Towards Building an AI Curriculum for High School Students

Maria Nisheva-Pavlova [1, 2]

[1] *Faculty of Mathematics and Informatics – Sofia University St. Kliment Ohridski, 5 James Bourchier Blvd., Sofia, 1164, Bulgaria*
[2] *Institute of Mathematics and Informatics – Bulgarian Academy of Sciences, 8 Acad. Georgi Bonchev Str., Sofia, 1113, Bulgaria*

Abstract

The paper discusses some issues in connection with the design of appropriate high school curricula, related to artificial intelligence. Further development and concretization of some previous results of the author on this topic are presented. A model curriculum of an artificial intelligence course has been proposed, which can play the role of an elective module for specialized training in informatics in high school.

Keywords

Artificial intelligence, high school education, problem solving, knowledge representation and reasoning, uncertainty, machine learning, neural network

1. Introduction

Over the last decade, there has been a particularly strong interest in AI and all AI-related activities and initiatives. In particular, the interest in appropriate inclusion of AI topics in education at all levels has significantly increased. And while there are long-established good practices and standards for higher education in AI, the issues of the gradual inclusion of AI topics at the level of secondary and high school education still do not have clear solutions.

The paper is a continuation of the author's research on the development of AI courses for secondary and high school [1], proposing a model curriculum for an Artificial Intelligence course for high school students.

2. Background and related work

This section discusses a number of strategic visions and common guidelines for the process of including various aspects of AI in school curricula. Some good

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EMAIL: marian@fmi.uni-sofia.bg (M. Nisheva-Pavlova)
ORCID: 0000-0002-9917-9535 (M. Nisheva-Pavlova)

practices of existing initiatives for design of AI courses, suitable for secondary and high school students, have been presented as well.

2.1. Strategic frameworks

The most comprehensive vision of the professional AI community for the process of including various aspects of AI in school and university curricula is the Beijing Consensus on Artificial Intelligence and Education [2] which sets out a number of common guidelines for this process. The most significant of them are based on some common principles such as: "take institutional actions to enhance AI literacy across all layers of society"; "develop local AI talent, in order to create a massive pool of local AI professionals who have the expertise to design, program and develop AI systems"; "be mindful of the importance of adopting principles of ethics-, privacy- and security-by-design"; "support the integration of AI skills into ICT competency frameworks".

The strategic documents at European and national level (e.g. [3], [4], and [5]) provide specific measures, the implementation of which would allow the education system in Bulgaria to develop the knowledge and skills needed for work in the field and AI, as well as for work in an AI environment. For the level of secondary and high school education, these measures are formulated quite generally and include [4, 5]:

- significant increase in the role of the so-called STEM (Science, Technology, Engineering, and Mathematics) disciplines and the disciplines related to the acquisition of digital competencies in school education;
- acquisition of digital skills specific to the creation and application of AI – both analytical and applied;
- increasing the competencies and culture of students in the field of ethical and legal issues related to the use of information technologies;
- focusing school education on the acquisition of four categories of skills and abilities: cross-sectoral cognitive skills; creative abilities; social and situational skills; precise abilities related to perception and handling.

The currently established Bulgarian state educational standards and curricula for specialized training in mathematics, informatics and information technology in secondary education[2] provide a good basis for further activities to implement the indicated measures.

2.2. Best practices

The largest and most popular program for inclusion of AI in school education is the AI for K-12 initiative (AI4K12)[3] which is aimed at developing guidelines

[2] https://mon.bg/upload/24016/ndrb-PP-izm092020.pdf

[3] https://ai4k12.org

for integration of AI in 12-year school education. The AI4K12 guidelines are organized in so-called grade band progression charts that include separate K-2, 3-5, 6-8, and 9-12 grade bands. The educational content is still under development. It is organized in thematic units, grouped around "the five big ideas of AI" (see Figure 1):

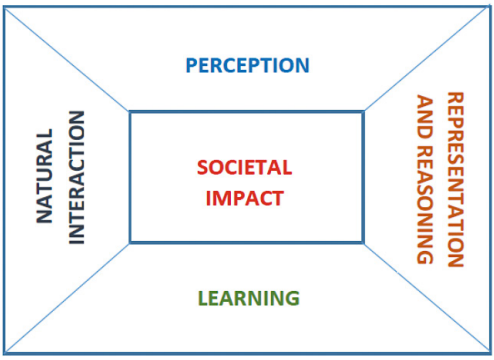

Figure 1: The "Five Big Ideas of AI" (adapted from [6])

