Knowledge-Grid Modelling for Academic Purposes

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Abstract. Nowadays, we face a huge amount of data and information sharing on the Web by different users worldwide. A multidimensional perspective in describing a university ontology seems to be very important for the modelling of higher education resources. This paper proposes a multi-dimensional knowledge model, designed to distribute and manage knowledge resources efficiently. We propose our model as the foundation of an advanced knowledge platform including the following dimensions: time, area and social. Three crucial domains should be considered in this model: educational, research and managerial. The ontology including the mentioned knowledge management aspects is prepared using Ontorion Fluent Editor.

Keywords: Knowledge grid · Knowledge management · Ontology

1 Introduction

These days, people and machines produce countless volumes of data and information, consciously and intentionally transformed into knowledge. Undoubtedly, the value of the obtained information and knowledge varies from a theoretically low value with a small number of applications to being widely appreciated (new theories and inventions) with a universal usage. In particular, knowledge generated and disseminated in academic and institutional research centres should be considered as an extremely precious resource for civilization.

The crucial quest is how to manage the scientific achievements attained in "knowledge centres" in order to fulfil all knowledge management expectations starting from the capture of knowledge through to its usage. All the steps performed in the broad sense of knowledge management lead to the formulation and maintenance of knowledge structures, therefore a key point is the care of knowledge dynamics including multidimensional aspects of the functioning of knowledge. Exploring the essence of collective intelligence is another key scientific challenge.

In considering a systematic approach to a global vision of a knowledge environment, we focus on collections or "islands" of wisdom – so the very natural concept of a

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knowledge grid initiated at the beginning of this century by Mario Cannataro and Domenico Talia in Europe and Hai Zhuge in China. In this context, we can say that human imagination, combined with expertise, and internal and external information, may serve as a medium to produce new non-trivial knowledge. Thus, knowledge may be regarded as a product of cognitive processes and is of great importance for solving many complex problems in a variety of domains.

The concept of a knowledge grid as a potential method of knowledge acquisition and management will be presented in the next section. The ultimate goal of broadly understood university knowledge is the performance of all essential activities pertaining to gathering and maintaining knowledge resources.

This chapter is organized as follows. In the next section the state of the art of the knowledge grid and related terms are given. In the third section, the selected domains of university knowledge management are discussed. In the fourth section, the models of university knowledge are depicted and described. The last section provides final conclusions.

2 Knowledge Grid and Ontology

The presence of numerous information resources is typical for an information society. We live in a world where countless systems deliver huge amounts of data that is not only necessary for operational management but also for more advanced applications including research and educational purposes. These last two are especially essential and valid in the case of the academic environment. In order to assure access to the results of educational and research activities we need advanced tools that contain knowledge resources, among which we can enumerate the following entities: courses, publications, projects, etc.

All of the aforementioned categories arise in a plethora of different fields thus creating specialized knowledge grids. Without doubt, the development of such a platform is a tremendous challenge, therefore many aspects of knowledge management should be taken into account – additionally, models prepared for this purpose should be multidimensional.

According to general assumptions of a knowledge grid (KG), **distributed knowledge resources** can be offered as a set of services supporting research, innovation and decision-making processes (compare with [1]). Therefore, a KG is an essential tendency in improving endeavours that deal with acquiring and maintaining different forms of collective knowledge and thus is investigated in terms of several important aspects. Generally speaking, three research streams seem to be crucial in the presentation of the related work: surveys on KG process infrastructure, an exploration of KG usability and an inquiry into KG features and effectiveness.

Surveys on knowledge grid processes are focused on an investigation of the components and transformations performed in KG frameworks. There are several papers devoted to one or more processes connected to KG concepts. Knowledge acquisition in a distributed environment is, in particular, one of the hottest topics; there are several authors that study this specific field: Shaw [2], Bhatia and Yao [3], Ford and Petry [4], as well as Talia and Trunfilo [5], and Goble et al. [6]. All of the aforementioned researchers have dealt with techniques and tools. Other researchers focused on the integration and platforms necessary in KG processing, namely: Mancilla-Amaya et al. [7]

who stressed the E-decisional community as an integrated knowledge sharing platform, and Cannataro and Talia [8], and Berman [9] who pictured parallel and distributed knowledge discovery platforms. The lack of proposals on how to model a KG is still challenging for research teams.

