Knowledge modelling for teaching and learning Artificial Intelligence by using educational robots

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Abstract: *Teaching and learning a specific university course can be facilitated by using educational robots, as for example courses of Computer Science domain. In particular, the course of Artificial Intelligence can use mobile robots as an educational resource for the development of various applications that apply the theoretical concepts and methods teached to students. An example is given by informed search strategies (e.g. A^*, Best First) applied to mobile navigation robot path planning. The paper presents a methodology for university course knowledge modelling and an ontology for the course of Artificial intelligence that uses educational robots as a technological tool.*

Keywords: Artificial intelligence, Knowledge modelling, Educational robots, Ontologies.

1. Introduction

University courses (online) teaching and learning activities are based on various educational resources such as textbooks (electronic textbooks), books (electronic books), scientific articles, tutorials, PowerPoint slides, simulations, demonstrations, hardware and software tools, that are theoretical and practical knowledge for the course. An efficient educational resource is given by ontologies that provide a conceptualization of the course domain and various knowledge graphs. Robotics proved to be a proper learning tool for education in general, and for artificial intelligence, in particular. Educational robots can enhance teaching and learning for certain courses, as for those related to Computer Science.

Knowledge modelling is an important issue for education. This activity includes: course knowledge modelling, pedagogical knowledge modelling and student knowledge modelling. As an educational process is composed of teaching, learning and examination, all these three activities have access to course specific knowledge sources and thus, require knowledge modelling and also, student knowledge tracing in order to evaluate the whole educational process efficiency related to a specific student or group of students.

Our research work focused on the integration of educational robotics into the processes of teaching and learning the university course of Artificial Intelligence

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(AI). We have designed a specific methodology for knowledge modelling and an OWL ontology, OntoEdu-AI-Robots, implemented in Protégé 4.3.

The paper is organized as follows. Section 2 focuses on university course knowledge modelling presenting a brief state of the art and the methodology that was followed in our work. Some issues related to the use of educational robots for teaching and learning the course of Artificial Intelligence are discussed in section 3. The ontology OntoEdu-AI-Robots that was developed for the course of Artificial Intelligence that uses mobile robots is presented in section 4. The last section concludes the paper and highlights some future work.

2. University course knowledge modelling

2.1 A brief state of the art of educational knowledge modelling

Modelling knowledge at university level (for teaching and learning university courses) can be performed with ontologies and knowledge graphs, complemented with various technological tools (software and hardware) such as simulators, demonstrators and educational mobile robots that have the potential to improve student performance by complementing theoretical issues with practical ones, increasing students' course better understanding degree.

Ontologies are basic educational resources that integrates domain knowledge in taxonomic hierarchies and knowledge graphs (Mizoguchi, 2004). An ontology is a conceptualization of a domain and is composed of concepts, relations between concepts and a set of axioms that are constraints related to concepts and relations (Uschold & Gruninger, 1996). An overview on educational ontologies developed in the period 2015-2019 and included in IEEE Xplore database is presented in (Stancin et al., 2020). An analysis of certain ontology learning methods (as e.g. linguistic, machine learning, statistical techniques, pattern matching and heuristic approaches) is discussed in (Konys, 2018). The author performed descriptive logic query on an OWL Protégé ontology. An ontology system for the Computer Science architecture is presented in (Wang et al., 2019). The ontology was developed for students. Examples of ontologies for university courses are given in (Oprea, 2016), (Oprea, 2019), an educational ontology for declarative programming and in (Wang et al., 2019), an ontology for computer science education.

Moreover, a competency-based education requires a continuous update of university courses to the knowledge related to industry. A case study of educational ontologies development in Protégé by matching concepts included in higher education curricula and industry is described in (Gasmi & Bouras, 2018).

Knowledge tracing is a powerful tool that track the status of students' knowledge and make predictions related to their future performances. A progressive knowledge tracing method that allows modelling the student learning process is introduced in (Sun et al., 2024).

