2022 IEEE 25th International Conference on Intelligent Transportation Systems (ITSC)
October 8-12, 2022, Macau, China

Artificial Intelligence in Engineering Education in the Case of Self-driving Vehicle Curriculum

Rui Zhou[1], Peng Zhi[1], Xiaowei Xu[1], Zhilin Liu[2], Xiyun Li[3] and Qingguo Zhou[1*]

Abstract— **Artificial Intelligence (AI) is currently a hot topic both in industry and engineering education. As a multidisciplinary field, self-driving vehicle (SDV) research has attracted much attention and is significant for applying and promoting AI. This paper presents our SDV curriculum for engineering education, which was developed with a fundamental basis in AI. The curriculum consists of five courses: Practical Methods Based on Robotics, Introduction to Artificial Intelligence, Innovation and Entrepreneurship, Digital Logic, and Embedded Development for Linux. Students with different academic backgrounds interested in AI or SDV can be trained by theoretical lectures and laboratory sessions at different levels. Students participating in the curriculum have inspired innovative ideas and practically implemented further work in the SDV field. In addition, we have produced educational resources including textbooks and an experimental SDV system. These case studies are discussed here. The curriculum has received highly positive feedback from students, which shows the effectiveness of our work. We are refining and promoting the curriculum for more students who are seeking knowledge and ability in AI and SDV fields.**

I. INTRODUCTION

Artificial Intelligence (AI) has been researched and developed for decades. In recent years, AI has been applied to demonstrate and promote various innovations in fields such as robotics, big data analysis, brain-inspired computing, and self-driving vehicles (SDV).

Similar to AI, the development of SDV has been a hot topic over the past decade, but it is not an emerging research area. From the 1960s to the 1980s, the Stanford Cart project was launched, and about a decade after it was built, the cart was reborn as an autonomous vehicle, and finally, it was equipped with 3D vision capabilities [1] [2]. In the 1990s, researchers at Carnegie Mellon University utilized the donated Navlab 5 vehicle for on-road navigation experiments, including autonomous lane keeping, lateral roadway departure warning and support, and curve warning based on portable advanced navigation support (PANS) platform that they developed [3]. The Defense Advanced Research Projects Agency (DARPA) held the Grand Challenge in 2004 and 2005 and the Urban Challenge in 2007, with the goal of spurring American ingenuity to accelerate the development of autonomous vehicle technology that could be applied to military applications [4], [5]. These challenges contributed to driving the invention of SDV and also fostered a community that now is leading the SDV industry [6]. To date, several participants of this community have been researching and developing SDV within well-known companies and institutes, making the SDV industry a reality. The SDV industry includes both traditional car manufacturers and internet companies, including representative enterprises such as Benz, Toyota, Tesla, Google, Baidu, and Huawei. For example, Google's self-driving car project developed into Waymo [7], which is currently one of the representative SDV companies. Furthermore, various institutes and researchers are contributing to components of SDV research, such as software and hardware for sensors, algorithms, communication, and batteries.

From the perspective of engineering education (EE), SDV is a multidisciplinary field comprising a range of topics, including automobile and transportation technology; AI, such as deep learning, reinforcement learning, and computer vision; Internet of Things (IoT), especially sensors such as LiDAR, millimeter wave radar, camera; robotics, including perception and motion planning; graphics processing unit (GPU); communication, such as 5G; and control systems, such as the proportional-integral-derivative (PID) controller. Therefore, SDV is a wonderful demonstration of science, technology, engineering, and math (STEM). However, to a great extent, the realization of SDV depends on the development of AI.

AI provides the fundamental capability for SDV to process perceived data, develop a motion plan, and finally control the vehicle. In addition, intelligentization is becoming integral to almost all aspects of daily life. For example, intelligent transportation has promoted the rise of AI, IoT and battery electric vehicles (BEV) are becoming increasingly popular, and 5G technology is gradually being promoted and deployed. Recalling and contrasting the era when feature phones were widely replaced by smartphones with the rise of mobile internet enabled by 3G/4G technology, it is now the era for SDV and related technologies to replace traditional vehicles with the development of 5G technology.

Focusing on EE, with the former acceleration of smartphone and mobile internet technologies, many students became developers after being trained in related technologies, such as Android or iOS development, and then fed back to push forward the related industries. Therefore, EE could

[*]Corresponding author
[1]Rui Zhou, Peng Zhi, Xiaowei Xu and Qingguo Zhou are with the School of Information Science & Engineering, Lanzhou University, and Gansu Provincial Key Laboratory of Intelligent Transportation, Lanzhou, P. R. China. {zr, zhip13, xuxw21, zhouqg}@lzu.edu.cn
[2]Zhilin Liu is with the Faculty of Electronic and Information Engineering, Xi'an JiaoTong University, Xi'an, P. R. China. lzl32947@stu.xjtu.edu.cn
[3]Xiyun Li is with the Institute of Automation, Chinese Academy of Sciences (CASIA) and the School of Future Technology, University of Chinese Academy of Sciences, Beijing, P. R. China. lixiyun2020@ia.ac.cn

2022 IEEE 25th International Conference on Intelligent Transportation Systems (ITSC) | 978-1-6654-6880-0/22/$31.00 ©2022 IEEE | DOI: 10.1109/ITSC55140.2022.9922348

also evolve with the continuous development of SDV. If EE is performed or strengthened based on SDV, the students can be trained with the essential state-of-the-art knowledge in AI. In addition to adequate theoretical study, the students can obtain practical experience with application scenarios of SDV to understand how AI works and how it is utilized to change daily life and the world.