Concepts of a knowledge grid can be implemented in many areas. **The exploration of KG usability** in different sectors, and some individual contextual demands, are critical for successful implementation. Skodras [10] checked the technologies that dealt with grid implementation in the educational sector, while Zhuge [11, 12] discussed the discovery of knowledge flow in science. Similarly, Qin and Fahringer [13], and Tofan et al. [14] made a survey about a novel domain-oriented approach for scientific purposes (compare with [15, 16]). In all of these papers, scientific orientation is present in grid visions.

The third research stream refers to **grid properties and effectiveness**. Zhuge introduced KGOL – a specialised language prepared for making operations on a knowledge grid [17]. Grid density and attraction, as important properties of stream data clustering, were considered by Tu and Chen [18]. The last example of work represents inquires into the discussed topic and refers to effective keyword search [19].

The topics presented in the discussed papers only partially cover the actual challenges of the KG area. However, the modelling of a knowledge grid for universities was not directly mentioned in any of the aforementioned papers. The special properties and components in such a model should be included in the hereby presented model.

Ontology, a term borrowed from philosophy, has played an essential role in computer science since 1967. According to T.R Gruber an ontology denotes an explicit specification of a conceptualization [20]. The body of knowledge representation is based on the conceptualization of the following categories: objects, concepts, terms and other entities, which by definition are in the area of interest. There are certain relationships among the defined categories which fulfil the picture of the described domain and its parts. In other words, it is an abstract, a phenomenon in which we are able to recognize important concepts. Formality refers to the possibility of processing ontology by a computer system, uniqueness means the definitive (primary) meaning of all concepts, and clarity indicates that their usage should be determined directly.

B. Smith singled out two approaches for the development of ontologies: **relevance** and **reductionism** [21]. The first is the search for taxonomy beings, in line with reality at all levels of aggregation from the micro-world to the cosmological. The second perception of reality takes place through the prism of a privileged being; the ontology is the result of the decomposition of reality into smaller components or the result of a reduction of the multiplicity of types. Thus, generally, in a first approach analysis things lead to a general description of all the entities, and subsequently, only a limited set of them is taken into consideration.

The main questions referring to the representation of crucial knowledge grid components as ontology objects concern the following:

- What kind of categories must be considered in order to cover the main academic activity areas?
- Assuming a multidimensional approach to modelling a university knowledge grid, the quest relates to potential aspects of the ontology built.

- The problem of how to present the discovered relationships among identified categories in such organizations is fundamental.

In addition is the quest about how to transform the knowledge grid in terms of using operators to generate new pieces of knowledge in order to achieve new generations of this knowledge (a topic partially presented in [22]). The itemised quests will be established as a starting point to create an ontology in the following sections.

3 Selected Domains of University Knowledge Management

Universities identified traditionally as higher education institutions play different roles in modern society. The first aspect of this relates to considering universities as organizations with determined goals and resources. Secondly, the main activity of such educational institutions is to provide facilities for teaching. Thirdly, in order to extend academic knowledge and scientific abilities, research specific for particular areas should be performed. Therefore, any university should deliver the mentioned activities: learning and research using the available resources which are components of the general university infrastructure. Selected aspects of particular knowledge management will be presented in the next section.

In considering any university as an **institution** with advanced information resources, a need for knowledge management (KM) appears. Therefore, complex IT infrastructures create the fundamentals of knowledge organization including an organizational culture as essential factors of the whole knowledge management process. At the very least the following factors for KM processes (apart from the mentioned organizational culture, IT infrastructure and knowledge organization) should be itemised: knowledge measurement and effective and systematic processes (see [23]). To be more precise: there are real interconnections between these factors and, in particular, certain additional impacts can be included, for example: direct influence of qualification levels on knowledge organization and knowledge measurement, years of experience on both the defined factors and finally, searching time and effort connected with systematic processes. All these factors are present in any academic center – the graph in Fig. 1 reflects the interconnection between the mentioned factors and determinants.

