Advances in Educational Technology and Psychology (2023)
Clausius Scientific Press, Canada

DOI: 10.23977/aetp.2023.070701
ISSN 2371-9400 Vol. 7 Num. 7

Development and Evaluation of a Gesture Recognition-Based Artificial Intelligence Science Popularization System

Shijia Tang

Tongji University, Shanghai, 200082, China
2495826499@qq.com

Keywords: Artificial Intelligence; Gesture Recognition; Remote Control; Science Education

Abstract: Currently, the Chinese government is actively promoting the integration of artificial intelligence (AI) technology into secondary school classrooms. However, the lack of teaching resources, heavy academic pressure, and unexpected public health events hinder the normal development of popular science teaching. In this study, based on the AI curriculum requirements in Beijing's Haidian District, a remote-control system for experiential teaching was developed using Mediapipe's keypoint recognition technology. This system enables remote control of smart homes and manipulation of robotic arm movements, allowing students to experience AI technology in a multi-sensory manner and overcome spatial limitations. To evaluate the effectiveness of this system in fostering students' AI literacy, 40 students from a high school in Hunan Province were selected as the research subjects. The t-value of the test scores between the experimental group and the control group was found to be 4.173. The results indicate that the adoption of the popular science system as a learning aid significantly improves students' mastery of AI knowledge.

1. Introduction

Artificial intelligence (AI) serves as a significant driving force leading the new wave of technological revolution and industrial transformation, profoundly changing the ways in which people produce, live, and learn. It propels human society into an intelligent era characterized by human-machine collaboration, cross-domain integration, and co-creation and sharing[1]. China actively promotes educational reform and innovation, harnessing the advantages of AI to accelerate the development of lifelong education for every individual, equal education opportunities, personalized education, and a more open and flexible educational system[2].

In April 2018, the Ministry of Education emphasized the "integration of artificial intelligence into compulsory education for widespread education" in the National Education Statistics Bulletin[3]. In 2020, five ministries jointly issued the "Guidelines for the Construction of National Standards System for Next-Generation Artificial Intelligence," which further specified the key directions and standards of artificial intelligence in the field of education. In 2021, the General Office of the Communist Party of China Central Committee issued the "Opinions on Further Reducing the

Burden of Homework and Extracurricular Training for Students in Compulsory Education," explicitly emphasizing the need to enhance the level of after-school services in schools and promote diverse activities such as popular science education, interest groups, and clubs[4]. The adolescent period is a critical time for nurturing interests, and young people, as the main driving force for future social development, should keep up with the ever-changing pace of science and technology. Therefore, it is necessary to integrate artificial intelligence into primary and secondary education.

However, due to uneven economic development, some schools lack teaching resources, including qualified faculty and equipment for AI education. Moreover, the recurring outbreaks of the COVID-19 pandemic have disrupted regular offline teaching activities in certain regions, affecting the progress of extracurricular activities and science popularization education. As an emerging field of information technology, artificial intelligence (AI) entails complex and intricate concepts. However, the country has not yet established unified curriculum standards and learning materials for AI education. Consequently, teachers often resort to didactic teaching methods without comprehensive teaching cases, which hinder the development of students' concrete understanding of AI. The traditional rote learning of AI fundamentals can lead to student resistance and disinterest. Therefore, the study aims to develop a remote-control system for experiential teaching, enabling students to connect AI knowledge with real-life experiences and construct their understanding of the subject.

2. Related Work

2.1. Popularization of Artificial Intelligence in Primary and Secondary Schools

The popularization of artificial intelligence science aims to enhance students' perceptual awareness, rational appreciation, and value judgment, while also deepening their comprehension of the constituent technologies, composition and characteristics, fundamental principles, and application values associated with artificial intelligence[5].

The US National Science Foundation, along with companies like Google and Microsoft, developed computer curriculum standards for K-12 schools, integrating knowledge mapping, machine learning, and ethics[6]. Deep learning technologies monitor student behaviour and assess their growth. In the UK, the ICT curriculum was revised to prioritize computing education, promoting the integration of AI and STEM[7]. Collaboration between schools and higher education institutions focuses on AI's impact on lifestyle improvements. Japan utilizes the "Essentials of Learning Guidance" as a curriculum standard, encouraging elementary students to explore the presence of AI technologies in their lives[8].

