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AN APPROACH TO TEACHING ARTIFICIAL INTELLIGENCE IN SCHOOL

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Abstract: *New realities in the digital age determine the comprehensive and rapid penetration of artificial intelligence in all areas of contemporary life. The article motivates the need to introduce the discipline "Artificial Intelligence" in high school and proposes an approach to the practical realization of this training. The possibility for development of a possible curriculum, selection and structuring of appropriate educational content, classification and creation of a package of learning tasks on the separate topics and sections in the curriculum are discussed. Opportunities are offered for the implementation of links with other school subjects, as well as with the everyday life of students.*
In the last two years, AI has been studied in various forms by more than 200 students from several experimental schools. The interest and motivation of students is constantly growing. Based on the experience gained and the results obtained, we can say that the discipline of AI can be successfully introduced in different degree, in different forms and in different volumes in the school education in Bulgaria.

Keywords: Artificial Intelligence (AI), Logic Programming, School Education.

INTRODUCTION

We are experiencing the beginning of a revolution that radically changes the way we live, work and interact. In its scale, scope and complexity, what we call the "Fourth Industrial Revolution" has no analogue in our history so far (Schwab, 2016). Artificial intelligence (AI) is now all around us – from self-driving cars and drones, intelligent agriculture, "smart" houses and cities (Chamoso, 2018) to virtual assistants, in-

telligent healthcare (Komninos, 2006) and so on. All this determines the need to train a wide range of IT professionals who in the near future must successfully manage all these processes. To achieve this goal, training in AI must begin at school.

The article presents an approach to conducting training in the subject "Artificial Intelligence" in secondary school, considering the following several aspects: creating an appropriate curriculum; structuring the learning content, according to the school methodology; providing interdisciplinary links with other school subjects; creating a system of learning tasks for the individual basic topics of classical AI, related to both the basic algorithms for solving problems through search and the presentation of knowledge through rules. The authors will share their experience in the study of AI and will present some opportunities to increase the effectiveness of training. The rest of the article is organized as follows: Section 1 provides a brief overview of research in this area. Section 2 discusses our approach to AI education in secondary school. Section 3 presents the possibility for classification and structuring of learning tasks, and in Section 4 the authors share their experience from conducting this training. Finally, section 5 presents the final concluions.

1. RELATED WORKS

Early in the digital age, the possibilities for AI training were discussed in (Jones, 1985), noting the crucial importance of this training.

Learning AI in school is a challenge, as the basic concepts and algorithms are too abstract and difficult to learn due to the lack of enough knowledge of students in school. In addition, teachers are not sufficiently prepared for this challenge. In the course of their university education in pedagogical specialties, they either did not study this discipline at all or have only a vague idea.

In Fahimirad (2018), the educational consequences of digital technologies on learning and teaching opportunities are discussed. According to authors of this article the main goal is to anticipate the role of AI in the future nature of education worldwide. The problems of the integration of AI in the various educational institutions are also considered and the challenges in the learning of AI in terms of training and teaching are discussed. An overview of the application of AI training and its use in special education is discussed by Drigas (2013).

Nevertheless, modern realities place an urgent need to start teaching AI in high school. The White Paper on the Artificial Intelligence of the European Community sets out the main directions in its development. According to the document, more than 20 billion euros will be raised each year under the Digital Europe, Horizon Europe and European Structural and Investment Funds programs. In addition, priority is given to developing the skills needed to work in the field of AI and to adapt the education systems of individual European countries.

Despite the demands and expectations of the digital society, the experience in studying AI in school level education worldwide is insufficient. This motivates us to offer an approach and to share our experience in implementing such training in Bulgarian high school (Glushkova, 2019).

2. OUR APPROACH TO AI EDUCATION IN HIGH SCHOOL

One of the main challenges in the development of the curriculum is its presentation in an abbreviated but correct form, so that on the one hand students get a more complete picture of the multidisciplinary field of AI, while on the other hand they are able to master the basic concepts and methods using algorithmic pseudocode, demonstration examples and practical tasks. A serious challenge is the transformation of the abstract and multi-layered content of classical and modern AI into a form accessible to students, without losing the authenticity and correctness of the teaching material. Perhaps the most important step in this process is the design of the curriculum. For this purpose, we have formulated the general philosophy, which is based on the following two possibilities:

- "Lighter" option – to look for a creative and entertaining presentation of the learning material, for example, in the form of a game.
- "More serious" option – a systematic and in-depth study of the basics of the discipline with a certain degree of formalization.