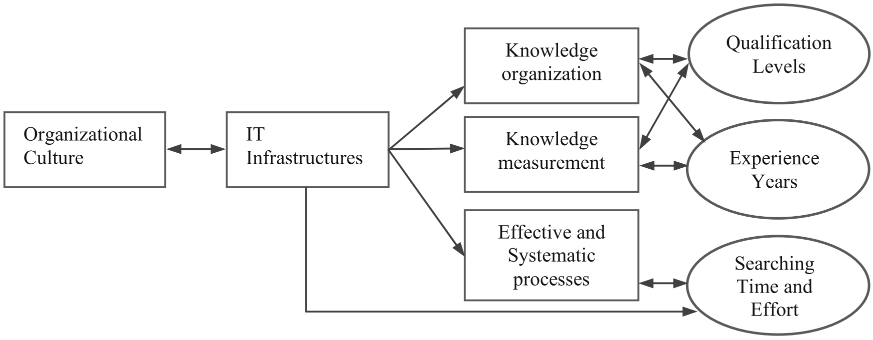

Fig. 1. Interconnection between KM success factors and determinants Source: [23]

The concept of knowledge management needs a discussion about the people involved in particular phases of the process performance. Very often these staff are referred to as **knowledge workers** (see [24]). The following roles are defined in order to cover the main domains of university activities (teaching, research and service): analysts, engineers and stewards. All the mentioned staff are responsible for keeping organizational knowledge in universities.

The preparation of an ontology for the whole university can be started from **specific areas or aspects**. In designing intelligent services for a smart campus, focused on people, infrastructure (including: buildings, rooms, grounds) and other instruments and tools [25]. These categories are essential in an ontology oriented on services.

Considering the assumptions of a smart university model for education, different perspectives and priorities should be included. Coccoli et al. (see: [26]) focused on opinion collection (supported by data mining algorithms) to generate some visions of teaching. In such an approach, the ontology is limited to standards existing in a university (see Fig. 2).

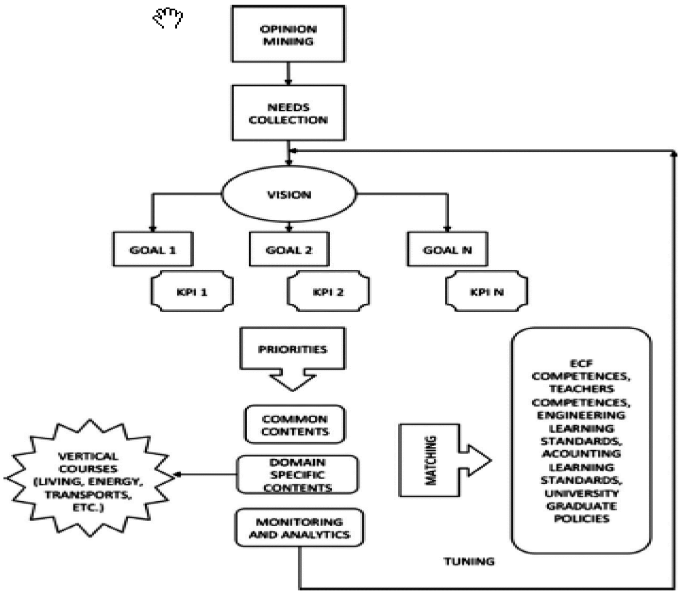

Fig. 2. The model of a smarter university Source: [26]

A more global approach is evident in the case of Knowledge Management System (KMS) implementation. Basically, three areas must be included in order to cover all the essential domains of university activities: Research, Education and Management. In M. Oprea's proposal of KMS [27] these areas are considered as a crucial background for a prepared university portal – see Fig. 3.