- Perception ("Making computers "see" and "hear" well enough for practical use is one of the most significant achievements of AI to date"),
- Representation and reasoning ("Agents maintain representations of the world and use them for reasoning. Representation is one of the fundamental problems of intelligence, both natural and artificial"),
- Learning ("Computers can learn from data. … Many areas of AI have progressed significantly in recent years thanks to learning algorithms that create new representations"),
- Natural interaction ("Intelligent agents require many kinds of knowledge to interact naturally with humans. Agents must be able to converse in human languages, recognize facial expressions and emotions, and … infer intentions from observed behavior"),
- Societal impact ("AI can impact society in both positive and negative ways").

The educational resources developed and/or available under the AI4K12 initiative[4] include a wide variety of books (see Figure 2), book chapters, curriculum materials, videos, online courses, tutorials, demos, software packages, competitions.

[4] https://ai4k12.org/resources/list-of-resources

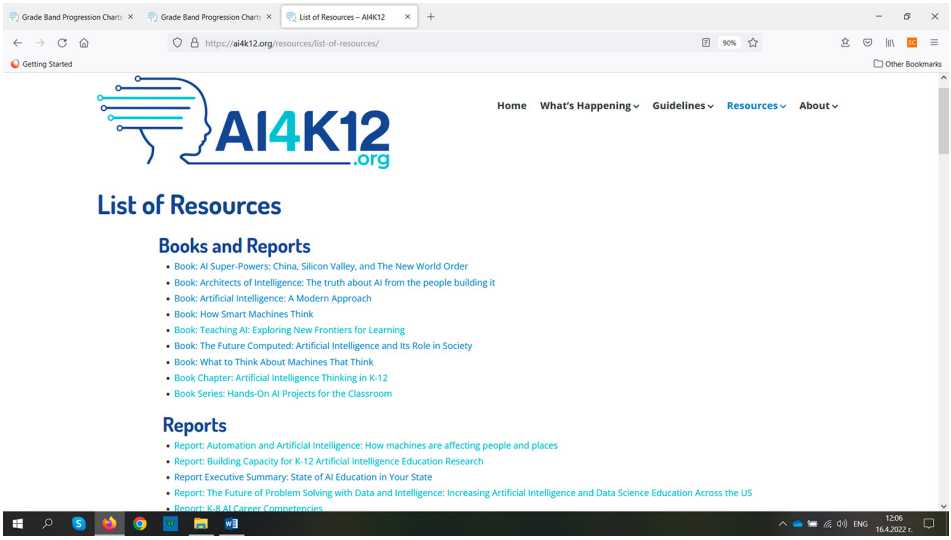

Figure 2: Educational resources available under the AI4K12 initiative

Along with AI courses specifically designed for secondary and high school, there exist more than 200 massive open online courses (MOOCs) in AI and related areas and some of them have content and volume, suitable for high school students. One of the best MOOCs in the world is the Finnish 'Elements of AI' course[5], whose basic version in English consists of two parts: 'Introduction to AI'[6] and 'Building AI'[7].

The presentation of the first part is oriented to users who have no mathematical or computing background and is illustrated by examples in relevant areas of interest to people of different ages and professions. It consists of six chapters, each of them divided into three sections: What is AI (How should we define AI, Related fields, Philosophy of AI); AI problem solving (Search and problem solving, Solving problems with AI, Search and games); Real world AI (Odds and probability, The Bayes rule, Naïve Bayes classification); Machine learning (The types of machine learning, The nearest neighbor classifier, Regression); Neural networks (Neural network basics, How neural networks are built, Advanced neural network techniques); Implications (About predicting the future, The societal implications of AI, Summary).

The second part of the 'Elements of AI' course – 'Building AI', addresses the same topics as 'Introduction to AI', but is oriented to a more technically compe-

[5] https://www.elementsofai.com

[6] https://course.elementsofai.com

[7] https://buildingai.elementsofai.com

tent audience and allows to go into more depth in the basic methods of AI. As we concluded in [1], "it is suitable for high school students with a mathematics or natural sciences or technology profile, but its content is available to most students aged at least 15–16".

