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IRobot: Teaching the Basics of Artificial Intelligence in High Schools

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Abstract

Profound knowledge about Artificial Intelligence (AI) will become increasingly important for careers in science and engineering. Therefore an innovative educational project teaching fundamental concepts of AI at high school level will be presented in this paper. We developed an AI-course covering major topics (problem solving, search, planning, graphs, data structures, automata, agent systems, machine learning) which comprises both theoretical and hands-on components. A pilot project was conducted and empirically evaluated. Results of the evaluation show that the participating pupils have become familiar with those concepts and the various topics addressed. Results and lessons learned from this project form the basis for further projects in different schools which intend to integrate AI in future secondary science education.

Introduction and motivation

Artificial Intelligence (AI) has already become part of our everyday life (e.g. *intelligent household appliances, smartphones, Google, Siri, AI in computer games, ...*). Many of us know about the existence of services and devices based on AI, but hardly anybody knows about the technology behind them. Therefore it is of great importance to already familiarize young people in school with the technical background and the underlying concepts including algorithms, data structures and programming/coding. Like classic literacy which includes writing, reading and mathematics, literacy in AI/computer science will become a major issue in future. Furthermore, with AI literacy pupils also receive a solid preparation for subsequent studies at university level and their future career. Currently, computer science education in school does not focus on teaching these fundamental topics in an adequate manner. In order to overcome this shortcoming we developed a high school AI-course (called '*iRobot*') dealing with major topics of AI/computer science (automatons, agent systems, data structures, search algorithms, graphs, problem solving, planning, machine learning). The course was divided into seven weekly teaching units of two hours, comprising both theoretical and hands-on components. We conducted and evaluated a pilot project in a representative Austrian high school which integrates robotics in its regular curriculum (e.g. participating in robotics competitions, offering robotics electives etc.).

Teaching the fundamental concepts and techniques of AI at school level (independent of any platform or programming language) is quite rare. Many approaches focus on undergraduate/graduate students at university level (e.g. (Torrey 2012; McGovern, Tidwell, and Rushing 2011)) or on teacher training courses (e.g. (Dilger 2005)). Common approaches at school level like (Heinze, Haase, and Higgins 2010; Fok and Ong 1996) only deal with some selected aspects of AI (e.g. history, Turing Test, chat bots, neural networks etc.) or use limited tools or platforms to illustrate AI concepts (e.g. (Featherston et al. 2014)). In the following sections we will briefly describe the methodology (structure, content, teaching methods), the evaluation and results/conclusions of this pilot project.

Methodology

The project has been divided into seven weekly teaching units (two hours each, held by university researchers) comprising theoretical and hands-on components based on the principles of constructionism (Papert 1993). Nine pupils from grades 9-11 (average age 16.5 years; 1 female, 8 male; all with prior knowledge in robotics but none in AI) participated in these lessons as part of their robotics electives. According to the concept of constructionism (Alimisis 2009) pupils were actively involved in the learning process. Activities included e.g. paper-and-pencil or programming exercises, robot construction, discussions, group works and homework. Contents were adapted and set in context with pupils' prior knowledge in robotics (which they had acquired from participating in junior robotics competitions). The course was structured around the following major AI topics as dealt with in (Russell and Norvig 2009)):

Automata were addressed in the beginning of the course since they form a neutral basis for describing systems/behaviours and illustrate the decision making process in a basic way. One of the practical assignments dealt with representing the pupils' existing robots as a deterministic finite automaton.

Intelligent agents (simple reflex, model-based reflex, goal-based, utility-based agents) were introduced subsequently, providing a good context to pupils' prior robotics experiences. Agent models are valuable tools to demonstrate the modelling of making and executing decisions. Exercises included building Braitenberg vehicles using Lego Mindstorms NXT.

Graphs and data structures (stack, queue, trees) as well as the definition of a problem in the field of AI were addressed to create the basis for subsequent units dealing with problem solving/search. A practical assignment was to program a robot to explore a small labyrinth and to build the corresponding graph.

Problem solving by search was one of the main emphases of the course since it is a fundamental technique in computer science/AI with many areas of application (e.g. Constraint Satisfaction Problems (CSP), Satisfiability Problems (SAT solving), planning). Pupils were introduced to the breadth-first-, depth-first- and A*-search algorithm by discussing the theory behind, doing paper-and-pencil exercises in order to analyze each algorithm and by implementing the A* algorithm in C#.

Classic planning was addressed by introducing pupils to propositional and predicate-logic, state-space planning as well as forward and backward chaining. Among other group exercises pupils had to solve a planning problem (given initial-/goal-state and actions with pre-/post-condition). In order to simulate the 'computer's view' on this problem and to block out pupils' common sense the whole problem domain was masked (e.g. substituting the goal state *Have(Bananas)* as *Eahv(Nnaaabs)*).

Machine learning constituted the conclusion of the course. The focus was put on presenting and discussing different approaches to learning agents, e.g. logic-based learning, knowledge based systems, reinforcement learning, decision trees, neural networks.

Evaluation

The project evaluation was done using reliable qualitative and quantitative empirical research methods (Diekmann 2007). In terms of quantitative evaluation we applied a paper-and-pencil post-questionnaire (Likert-scale, open-ended questions) comprising a self-assessment of acquired skills as well as feedback on the structure and teaching method of the weekly teaching units. In terms of qualitative evaluation we conducted semi-structured interviews with all participating pupils using a set of predefined questions as guideline (Hove and Anda 2005). A content analysis (Neuendorf 2002) was performed after transcribing all recorded interviews. Further qualitative data was collected by using techniques of participant observation (field notes, discussions, taking pictures) during the weekly teaching units (Jorgensen 1989). All collected data were treated confidentially and anonymously.

Summarizing the evaluation results, the project succeeded in teaching high school pupils the foundations of AI. Pupils got a well founded understanding of those concepts and the growing importance of AI. They are now familiar with various topics addressed during the weekly teaching units and will benefit from the acquired content in future, e.g. when participating in robotics competitions, starting engineer or science studies at university. Questionnaire, interview guiding questions and data are available upon request.

Conclusion and future work

In this paper we presented an educational project teaching fundamental concepts of Artificial Intelligence (AI) and computer science at high school level (grades 9-11). We conducted and empirically evaluated a pilot project in a representative high school with nine voluntarily participating pupils in spring 2015. Weekly courses (theory and hands-on; held by university researchers) covered major AI topics. Contents were adapted and structured with respect to pupils' prior knowledge and educational background. Results indicated that pupils are confident about the various topics addressed during the teaching units. The first pilot project was successful, nevertheless there were some drawbacks and shortcomings to be dealt with in future. These were not enough teaching units, small sample of participating pupils, partly different expectations of pupils prior to the course and partly too extensive homework. Further analysis of gathered data is still ongoing and will be published on a later date, along with a detailed description of the course contents and structure. Results and lessons learned from the pilot project form the basis to adapt and improve the present AI course. We are planning to conduct the project in other high schools in the next few years, pursuing our long-term goal of integrating AI in regular science education in high schools and to foster 'AI literacy'.

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