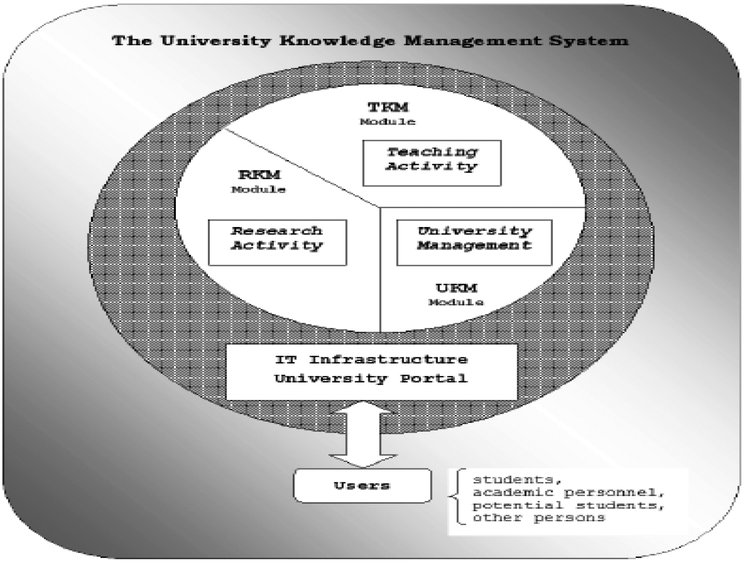

Fig. 3. The structure of a generic University Knowledge Management System Source: [27]

The discussed solutions of university knowledge management components are important in the ontology presented in the next section.

4 Ontology of Academic Knowledge

4.1 Short Presentation of Ontorion

The Ontorion Fluent Editor is a comprehensive tool for editing and manipulating complex ontologies, developed in Controlled Natural Language [28]. Controlled English is the main built-in feature, which makes this tool more suitable than other XML-based OWL editors. It is also supported via Predictive Editor, which prohibits one from entering any sentence that is grammatically or morphologically incorrect and actively provides help to the user during sentence writing [29].

For each edited OWL file, a taxonomy tree is built upon data from this file and all the included ontologies. Each tree can be visualized using a user-friendly palette of colours and divided into four parts: **thing** (shows “is-a” relations between concepts and instances), **nothing** (shows concepts that cannot have instances), **relation** (shows the relations hierarchy between concepts and/or instances) and **attribute** (shows the attributes hierarchy).

In our opinion, the implementation phase of the creation of an ontology is a straightforward task, because a user just types simple sentences expressing dependencies between things at the assumed level of detail using the editor available in Fluent Editor. The package for the created documents provides automatic and real-time help in several ways, such as: hint box, predicted word list and syntax error markers [30].

4.2 Models of a University Knowledge Ontology

In order to present an ontology for knowledge management embracing crucial areas for university purposes three models representing: research, education and management are necessary. All of the models are presented in the form of "Documents" (describing components of each particular area) and "Force Directed Layouts" (visualising relationships coming from the introduced components).

In Fig. 4 a partial description of the **educational** area for university knowledge is presented. Particular statements express categories and relationships among the defined objects including their instances. The presented ontology can be extended through more detailed characteristics of the concrete objects and instances, as well as through the insertion of new elements and rules essential in the domain.