Both options have disadvantages and advantages. The second option is associated with more risks related to both the insufficient basic training of students and the need for additional specialized qualification of teachers. Despite the difficulties, we chose the second option, as we want to present more fully and in considerable depth the considered algorithms and concepts of classical AI. To make it easier for students, we try to include a variety of practical tasks, additional rubrics, such as interesting facts, short biographies of the creators of AI, etc., which will ultimately make the learning material more attractive. We will consider our approach in several aspects: creating a curriculum, developing and structuring the learning content, links with other school subjects and creating a system of examples and learning tasks.

2.1. Curriculum development

The AI curriculum developed by us and approved by the Ministry of Education and Science of Bulgaria is basic and is intended for training high school students in secondary schools as well as in some vocational colleges. The curriculum is structured in four sections and includes twenty selected topics. Each school, according to its specifics, the form of education, the type of classes, etc., determines the topics that will be dropped and the topics that can be expanded and supplemented.

The main goal of the training is to acquire knowledge, skills and competencies related to the basics of AI. To achieve this goal, it is necessary to fulfill the following:

- acquire knowledge about the subject and tasks of AI and its role in the Industry 4.0;
- acquire the knowledge of the agent-oriented paradigm and agent architectures;
- acquire knowledge and skills for solving problems through searching;
- acquaint with the opportunities for knowledge presentation and semantic modeling;
- acquire knowledge and skills for modern trends in the development of AI, such as the „Internet of Things", intelligent agents, machine learning, cognitive robotics, etc .;
- acquire skills for independent solving of specific tasks and problems.

The structure and the main topics of the developed curriculum are presented in Table 1.

Table 1

Structure and main topics in AI curriculum

Sections & Topics
Section 1: Introduction to Artificial Intelligence (AI)
1. Definition of AI. Origin and history.
2. Modern AI. 4th technological revolution (Industry 4.0). The relationship between AI and Industry 4.0
3. Agent-oriented paradigm. Agent architectures
Section 2: Solve problems through search
4. An overview of search problem solving methods. Complete search methods.
5. Exponential explosion. Concept of heuristics. Heuristic search methods. Algorithm A *.
6. Local search methods. Climber's method. Evolutionary strategies
7. Constraint Satisfaction Problems
8. Search in competitive spaces. Game spaces.
Section 3: Knowledge and semantic modeling
9. The concept of knowledge. Classification. Presentation of knowledge..
10. Presentation of knowledge through logical rules.
11. Semantic models. Classification. Semantic networks.
12. The concept of ontology. Ontological engineering.
Section 4: Selected topics from modern AI
13. Intelligent agents. General definition. Mental properties. Rational BDI agents.
14. Intelligent user interfaces. Personal assistants. Motivation and use.
15. Internet of Things (IoT). Basic concepts. Applications.
16. General architecture. Building IoT applications.
17. Machine learning. Definitions. Classifications. Approaches.
18. Selected methods for machine learning.
19. Cognitive robotics. Types of work. Architecture.
20. Cognitive robotics. Robot programming.

S o u r c e: Own work.

2.2. An approach to learning content development

The approach to the development of the learning content can be presented as a sequence of the following steps:

1. Structuring the learning content.
2. Creating a template (standard) of individual topics.
3. Consistent transformation of individual topics.
4. Completion of the main content with additional sections, such as additional knowledge, short biographies of the classics in the field of AI, interesting facts, practical tasks, etc.

The structuring of learning knowledge within a specific template is especially important for greater clarity and easier perception by students. We use two different templates to present new knowledge. In the first of them, we initially introduce informally descriptively the new knowledge, formally define the new concepts and present the algorithms textually or as a pseudocode. Then we present a typical example by discussing the application of the acquired knowledge in the specific situation. We offer assignments for independent work with gradually increasing difficulty. If necessary, additional knowledge is offered in the topic. A glossary of terms entered is available

