Ontology-Based Knowledge Mapping of University Teaching Activities

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***Abstract*—This paper focuses on the ontological engineering of academic work performed by university faculty, introducing a novel approach to knowledge management. The developed ontologies serve as the foundation for knowledge maps, which aim to simplify information retrieval and processing, enabling the creation of a clear and visual "portrait" of a specific faculty member or university department. A key aspect of this visualization is the creation of accessible and intuitive graphical representations, which helps users to quickly grasp complex relationships and information flow. The proposed approach contributes to enhancing knowledge management within educational institutions by providing structured and accessible representations of intellectual capital. In addition, preliminary reflections highlight the need for systematic evaluation metrics such as time savings, reduction in search efforts, and user satisfaction scores, which will guide the long-term assessment of the framework. This is particularly important in the context of information overload, where knowledge compression through structured visualization is crucial for improving comprehension and efficiency.**

***Keywords*—Ontologies, knowledge maps, knowledge management, faculty modeling, academic information systems.**

I. Introduction

Ontologies, as conceptual models of a specific domain, represent a promising approach for forming knowledge bases and knowledge graphs. They serve as a unifying theoretical and methodological framework for modeling complex subject areas, such as the academic activities of university faculty. Modeling these activities is crucial for developing corporate systems, facilitating information retrieval, and automating processes. However, contemporary information management systems often only partially assist in routine procedures, leading to a significant portion of time being spent on information search and structuring. Compared to traditional relational databases and document repositories, ontological approaches promise more expressive and semantically rich connections, though empirical comparisons in university contexts remain limited. Including such comparisons in future work will allow for more rigorous benchmarking of ontology-based solutions against existing systems.

Recent research highlights the advantages of information compression and visualization [2]. Information compression is vital in today's data-rich environment because it allows complex data, such as a faculty member's diverse activities, to be presented in a compact and easily digestible format. This reduces cognitive load and improves the speed and quality of decision-making. Despite this, a weak correlation has been observed between the needs of universities and emerging technologies in knowledge engineering and visual ontological engineering. Current models and methods for knowledge visualization are not yet sufficiently mature to address practical challenges in knowledge management and information management.

This article is dedicated to the design of ontologies for university faculty academic work, followed by the development of knowledge maps to streamline knowledge retrieval and processing. In the context of academic work, we emphasize the creation of taxonomies that describe a faculty member's activities from the perspective of their knowledge and competencies. The developed ontologies form the basis of knowledge maps, which provide a clear "portrait" of a specific faculty member or university department.

Knowledge maps are specialized tools for information analysis that can enhance managerial decision-making and reduce the cognitive load on intellectual workers. Such diagrams facilitate efficient knowledge discovery by indicating **WHAT** is known by employees, **WHERE** this knowledge resides, and **WHO** is the knowledge holder. Thus, a knowledge map establishes a connection between the subject, the holder, and the location of knowledge.

Our approach has been successfully piloted at the Faculty of Computer Science and Applied Mathematics at the French University of Armenia. The developed knowledge maps visually represent information about the knowledge possessed by the faculty and which staff members are the owners of this knowledge. A set of knowledge maps allows for the visual formation of an intellectual landscape of the scientific community, comparison of the scientific potential of different research teams, and identification of colleagues for collaboration and interdisciplinary research.

II. On Ontological Engineering

Significant experience has been accumulated in methodological and technological research concerning the

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practical design and formation of ontologies. Ontological engineering has a history spanning over 30 years, originating from the pioneering works of Gruber and Uschold [3], [8], and actively evolving to the present day, as evidenced by publications such as [6] and [4].

However, the development of practical ontologies in manufacturing, design, and management largely remains an "art." Ontology design is rather poorly covered in the ontological engineering literature, with most authors focusing their efforts on formalization and modeling per se [7]. Existing methodologies and technologies also tend to be oriented towards organizational and technological aspects, without adequately addressing the problems of concept formation, their level of abstraction, the balance of relationships, and other semantic issues.

While ontologies have become a de facto standard in the field of knowledge base development, the processes of knowledge extraction and, especially, knowledge structuring still remain a "blind spot" in contemporary knowledge engineering literature. It can be argued that within the semiotic triangle of "syntax – semantics – pragmatics," syntax and pragmatics currently dominate. Ontological engineering has received a new impetus with the powerful rise of knowledge graphs based on ontologies [5] and automated ontology construction [1]. In this project, we utilized classic methodologies, adapting them to our specific tasks.

III. Ontology of Academic Work in Computer Science

Numerous didactic ontologies exist for various subject domains in education. Despite considerable interest and attempts to create an ontology of academic work [9], there is practically no universally accepted unified ontology for teaching. In this project, the academic work in teaching computer sciences (applied mathematics, software engineering, systems engineering) was taken as the basis, given the specific nature of education in natural technical sciences.