Document

```
Title: 'University Education Ontology'.
Author: 'Mieczysław Lech Owoc  & Krzysztof Hauke'.

Comment: 'Sample Education Ontology'.

Part:  Area-------------------------------.
Area-1 is an area.
Area-2 is an area.

Part:  Infrastructure-------------------------------.
Infrastructure-1 is an infrastructure.
Infrastructure-2 is an infrastructure.

Part: Effect------------------------------.
Effect-1 is an effect.
Effect-2 is an effect.
Every effect is-part-of a course.

Part:  Course-------------------------------.
Course-1 is a course.
Course-1 is-part-of Area-1.
Course-1 needs Infrastructure-1.
Course-1 implements Effect-1.
Course-2 is a course.
Course-2 is-part-of Area-2.
Course-2 needs Infrastructure-2.
Course-2 implements Effect-1 and implements Effect-2.
Course-3 is a course.
Course-3 is-part-of Area-1 and is-part-of Area-2.
Course-3 needs Infrastructure-1 and needs Infrastructure-2.
Course-3 implements Effect-1.
Every area should teach a course.
Every teacher must have-status something that be a lectures and be
either Active or Nonactive.
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Fig. 4. Sentences describing educational university knowledge

A graphical form of this domain is presented in Fig. 5. There are several relations among the defined concepts/instances, determining the roles (be-part-of, teach, taught, participate) or goals of relationships (need, implement). The effects of education can be clarified as acquired knowledge, possessed abilities or social competences.

The next part of the presented ontology concerns the **research** area of university activities. The following parts constitute the content of the described domain: Researcher, project, source, publication, infrastructure and result – see Fig. 6 [31].

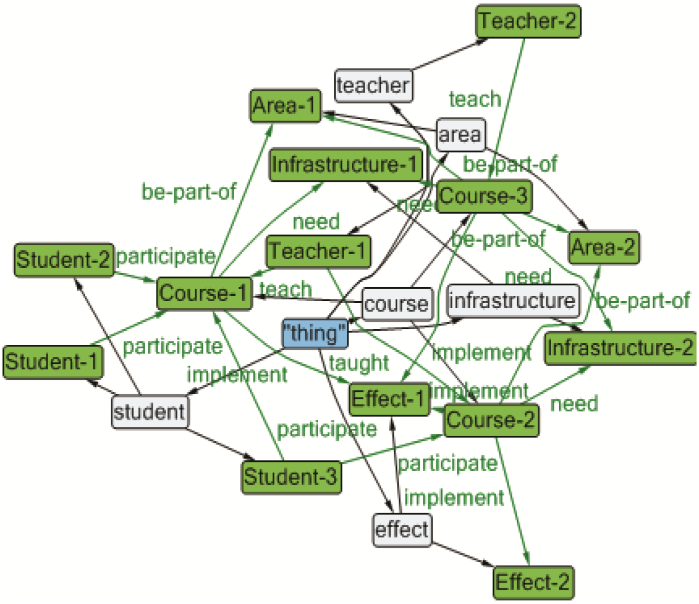
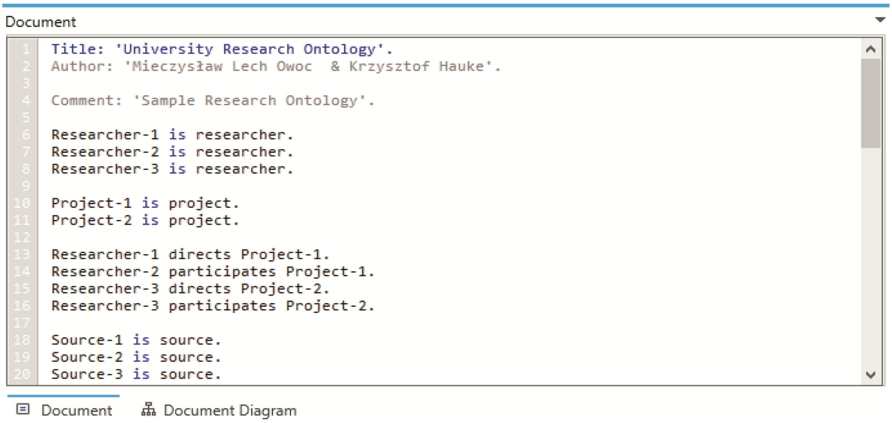


Fig. 5. Graph presenting educational university knowledge



Document

```
Title: 'University Research Ontology'.
Author: 'Mieczysław Lech Owoc  & Krzysztof Hauke'.

