present, there are some AI-based KM tools developed to be applied in universities. Some recent examples are given in [1], [9] (data mining tools for the teaching activity analysis), [13] (an expert system for the research activity analysis according to the IC6 indicator [21]), and [14] (a rule-based system for research activity analysis at the department level of a university). In [2] there are presented specific ways in which indicators and artificial intelligence methods and tools can be used for the evaluation of research projects and programs. A special emphasize is given to the use of data mining techniques. The potential benefits of using case based reasoning in knowledge management systems are discussed in [18]. The technique can be used also in university KM systems were past experiences of the university itself, or of other universities can be used to solve new problems. The role of collective intelligence in modern organizations is discussed in [3], and could be easily applied to modern universities, that have KM systems. Some knowledge discovery techniques as well as knowledge modeling methods are discussed in [4], were creative knowledge extraction in the case of knowledge based systems is detailed, focusing on machine learning methods.

## 3 Academic research activity evaluation

The continuous improvement of the academic activity is the main objective of any university. In this sense, the teaching and research activities are evaluated periodically (e.g. yearly, the last five years) by the university itself through an internal evaluation procedure, and by external institutions (e.g. ministry, institutions that make evaluations or that fund the university). Such evaluations provide classifications of the universities according to specific indicators [16]. The most used indicators are those used by the Thomson Reuters classifications. In the particular case of research evaluation, Thomson Reuters uses several tools such as high impact papers, InCites, Institutional Citation Report, Journal Analysis Database, Journal Performance Reports, National Citation Report, Journal Performance Indicators and others [20]. Most of the countries have their own institutions that evaluate the academic activity of their universities. For example, in Japan there is the National Institution for Academic Degree and University Evaluation, NIAD-UE [23], which makes a performance-based evaluation of national university corporations and inter-university research institute corporations, using their annual plans, mid-term plans, and mid-term objectives for education, research and management. In Australia there is a Centre for Policy Innovation (CPI) [22], that makes systematic evaluation and mapping of research across all fields of scholarship. In Romania, the academic activity evaluation is made by the Ministry of Education, Research, Youth and Sports, and by UEFISCDI [21]. These evaluations makes bibliometric analysis of the scientific production (e.g. research publications) produced under the patronage of publicly funded institutions (e.g. ANCS and CNCS, in Romania). The academic research activity evaluation is done according to specific indicators and to the updated bibliometric databases that contains information about all the scientific production in a certain period of time. Such databases contain information about each publication, for example, the ISI publication code, name of the journal, publication year, tape year (the year when the publication entered into the ISI Web of Knowledge database, number of authors, number of pages, publication type (article, review), ISI index in which the publication is found, citations of the publication, the impact factor, the relative impact factor, and others. There are three types of major domains that are analyzed: science, social sciences, humanist sciences. For each domain there are specific indicators of the research activity analysis.

The evaluation of the research activity performed in a university involves the analysis of several key activities for each domain of research: 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) 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.

The academic research activity evaluation can be assisted by specialized software tools. The use of artificial intelligence (AI) techniques could improve the efficiency of such tools, knowing that the databases with the research production are usually, huge. Some AI techniques that can be used are machine learning and data mining for applications of knowledge/rules extraction from large bibliometric databases, knowledge based systems and expert systems to make different qualitative analyses and evaluations, case based reasoning to solve/make similar prob-

lems/analyses, and intelligent agents to search information in the bibliometric databases.
In the next section it is presented an expert system, named ACDI_UPG, that was developed for the academic research activity evaluation.

## 4 The ACDI_UPG expert system

We have developed a prototype expert system [6] for the university research activity evaluation, named ACDI_UPG that was implemented in VP-Expert, an expert system generator [24]. The system can be used as an analysis support tool in the RKM module of the generic university KM system, proposed in section 2. Also, it can be used as a decision support tool for the adoption of new strategies for the research activity improvement.
In this section it is presented the architecture of the ACDI_UPG system, the ontology that was used, the knowledge base that was developed, and two case studies of the system run.

*The architecture of the ACDI_UPG system*
Figure 4 shows the modules of the ACDI_UPG system architecture.