Therefore, this paper presents the development and organization of the curriculum based on SDV for teaching AI in EE. We share the experience, achievements, and effects of this curriculum applied in Lanzhou University.

The rest of this paper is organized as follows. In Section II, the related work for AI in EE, especially the topic of SDV, is reviewed. The design scheme of the curriculum is discussed in Section III. Section IV introduces and analyzes the case study inspired by the course content. The evaluation is presented in Section V. Finally, Section VI concludes this paper and discusses future work.

II. RELATED WORK

A. FUNDAMENTAL ISSUES FOR AI IN EE

From the perspective of the fundamental issues related to AI in EE, it is clear that purely theoretical study is tedious, and the study of AI should combine theory and practice. Therefore, various works in EE have been applied to teach AI, such as expert systems [8], programming languages [9], hardware design [10] [11], robotics [12] [13], and computer-aided instruction [14] [15].

In the early days, [9] discussed the two most commonly used AI programming languages, LISP and PROLOG in EE, and showed that the study of such languages should be included in engineering curricula as AI applications become more accepted in both science and engineering. [14] presented the results of an innovative teaching experiment obtained from using a collaborative teaching system as support for AI study. Furthermore, the school provided a rich learning environment, making the EE experience highly productive.

In the past decade, [10] presented an introductory practical project on artificial neural network (ANN) offered as an elective to the undergraduates in the author's department, which allowed the students to become familiar with ANN hardware techniques. [11] introduced an educational system based on field programmable gate array (FPGA), focusing on the modeling, implementation, and evaluation of hardware architectures of ANN-type multilayer perceptron networks. The method in [11] helped the teaching-learning process by providing a design environment where undergraduate students can apply the knowledge acquired in lecture-based courses related to AI, such as pattern recognition and neural networks. [8] described artificial intelligence based student learning evaluation tool (AISLE) to improve the use of AI techniques in evaluating the students' understanding of particular topics using concept maps developed by students in the area of mathematics, which is one of the most important topics for EE. [12] proposed a problem-based learning (PBL) method that was applied in an AI course. The proposal included problems associated with mobile robotics, in which the students developed AI solutions to optimize robot movement in an unknown environment to avoid obstacles. [13] presented a multidisciplinary model for using robots in the course of AI. The robots provided opportunities for students of computer science (CS) and computer engineering to design and create autonomous agents in the physical world and explore a variety of advanced concepts, including intelligent agent design, robot control, managing uncertainty, and planning. [15] presented a gamified experience to teach AI to CS engineers. The competition and other game elements in the course proved to be fun for the students. By attending more classes, the students achieved continuous improvement in their work and independently accomplished high-quality assignments.

In addition, AI was applied in some specific areas of EE. [16] presented the theoretical and legal study of the application of AI in geotechnics and EE, studied AI in the geological industry, and traced the practical use of AI in geotechnics. Even for special education, [17] reviewed AI application tools that were applied in an attempt to solve major issues in the diagnosis and intervention of specific difficulties, including the learners with sensory and/or physical impairments; autistic spectrum disorders; reading, writing and spelling difficulties; dyslexia; difficulties in mathematics; and attention deficit hyperactivity disorder and attention deficit disorder.

B. SDV IN EE

In addition to the fundamental studies on AI in EE discussed above, to keep pace with the times, considering the emerging focus on SDV as a comprehensive and advanced application area of AI, there also have been several applications of SDV in EE.

SDV exists within the broader context of transportation. A previous study [18] presented applications of AI for designing a simulation system for teaching concepts in transportation engineering, including key features for SDV, such as the road system, vehicle, rectilinear and curvilinear motion, and braking patterns. [19] presented a traffic simulation tool with great versatility for urban circuits as a teaching tool to provide an intuitive introduction for students. [20] described the use of a customizable 3D vehicle dynamics simulation program as a support for teaching the course of Road Vehicles Theory, and the simulation resulted in a deeper understanding of vehicle dynamics concepts.

Furthermore, SDV can be treated as mobile robots with similar fundamental concepts, so research in robotics is beneficial and transferable to the research and development of SDV. [21] developed a 3D animated graphical simulation of the movement of a wheeled vehicle, and described the mathematical formulation of the dynamics and programming procedure to visualize vehicle movement. [22] presented a webcam-based vision system for performing image processing in real-time, which was implemented as part of an AI and robotics educational platform designed to study collaborative moving robots in a dynamic environment. [23] described a MATLAB computer simulation course project implemented as part of an introductory graduate course in autonomous robotics and showed that a meaningful autonomous robotics computer project could be developed to allow students to be individually creative and also to understand and share ideas, tools, and methods with others. [24] presented a simulation and animation software to help visualize different robot localization solutions, which proved powerful for performance analysis and optimization of robot localization, mapping, and autonomous navigation. [25] presented a common line-tracing robot feedback control system, which used an inexpensive CCD camera mounted on the ceiling for feedback. This experimental system was feasible for educational purposes.