3. Model curriculum project

According to the conclusions and recommendations we formulated in our previous work [1], the model curriculum is based on an appropriate combination of the two parts of the 'Elements of AI' course, extended with a unit on Knowledge representation and reasoning. Some additional topics in the areas of Dealing with uncertain data and knowledge and Machine learning are also included. The areas of Planning, Natural language processing, Perception and Robotics remained uncovered due to fears of excessive volume of the curriculum, but it is appropriate that they be indirectly addressed in conducting specific trainings with well-thought-out illustrative examples and topics for homework and small projects.

Figure 3 shows the structure of the curriculum and the main topics covered by it. The learning content is structured in seven units: Introduction; AI and problem solving; Knowledge representation and reasoning; Dealing with uncertain data and knowledge; Machine learning; Neural networks; Implications and future of AI.

Part 1. Introduction: What is AI?
1.1. How should we define AI?
1.2. Related fields
1.3. Philosophy of AI

Part 2. AI and problem solving
2.1. Search and planning
Solving problems by searching; uninformed search; planning in AI
2.2. Heuristic search
Heuristic functions; informed search strategies; greedy best-first search; A* search; hill climbing
2.3. Game playing
The minimax algorithm; alpha-beta pruning

Part 3. Knowledge representation and reasoning
3.1. Key concepts. Knowledge engineering
Key terminology; knowledge representation and reasoning; building a knowledge base; properties of good knowledge bases
3.2. Rule-based knowledge representation and reasoning
Production rule systems; type of reasoning in rule-based systems; rule-based expert systems
3.3. Object-oriented knowledge representation and reasoning
Objects and frames; a basic frame formalism; example of using frames

Part 4. Dealing with uncertain data and knowledge
4.1. Probability for knowledge-based systems
Probability fundamentals; Monte Carlo method; use of conditional probability in making inferences
4.2. The Bayes rule in knowledge-based systems
The Bayes rule; real-world examples of application of the Bayes rule for probability calculation
4.3. Naïve Bayes classifiers
What does a Naïve Bayes classifier do; real-world examples of application of Naïve Bayes classifiers

Part 5. Machine learning
5.1. Definition and types of machine learning
Key terminology; supervised learning; unsupervised learning; reinforcement learning
5.2. Classification. NN and *k*-NN classification
Terminology; vector distances; nearest neighbor; k nearest neighbors
5.3. Regression. Linear regression
Terminology; definition and examples of linear regression; use of linear regression to make predictions
5.3. Text classification
Basics of working with text via NLP; bags of words; TF-IDF
5.4. Overfitting
Key terminology; risks of overfitting
5.5. Clustering. The *k*-means method
Terminology; centroid-based clustering and the k-means method; hierarchical clustering

Part 6. Neural networks
6.1. Neural network basics. Popular neural network models
Notation; simple computing elements; network structures; perceptrons
6.2. Logistic regression. From logistic regression to neural networks
Terminology; difference between linear regression and logistic regression; sigmoid functions and logistic regression
6.3. Deep learning
Multilayer feed-forward networks; convolutional neural networks; recurrent neural networks and transformers

Part 7. Implications and future of AI
7.1. Modern AI. The societal implications of AI
7.2. The hype cycle for AI. Main trends driving near-term AI innovation
7.3. Legal and ethical aspects of AI

Figure 3: Model curriculum – main topics covered

The planning and conducting of Bulgarian language courses based on this model curriculum requires the creation of a lot of teaching and training materials in Bulgarian, consistent with the age, background knowledge and life experience of students. In our opinion, these materials can be based on a proper adaptation of the Bulgarian version of the 'Elements of AI' course in combination with some textbooks in Bulgarian, issued at different times (such as [7] and [8]). Reduced and properly simplified Bulgarian versions of Part II and Part III of [9], enriched with appropriate examples, could be developed and used for the purpose. Some of the publicly available resources created and/or accumulated within the AI4K12 initiative (such as the online courses and demos for K-12 students as well as the handouts for AI projects in the classroom [10]) could also be adapted and used.

4. Conclusion

The analysis of the proposed model curriculum shows that it would be comprehensible and suitable in scope and content in terms of its applicability for various educational purposes, including as an elective module for specialized training in Informatics in high schools. It corresponds sufficiently to the "Five Big Ideas of AI" and allows easy expansion in order to cover other areas of AI, in particular the only relatively underrepresented "big idea" of perception.

Appropriate support with teaching materials in Bulgarian and illustrative examples suitable for the age, life experience and interests of high school students would make it applicable for various purposes in Bulgarian schools, as well as in extracurricular activities with distinguished students.

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