A recent example of student knowledge modelling by taking into account students' learning preferences, skill levels and learning style in order to improve educational students' achievements through personalized learning is given in (Abu-Issa et al., 2024).

A literature review on intelligent techniques that were applied in e-learning is presented in (Ilić et al., 2023). The authors performed an analysis of the artificial intelligent based techniques that were applied during the online educational activities in the period 2020-2022 when the need of electronic platforms and tools was high. Examples of such techniques are machine learning techniques (decision trees, deep learning), intelligent agents, artificial neural networks, Bayesian network, Fuzzy logic etc.

A recent research work that tackles ontology engineering as a way to take into account the complexity of software management and use virtual machines is described in (Stolic et al., 2023). The solution proposed by the authors has the potential to improve students' learning outcomes.

2.2 The methodology for educational knowledge modelling

In order to derive university course knowledge, we propose a general methodology that was applied for the course of Artificial intelligence. The development of the methodology has started from the observation that each course has some main educational resources (for basic/fundamental elements and advanced knowledge such as textbooks, PowerPoint slides, tutorials, e-learning platforms), associated with the course domain theory, and other resources, such as case studies, examples of problem solving, simulations and demonstrations, real world applications associated with the course domain practice.

For example, in the case of Artificial intelligence course, the application of different methods (as e.g. prediction methods based on artificial neural networks, informed search strategies for mobile robot path planning) can be included as educational resources that show how to solve real world problems (such as air pollution forecasting and environment monitoring with navigation robots). Two educational applications are described in (Oprea et al., 2020), an air pollution prediction system based on deep learning and a cooperative multi-robot system simulated in webots showing their potential to facilitate a better understanding of specific AI methods by students.

We have designed a methodology that allows educational knowledge modelling for a university course (e.g. Artificial Intelligence - AI). The main steps of the methodology are as follows:

Methodology for University Course Knowledge Modelling (AI)

Input: university course domain – Artificial Intelligence

Output: educational ontologies (Theory and Practice) and knowledge graphs

Algorithm:

1. **identify and define** the main basic concepts for the university course domain (i.e. basic Artificial Intelligence).

2. **identify and define** the main advanced concepts for the university course domain (i.e. advanced Artificial Intelligence).

3. **identify and define** the relations between the concepts that were derived in steps 1 and 2.

4. implement the ontology of the university course, **OntoEdu-UCD-Theory** by using the output from steps 1, 2, 3.

5. identify related domains and problems that can be solved by using methods from the theory of the university course.

6. design and implement a university course domain practice ontology (i.e. **OntoEdu-UCD-Practice**) by using different technological tools (e.g. mobile robotics or educational games such as chess, TIC-TAC-TOE).

7. validation of the two ontologies, OntoEdu-UCD-Practice and OntoEdu-UCD-Theory – querying and validation by teachers.

The methodology performs an incremental knowledge modelling, starting with basic concepts, followed by the identification of advanced concepts from the university course domain and the relations between the concepts that were derived, and integrate all concepts and relations in the ontology related to the theory of that course. Next, related domains and problems that can be solved with methods included in the theory of the course are identified and it is designed and implemented an ontology for the practice of that course. Finally, both ontologies are validated by teachers.

3. Educational robots for Artificial Intelligence teaching and learning

Mobile robotics can be used as an educational resource for teaching and learning Artificial Intelligence. Several types of mobile robots are proper for didactical activities as for example, Pioneer robots, Lego Mindstorms NXT robots, TurtleBot Burger, e-puck robots, webots robots, Robotino etc. The robots may be integrated in real world applications or in simulations. Various types of AI methods can be tested on robots as e.g. A^* strategy, BF strategy, rule-based systems etc.

Two type of knowledge is associated with each robot type: robot structural knowledge (i.e. the construction of the robot, its component elements: sensors, actuators, on-board computer, mechanical structure etc) and robot functionality knowledge (e.g. how can the robot function? how is the robot coordinated and controlled?). All knowledge related to each educational robot is integrated in the ontology related to the practice of the AI course.