Along with the significant attention attracted by SDV, this field requires the cultivation of high-level talent. CommonRoad [26] is a collection and simulation of composable benchmarks for motion planning on roads. It is also a useful tool for teaching the lecture Foundations of Artificial Intelligence by providing motion primitives for students to solve planning problems as a programming exercise, which can be evaluated on the benchmark website [27]. [28] presented a modular and integrated approach for teaching autonomous driving with three case studies: (1) an introductory class on autonomous driving for students; (2) a new session in an existing embedded system class; (3) an industry professional training session. It also showed that this approach was an effective method for teaching autonomous driving. [29] constructed a simulator related to the Portuguese Autonomous Driving Competition using Gazebo [30] as the 3D simulator and robot operating system (ROS) [31] as a middleware, which focused on the autonomous driving competition task, such as semaphore recognition, localization, and motion control. [32] introduced the ISEAUTO project that aimed to design and development of an SDV in cooperation with a private company, university researchers and students in Estonia. [33] described a high-school STEM program utilizing an exciting 1/10-scale self-driving race car platform with state-of-the-art sensors and embedded computers, allowing the students to design and develop complex software systems. [34] provided an educational case study of SDV where perceptional concerns, as well as innovation adoption trends, were investigated considering the United Arab Emirates population. A leader in EE for AI and SDV is Udacity [35], which provides online courses in topics such as AI, SDV, deep learning, machine learning, and robotics. Specifically, in China, Udacity cooperates with Baidu Apollo [36] to teach the course Introduction to Apollo Self-driving, Tier IV [37], and Pix [38] to build the first SDV-engineer training base in Guiyang [35].

At present, typical training for SDV can be divided into online and offline. For online training, one major limitation is that it is difficult for students to practice applying the codes to real SDV systems [35]. Offline training [39]–[41] is mostly directed at car manufacturers. This kind of training generally lasts for several days, and it is difficult for students to fully understand the topic of SDV in such a short time. In addition, both online and offline training is expensive. To overcome these limitations, this study explored the training methods for SDV in light of the characteristics and advantages of universities.

C. OBJECTIVE ANALYSIS

Although there have been several contributions to SDV in EE, some challenges still need to be further considered:

Social objective: As SDV is a multidisciplinary field, we aim to draw more attention and interest from students from different academic backgrounds, and try to satisfy their various study aims. Once successful, our achievements could be promoted outside the campus to cultivate more talent in the broader society.

Academic/technical objective: The systematic curriculum should be designed with a combination of theoretical lectures and practical exercises delivered to students from different academic backgrounds. This will enable students to understand the fundamental concepts of SDV, mainly AI techniques, and also learn how to apply them in practical situations.

III. CURRICULUM DESIGN

Considering the objectives described above, here we present the developed curriculum for SDV in EE, including two introductory courses for liberal study, one session in another multidisciplinary introductory lesson, and updated sessions in two existing professional courses: Digital Logic and Embedded Development for Linux, with supporting theoretical lectures and laboratory sessions. The curriculum framework is shown as Fig. 1, and the curriculum details are summarized in Table I. The curriculum enables students from various majors to easily enter the SDV field. In addition, for enthusiastic students wanting to learn more, we provide advanced theory and practical tasks for them.

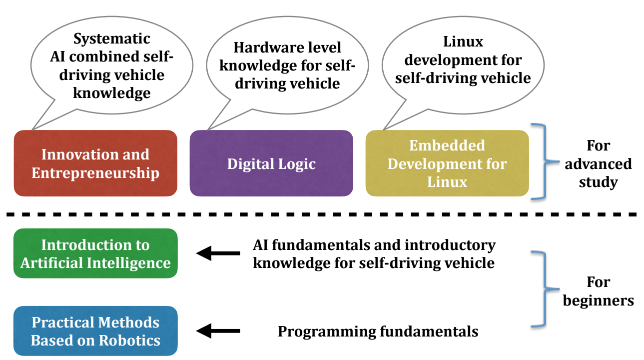


Fig. 1: SDV curriculum framework

A. COURSES FOR LIBERAL STUDY

To attract students from different majors, we developed two introductory courses for liberal study as a basis: Practical Methods Based on Robotics, and Introduction to Artificial Intelligence.

TABLE I: SDV curriculum information

	Course Name	Student Grade	Student Major	Course Attribute	Class Hour
Self-driving Vehicle Curriculum	Practical Methods Based on Robotics	Freshman - Senior	All	Liberal Study, Elective Course	36
	Introduction to Artificial Intelligence	Freshman - Senior	All	Liberal Study, Elective Course	36
	Innovation and Entrepreneurship	Sophomore	School of Information Science & Engineering	Liberal Study, Compulsory Course	4
	Digital Logic	Sophomore	CS	Professional, Compulsory Course	54
	Embedded Development for Linux	Senior	CS	Professional, Elective Course	54

There will be students who know nothing about programming, but are interested in SDV or AI, so they first need to develop fundamental knowledge and skills in programming, which are provided in the Practical Methods Based on Robotics course. This course enrolls students from freshmen to seniors across all majors, including CS, mathematics, and physics. The lectures include topics such as computational thinking and how to program with the visualized user interface of Blockly [42]. This is a visualized tool for fast and easy programming without writing lines of codes, but rather by dragging and connecting different functional blocks (Fig. 2 (a)). Therefore, Blockly is suitable for training students from different majors with a range of programming abilities. Even for CS students, it is beneficial for them to master one more programming tool.

In addition to theoretical lectures, practical sessions in this course include exercises showing how to use Blockly and then advanced experiments to build a model SDV. The students are evaluated by their performance in the advanced experiments. The students are divided into groups of 5-8 persons depending on the total number of enrolled students in that semester. Each group must build a model SDV, called FreDuino, from scratch with a manual and a set of components provided by the teachers (Fig. 2 (b) and (c)). The components include embedded developing boards, sensors, metal plates, batteries, cables, wheels, nuts and bolts. Then, they must program FreDuino with Blockly and try to drive the model successfully to enter and complete a maze during a classroom competition by processing perceived data from sensors and using this to control the wheels (Fig. 2 (d)). Finally, the groups need to present their algorithms, debugging, and teamwork details to conclude what they have learned in the course for that semester.