The 2017 edition of the "General High School Information Technology Curriculum Standards" in China requires students to comprehend the developmental trajectory and concepts of artificial intelligence, describe the implementation processes of typical AI algorithms, construct simple AI application modules, and foster a sense of responsibility in utilizing intelligent technology for human development[9]. Although the state strongly supports the popularization of AI science education in primary and secondary schools based on their individual circumstances, there is still a lack of unified teaching standards. To address this, the study draws upon the curriculum frameworks of developed countries such as the UK, the US, Japan, as well as the advanced AI education system in Beijing's Haidian District primary and secondary schools[10]. Taking gesture recognition technology, widely employed in AI applications, as a starting point, it aims to cultivate students' thinking abilities through experiential learning and sensory perception.

2.2. Gesture Recognition Technology in the Education Field

Gesture recognition plays a significant role in artificial intelligence, enabling machines to interpret and respond to human gestures through intelligent algorithms or devices. It facilitates interaction between gestures and machines, finding wide applications in sign language translation, interactive education, home entertainment, and smart toys for children[11]. The Horizon Report, published by the American Association for Information Technology in Higher Education, has highlighted gesture recognition as a key technology for education on multiple occasions[12], indicating its vast potential in the field.

Researchers like Fan Wenyuan[13] have developed systems utilizing Support Vector Machines (SVM) and Whale Optimization Algorithm (WOA) to classify and recognize gestures. Additionally, Qian Heqing[14] leveraged Kinect somatosensory devices and dynamic pose recognition algorithms to enhance natural human-computer interaction. These examples demonstrate the use of gesture recognition in various educational applications, such as sEMG gesture recognition systems and virtual globe educational aid systems. However, it is worth noting that the current implementation of gesture recognition technology in education often relies on specialized hardware sensors, which can create barriers for broader adoption and utilization.

2.3. Remote Interactive Experiment Applied in Teaching

Remote interactive experiments involve directly controlling actual experimental equipment located at the other end of the server through a network operator interface. A series of information obtained from the experimental equipment can be transmitted in real-time to the client's display screen via the network[15]. Students participating in the experiment can remotely issue commands to the real experimental equipment through a web interface and observe the operation of the equipment online.

Yang et al.[16] utilized Gazebo simulation software to establish virtual environments and robot models. They designed various components such as keyboard control, mapping, navigation, tracer carts, multi-robot simulations, and maze simulations. Python programming was employed to execute the corresponding functions. Qian et al.[17] developed the "520 Remote Chemistry Experiment" using the B/S model. Operators can remotely control real automated instruments in a chemistry lab located at a different location through a standard browser supporting Java.

Remote experimental teaching enables the sharing of high-quality educational resources, improves resource allocation efficiency, and reduces educational costs[18]. Applying university resources to secondary school education helps alleviate the supply pressure of inadequate basic education, improves the level of secondary school education, and fulfils the function of university social services.

3. Research Methodology

The gesture recognition technology used in this study is based on the open-source remote library called MediaPipe. MediaPipe has been trained in advance with datasets consisting of images of various hand poses in natural environments, multiple angles of hand pose in the laboratory, and computer-rendered 3D models of hand poses, for palm detection and keypoint annotation. Operators can directly access the pre-trained gesture detection neural network through the internet in a remote setting[19].

When the operator activates the RGB camera, the live video stream is captured and transmitted to the remote cloud server of MediaPipe in the form of multiple frames. The palm detection algorithm in the server utilizes rectangle recognition boxes to locate the position of the palm and crops the image accordingly. The keypoint annotation algorithm uses the pre-trained results to regress the 2.5D coordinates of 21 keypoints into the cropped image, and predicts the approximate position of the hand in the next frame. The 2.5D coordinates of 21 keypoints are shown in Figure 1. By comparing the predicted hand region with the actual hand information in the next frame, the palm detection algorithm can be stopped under certain confidence conditions, and the predicted values can be used instead of the palm position. Through these steps, critical information such as hand size and position are transformed into a language recognizable by computers, enabling remote and cross-regional human-machine collaboration[20]. The gesture recognition process based on Mediapipe is shown in Figure 2.