Comment: 'Sample Research Ontology'.

Researcher-1 is researcher.
Researcher-2 is researcher.
Researcher-3 is researcher.

Project-1 is project.
Project-2 is project.

Researcher-1 directs Project-1.
Researcher-2 participates Project-1.
Researcher-3 directs Project-2.
Researcher-3 participates Project-2.

Source-1 is source.
Source-2 is source.
Source-3 is source.
```

Document   Document Diagram

Fig. 6. Sentences describing research university knowledge

The list of relations proposed for this sector includes the behaviour of concepts (direct, participate) or their functionality (generate, need, provide, received and use).

Next, Fig. 7 shows interconnections between objects and instances according to their defined roles and functionalities. Some of the presented objects or instances can be divided into smaller parts; for example – "Infrastructure" representing tools, materials, teams and funds necessary for the undertaken projects.

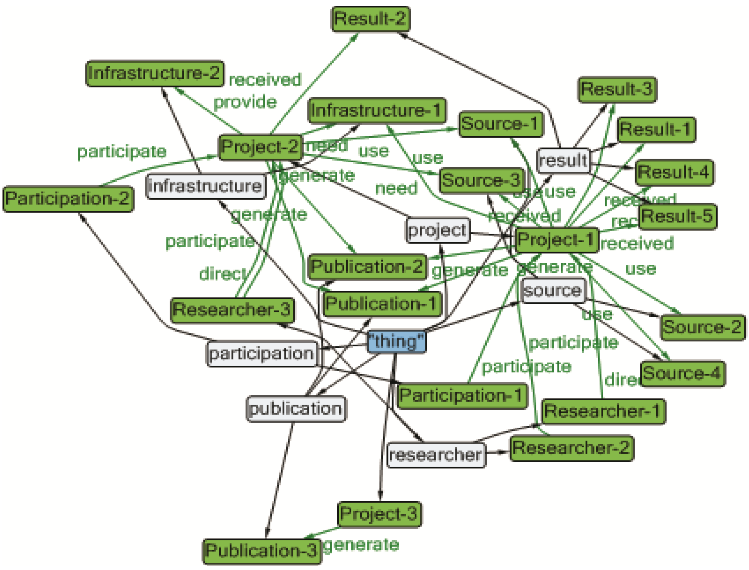


Fig. 7. Graph presenting research university knowledge

Similarly, the "Source" can be represented in many ways - in particular as the result of external projects or publications. In practice, a large number of interconnections is typical for advanced projects.

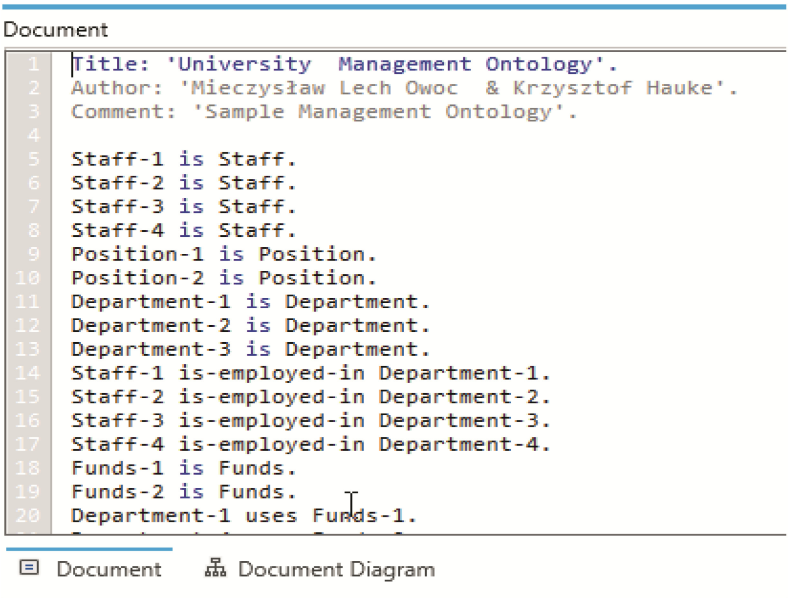


Fig. 8. Sentences describing managerial university knowledge

The last, **managerial**, area of the presented knowledge management seems to relate to any institution but some elements are specific for academic purposes. In Fig. 8 the particular components represented are not limited just to a list of typical categories: departments, positions, staff, but additionally include more global objects present in previous descriptions such as "Education" and "Research".