at the end of the topic. Each topic is accompanied by additional assignments, through which the students can work individually or in groups at the beginning of the next lesson. The curious facts related to the development of various fields in AI, as well as those related to scientists, bibliographic films, key achievements, etc. provide an opportunity to increase the activity, motivation and curiosity of students.
The second option for presenting the learning content is related to the introduction of a specific motivating example, which cannot be solved with the knowledge gained so far. By provoking the activity of students and their desire to experiment and make specific assumptions, the new learning content is motivated. The new concepts and rules are defined, and when they are related to a new algorithm, it is described by formal means. A good approach is to use a certain programming language through which students can directly check the correctness of their assumptions and conclusions.
As can be seen from the presented structure, our desire is to introduce the difficult and abstract learning content by decomposing individual small meaningful parts and to provide more practical examples, entertaining and interesting challenges for individual and group work. Formalizing basic algorithms using pseudocode is another challenge for authors. Because students already know that algorithms can be represented in different ways (verbal, graphical, formal), we have adopted the approach of using pseudocode, supplemented and extended with more descriptions, comments and clarifications.

2.3. Using of knowledge from other school subjects

AI is an interdisciplinary field, the basics and terminology of which can be found in various theories and concepts of philosophy, modeling, mathematics, linguistics, economics, psychology, sociology. The aim of the authors is to provide abstract and difficult concepts of AI both through relations with the common knowledge and interests of students and with other school subjects.
The connection of AI with mathematics is on many levels. Since much of the required knowledge is not fully studied in the school mathematics course, the authors briefly introduce this additional knowledge. For example, for modeling a state space, it is necessary to introduce additional knowledge of graph theory; in the presentation of knowledge through rules, the basic operations and laws of classical and predicate logic are introduced; in determining the complexity of a particular algorithm, knowledge of mathematical analysis is introduced. Probability theory, statistics, etc. are also widely used.
The relationship of AI with informatics and programming is natural. Initially, by presenting the algorithms in pseudocode as well as later by implementing them in different programming languages, knowledge of both recursion and basic algorithms and data structures is required. In the training in the field of „Presentation of knowledge through logical rules“ it is proposed to use a declarative style of programming through the language Prolog. Training in computer science in the school course through C ++, C # or Java can be especially important in the implementation of practical tasks such as robot programming, game development, and the creation of intelligent agents, etc.
The using of knowledge in biology, geography and physics are also very important in understanding AI. For example, evolutionary strategy and genetic algorithms are directly inspired by Darwin‘s theory in biology. The coloring in several colors of the neigh-

boring administrative districts is a typical example of „constraint problems“. The various methods of searching for routes in a road map stimulate students to use their active knowledge of geography, and the knowledge of mountain terrains is used mainly in clarifying the „climber‘s method“, etc. Programming robots, their movement and interaction in the real world requires in-depth knowledge of physical laws and mechanics. Students’ natural desire to play can be used both in examples of many search algorithms and, in particular, in the topic „Searching in competitive spaces or games”. Games „8-puzzle”, cards, „Eight Queens”, „Chess”, „Go” and many others are an excellent, well-known basis for introducing theoretical material.

The authors believe that the introduction and use of not yet studied additional material in various school disciplines is not a problem. Motivating the need for this knowledge can increase students‘ curiosity and activity. Conducting independent research and seeking additional information is also a goal of the training.

3. CLASSIFICATION AND STRUCTURING OF LEARNING TASKS

Table 2

Classification of learning tasks

Topic in AI	Methods and Algorithms	Main Tasks
Search in the status space (SS). Complete methods.	Route planning by SS expanding	Planning the route from home to school
	Tree-Search algorithm	Movement of a robot in a square grid
	Graph-Search algorithm	The "commercial traveler" task
	Search at equal cost	Search for a route between two cities with minimal costs
Heuristic search	„Greedy Search“ algorithm	Generate a route with a given air distance between cities.
	Algorithm A*	With the least coins you can return a balance of X cents
		Finding the optimal route between two cities.
Local search	The "climber" method	The task “Eight Queens”
Evolut. strategies	Genetic Algorithms	The "Eight Queens" task through a fitness function
Constraint Problems	Algorithms for solving constraint problems	Coloring of the folklore areas in Bulgaria with a minimum number of different neighboring colors
Competitive spaces. Games.	Search in competitive spaces.	Competitive game for two players.
	Min-Max algorithm	Assessment of a specific position in chess
	Alpha-beta search	Score a position in a card game.
Knowledge processing with logical rules.	General knowledge. Facts, rules and goals	Presentation and processing of knowledge from history, literature, geography, etc.
	Variables and logical operations.	Family relationships
	Unification. Backtracking.	Tasks similar to Einstein's problem
	Recursion	The game for the Towers of Hanoi, Calculate n!
Logical conclusions	Search tasks.Stack, queue, combinatorial tasks	Tasks,similar of the "Farmer and wolf " problem
		Route to the Black Sea
Semantic modeling	Ontological modeling	Bulgarian writers, Remarkable personalities
Application of AI	Applied tasks and games	A task for children-talents

Source: Own work.