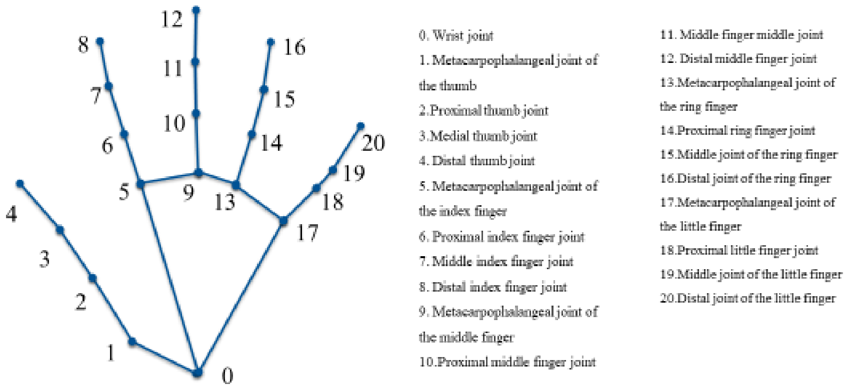

Figure 1: 2.5D Hand Pose Estimation: Coordinate Map of Hand Joint Positions.

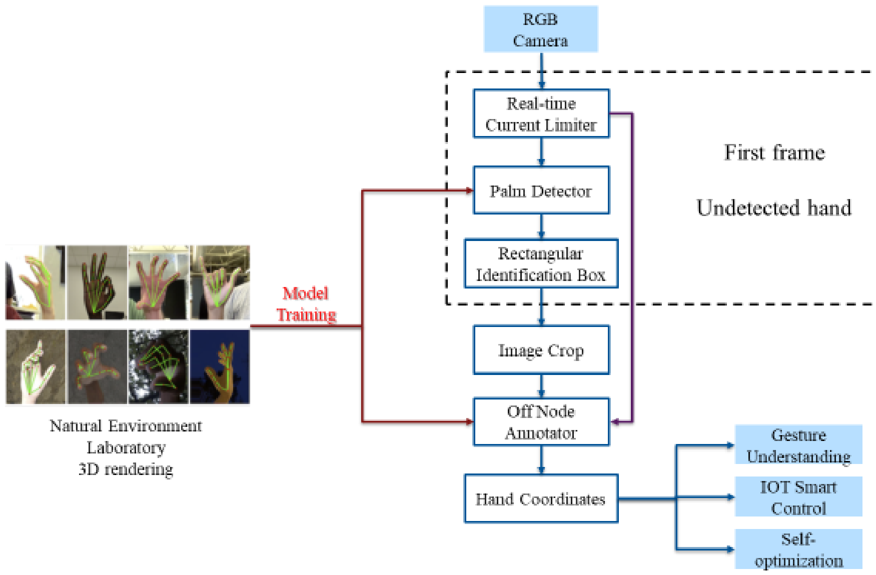

Figure 2: Gesture Recognition Process Based on Mediapipe.

Utilizing gesture recognition technology and cloud computing, a remote-control system can achieve functionalities such as gesture semantic recognition, home automation control, and digital twinning. The working principles of these functionalities are as follows:

Gesture Semantic Recognition: Gestures are determined by the bending angles of multiple joint nodes[21]. Therefore, it is possible to map various joint bending states to a set of predefined gesture collections. When the arrangement of 21 2.5D joint nodes obtained from the gesture tracking model matches the data in the gesture collection, the system automatically recognizes the semantic meaning of the gesture, such as "thumbs up," "fist," "OK," "rock-on," or "Spider-Man," enabling gesture semantic recognition.

Home Automation Control: Two recognition boxes, one for red and one for green, are set as input terminals for smart home control commands. When the eighth joint node appears within the recognition box, the system specifically outputs a 0/1 command. This command is then sent via the TCP/IP protocol to the central control device of the smart home, enabling remote control of the home automation system.