For this course, we published a textbook titled Creative and Interesting Programming with Blockly (Fig. 3 (a)) [43]. It provides an easy entrance into the world of CS and engineering for beginners.

Introduction to Artificial Intelligence is also an introductory course and enrolls students ranging from freshmen to seniors across all majors. This course mainly introduces AI fundamentals, including machine learning, neural networks, deep learning, transfer learning, and deep reinforcement learning. In addition, the students are given a brief introduction to advanced knowledge related to SDV, including ROS, localization, sensor fusion, visual perception, planning, vehicle model, and control. The students are evaluated individually by implementing their own ideas in AI. They are encouraged to present work related to SDV, but the topic is not limited and they usually try to solve general issues in AI.

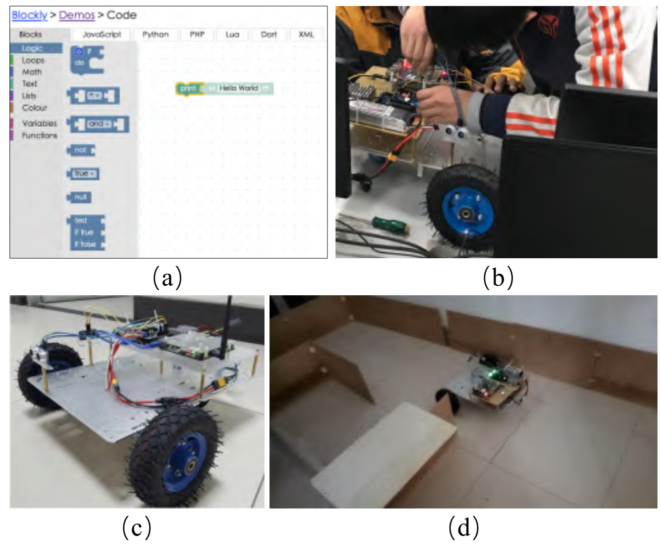


Fig. 2: Practical Methods Based on Robotics course: (a) Blockly GUI, (b) students assembling FreDuino, (c) an assembled FreDuino, (d) a maze competition

Fig. 3: Textbooks: (a) Creative and Interesting Programming with Blockly (b) Theories and Practices of Self-Driving Vehicle

Apart from the two introductory courses for all majors, we provide Innovation and Entrepreneurship only for our school, the School of Information Science & Engineering. The students are sophomores and major in CS, electrical engineering, communication engineering, data science, and information security. We are in charge of one session of this course. Considering that these students know how to program and some of them have project experience in research and development, we present content focusing on SDV, including the history, motivation of their ideas for innovation, and some detailed AI-related self-driving knowledge, such as localization, deep learning for visual perception, transfer learning for end-to-end self-driving, and deep reinforcement learning applications in SDV. For students, the general evaluation for this session is to submit a technical report on SDV individually. Further, we observed exciting achievements, where some students performed a series of practical experiments in addition to the required report. We introduce their work in detail in Section IV.

Furthermore, we have published another textbook titled Theories and Practices of Self-Driving Vehicle (Fig. 3 (b)) [44]. It covers both AI principles and SDV practical applications and helps readers enter these topics quickly.

B. PROFESSIONAL COURSES

Our school is in charge of two existing professional courses: Digital Logic and Embedded Development for Linux, which are delivered for sophomores and senior students of our school, respectively, with a CS background. Recently, we have updated the lectures with cutting-edge SDV content.

Digital Logic is a compulsory course and is based on hardware scenarios. We generally introduce the hardware relevant for SDV, mainly sensors, such as LiDAR, millimeter wave radar, and cameras, and how these are operated at the circuit level. In addition, we teach a session to train students how to use FPGA, and they are divided into groups to apply FPGA to implement a simple adder based on convolutional neural network (CNN), which is frequently used in visual perception for SDV. This is a comprehensive assignment, and for each student, the result of teamwork is part of the final grade of this course.

Embedded Development for Linux is an elective course and requires practical exercises during the lectures. It mainly introduces kernel-level development in Linux. Additionally, we instruct the students on how to install developing environments for SDV, including Linux distributions, ROS, Autoware [45], and OpenCV, and how to program with these tools. Figure 4 presents a course exercise with ROS and Autoware.

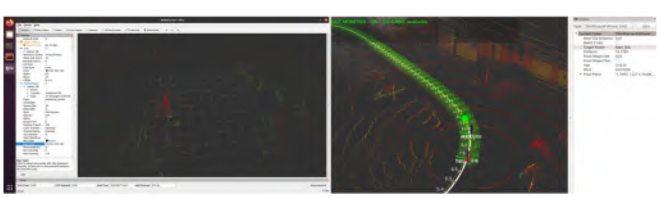


Fig. 4: Course exercise for simple model predictive control in ROS and Autoware, with point cloud in Rosbag on the left and reference waypoints in Autoware on the right

IV. CASE STUDIES

A. FURTHER WORK BY STUDENTS

As mentioned in Section III, some students involved in the curriculum did work beyond that required by the class. Although they were all from a CS background, some of them took part in the Practical Methods Based on Robotics course, and all of them completed Innovation and Entrepreneurship and Digital Logic. These students were particularly interested in SDV, and they studied AI principles based on some other projects they participated in. Therefore, after meeting the course requirements, they decided to implement a vision perception control system for FreDuino. Their hard work received support from the National College Students' Innovation and Entrepreneurship Training Program.