Below, a graphical form of managerial university knowledge is demonstrated (Fig. 9).

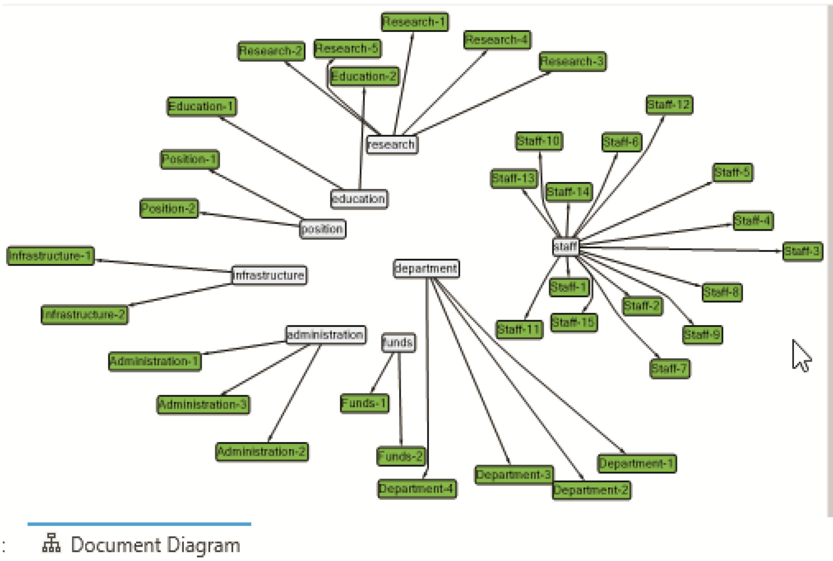
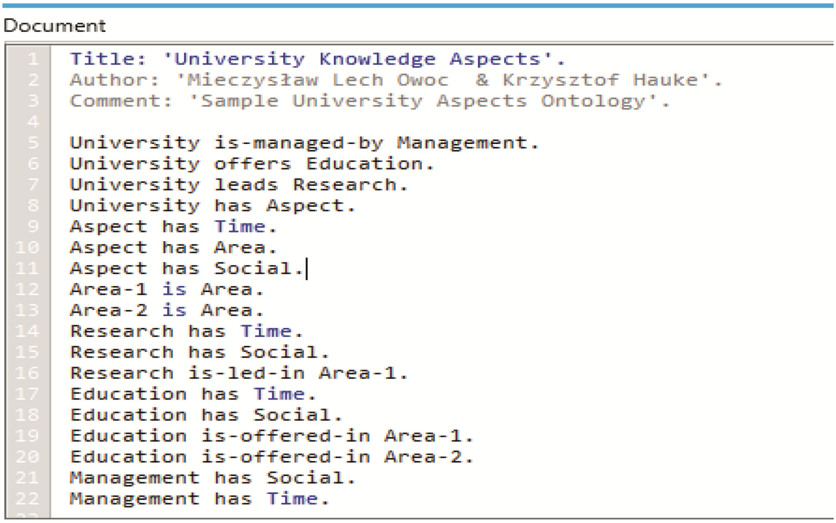


Fig. 9. Diagram presenting managerial university knowledge

In the last part of the ontological approach to the description of university knowledge we focus on potential aspects of **knowledge perspectives**. At least three aspects must be considered: time, space and social. In all previously presented ontologies these aspects can be applied. The document presenting the initial version of this problem is proposed in Fig. 10.

The infrastructure of a university is presented as the three previously presented domains: Management, Education and Research, with specific relationships to the category University. Additionally, three aspects are underlined: Time, Area and Social. Special features representing particular domains are subordinated to Management, Education and Research, respectively. In practice these aspects can express the social characteristics of all the domains and the activeness of university staff in the defined areas (Research and Education are selected as examples). The third dimension "Time" denotes versions of the Research, Management and Education solutions through time.

The graphical form of the determined relationships is shown in Fig. 11. University, as the three joined domains of Education, Research and Management represents very specialised roles fulfilled in these areas (offered, lead and be-managed-by, respectively).



Document