Digital Twinning: By extracting the state and trajectory of the gesture, the control system maps the gesture information to three-dimensional motion commands for a robotic arm. The motion commands for the robotic arm are then transformed into servo control commands based on the motion model. This process ultimately realizes remote gesture control of the robotic arm.

4. Experimental Design and Implementation

To verify the effectiveness of the gesture recognition remote control system in improving the artificial intelligence literacy of primary and secondary school students, we selected a total of 100 seventh-grade students from a middle school in Zhangjiajie City, Hunan Province as the research subjects. The students were randomly divided into an experimental group and a control group. The experimental implementation process is shown in Figure 3. To assess the artificial intelligence literacy of the students, we randomly selected 10 out of 20 pre-prepared test questions (with a Cronbach's alpha reliability coefficient of 0.794 and a Guttman split-half reliability coefficient of 0.789). Independent samples t-test was conducted between the experimental group (mean = 51.12, SD = 5.64) and the control group (mean = 52.28, SD = 5.64) based on the test scores. The calculated t-value was -1.021, with a corresponding p-value of 0.889, which is greater than 0.05. This indicates that there is no significant difference in artificial intelligence literacy between the experimental group and the control group.

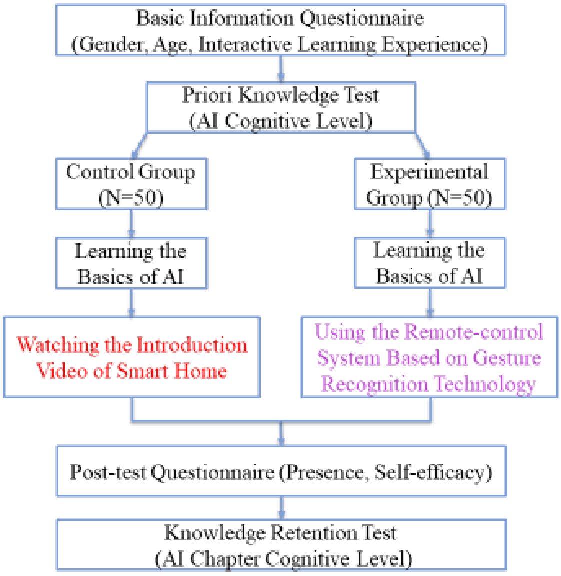

Figure 3: Process of Experimental Implementation.

This experiment was conducted in the information technology classroom of the secondary school. The duration of the experiment was 40 minutes, consistent with the regular class duration for students. After collecting basic student information and measuring prior knowledge, the normal teaching commenced. Both the experimental group and the control group received basic knowledge about artificial intelligence to ensure they had a certain understanding of gesture recognition technology. The control group students experienced the transformation of lifestyle through gesture recognition technology by watching an introduction video on smart homes. The experimental group students, on the other hand, were able to use a remote-control system to give instructions to remote smart home devices, allowing them to experience and perceive the practical applications of gesture recognition technology in daily life. After the classroom teaching concluded, the remaining 10 questions were used to test and record the students' knowledge retention, followed by a post-test questionnaire for both the experimental and control group students to evaluate their learning experience using the two teaching methods.

5. Results and Discussion

In order to investigate whether a remote-control system based on gesture recognition technology can effectively enhance students' AI literacy, we analysed the post-test scores of the students. Firstly, we conducted a dimensionality reduction analysis on 10 test questions and plotted a scree plot (Figure 4). According to the results of the factor analysis test (Table 1), three factors accounted for 61.289% of the variance in the results. These three factors respectively reflect students' abilities in perceiving, experiencing, and transferring AI knowledge.

Table 1: Principal Component Analysis of Post-Test Questionnaire.

Total Variance Explained							
Factor	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings[a]
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	4.024	40.236	40.236	4.024	40.236	40.236	4.019
2	1.059	10.590	50.825	1.059	10.590	50.825	1.083
3	1.046	10.464	61.289	1.046	10.464	61.289	1.066
4	.817	8.170	69.459				
5	.741	7.409	76.868				
6	.613	6.132	83.000				
7	.514	5.144	88.144				
8	.460	4.605	92.748				
9	.410	4.097	96.845				
10	.316	3.155	100.000				
Extraction Method: Principal Component Analysis.							
a. If the components are correlated, the sum of squares of the loadings cannot be added to obtain the total variance.							

