AI Educational System for Primary and Secondary Schools

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Abstract: this paper presents an AI education system and related AI curricula specifically designed for primary and secondary students at different cognitive levels. In this system, complicated AI algorithms are encapsulated and modularized with friendly and easy-to-use interfaces. AI curricula are developed based on constructivism, project-based learning and multidisciplinary integration. Typical teaching cases, such as speech recognition, text recognition, image recognition, intelligent transportation, smart home, intelligent robots, etc., which are used to enhance comprehension of AI concepts and applications, are also discussed.

Keywords : AI Education, Innovation Capability, Constructivism, iSTREAM

1. Introduction

The radical and transformative technological revolution of artificial intelligence (AI) has resulted in fundamentally new ways of science and engineering practice. Countries around the world have released national strategies to promote the development and use of AI. For instance, on Mar. 1st, 2018, the Center for Strategic and International Studies (CSIS) released “A National Machine Intelligence Strategy for the United States” [1]. Other countries, such as Britain, Germany, France,Japan, Korea, Singapore, and Canada have also issued strategies on various aspects of AI policy.

This paradigm shift has a significant impact on skills needed for a diverse science and engineering workforce that is capable of designing and deploying AI-based systems, tools and services. However, our education has not kept pace with this evolution, especially at K-12 level. In fact, there is a crucial need to bring AI learning experiences into classrooms of primary and secondary education. As suggestedbyState Council in its recently released “New Generation Artificial Intelligence Development Plan”[2], we should “gradually carry out national intelligent education projects, set up AI courses in primary and secondary schools, gradually promote programming education, build AI disciplines and cultivate AI talents”.

Therefore, it is necessary and urgent to set up AI courses especially in primary and secondary schools. To this end, AI education systems and related teaching systems are indispensable. However only few AI education equipment are available at market such as Cheng Xiaoben of Makeblock and Abilix’s Oculus, which are affordable programming education robots learning systems, integrating more than 10 electronic modules such as sound sensors, light sensors and LED dot matrix screens to easily realize face recognition, speech recognition and so on. But there are different kinds of such systems with less systematic design for school students and insufficient well-designed curriculum systems, which make it a headache for schools to pick. Therefore, it is imperative to develop a convenient and practical AI teaching systemsto carry out AI education in primary and secondary schools.

To this end, this paper develops an AI teaching system for primary and secondary students under iSTREAM (intelligence for Sciences, Technology, Robotics, Engineering, Arts, and Management) Educational structure, where parallel intelligence theory and ACP framework [3]-[7] are applied. In this system, typical AI applications, such as speech recognition, text recognition, image recognition, intelligent transportation, smart home and intelligent robots, are included to make AI teaching effective and fun. The rest of the paper is organized as follows. Section II overviews system design that provides standardized teaching equipment and curriculum systems for K-12. Section II discusses AI contents and topics specifically designed for primary and secondary school students. Section III presents the design and package functional modules for students at different cognitive levels. The evaluation criteria are then discussed in Section VI, followed by the conclusion in Section V.

2. System Design

Based on practical teaching requirements, AI course-based system is designed into two parts: cognitive part and practice part. Cognitive part allows students to learn and understand basic knowledge based on constructivism, which lets students enhance basic knowledge understanding by hands-on experiments.

2.1 AI Education System

Main features of this system are scalability and knowledge continuity. Due to different cognitive levels among primary school students, middle school students and high school students, in order to enable students on different levels to learn AI as easy as possible within an understandable range, this system will unfold different learning content systematically at different ages to achieve desired learning effects.

Table 1 System Design

	Teaching Focus			Contents	Goals
	Experience of AI	Logical Thinking	Engineering Skills		
Primary	✓			Experience AI technology on cognitive level Experience graphical programming Solve practical problems in our life	Let students realize AI exists in our lives with profound impact Introduce programming to students Let students understand basic concepts and methods of programming

Junior High	✓	✓		Understand working principle of AI algorithms. Conduct preliminary programming where codes are encapsulated Solve practical problems in our life	Let students go deeper into AI application Let students know how typical AI applications work and how to apply them in real life. Train students' programming skills at preliminary level.
Senior High	✓	✓	✓	Unfold part of working principle of AI algorithms. Conduct mediate programming where codes are half-encapsulated Solve practical problems in our life	Let students understand principle of AI algorithm and related cases. Improve students' ability to use AI to solve real-world problems. Help students improve programming skills through practice.