1) SYSTEM UPDATES: The main idea of the vision perception control system was that FreDuino would first capture images from the surrounding environment. The results after target detection and semantic segmentation are used to drive the model car. The system architecture was designed as shown in Fig. 5.

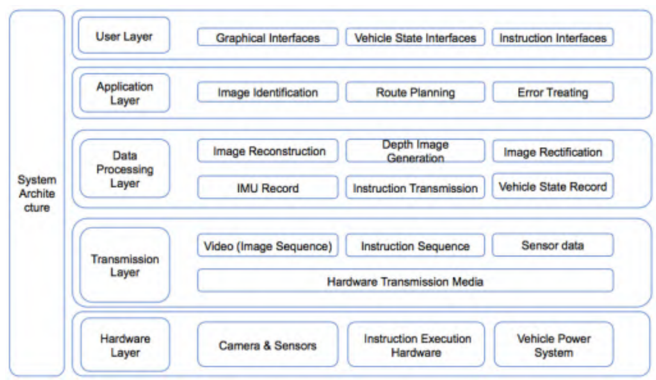


Fig. 5: System architecture

As FreDuino is only a prototype originally constructed for Blockly program control, it was updated by the students to NovaDuino for vision perception applications. The differences between FreDuino and NovaDuino are shown in Table II.

In particular, a binocular camera was added as the perception device, combined with a 2-degree-of-freedom tripod head, driver board, and damping device. An NVIDIA Jetson Nano computer was used as the new brain of NovaDuino. It was installed with Ubuntu 18.04, Anaconda, CMake, OpenCV, and SDK for operating the binocular camera. The Jetson Nano was directly linked with the camera, so it could receive and process perceived data in real-time with low latency. The movement of the car is controlled after data processing and manipulated by an Arduino system. The system dataflow is shown in Fig. 6.

2) DATASET: The model car was launched to navigate the campus and take pictures and videos using the binocular camera. Then, the pictures were processed manually by labelme [46] to produce a semantic segmentation dataset similar to Pascal VOC 2012.

TABLE II: Main differences between FreDuino and NovaDuino

	FreDuino	NovaDuino
Development Board	Raspberry Pi 3b	Nvidia Jetson Nano
Operating System	Ubuntu 16.04	Ubuntu 18.04
Main Sensor	Ultrasonic	Binocular Camera
Other	3 Wheels	4 Wheels

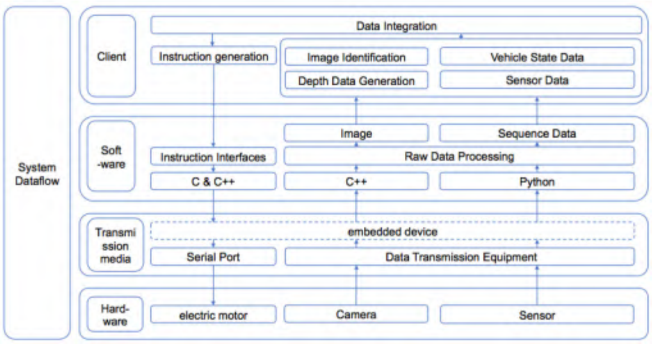


Fig. 6: System dataflow

3) MODEL APPLICATION: For object detection and semantic segmentation, YOLO v3 [47] and Mask R-CNN [48] were optimized for the customized dataset discussed in Section IV-A.2. Lane detection was attempted using OpenCV and LaneNet + H-Net [49] for other datasets and the customized dataset in Section IV-A.2, respectively. Furthermore, for convenient application and further promotion, the trained model for object detection and semantic segmentation was packed as an iOS App and implemented by Core ML [50].

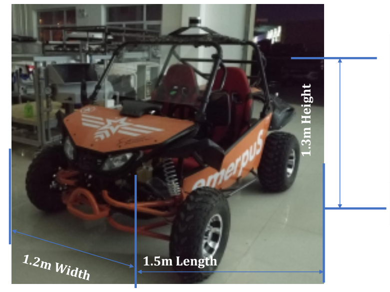
This work was a significant achievement from our SDV curriculum. The students utilized the knowledge systems learned from the courses and inspired themselves to solve practical issues in SDV. They not only trained themselves by mastering mainstream technologies but also experienced the strong teamwork required during practical engineering tasks.

B. EDUCATIONAL RESOURCES

In addition to the two textbooks mentioned in Section III and FreDuino/NovaDuino, we provide another comprehensive educational resource, which is a real experimental SDV for EE (Fig. 7) inspired by our curriculum.

This vehicle was designed and manufactured via a collaboration between our school and Venus Intelligent [51] derived from China First Auto Works Group Co., Ltd. Here we compare our solution with two similar SDVs [28] [32] (Table III). From the perspective of EE, the fundamental configurations are not that different, but our solution is less expensive.

If there is no real SDV used in related curricula, teachers and students may not face the practical issues emerging on the road, so it is necessary to configure, program and debug a real SDV. Therefore, our educational resources include a full solution, covering theoretical lectures and an experimental



Parameter	Value
Size (mm)	1500*1200*1300
Net Weight (kg)	260
Max Capacity	2 Persons
Max Speed (km/h)	30
Mileage (km)	100
Battery Capacity (AH)	40
Self-driving Level	L3
Operating Temperature	-30°C~50°C

Fig. 7: Photograph and parameters of the first-generation experimental educational SDV

engineering environment. According to our investigation, the cost of our experimental SDV should be acceptable to most universities, companies, and even middle schools in China. We hope that it could help attract more students to dedicate themselves to AI, and especially SDV research, in order to increase the contribution to this field.