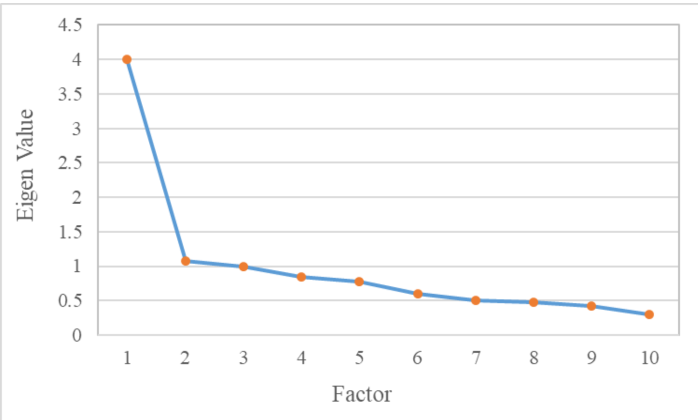

Figure 4: Scree Plot.

Afterwards, independent sample t-tests were conducted on the post-test data using SPSS 23.0, and the calculated results are listed in the table 2. The independent sample t-test value for the experimental group and the control group's post-test scores is 8.354, with a corresponding p-value of less than 0.05, indicating that the use of gesture recognition remote control systems significantly improves the cognitive abilities of primary and secondary school students in relation to artificial intelligence. The independent sample t-test value for the experimental group and the control group's sense of presence is 7.423, with a corresponding p-value of less than 0.05, suggesting that the application of embodied gesture recognition technology in daily life can help students gain a better sense of presence. According to the constructivist learning theory, a conducive learning environment can facilitate meaningful teaching and aid students in mastering knowledge. The independent sample t-test value for the experimental group and the control group's self-efficacy is 8.782, with a corresponding p-value of less than 0.05, indicating that the students in the experimental group possess higher self-efficacy and fully experience the empowerment of artificial intelligence technology in education. The t-test value between the pre-test and post-test scores for the experimental group is 16.995, with a corresponding p-value significantly less than 0.05, indicating that the predetermined educational objectives were achieved in this teaching course. Students gained initial perception and experience with artificial intelligence, effectively enhancing their thinking abilities.

Table 2: Independent Samples t-Test Results between Experimental Group and Control Group.

Name	Experimental Group (N =50)		Control Group (N =50)		T value	P value
	Mean	S.D.	Mean	S.D.		
Test Results	75.15	5.02	65.96	5.94	8.354	0.000
Presence	4.53	0.25	4.08	0.34	7.423	0.000
Self-efficacy	4.45	0.20	4.10	0.19	8.782	0.000

6. Conclusion and Future Work

The remote-control system based on gesture recognition technology has changed the way information is represented. The initial impression of artificial intelligence for primary and secondary school students is no longer the obscure neural network formulas in textbooks, but rather the mechanical arm that can be controlled by hand gestures. This system has transformed the teaching mode from traditional didactic instruction to experiential learning through active participation. It empowers education with artificial intelligence technology, overcoming the limitations of time and space. Students can now deepen their understanding of cloud computing and artificial intelligence technology anytime, anywhere through gestures. This addresses the problem of disruptions to AI popularization courses caused by the pandemic and the interruption of normal learning progress.

In future work, we will add functionality to the control system to record students' behaviors. By integrating multimodal analysis of physiological data such as heart rate, brain waves, eye movements, behavioural data such as gestures and facial expressions, and psychological data such as textual emotions and tones, we will provide students with learning alerts and recommend learning resources. We will also analyse changes in students' attention levels and provide teaching method improvement suggestions to teachers. Process-oriented indicators of students' performance will be incorporated into the final evaluation system.