Figure 1 shows a TurtleBot3 Burger robot that we are using at Petroleum-Gas University of Ploiesti. The robot has a Lidar sensor and uses Raspberry PI.

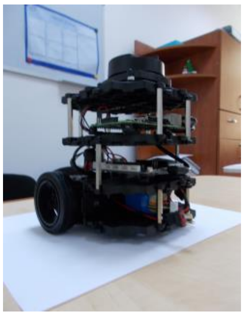

Figure 1. A TurtleBot3 Burger robot

In the case of Lego Mindstorms NXT robots, they are composed of various parts, starting with the main brick, continuing with the sensors and actuators, cables, servo motors and so on. Each educational robot needs to be correctly assembled in order to perform the tasks.

4. The ontology, OntoEdu-AI-Robots

The ontology was designd and implemented by following the methodology of developing OWL ontologies in Protégé (https://protege.stanford.edu) and the methodology described in section 2. The main textbook on which is based the developed ontology is (Russel and Norvig, 2020).

Figure 2 shows a part of the class hierarchy for basic AI.

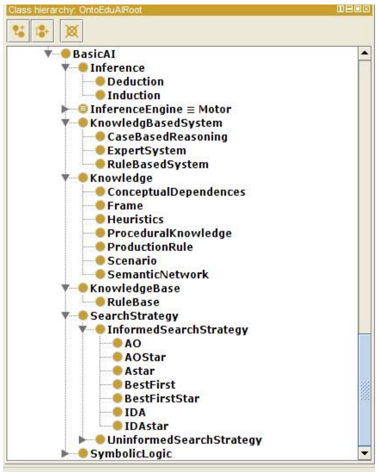

Figure 2. Part of the class hierarchy for BasicAI from OntoEdu-AI-Robots ontology

A number of 14 object properties were already included in the ontology. These properties are of type **part_of** and **has**. Several taxonomies were identified and implemented in the OntoEdu-AI-Robots ontology. Figure 3 shows a taxonomy for mobile robots, figure 4 shows a taxonomy for sensors, and figure 5 shows a taxonomy for informed search strategies.