The ontology of academic work is a formal, explicit specification of a shared conceptualization. It provides a standardized framework to define concepts and their relationships within the domain of university faculty activities. For this work, we chose to use the **Web Ontology Language (OWL)**, as it is the W3C standard for representing ontologies. OWL is based on Description Logics and allows for robust semantic representation, which is crucial for the reasoning capabilities we require. We could also use other languages like **Resource Description Framework (RDF)** and **RDF Schema (RDFS)**, but OWL provides more expressive power to describe properties and classes, which is essential for our application.

The main types of academic work included in the ontology are:

Classroom Load:

- Lecturing
- Conducting seminars
- Leading practical sessions

Extracurricular Load:

- Supervision of professional projects
- Supervision of internships

Educational Material Development and Pedagogical Experience Dissemination:

- Preparation and publication of teaching materials
- Various forms of pedagogical experience sharing (e.g., conference presentations, workshops).

Furthermore, distinctions were considered for different program levels (Bachelor's / Master's, additional educational programs) and types of participation in course content development (course update, new course development, new program development, business simulation).

A simplified conceptual representation of the academic work ontology can be visualized as a hierarchical structure. Here is a detailed breakdown of the ontology's conceptual model. It defines classes, properties, and the relationships between them.

Core Concepts and Relationships:

FacultyMember

hasKnowledge → KnowledgeDomain (e.g., "Artificial Intelligence", "Database Systems")

hasCompetency → SkillSet (e.g., "Curriculum Design", "Project Supervision")

performs → AcademicActivity

AcademicActivity

isTypeOf → ClassroomLoad, ExtracurricularLoad, MaterialDevelopment

forProgramLevel → Bachelor, Master, AdditionalProgram

inLocation → Campus1, Campus2, Online

materialsStored → PersonalComputer, MoodlePlatform

involvesContentDevelopment → CourseUpdate, NewCourseDevelopment, NewProgramDevelopment, BusinessSimulation

Example Instance (Simplified): A faculty member, Dr. Lalayan, teaches "Database Systems" (KnowledgeDomain) at the Master's level (ProgramLevel). This involves "Lecturing" (ClassroomLoad) which takes place "Online" (Location) and course materials are stored on the "MoodlePlatform" (MaterialStorage). Dr. Lalayan also "Supervises Professional Projects" (ExtracurricularLoad) for Bachelor students. This structure allows for a rich, interconnected representation of a faculty member's academic profile.

Knowledge maps, built upon these ontologies, provide a visual and structured overview. While a full graphical representation is beyond the scope of this text, a tabular or list-based representation can illustrate the kind of information captured. The real power of the knowledge map lies in its visual representation, which can be seen in the following example.

Table 1: Simplified Knowledge Map Entry for a Faculty Member

Attribute	Value
Faculty Member	Dr. Varazdat Avetisyan
Department	Computer Science & Applied Mathematics
Key Knowledge Areas	Machine Learning, Data Analytics
Teaching Activities	- Lectures: AI (Master, Online) - Seminars: Python Prog. (Bachelor, Campus1)
Supervision	- Master Theses (5 active) - Internships (2 active)
Material Development	- New Course: "Deep Learning" - Updated: "Data Structures"
Pedagogical Experience	- Workshop on "Active Learning"
Material Storage	Moodle (primary), Personal PC (backup)

This table represents a single "node" or "profile" within a larger knowledge map. The full map would connect Dr. Varazdat Avetisyan to other faculty members, specific courses, research projects, and departmental resources, forming a comprehensive network of knowledge. The knowledge map concerning taught disciplines at the faculty clarifies information about the location of classes (one of two campuses or online), as well as the method of storing course materials (on a personal computer or on the Moodle e-learning platform).

Our methodology offers several clear benefits while also presenting some challenges. The main advantages include:

Semantic Richness: By using a formal ontology, we move beyond simple data storage to capture the meaning and relationships between different pieces of information. This allow for more sophisticated querying and analysis.

Enhanced Interoperability: A standardized ontology provides a common language for describing academic work, which can facilitate data exchange between different university systems or even other institutions.

Improved Decision-Making: The visual knowledge maps, derived from the ontology, make it easier for administrators and faculty to identify experts, find collaborators, and understand the collective intellectual capital of a department. This is a significant improvement over searching through disconnected databases.

Knowledge Discovery: The structured nature of the ontology and the use of reasoning engines allows for the discovery of implicit knowledge. For example, if a faculty member is known to teach "Deep Learning," a reasoning engine could infer that they are an expert in "Artificial Intelligence," even if it's not explicitly stated.