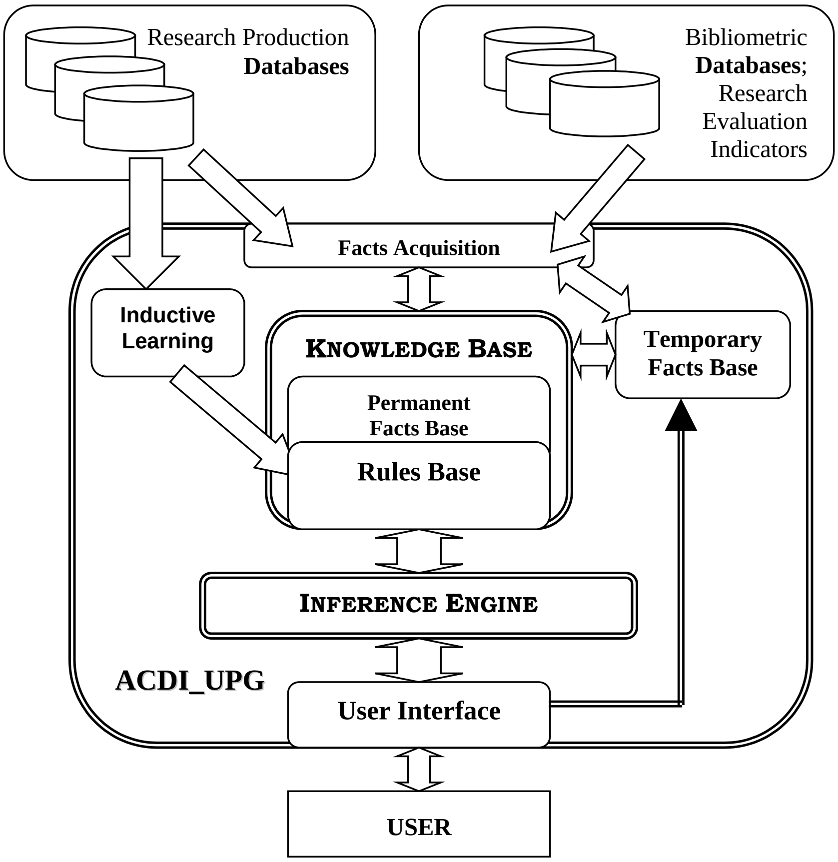


**Fig. 4.** The architecture of the ACDI_UPG system

The main modules of the system are the knowledge base and the inference engine. The knowledge base contains the knowledge used by the system under the form of productions rules (rules base), and the permanent facts that are used during the evaluation. The inference engine is doing the evaluation reasoning by using the knowledge from the knowledge base and the temporary facts that define the current context of the system consultation. The temporary facts base is initialized by the user, through a user interface, with the initial facts regarding the research domain for which it is done the evaluation, the period of time for which the research activity is evaluated, and other initial facts that will guide the process of facts acquisition from the databases with the research production (e.g. of the department), the bibliometric databases, and other databases with research evaluation indicators. Some of the rules from the knowledge base were extracted by inductive learning.

The Research Production Databases contain data about all aspects and outcomes of the academic research activity done in a specific period of time (e.g. publications, research projects, international research activity, patents, innovations, software products etc).

*The ontology of the ACDI_UPG system*

We have developed an ontology of the ACDI_UPG system by defining all terms (i.e. concepts, properties, and relationships) from the domain of application (the evaluation of the academic research activity). The ontology extends the research ontology of the UPG_UniMan ontology described in [12]. In Figure 5 it is shown a part from the ontology hierarchy of the ACDI_UPG expert system.

Examples of terms defined in this ontology are: research projects, books (published in national and international publishing houses), papers, patents, innovations.