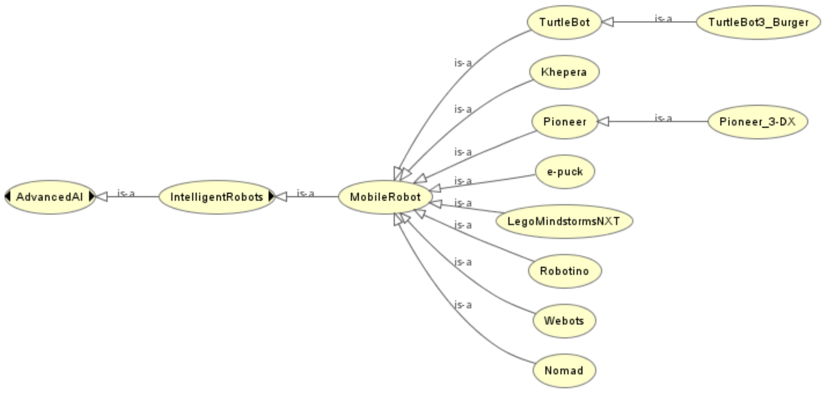

Figure 3. Taxonomy for mobile robots – OWL Viz

Figure 4. Taxonomy for robot sensors – OWL Viz

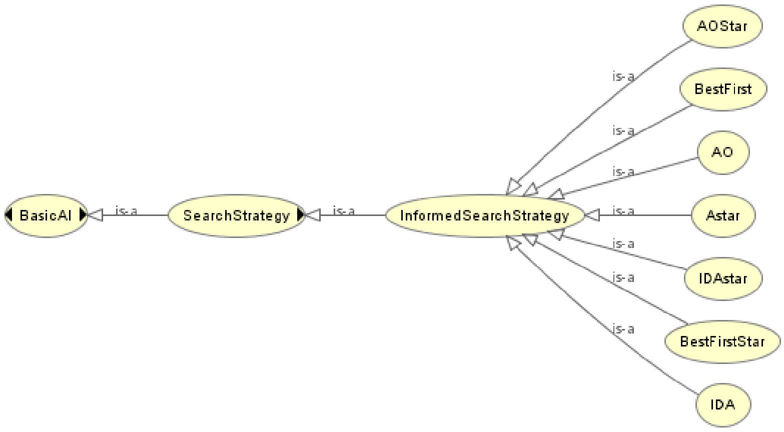

Figure 5. Taxonomy for informed search strategies – OWL Viz

When teaching the AI course based on mobile robots, it is important to explain the structure of the robot (as e.g. TurtleBot3 Burger) and the robot functioning scheme. Figure 6 shows a knowledge graph related to this topic.

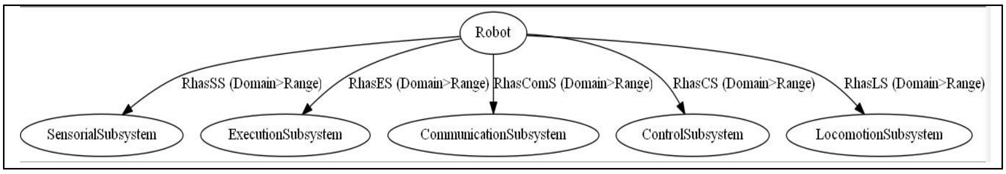

Figure 6. Mobile robot structure (knowledge graph) viewed with GraphViz

In particular, it is provided the knowledge graph related to Lego Mindstorms NXT robot sensorial subsystem as shown in Figure 7.

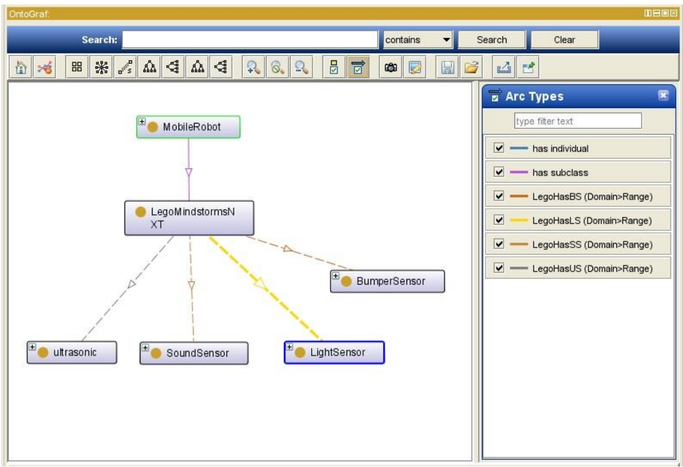

Figure 7. The sensorial subsystem of a Lego Mindstorms NXT robot (knowledge graph) viewed with OntoGraph

In Figure 7 some object properties are visualized, being coloured with a different colour (see the right part of Figure 7).

A part from the ontology hierarchy that includes advanced concepts of AI is shown in Figure 8. Machine learning, artificial neural networks and other AI methods are included in the hierarchy. For example, mobile navigation robot path planning can be realized with A* (Astar) strategy or with ACO.

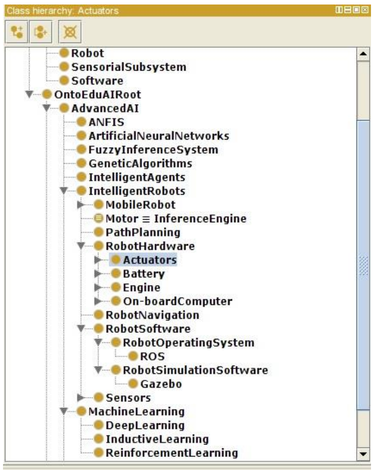

Figure 8. Class hierarchy for AdvancedAI concepts (in Protégé 4.3)

Another example of knowledge graph is given by the use of knowledge-based systems. Figure 9 shows the structure of a knowledge-based system that is composed of a knowledge base and an inference engine.