The main goal of the training is for students to acquire knowledge, skills and competencies related to the theoretical foundations and opportunities for practical appli-

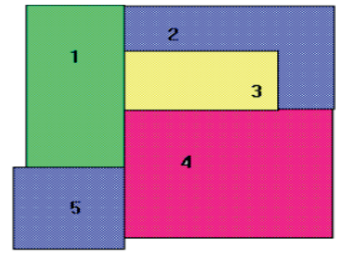
cations of AI. For the successful mastering of new knowledge it is of special importance the selection of appropriate learning tasks that motivate the introduced knowledg and are related to the daily activities of the students.

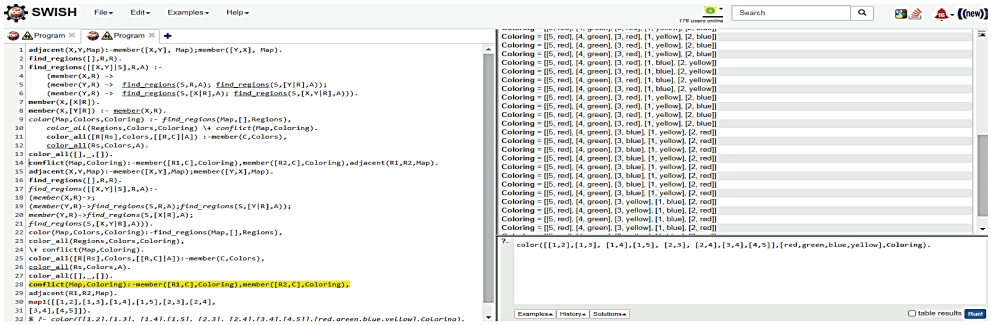
For the purposes of AI training, we believe that the use of logic programming languages is appropriate. Prolog is specially developed for AI applications. It is a declarative language and in order to solve a problem, it must be described correctly as rules and facts. Prolog interpreter derives the conclusion using different inference rules and logical laws. Prolog is extremely useful for solving problems in AI in topics related to searching, planning and presenting knowledge.

The authors have developed and propose a classification of the learning tasks on the main topics of the curriculum (Table 2).

For example, when mastering the algorithm „Constraint Problems“, which is inherently quite abstract, we solve the following problem: “To color adjacent plain areas with a minimum number of colors, with no two adjacent areas of the same color”. In Prolog, one solution is presented in Figure 1.

```
adjacent(1,2).      adjacent(2,1).          // neighborhood description
color(1,red,a).     color(1,red,b).
color(2,blue,a).    color(2,blue,b).        // Presentation of the colors of the areas through facts
conflict(Coloring):-                        // Conflict rule
adjacent(X,Y),
color(X,Color,Coloring), color(Y,Color,Coloring).
adjacent(1,2).  adjacent(2,1).  adjacent(1,3).  adjacent(3,1).
adjacent(1,4).  adjacent(4,1).  adjacent(1,5).  adjacent(5,1).
adjacent(2,3).  adjacent(3,2).  adjacent(2,4).  adjacent(4,2).
adjacent(3,4).  adjacent(4,3).  adjacent (4,5).  adjacent(5,4).
color(1,red,a).  color(1,red,b).  color(2,blue,a).  color(2,blue,b).
color(3,green,a).   color(3,green,b).     color(4,yellow,a).
color(4,blue,b).    color(5,blue,a).      color(5,green,b).
conflict(Coloring):-  adjacent(X,Y),  color(X,Color,Coloring),
color(Y,Color,Coloring).
conflict(R1,R2,Coloring):-adjacent(R1,R2),color(R1,Color,Coloring),  color(R2,Color,Coloring).
```





F i g u r e 1. Programming and solving the search problem by Prolog Interpreter

S o u r c e: Own work.