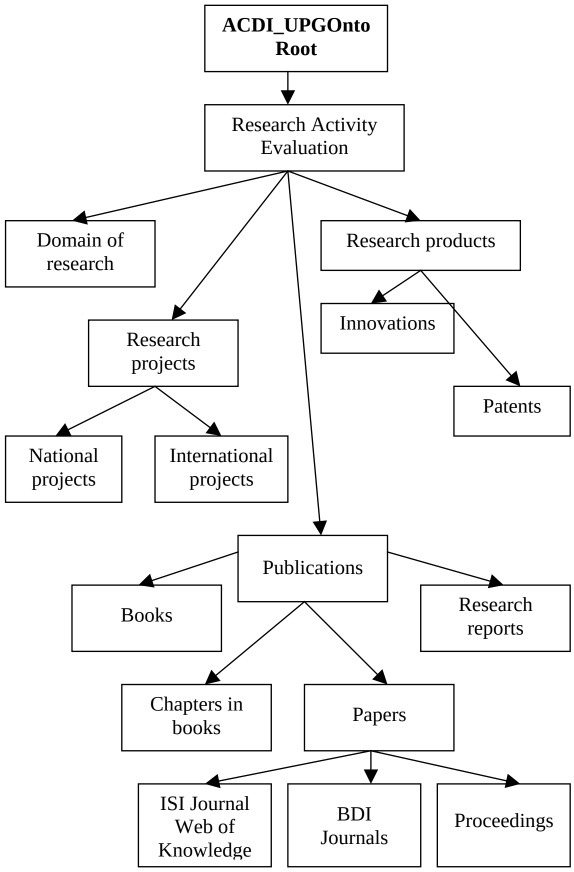


**Fig. 5.** The ontology hierarchy for the ACDI_UPG expert system (selection)

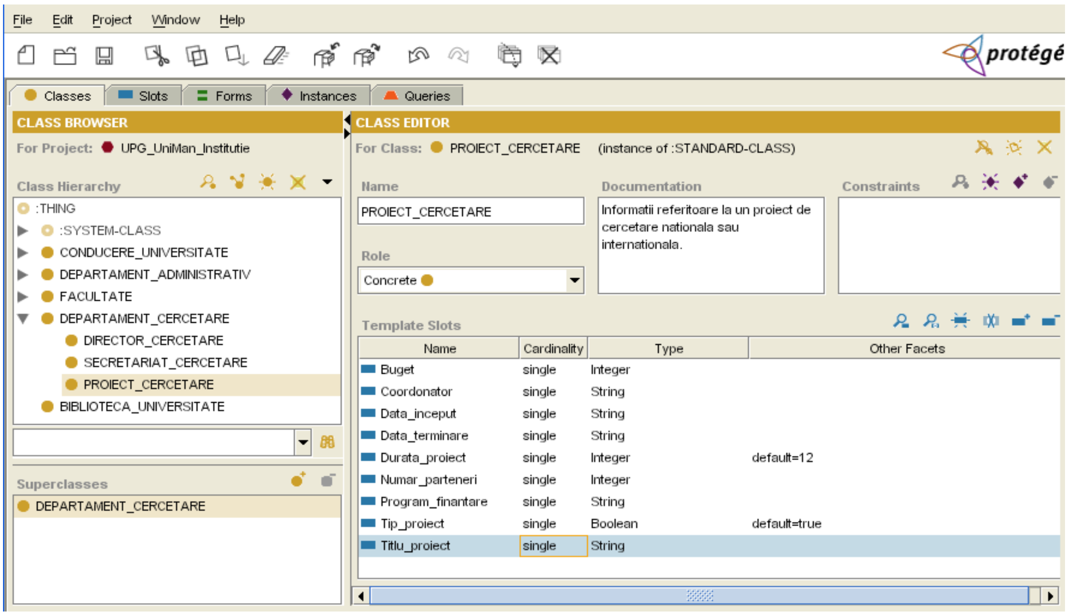


**Fig. 6.** A screenshot from the UPG_UniMan ontology (with Romanian Terms) in Protégé 3.0

Figure 6 presents a screenshot from this ontology with Romanian terms, implemented in Protégé [15], a Java based ontology editor.

All the terms were mapped on classes (abstract or concrete) with their correspondent description under the form of slots (defined by name, cardinality, type, other facets)

*The knowledge base of the ACDI_UPG system*

The knowledge base of the system has a permanent facts base and a rules base. The permanent facts base contains all facts about the university related to its organization, research activity and research evaluation (e.g. the internal evaluation criteria, the departments, the domains of research that are recognized, the PhD supervisors, the research centers). The rules base contains sets of rules grouped by their evaluation goal, according to the parameters that are analyzed. In order to reduce the complexity of the analysis we have considered the most important parameters that reflect the quality of the research activity: number of research projects (national and international), number of articles published in ISI Web of Science journals (with impact factor < 1; >=1 and <2; >=2; with relative score), in BDI journals, books published in national and international publishing houses, chapters of books published in national and international publishing houses, international research collaboration projects, articles published in ISI proceedings, in the proceedings of international and national conferences organized by professional societies (not ISI proceedings), research projects proposals submitted (in national and international competitions), research projects proposals accepted for funding. The codification of these parameters is presented in Figure 7. Each parameter has a numerical value that is compared with some thresholds (T) specific to that parameter and established either at national level (e.g. by the Romanian Ministry of Education, Research, Youth and Sports) or at the university level. The comparison between the numerical values and the thresholds will provide symbolic values of the parameters (named <*parameter_code*>S, e.g IRPS, ISI_JS), such as *high*, *medium*, *small* etc. We have to note that in order to make comparisons (e.g. between the universities), the numerical values are normalized.