V. EVALUATION

We have used our proposed SDV curriculum for two academic years. There have been 103, 94, 656, 243, and 47 students participating in Practical Methods Based on Robotics, Introduction to Artificial Intelligence, Innovation and Entrepreneurship, Digital Logic, and Embedded Development for Linux courses, respectively. An evaluation of the student satisfaction with the teaching system is an important criterion to measure the quality of the provided education. Therefore, we have established a curriculum satisfaction model considering three aspects: Course Targets, Course Content, and Teaching Methods. The model uses a questionnaire with 7 questions (Table IV) for each course in the form of a 3-point Likert scale [55] [56]. Each question is given a rating on a 3-point scale: Excellent, Qualified, or Unqualified. At the end of the semester, we distribute the questionnaires to students enrolled in our curriculum. The evaluation statistics are shown in Fig. 8.

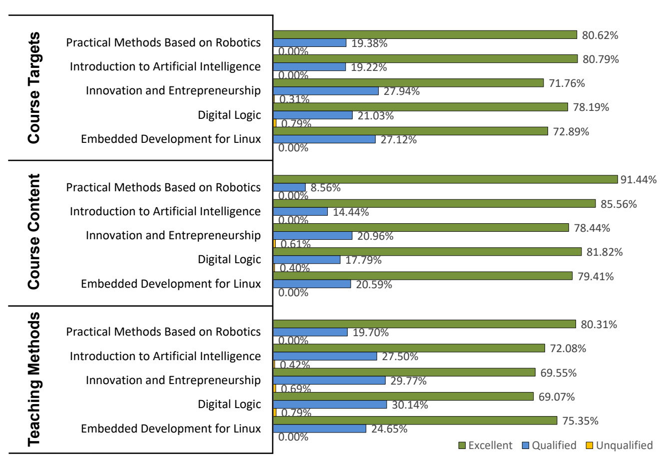


Fig. 8: Curriculum evaluation results from the students

The average excellent rates for the five SDV courses based on the three aspects of Course Targets, Course Content,

TABLE III: Comparison between our educational SDV and other similar SDVs

	Sensors	Size (L*W*H)(mm)	Max Capacity	Battery Capacity	Cost
DragonFly Pod by PerceptIn [28] [52]	DragonFly Computer Vision Module, 77 GHz Millimeter Wave Radar, RTK-GNSS, Sonar	Unknown	2 Persons	Unknown	40,000 USD [53]
ISEAUTO [32]	LiDAR (Velodyne, VLP-16 x 2), Ultrasonic Sensors (front and back x 8), Ultrasonic Sensors (door side x 6), Short Distance Radar, Cameras x 8, RTK-GNSS, IMU	3500*1300*2300	6 Persons	16 kWh	260,000 EUR*≈266,000 USD *This is the total project cost according to [54]
Our solution	LiDAR (LeiShen, 16 Line x 1), HD Camera (Logitech, front x 1), Millimeter Wave Radar (Continental 404, front x 1), Ultrasonic Sensors (Venus Intelligent, 2 per orientation), RTK-GNSS (Venus Intelligent)	1500*1200*1300	2 Persons	40 Ah	100,000 CNY≈14,800 USD

TABLE IV: Details of the course satisfaction questionnaire

	Weight	Question
Course Targets	100%	Does the course encourage students to explore and participate, emphasize self-motivation and capacity building, and satisfy personalized needs?
Course Content	25%	Is the content scientific and correct, with an accurate and normalized presentation of the basic concepts and theories?
	25%	Is the content substantial, with a strong logical and systematic knowledge structure, highlighted key points, and thorough explanation of the challenges?
	25%	Is the new and previous knowledge connected closely and handled correctly and smoothly to reflect the latest research achievements of related disciplines?
	25%	Does the content combine theories and practices according to the course characteristics, with correct and accurate literature to introduce the latest progress in related disciplines?
Teaching Methods	50%	Is the teacher good at inspiring, guiding, and encouraging students to think, without being scripted, while explaining profound knowledge in simple language with strong logic in line with the students' cognitive principles and psychological characteristics?
	50%	Is the teacher good at interacting with students, grasping the atmosphere of the classroom effectively, keeping abreast of students' problems in course study and providing timely solutions?

and Teaching Methods were 76.85%, 83.33%, and 73.27%, respectively. The overall excellent rate of the SDV curriculum was 77.82%. It is clear that the vast majority of students rated the curriculum positively. Of course, we have been continuously developing and improving the curriculum, trying to satisfy all students involved to ensure that they are fulfilled by the obtained knowledge.

VI. CONCLUSION

To cultivate qualified AI talent, we need EE to provide both theoretical lectures and practical engineering exercises. As a multidisciplinary field, SDV is fundamentally based on AI and includes various engineering topics. Therefore, in this paper, we presented our curriculum developed for SDV. This curriculum covers basic programming skills, AI fundamentals, and advanced SDV practices, and can satisfy various requests from students with different majors. We also introduced the further academic and engineering achievements generated by students from this curriculum, including object detection and semantic segmentation work based on a model SDV. In addition, the teachers published two textbooks, and a real experimental SDV was designed and manufactured in collaboration with partner institutes. The students can gain both theoretical and practical knowledge from this curriculum on the topics of AI and SDV and can apply their innovative ideas to a FreDuino/NovaDuino model car or even the experimental SDV. Therefore, the curriculum is considered a total academic and engineering solution for studying SDV. The curriculum has been taught for two academic years and it has been highly welcomed by the students with positive and satisfactory feedback. This shows that the curriculum is quite effective for AI education in the specific case of SDV.