Another task for studying problem-solving algorithms by searching and application of AI is the task for children-talents: „In one family there are 5 siblings, on 4, 5, 6, 7 and 8 years old, respectively, who have different talents. One child‘s name is Nevena,

and another child plays the piano. Ivanka is 4 years old and does not understand mathematics. The child who is a programmer is one year older than Ivan. The child who plays the guitar is 7 years old. The girl Joanna is not 8 years old. Stanko is 5 years old and he is younger than the child who loves literature. How old is every child and what is his/her talent?". One possible Prolog – solution is presented in Figure 2:

F i g u r e 2. Solving the task by Prolog Interpreter

S o u r c e: Own work.

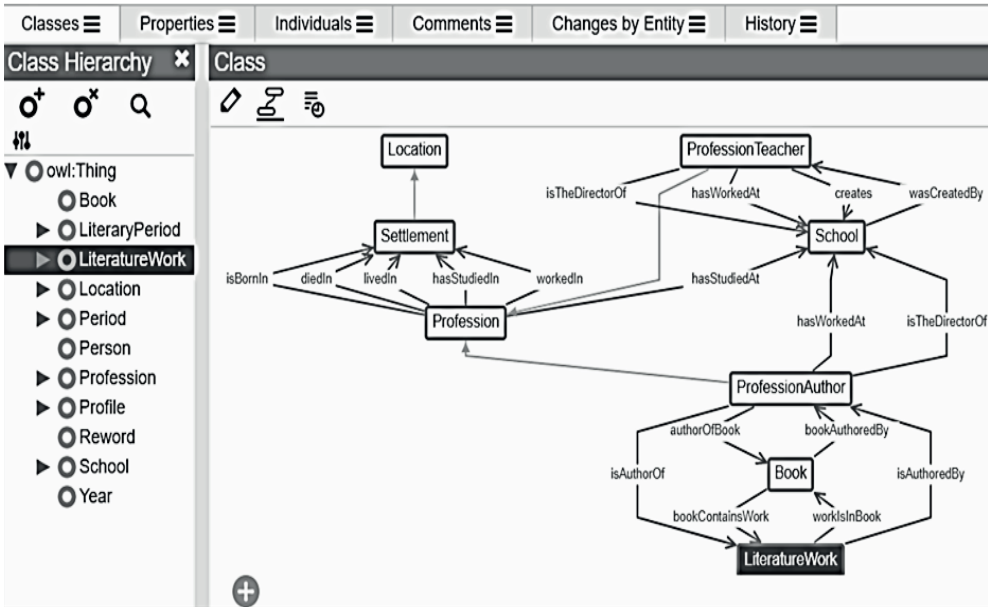
Cross school subjects links are very important in school education. For example, on the topic „Facts, rules and goals " we can look at problems with family relationships by making interdisciplinary connections with literature and history. We clarify the way of setting facts and the correct description of predicates through the surnames of Elin Pelin's novel „The Geraks", the historical novel „The Iron Candlestick" by Dimitar Talev; we build family trees of bulgarian national hero Vasil Levski and the king Krum dynasty, etc.

```
arc('Sofia','Klisura',237). /*Database with distances between cities*/
arc('Sofia ','Ihtiman',53). arc('Klisura','Karlovo',33). arc('Karlovo','Kazanlak',55).
arc('Kazanlak','StaraZagora',37). arc('StaraZagora','Plovdiv',102).
arc('Ihtiman','Pazardjik',59). arc('Pazardjik','Plovdiv',50).
h(Path,Goal,H).      /*use algoritm Best-First Search*/
([Node|Path]Goal,H) :- stright_line_distance(Node,Goal,H).
best_first([[Goal|Path]|_],Goal,FinalPath):- reverse([Goal|Path],FinalPath).
best_first([Path|List],Goal,FinalPath):-extend(Path,NewPaths),  append(List,NewPaths,NewList),
    sort(NewList,Goal,SortedList),  best_first(SortedList,Goal,FinalPath).
extend([Node|Path],NewPaths) :-
    findall([NewNode,Node|Path],(arc(Node,NewNode,_),not(member(NewNode,[Node|Path]))),  NewPaths).
reverse([],[]).
reverse([X|Rest],List):- reverse(Rest,NewRest), append(NewRest,[X],List).sort([],Goal,[]).
sort(List,Goal,[MinPath|SortedList]):- min(List,Goal,MinPath,NewList), sort(NewList,Goal, SortedList).
min([Path1|List],Goal,Path2,[Path1|NewList]):- min(List,Goal,Path2,NewList),
    h(Path1,Goal,H1), h(Path2,Goal,H2), H2<H1,!.
min([Path|List],Goal,Path,List).
/* Query is:?- best_first([['София']],'Смара Загора',Path)*/
```

F i g u r e 3. Solving task for searching a route

S o u r c e: Own work.