The knowledge base of the ACDI_UPG expert system consists in a set of rules that were generated by inductive learning (starting from decision tables extracted from human experts) or were taken from the research methodologies and norms provided by the Romanian Ministry of Education, Research, Youth and Sports, and its specialized commissions.

| | | |
|---|---|---|
| Number of national research projects | - | NRP |
| Numer of international research projects | - | IRP |
| Number of international research collaborations | - | ICO |
| Number of papers published in ISI journals | - | ISI_J |
| - impact factor < 1 | - | ISI_J0_1 |
| - impact factor >= 1 and < 2 | - | ISI_J1_2 |
| - impact factor >= 2 | - | ISI_J2_4 |
| Number of papers published in BDI journals | - | BDI_J |
| Number of papers published in ISI Proceedings | - | ISI_Proc |
| Number of papers published in international conferences organized by professional societies others than those with ISI proceedings | - | ICPS |
| Number of books published in | | |
| national publishing houses | - | NB |
| international publishing houses | - | IB |
| Number of chapters in books published in | | |
| national publishing houses | - | NCB |
| international publishing houses | - | ICB |
| Number of research project proposals | | |
| National competitions | - | NRPP |
| International competitions | - | IRPP |
| Number of research project proposals accepted for funding | | |
| National competitions | - | ANRPP |
| International competitions | - | AIRPP |

**Fig. 7.** Codification of the parameters analyzed by the ACDI_UPG expert system

Some examples of rules used by the knowledge base of the ACDI_UPG system are given in Figure 8. Rules IndR28, Ind37 and Ind57 were generated by inductive learning.

**Rule T12**
**IF** NRP < $T^{nrp\_1}$
AND IRP >= $T^{irp\_1}$
AND ICO > $T^{ico\_1}$
AND ISI_J0_1 >= $T^{isi\_jo1\_1}$
AND BDI_J >= $T^{bdi\_1}$
AND IB >= $T^{ib\_1}$
AND NB >= $T^{nb\_1}$
**THEN**
RQ_Analysis_Result = very_good;

**Rule IndR28**
**IF** ISI_JS = small AND NRPS = small
**THEN**
RQ_Analysis_Result = poor;

**Rule IndR37**
**IF** BDI_JS = high AND NRPS = medium AND ISI_JS = small
**THEN**
RQ_Analysis_Result = acceptable;

**Rule IndR57**
**IF** ISI_JS = medium AND NRPS = high AND IRPS = medium
**THEN**
RQ_Analysis_Result = good;

**Fig. 8.** Examples of rules from the knowledge base of the ACDI_UPG expert system

Examples of rules regarding the evaluation of the research activity dissemination (publication):

RULE P22
IF ISI_JS=small AND
BDI_JS=small AND
ISI_ProcS=small AND
NBS=small AND
IBS=none AND
NCBS=none AND
ICBS=none
THEN Publication=poor;

RULE P24
IF ISI_JS=small AND
BDI_JS=high AND
ISI_ProcS=medium AND
NBS=high AND
IBS=small AND
NCBS=medium AND
ICBS=small
THEN Publication=good;

RULE P25
IF ISI_JS=medium AND
BDI_JS=high AND
ISI_ProcS=high AND
NBS=high AND
IBS=small AND
NCBS=high AND
ICBS=medium
THEN Publication=very_good;

Examples of rules regarding the evaluation of the involvement in research projects and international research collaborations:

RULE R55
IF NRPS=medium AND
IRPS=small AND
ICOS=high
THEN Projects=good;

RULE 56
IF NRPS=small AND
IRPS=none AND
ICOS=small
THEN Projects=poor;

RULE 59
IF NRPS=medium AND
IRPS=high AND
ICOS=medium
THEN Projects=very_good;

The above presented rules were generated by induction from decision tables extracted from past experiences.
Other examples of rules are those used for the evaluation of the academic research ac-

tivity for research proposals eligibility/classification in case of research projects funding competitions (e.g. the IDEI competitions). In this case, the indicators that are used are the relative influence score of the papers published in ISI Web of Knowledge journals (RIS) and the cumulative relative influence score (CRIS). For the domains different from the social and humanist domains, the two indicators must fulfill the following conditions: RIS>=0.5 and CRIS>=2. Also two types of documents are analyzed: article and review. The eligibility rules are given the type of project proposal, eligible, not eligible, and the classification rules are doing an individual evaluation of the proposal according to specific criteria established by the competition.