For primary school students, focus of this system is graphical presentation and AI experience. Considering their cognitive levels, this system applies simple and graphical interface to dynamically display application cases from real lives, which could enable primary school students to understand application of AI and its profound impact on our daily lives at a cognitive and experiencing level. In addition, this system also introduces graphical programming software such as Scratch and let students experience graphical programming. It also explains basic programming knowledge and guides students to make preliminary programming efforts.

For junior high school students, focus of this system is logical thinking and deeper AI experience. Considering that junior high school students have already acquired certain abilities of logical analysis and comprehension abilities, this system takes intelligent transportation as teaching cases and completely exposes overall logical framework to students with codes modularized and encapsulated. Through this way, students can see how AI algorithms work. In addition, while codes are hidden, parameters are exposed so that students can understand their functions by modifying them.

For high school students, focus of this system is logic thinking, engineering skills and AI experience. Core of engineering education is to solve complex problems with basic principles. Modular packaging provides raw materials and prerequisites for students to solve problems. With modularly packaged and standard interfaces, modules can be assembled freely to achieve desired functions, which can not only increase flexibility of the system, but also inspire students to try more interesting functions through free combination.

Of course, students can also package complex functions into new modules by performing second assembly of existing modules following standards. Students can design and program their own AI applications based on real-life applications. As a result, students' programming skills could be greatly improved.

2.2 Cognitive part

Goal of cognitive part: This part allows students initially understand specific application scenarios and cases of AI technology in real life, and have a visual cognition of core algorithms used by AI.

Visualization of teaching cases: Through analysis of teaching modes of AI courses, visual teaching tools will make students' learning more efficiently. Visualization of teaching cases is mainly reflected in two aspects: visual explanation and visual programming.

1) Visual Explanation

Usually at class, when teachers need to explain certain complicated problems, if they use only verbal language to describe them or use abstract methods such as formulas, students may find it difficult to understand. However, if teachers use visual explanation methods such as animation to visualize complex problems graphically, students might find it easier to accept. To this end, a visual explanation module is designed to transfer abstract algorithms into some figures or video clips easy to understand.

2) Visual Programming

Since many algorithms of AI are relatively complicated, considering different levels and abilities of primary and secondary school students, codes of AI algorithms cannot be directly exposed to them, so a visual programming module is designed to ease coding part.

2.3Practice Part

Goal of practice part: According to their own interests, students use teaching platform of modular package of hardware and software to design and implement simple applications. By this way, students can further understand related knowledge and improve logical thinking abilities[8].

Modularization and standardization: Students' creativity is infinite. In order not to limit imagination of students by type and number of hardware modules, this project has modularized all hardware modules and standardized interface design. In this way, each module can be combined freely, plug and play, which greatly increases flexibility and scalability of hardware in order to achieve more functions. All modules are extensible, which could implement new interfaces to extend their functionality while retaining exsiting funtions,which add more vitality to this system. This not only reduces cost of updating hardware and learning cost, but also cultivates students' maker thinking .

2.4Key technologies

Following are key technologiesapplied in this system.

Qt framework: Qt is a C++ based, object-oriented, easy-to-use, cross-platform graphical user interface application development framework with a whole set of libraries and development tools.Based on Qt, friendly GUI(Graphical User Interface) could be developed.

Distributed system organization: In order to realize modular design[9], this system adopts a distributed system[10] organization structure with three layers: data acquisition layer, data processing layer and control layer. By connecting modules in three layers in turn, complete functions can be realized, which is convenient for students to learn and use.

Microservice Architecture: Microservice architecture is a distributed system architecture in which each service is treated as a separate entity that can be compiled and deployed independently. This not only avoids wasting time on compilation, but also improves overall fault tolerance.

Interface Oriented Programming: Interface-oriented programming is one of the main methods to achieve software modularization.Reasonable use of interface design can decouple functional modules and application platform by separating definition and implementation.

REST Design Style: REST (Representational State Transfer) design style is a resource-oriented interface specification most widely used in software interface design. Resource is accessed by a URL (Uniform Resource Locator), and text resource is transmitted through a specific format such as html, xml, or json.