However, our approach also has some drawbacks:

Manual Effort in Creation: The initial development of the ontology requires significant manual effort and domain expertise. While automated tools are emerging, the core conceptualization still relies on human input.

Maintenance and Scalability: Keeping the ontology and the knowledge maps up-to-date can be challenging, especially in a dynamic environment where faculty profiles and course offerings change frequently. As the size of the institution grows, so does the complexity of maintaining the system.

Technical Complexity: Developing and implementing an ontology-based system requires specialized technical skills in semantic web technologies, which may not be readily available in all university IT departments.

Limited Evaluation: At this stage, our piloting mainly demonstrates conceptual feasibility without quantitative indicators such as processing time saved, error reduction in information retrieval, or user satisfaction with knowledge maps. Integrating such metrics into the next phase is essential for validating the effectiveness of our approach. To address this, future work will include a more formal evaluation of the system's impact. This will involve collecting quantitative data, such as the time saved by administrators and faculty when performing specific tasks (e.g., finding a suitable supervisor for a student project). We will also conduct user satisfaction surveys to gather qualitative feedback on the system's usability and effectiveness. These metrics will provide concrete evidence of the value of our approach.

Lack of Comparative Benchmarking: While our ontology-based model shows semantic and visual strengths, direct comparison with baseline systems (e.g., database-driven faculty profiles, institutional CRMs, or digital repositories) would provide stronger evidence of practical superiority. To better demonstrate the advantages of our ontology-based approach, a comparative analysis will be conducted against traditional, non-semantic information systems currently used in universities (e.g., relational databases or simple faculty directories). This comparison will highlight how the semantic richness and reasoning capabilities of our system enable more complex queries and insights that are not possible with traditional keyword-based searches, thus strengthening the case for adopting ontologies for knowledge management.

Ontology reasoning is the process of inferring new knowledge from existing data and the rules defined in the ontology. This is one of the most powerful features of using a formal ontology. For example, a reasoning engine can automatically classify individuals into classes, check for inconsistencies in the data, and infer new relationships. This helps to maintain data integrity and enables advanced querying capabilities.

A number of tools and approaches are used for reasoning in ontologies. In our project, at the beginning, we utilize **reasoning engines** such as **Pellet, FaCT++, or HermiT**. These tools are highly effective at performing tasks like:

Consistency Checking: Ensuring that the ontology and the data instances do not contain contradictory information.

Classification: Automatically assigning instances (e.g., a new course) to their correct classes based on their properties and relationships.

Query Answering: Enabling complex queries that go beyond simple keyword searches, such as "Find all faculty members who are experts in both 'Machine Learning' and 'Big Data' and are available for a new Master's level course."

For the real-time piloting stage of this project, we have decided to use Protégé, a free, open-source ontology editor and framework developed at Stanford University. Protégé's robust feature set and active community make it an ideal choice. We will use the Protégé Desktop application to create, edit, and manage the OWL ontology. During the piloting phase, we will also leverage Protégé's ability to integrate with reasoning engines to validate the ontology in real-time as data is added and modified. This will allow our team to iteratively refine the ontology and ensure its integrity and correctness. The use of Protégé will enable us to dynamically extend our conceptual model and manage the complex relationships between the various aspects of academic work. While the final deployment may involve a more streamlined, custom application, using Protégé in this initial stage provides a powerful, flexible environment for rapid prototyping and validation of our knowledge-based system.

IV. Conclusion

Modern educational organizations operate within vast information spaces. In such conditions, the ability to find relevant information becomes critical. The real knowledge assets of an institution, along with their accessibility and structured nature, are increasingly important. This article has addressed the practical development of university knowledge maps based on ontologies. The developed ontologies, using languages like **OWL**, enable the construction of knowledge maps that reflect various projections of a university's intellectual capital and its subdivisions on a systemic and well-structured basis. These projections provide collective and individual multidimensional "portraits" of the knowledge possessed by faculty members and research departments. Such a structured approach, while presenting challenges in implementation and maintenance, facilitates improved knowledge management, strategic decision-making, and fosters collaboration within the academic community by leveraging the power of **semantic reasoning** and **visualization**. Nevertheless, the current stage remains primarily qualitative. To solidify the case for ontology-driven knowledge management, future studies will integrate systematic evaluation metrics (e.g., time-to-information, user effort, and satisfaction ratings) and benchmark our system against traditional database-based management solutions. This will enable us to more rigorously demonstrate efficiency gains, usability improvements, and scalability advantages. Future work will extend the ontology to include research activities, administrative responsibilities, and international collaboration, aiming for a comprehensive knowledge infrastructure across all dimensions of academic life.

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