*Case studies*
We have implemented the ACDI_UPG expert system in VP-Expert (the educational version), and we have run it for several scenarios. In this paper we shall present two case studies. The first one is doing the evaluation of the academic research activity at the department level, and the second one is doing the analysis at university level, for university classification in a specific domain of research. In this case the evaluation point out the weak and the strong points of the main activities of the research: dissemination and involvement in research projects and collaborations.

*Case study 1*
The first case study refers to academic research evaluation at department level, given the quality of the whole research activity performed by all the academic staff from the department. The system takes the numerical values of the parameters presented in Figure 7 regarding the research activity of all research staff from the department, and will provide a qualitative analysis of the research activity. The evaluation result can be used by upper levels of the RKM module. A screenshot from the ACDI_UPG expert system consultation done in for this case study (run 1) is shown in Figure 9. We have run several scenarios in order to validate the rules that were generated by induction from decision tables.

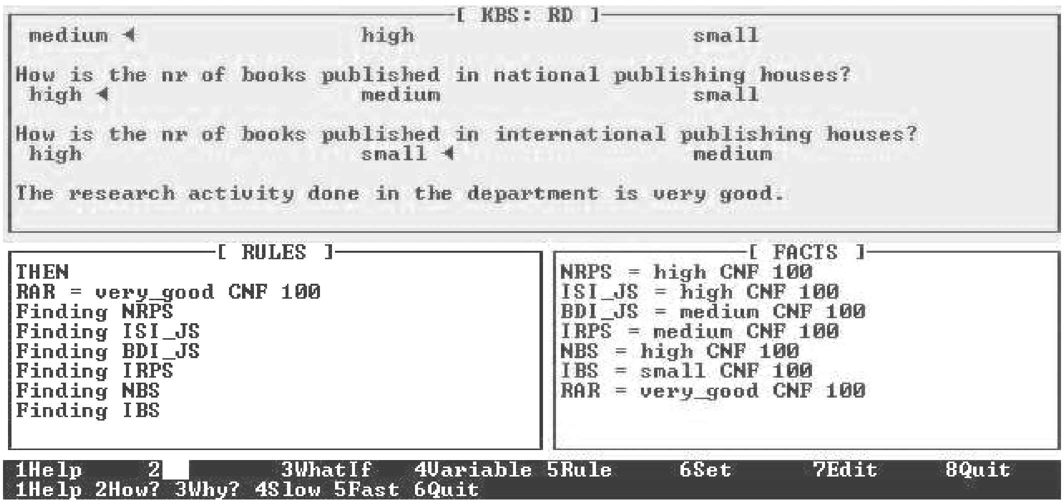


**Fig. 9.** Screenshot of the ACDI_UPG expert system consultation in VP-Expert (run 1)

*Case study 2*
The second case study refers to academic research evaluation at the university level for a certain domain of research in order to send the evaluation reports for the classification of the university at upper levels (at the ministry, for example). In Figure 10 it is shown a screenshot from the ACDI_UPG system run (run 2) in the case of an evaluation done at the university level for a specific domain of research (Computer Science), in a certain period of time (2001-2010). In this case the re-

search activity evaluation is very good and the strong points are the dissemination and the involvement in research projects and collaborations.

Another run (run 3) was done for the analysis of the research activity performed in the domain of Informatics in the period 2006-2010. The screenshot with the evaluation result given by the ACDI_UPG system run is shown in Figure 11. In this case, the evaluation result is acceptable and the weak point is the dissemination activity.