The connection with biology education are tasks and games such as „Guess the animal“, and for connection with geography can be used tasks to find a route between two cities in Bulgaria. Finding such a route can be presented as a problem and can be programmed on Prolog (Figure 3).
In training on topics related to environments for semantic modeling through ontologies, one can also consider tasks related to writers, the works written by them, genres, plots, as well as various relations such as birthplace, facts from the biography, etc. (Figure 4). The free program environment Protégé of Stanford University can be use for the training (https://protege.stanford.edu).



F i g u r e 4. Creating an ontology for Bulgarian writers in the Protege
S o u r c e: Own work.

4. OUR EXPERIENCE: RESULTS

The experience we have in working with students in secondary schools in the last two years shows that this discipline can be studied both as a compulsory subject in innovative classes (eg Math High School – Plovdiv) and as an elective subject in interest clubs in different types of schools and vocational high schools (Secondary school in Brezovo, Vocational High School of Electronics and Electrical Engineering, etc.). While these schools have professional or specialized training in the field of computer science, it is interesting to try to create a club of interests in the humanities classes. In the Humanitarian High School in Plovdiv, a club was established under the project “Education for tomorrow”. The adapted curriculum includes certain introductory topics. In order to enter this new and atypical for them matter, the students got acquainted with the concept of „problem“, defined by the initial state, purpose, goal,

possible operators, model of transitions and function of costs. Numerous diagrams, images, specific situations and examples are used to visualize and illustrate the set goal. We decided to find out to what extent the methods known as „search methods" can be understood and applied by students with humanitarian interests. In order to more fully master the different ways of searching, it was necessary to introduce a set of new concepts. When choosing the learning tasks, we were guided by the understanding that they must be in accordance with the interests of students and be related to their familiar everyday life. For example, as an introductory example in the rather abstract algorithm „Tree search" we used the profiled classes and profiled school subjects in every of them in the high school.

In the last two years, AI has been studied in various forms by more than 200 students from several experimental schools, classes and clubs. The interest and motivation of students is constantly growing. As a result, the average success of the training is within the limits of the excellent grade. Based on the experience gained and the results obtained, we can say that the discipline of AI can be successfully introduced in different degree, in different forms and in different volumes in the school education.

CONCLUSION

Based on the approved curriculum in the last two years, the authors create textbooks and teaching aids in which the approach shared in the article is applied in practice (Stoyanov, 2019).

The proposed curriculum and the developed teaching resources can be used for training of students from the mathematical high schools in Bulgaria, as well as of students from different professional, profiled or innovative classes. In addition, it can also be used by students in various specialties to understand the fundamental concepts of AI. The proposed classification of basic tasks related to the teaching of AI in secondary schools is exemplary and in development. Choosing appropriate learning tasks can help in understanding and presenting abstract and theoretical knowledge. The use of the declarative style of the Prolog logic programming language enables the presentation of the problems in a clear and understandable way and promotes the development of the logical, algorithmic and abstract thinking of the students. The combination of Prolog and Java programming languages provides the basis on which students can program the knowledge base and goals of intelligent agents. This is one of the main tasks in the development of multi-agent intelligent systems needed to create „smart" homes and cities, „smart" health and agriculture, education, etc.

Our plans are to complete the process of creating textbooks and manuals with learning tasks while expanding the range of schools in different regions and cities in Bulgaria. The history of the development of human civilization – starting from the agrarian, and then the first, second and third industrial revolutions –has nowadays reached the fourth industrial revolution, in which the turning points contain the main characteristics of AI (Geng, 2018; Russel, 2016). With this course, we hope that the students will form the belief that in AI there are many more tasks that need a solution, as well as call forfuture researchers.

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