Therefore, it is an ongoing task to refine the curriculum content. More importantly, we are developing adequate engineering cases for the experimental SDV and trying to promote it to more institutes. Then, more students can experience EE with diversity and conveniently enjoy the fun, experience and benefit of SDV. Our solution makes it possible for more people to realize their interest in AI, especially SDV. In addition, the broad ideas generated in these EE settings will help to further promote this field and enable the widespread realization of SDV as early as possible.

ACKNOWLEDGMENT

This work was partially supported by the Gansu Provincial Science and Technology Major Special Innovation Consortium Project (21ZD3GA002); the Virtual Teaching and Research Section of the Ministry of Education of P. R.

China for the Computer System and Processor Courses; University-Industry Collaborative Education Program of the Ministry of Education of P. R. China (202002001074); the Fundamental Research Funds for the Central Universities (lzujbky-2021-sp57); National College Students' Innovation and Entrepreneurship Training Program (201910730089); and Ministry of Education - China Mobile Research Foundation (MCM20170206). We also acknowledge the students: Zhaoyan Yan, Tingting Yu, Yikun Sun, Zhongjie Chen, Xianping Li, Haodong Li, Shiqi Zeng, Yihan Wu and Guimin Wang, for their contributions to this paper.

REFERENCES

[1] T. Kubota, "Stanford's robotics legacy," available: https://news.stanford.edu/2019/01/16/stanfords-robotics-legacy/, 2019.

[2] H. P. Moravec, "The Stanford Cart and the CMU Rover," Proceedings of the IEEE, vol. 71, no. 7, pp. 872-884, 1983.

[3] T. Jochem, D. Pomerleau, B. Kumar, et al., "PANS: a portable navigation platform," in Proc. of the Intelligent Vehicles '95. Symposium, 1995, pp. 107-112.

[4] DARPA, "The Grand Challenge," available: https://www.darpa.mil/about-us/timeline/-grand-challenge-for-autonomous-vehicles, 2004.

[5] DARPA, "The DARPA Grand Challenge: Ten Years Later," available: https://www.darpa.mil/news-events/2014-03-13, 2014.

[6] A. Davies, "Inside the Races That Jump-Started the Self-Driving Car," available: https://www.wired.com/story/darpa-grand-urban-challenge-self-driving-car/, 2017.

[7] Waymo, available: https://waymo.com/.

[8] G. P. Jain, V. P. Gurupur and E. D. Faulkenberry, "Artificial Intelligence Based Student Learning Evaluation Tool," 2013 IEEE Global Engineering Education Conference, 2013, pp. 751-756.

[9] J. G. Rowland, L.C. Jain, "Artificial Intelligence Languages in Engineering Education," Int. J. Electr. Eng. Educ., vol. 31, no. 2, pp. 138-143, 1994.

[10] I. S. Halkiadis, "A Practical Approach to Introducing Electrical Undergraduates to Artificial Neural Networks," Int. J. Electr. Eng. Educ., vol. 46, no. 2, pp. 121-132, 2012.

[11] G. R. Enrique, G. Ivan, and G. J. Magdiel, "A 'learning by design' application for modeling, implementing, and evaluating hardware architectures for artificial neural networks at undergraduate level," Comput. Appl. Eng. Educ., vol. 27, no. 5, pp. 1236-1252, 2019.

[12] M. A. C. Fernandes, "Problem-based learning applied to the artificial intelligence course," Comput. Appl. Eng. Educ., vol. 24, no. 3, pp. 388-399, 2016.

[13] J. Weinberg, G. Engel, K. Gu, et al., "A Multidisciplinary Model for Using Robotics in Engineering Education," in Proc. of the 2001 American Society for Engineering Education Annual Conference & Exposition, Jun. 2001.

[14] F. Díez, R. Cobos, "A case study of a cooperative learning experiment in artificial intelligence," Comput. Appl. Eng. Educ., vol. 15, no. 4, pp. 308-316, 2007.

[15] R. Mas-Sansó, C. Manresa-Yee, "Gamifying an Artificial Intelligence Course in Engineering Education," Int. J. Electr. Eng. Educ., vol. 32, no. Extra 1 (Part B), pp. 513-520, 2016.

[16] L. Victoria, N. Semeryanova, A. Kopytova, et al., "Application of artificial intelligence in the field of geotechnics and engineering education," in Proc. of E3S Web of Conferences, 2019, 110 (1): 02094.

[17] Athanasios S. Drigas, Rodi-eleni Ioannidou, "Artificial Intelligence in Special Education: A Decade Review," Int. J. Electr. Eng. Educ., vol. 28, no. 6, pp. 1366-1372, 2012.

[18] M. T. Chan, J. T. Chan, C. Gelowitz, et al., "Application of video game artificial intelligence techniques for design of a simulation software system for transportation engineering education," Int. J. Electr. Eng. Educ., vol. 32, no. Extra 1 (Part B), pp. 542-552, 2016.

[19] F. Jiménez, S. Monzón, "A simulation tool as a support for teaching the concepts of urban traffic flow," Comput. Appl. Eng. Educ., vol. 25, no. 2, pp. 320-329, 2017.