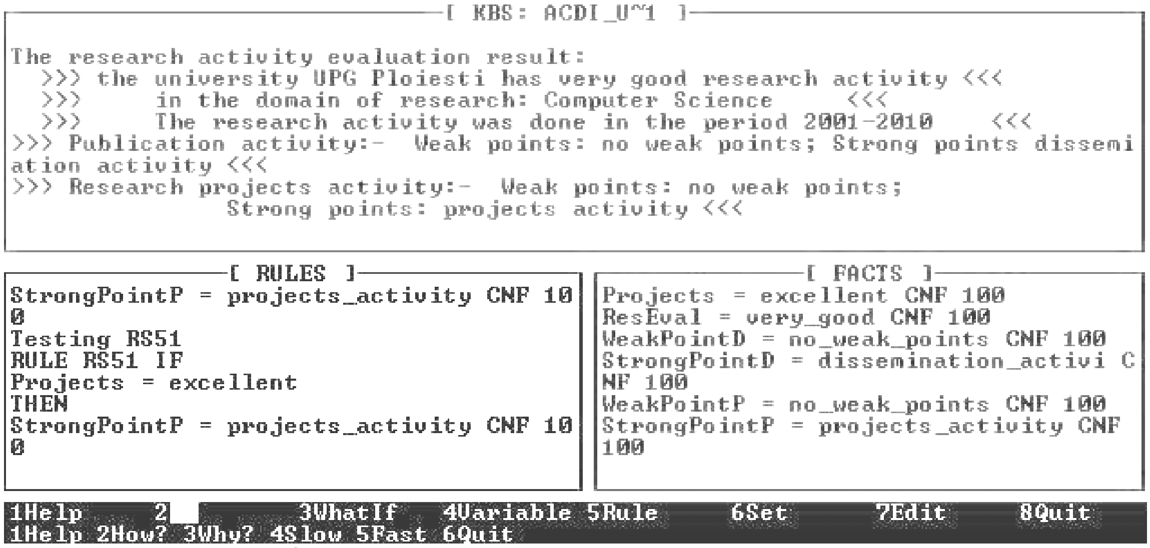


**Fig. 10.** Screenshot of the ACDI_UPG expert system consultation in VP-Expert (run 2)

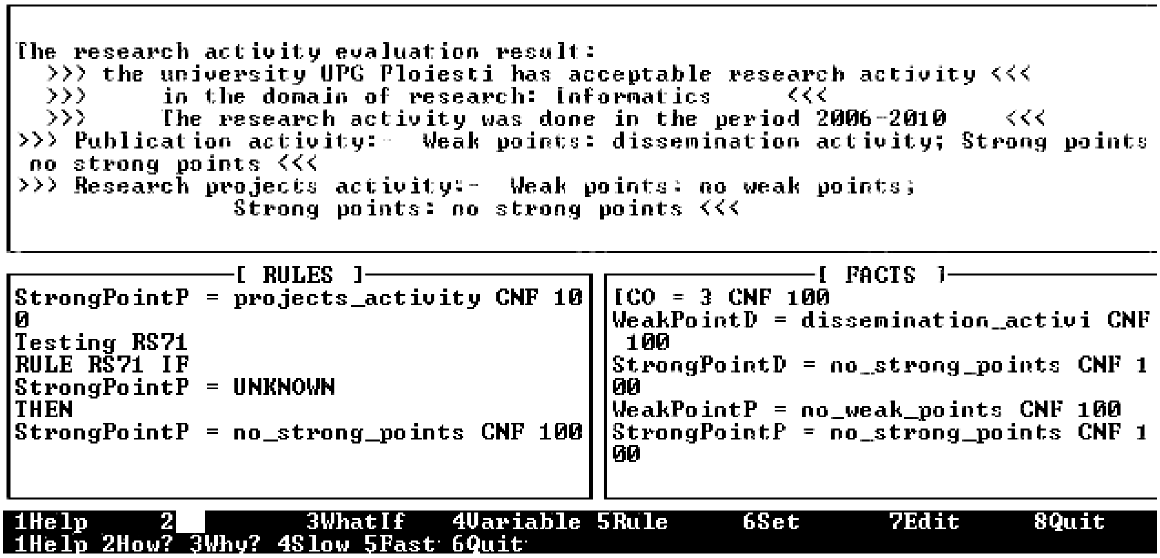


**Fig. 11.** Screenshot of the ACDI_UPG expert system consultation in VP-Expert (run 3)

## 5 Conclusion

The development of university knowledge management systems became an important research area in the last years. Most of the universities have started the implementation of different KM tools. The paper proposed a generic structure of a university knowledge management system, with the overviews of the teaching and research KM modules, and presented the ACDI_UPG expert system that was developed for the evaluation of the academic research activity. The system uses inductive learning for the generation of some rules from the knowledge base, and the ontology UPG_UniMan, previously developed and extended with new concepts for the applications presented as case studies. The ACDI_UPG 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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**Mihaela OPREA** received her MSc degree in Computer Science from University Politehnica Bucharest in 1990 and her PhD degree in Automated Systems from University Petroleum-Gas of Ploiesti in 1996. Currently, she is a full professor at the Informatics Department of the University Petroleum-Gas of Ploiesti. Her main research interests include pattern recognition algorithms, machine learning, knowledge modeling, applications of multi-agent systems and artificial intelligence techniques in various domains such as environmental protection, engineering, and education. She has published 10 books and over 70 papers in the field of artificial intelligence in international journals, and in the proceedings of international conferences and workshops.