3. Teaching Case: Smart Cars

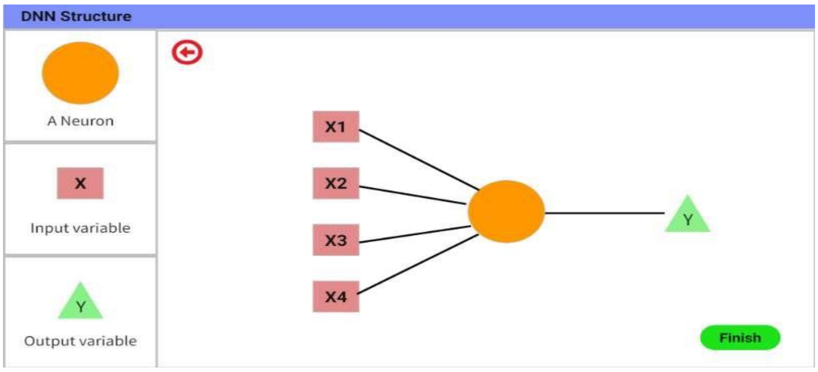


Fig. 1 Interface of AI teaching System for senior high schools

As shown in Fig. 1,this is configuration interface for senior high school students.The left side is modules area while the right side is workspace. A new instance is created by simply dragging and dropping elements from modules area into workspace. Instances can be dragged and set up parameters by double clicks.

3.1 Modules

As shown in Table 2, Smart carsincludes following modules:

Table 2 Main Modules in Smart Cars

Module	Control chip	Function	Input	Output
Car Module	Arduino	Control left and right motors of cars to control actions of cars	String	Voltage control signals for leftand rightwheel motors
Speech Recognition Module	Raspberry pi	Convert speech to text by speech recognition	Voice	String
Handwritten Number Recognition Module	Raspberry pi	Identify numbers handwritten by students and return corresponding numbers	Picture	Digit
Custom Module 1	Arduino	Deal withtexts from Speech Recognition Moduleand give signals to Car Module	String	Start signal
Custom Module 2	Arduino	Deal with numbers from Handwritten Number Recognition Module and send speed setting signal to Car Module	Digit	Speed signal

1) Car Module:

Control voltages of left and right motor of cars. Keep monitoring input ports and reset motor parameters when a valid signal is detected, and received signals include:

"start": "0 or 1" Start signal of the car, 0 is stop, 1 is off;

"speed": "speed value" The speed of the car is set to speed value;

"left_wheel": "value" The revolver voltage of the car is set to value;

"right_wheel": "value" The right wheel voltage of the car is set to value;

"run_time": "value" The time for this command to execute is value.

2) Handwritten Number Recognition Module:

A handwriting recognition module (mnist) based on Google's TensorFlow implementation. The module uses a simple single-layer neural network, with gradient descent method for training. Finally output layer uses Softmax to finish classification model. Then the module can output identified numbers. Output signal format: "Digit": "value" value is the recognized number.

3) Speech Recognition Module:

Calling Baidu's voice recognition API offline or online, and the corresponding text information can be recognized and outputted. Output signal format: "String": "value" value is sequences of characters recognized.

4) Custom Module 1:

Students can process sequences of characters obtained by Speech Recognition Module by creating Custom Module 1. If character sequence contains 'start car ', pass "start": "1" to the car to enable the car to start; if character sequence contains 'stop car ', the car is given "start": "0" to stop.

5) Custom Module2:

Students can use Custom Module 2 to process numbers obtained by Handwritten Number Recognition Module, pass numbers to the car, and set speed of the car. For example, if the number obtained by the camera is 5, then “speed”: “5” is entered, and the speed of the car is set to 5 gears.

3.2 Configuration

Students use hands-on modules to implement collaborative work of Car modules, Speech Recognition Modules and Image Recognition Modules, thereby adding functions of Speech Recognition and Image Recognition to Car Module.

In order to achieve systems with low coupling, in architecture design, hardware does not adopt design of master-slave structures [11], but draws micro service, a software architecture idea, completely decouples system and distributes functions into individual hardware modules. A simple serial communication protocol is used between modules, and transmitted signals are uniformly set to forms of "key: value". Modules are mainly connected by USB, and data can be transmitted while ensuring supply of power. Simultaneously set up paired Wi-Fi and Bluetooth modules to provide remote connectivity. Fig. 2 shows hardware architecture about control models of cars. Fig. 3 shows software architecture about control models of cars.

3.3 Steps

Steps of configuring Smart cars are as following:

1) Find Car Module, Handwritten Number Recognition Module, Webcam module, Power Module, a pair of Wifi Connection Modules, and a Custom Module;

2)Connect Power Module, Handwritten Number Recognition Module, and Wifi

Connection Module A in sequence, and connect another part of Wifi Connection Module B to webcams;

3) Debugging wifi: Turn on Power module to check if Wifi module is successfully paired;

4) Unplug Power module, then connect Test Modules and connect Power Supply to the other end of Test Modules to supply power to the system;