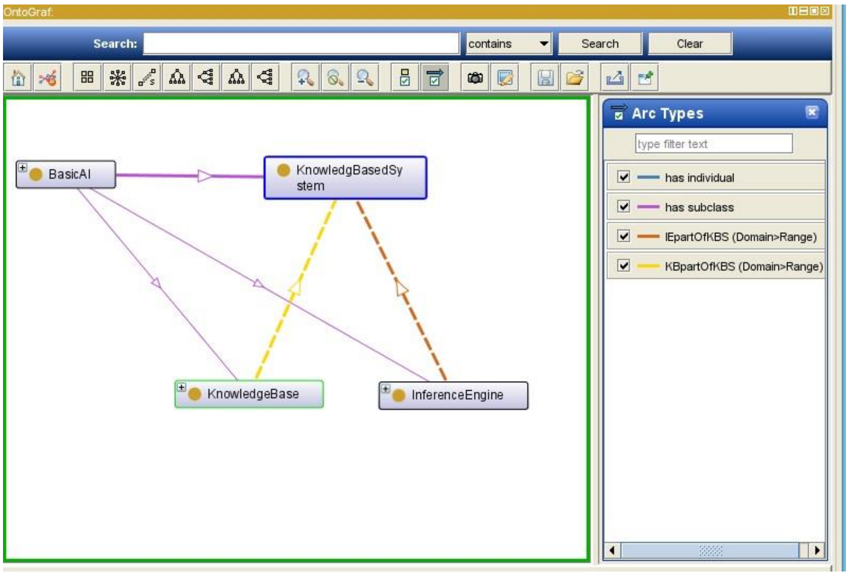

Figure 9. The structure of a knowledge-based system - viewed with OntoGraph

The quantitative evaluation of the ontology is given by some metrics. A part of the ontology metrics is shown in Figure 10. Thus, the ontology has 111 concepts (i.e. Protégé classes) and 14 object properties (i.e. relations between concepts).

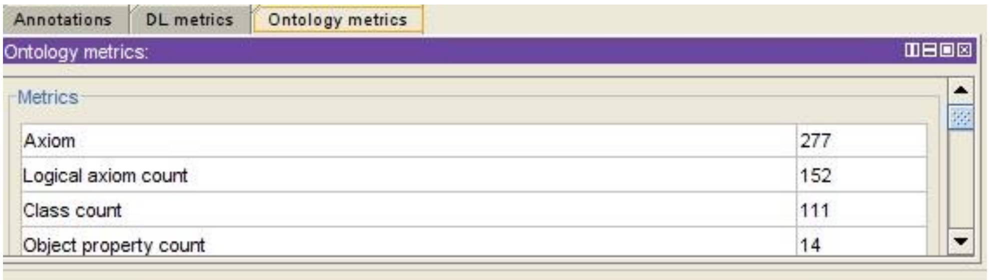

Figure 10. Ontology metrics (selection)

Each knowledge graph is derived from the ontology by using a certain visualization tool, as for example, OntoGraph, OWLViz or GraphViz. Students will access the knowledge graphs when learning AI methods (as e.g. knowledge-based systems, A* search strategy, ACO – an optimization method that can be applied to determine the optimal path of a mobile robot to a target position).

5. Conclusion

The paper presented a methodology for university course knowledge modelling with a focus on AI course that uses technological tools as for example, mobile robots to illustrate the use of AI methods. Also, it was designed and implemented in Protégé an OWL educational ontology for the AI course that includes applications of mobile robots.

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