[20] F. Aparicio, F. Jiménez, and J. Sánchez, "Development and use of vehicle dynamics simulation software as support for road vehicles theory teaching," Comput. Appl. Eng. Educ., vol. 17, no. 4, pp. 467-478, 2009.

[21] J. A. Gomez-Pulido, J. M. Giron-Sierra, and B. Andres-Toro, "Graphical simulation of a mobile robot," Comput. Appl. Eng. Educ., vol. 2, no. 1, pp. 15-22, 1994.

[22] J. F. Martin, L. Chiang, "Low cost vision system for an educational platform in artificial intelligence and robotics," Comput. Appl. Eng. Educ., vol. 10, no. 4, pp. 238-248, 2003.

[23] S. S. Joshi, "Development and implementation of a MATLAB simulation project for a multidisciplinary graduate course in autonomous robotics," Comput. Appl. Eng. Educ., vol. 12, no. 1, pp. 54-64, 2004.

[24] M. Farrokhsiar, D. Krys and H. Najjaran, "A teaching tool for the state-of-the-art probabilistic methods used in localization of mobile robots," Comput. Appl. Eng. Educ., vol. 20, no. 4, pp. 721-727, 2012.

[25] S. Simončič, P. Podržaj, "Vision-based control of a line-tracing mobile robot," Comput. Appl. Eng. Educ., vol. 22, no. 3, pp. 474-480, 2011.

[26] M. Althoff, M. Koschi, S. Manzinger, "CommonRoad: Composable benchmarks for motion planning on roads," 2017 IEEE Intelligent Vehicles Symposium, pp. 719-726, 2017.

[27] CommonRoad, available: https://commonroad.in.tum.de/.

[28] J. Tang, S. Liu, et al., "Teaching Autonomous Driving Using a Modular and Integrated Approach," 2018 IEEE 42nd Annual Computer Software and Applications Conference, pp. 361-366, 2018.

[29] V. Costa, R. J. F. Rossetti and A. Sousa, "Autonomous driving simulator for educational purposes," in Proc. of 11th Iberian Conference on Information Systems and Technologies (CISTI), 2016, pp. 1-5.

[30] Gazebo, available: http://gazebosim.org/.

[31] ROS, available: https://www.ros.org/.

[32] R. Sell, M. Leier, et al., "Self-driving car ISEAUTO for research and education," in Proc. of 19th International Conference on Research and Education in Mechatronics, 2018, pp. 111-116.

[33] S. Karaman, A. Anders, M. Boulet, et al., "Project-based, collaborative, algorithmic robotics for high school students: Programming self-driving race cars at MIT," 2017 IEEE Integrated STEM Education Conference (ISEC), 2017, pp. 195-203.

[34] A. Mushtaq, S. Riaz, H. Mohd and A. Saleh, "Perception and technology adoption trends for autonomous vehicles: Educational case study," in Proc. of 2018 Advances in Science and Engineering Technology International Conferences (ASET), 2018, pp. 1-5.

[35] Udacity, available: https://cn.udacity.com/us.

[36] Apollo, available: http://apollo.auto/.

[37] Tier IV, available: https://tier4.jp/.

[38] Pix, available: https://www.pixmoving.com/.

[39] "The first autonomous driving technology course in China was successfully held," available: https://eecs.pku.edu.cn/info/1040/3574.htm, 2018.

[40] "Shenlanxueyuan Autonomous-Driving Training Base," available: https://www.shenlanxueyuan.com/page/129, 2022.

[41] X. Gao, H. Long, "Exploration on the construction of autonomous driving technology case courses," J. High. Educ., vol. 7, no. 34, pp. 96-99, 2021.

[42] Blockly, available: https://developers.google.com/blockly.

[43] Q. Zhou, X. Cui, P. Zhi, "Creative and Interesting Programming with Blockly," Chinese Version, China Machine Press, 2019.

[44] Z. Shen, B. Yong, Q. Zhou, L. Li, K. Li, "Theories and Practices of Self-Driving Vehicle," Chinese Version, China Machine Press, 2019.

[45] Autoware, available: https://www.autoware.org/.

[46] labelme, available: https://github.com/wkentaro/labelme.

[47] YOLO, available: https://pjreddie.com/darknet/yolo/.

[48] K. He, G. Gkioxari, et al., "Mask R-CNN," in Proc. of 2017 IEEE International Conference on Computer Vision, 2017, pp. 2961-2969.

[49] D. Neven, B. D. Brabandere, S. Georgoulis, et al., "Towards End-to-End Lane Detection: an Instance Segmentation Approach," available: https://arxiv.org/abs/1802.05591, 2018.

[50] Core ML, available: https://developer.apple.com/machine-learning.

[51] Venus Intelligent, available: http://www.vsitk.com/vs/.

[52] PerceptIn, available: https://www.perceptin.io/.

[53] "PerceptIn to launch an autonomous vehicle pilot in Indiana in early 2020," available: https://venturebeat.com/2019/11/21/perceptin-plans-to-launch-an-autonomous-vehicle-pilot-program-in-indiana-in-early-2020/, 2019.

[54] ISEAUTO, available: https://iot.ttu.ee/projects/iseauto/.

[55] Jacob Jacoby, Michael S. Matell, "Three-Point Likert Scales Are Good Enough," J. Mark. Res., vol. 8, no. 4, pp. 495-500, 1971.

[56] Haiyin Zhou, "Empirical Study on University Curriculum Satisfaction of University Graduates," Open J. Soc. Sci., vol. 4, no. 1, pp. 132-137, 2016.