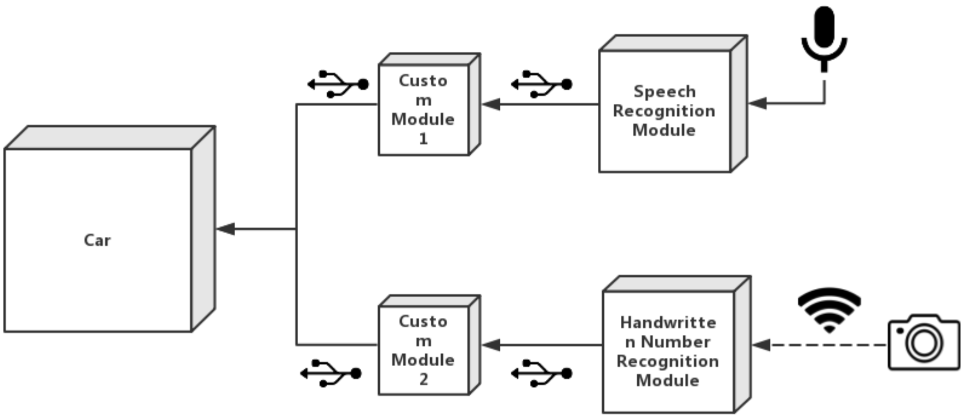


Fig. 2 Hardware Architecture of Control Model on Smart Cars

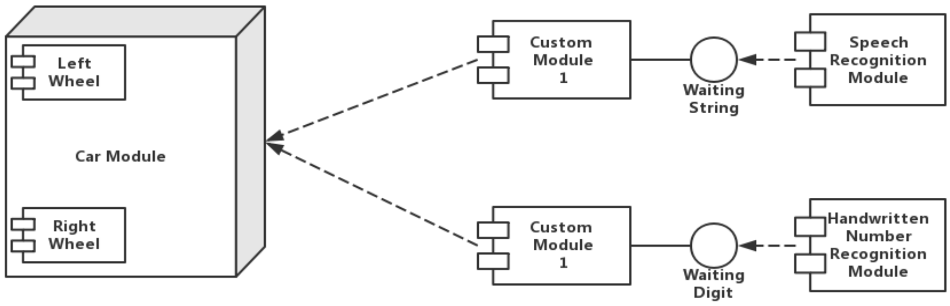


Fig. 3 Software Architecture of Control Model of Smart Cars

5) Debug Handwritten Number Recognition Module: put a handwritten number under the camera to see if Test Modules can display numbers normally. If it is correct, tests pass;

6) Students write a simple input/output conversion program on PC, which converts inputs into a signal format to control by Car Module (for example: "start": "input number"). Then downloads it to prepared Custom Module;

7) Connect Custom Module and Car Module in turn after Handwritten Number Recognition Module, and finally connect Power Module to Car Module;

8) Turn on Power Module and put a piece of paper with number “1”in front of the camera to see if cars can start normally.

Whole system can be freely spliced, students only need to use their own Custom Module to do conversion of input and output signals, and it is convenient for debugging and troubleshooting. All required modules have been well packaged and students do not need to perform additional operations, which reduces difficulty of learning.

Through this teaching case, students can initially understand basic principles of speech recognition and image recognition on hands-on practice to inspire students' creativity and thinking while learning artificial intelligence by fully embodiments convenience brought by modularization of hardware and software.

4. Discussion

To sum up, this system provides a complete AI teaching system in line with actual teaching needs for primary and secondary school students, so that processes of learning AI from primary schools to high schools is continuous and progressive. Compared with other commercial teaching systems, this system mainly solves following problems.

1) This system aims at artificial intelligence education in primary and secondary schools, and it pays more attention to artificial intelligence knowledge and relevant algorithms rather than just students' hands-on abilities and coding abilities.

2) This system has independently designed API for visual display, which makes development process much easier than before. On the basis of visual teaching software, it is convenient for teachers to explain related topics to students.

3) Encapsulation of hardware modules: each hardware module is an independent embedded device, so combination of modules is more flexible and conducive to give full play to students' creativity. At the same time, this teaching system has developed a debugging module, which is convenient to verify and troubleshoot errors quickly when coding.

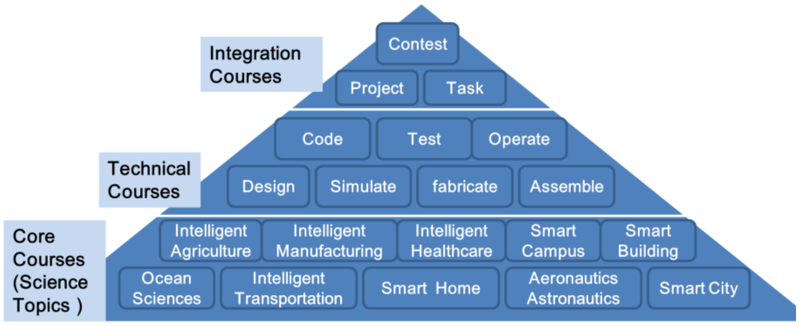
Meanwhile, Follow-up work to improve the system is as follows.