```
Title: 'University Knowledge Aspects'.
Author: 'Mieczysław Lech Owoc  & Krzysztof Hauke'.
Comment: 'Sample University Aspects Ontology'.

University is-managed-by Management.
University offers Education.
University leads Research.
University has Aspect.
Aspect has Time.
Aspect has Area.
Aspect has Social.
Area-1 is Area.
Area-2 is Area.
Research has Time.
Research has Social.
Research is-led-in Area-1.
Education has Time.
Education has Social.
Education is-offered-in Area-1.
Education is-offered-in Area-2.
Management has Social.
Management has Time.
```

Fig. 10. Sentences describing university knowledge aspects

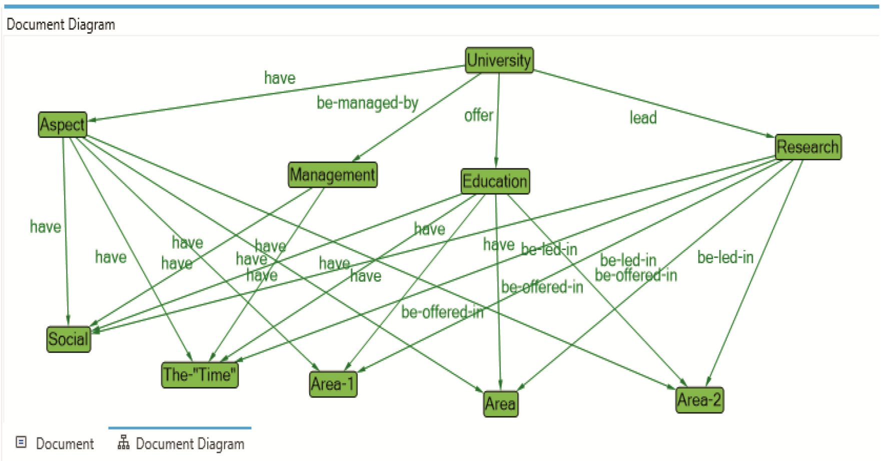


Fig. 11. Sentences describing university knowledge aspects

Other connections express attributes representing characteristics of the defined university domains, including three-dimensional aspects: Time, Area and Social.

Concluding, the presented ontology describing university categories can be applied to any educational and research institution at least as an initial framework for the creation of real knowledge management systems.

5 Conclusions

For such organizations as universities, knowledge has always been the most crucial and prominent asset together with academic scholars and teachers. Previous attempts at the presentation of knowledge management in universities were limited to discussions about essential factors determining successful knowledge management processes in universities, knowledge workers in the educational sector or the presentation of a general infrastructure for the creation of university knowledge systems.

Undoubtedly, academic knowledge represents all features typical for a knowledge grid approach. Especially in the case of presenting the three domains of the university structure: managerial, educational and research. An analysis of KG infrastructures present in universities allowed for the modelling of these three domains and the presentation, on the surface, of relatively autonomous ontologies describing the main categories and relationships for Management, Education and Research. Additionally, an integrated perspective considering three aspects of university knowledge: time, area and social was proposed as a three-dimensional ontology typical for academic centres.

The elaborated version of an academic ontology should be extended through the insertion of dynamic features of the knowledge management process. For example, particular models can be enriched with the validation of knowledge models or with proposals of the implementation of active rules for the defined categories. This way our further research will allow for more advanced solutions in academic knowledge management systems.

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