1) Visual encapsulation of API still needs to be improved, because for some complex programs are not good enough to meet requirements. 2) In order to save cost of power consumption, this project needs to find methods to reduce magnitude of processors and integration design. 3) Appearance of hardware module needs to be designed more reasonably to make modules configurations much friendly and easier.

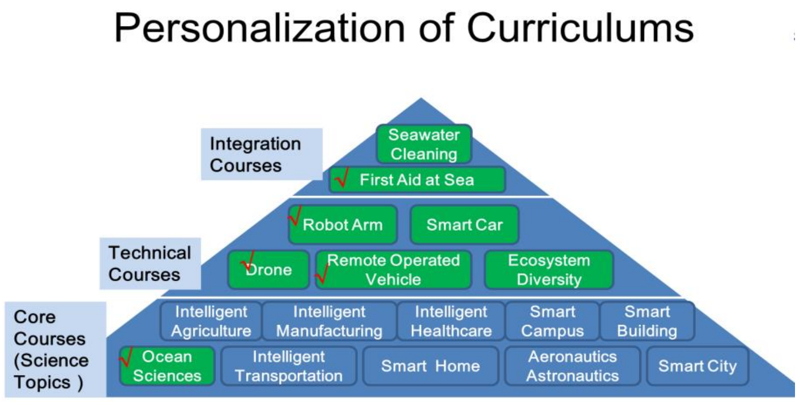
5. Conclusions and Further Plan

This paper introduces design and implementation of a modular AI education system. The goal is to design a modular, well-packaged, and expandable platform that is conducive to education of AI disciplines, allowing students to generate interests and deeper understanding on AI. Through configuration of software and hardware modules, teachers and students are provided with easy-to-learn and easy-to-use teaching and learning tools.

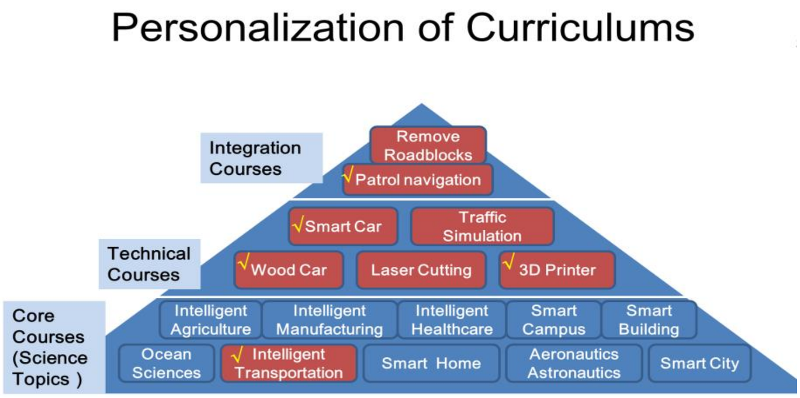
Afterwe complete this AI Education System, we will start applications of this system in couple of primary and secondary schools in Bejing. Then based on comments and suggestions from schools, we will optimize it step by step. Since network can greatly enrich learning resources, so next we will develop an open source community to collect developers' ideas. In open source community, other developers can actively participate in development of platform, share their course designs to make this teaching system expand and grow rapidly.



4.a Normal Curriculum System



4.b Personalized Curriculum System A



4.c Personalized Curriculum System B

Figure. 4 Future Plan

As shown in Figure. 4, our future plan is a Standlized, Modulized and Personlized AI Curricula Systems, including standard curricula system and personalized curricula systems,core courses, techinical courses and integration courses. For standard curricula system, core courses consist of Ocean Sciences, Intelligent Transportation, Smart Home and etc., technical courses consist of designing, simulating, fabricating, assembling, coding, testing and operating, and integration courses consist of projects, contests and tasks. For personlized curriculum system, core courses are the same with different teaching cases, while techincal courses will be changed into wood cars, laser cutting, smart cars and etc or Robot arms, Drones, and Ecosystem Diversity and etc. Integration courses will be patrol navigation and remove roadblocks or First Aid at seashore and Seawater Cleaning. It can not only meet learning standards but also meet personalized requirements by changing related modules from standard modules into personalzied modules according to their interests.

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