References

[1] Huang, Ronghuai, Zhou Wei, Du Jing, et al. "Three Fundamental Computational Problems for Intelligent Education." Open Education Research, vol. 25, no. 5, 2019, pp. 12.
[2] Liu, Bangqi. "Construction and Application of the 'Teaching According to Individual Differences' Teaching Model Supported by Intelligent Technology—Taking Smart Classroom as an Example." China Electric Education, no. 09, 2020, pp. 30-39.
[3] Zhang Shanshan, Du Xiaomin, Zhang Anran. "Challenges, Priorities, and Strategies for AI Education in Primary and Secondary Schools." China Electric Education, no. 11, 2020, pp. 67-72+96.
[4] Zhang, Ying. "General Office and State Council Issued the 'Opinions on Further Reducing the Academic Burden of Compulsory Education Students and the Burden of Off-campus Training'." Study Abroad, no. 15, 2021, pp. 1.
[5] Zhao, Feilong, Zhong Kun, Liu Min. "Exploration of Popular Science Education of Artificial Intelligence: Taking the 'Speech Synthesis' Course in Junior High School as an Example." Modern Educational Technology, vol. 28, no. 5, 2018, pp. 7.
[6] Fang, Yuanyuan, Huang Xuguang. "AI Education in Primary and Secondary Schools: What to Learn and How to Teach—Inspiration from 'K-12 AI Education Action' in the United States." China Electric Education, no. 10, 2020, pp. 8.
[7] Lu, Yu, Tang Xiaoyu, Song Jiachen, et al. "AI Education in Primary and Secondary Schools in the Intelligent Era: Overall Positioning and Core Content Areas." China Distance Education, no. 5, 2021, pp. 11.
[8] Sun, Lihui, Liu Siyuan, Li Manman. "Action Path for Children's Programming Education in the AI Era—Based on the Investigation Report on the Necessary Conditions for the Development of Children's Programming Education in Japan." Educational Technology Research, vol. 40, no. 8, 2019, pp. 8.
[9] Liang, Yingli, Liu Chen. "Analysis, Typical Features, and Development Trends of AI Education Application." China Electric Education, no. 3, 2018, pp. 7.
[10] Ma, Tao, Zhao Feng, Wang Youxue, et al. "Development Path of AI Education in Primary and Secondary Schools in Haidian District." China Electric Education, no. 5, 2019, pp. 5.
[11] Wang, Suzhen. "Research on Gesture Recognition Technology Based on Deep Learning." Zhejiang University, 2019.
[12] Wang, Mengyu. "Key Trends and Major Challenges of the Horizon Report: Evolution and Analysis Based on the Higher Education Edition from 2015 to 2019." Journal of Distance Education, vol. 37, no. 4, 2019, pp. 9.
[13] Fan, Wenyuan. "Research and Design of sEMG Gesture Recognition System Applied to AI Education." Shanghai Normal University, 2021.
[14] Qian, Heqing. "Augmented Reality Educational Assistance System Based on Kinect and Gesture Recognition." Shanghai Jiao Tong University, 2012.
[15] Zong, Guosheng. "Current Problems and Countermeasures of Remote Experimental Teaching." China Distance Education, no. 9, 2008, pp. 4.
[16] Yang, Wenyu, Zheng Xianghua, Sun Dianbin. "Exploration of Remote Experimental Teaching of Mobile Robot Course Based on the Internet." Research in Higher Engineering Education, no. 3, 2021, pp. 5.
[17] Qian, Yangyi, Huang Xiaoyan. "Application and Exploration of '520 Remote Chemistry Laboratory' in Secondary School Experimental Teaching." China Electric Education, no. 1, 2011, pp. 97-100.
[18] Moore, S., Stamper, J., Bier, N., et al. "A Human-Centered Approach to Data Driven Iterative Course Improvement." 2020.
[19] Zhang, F., Bazarevsky, V., Vakunov, A., et al. "MediaPipe Hands: On-device Real-time Hand Tracking." 2020.
[20] Wu, T. L., Senda, T. "Pen Spinning Hand Movement Analysis Using MediaPipe Hands." 2021.
[21] Xu, Yan, Huai Jinpeng, Wang Zhaoqi. "Gesture Data Mining and Visualization of Mining Results." Journal of Computer-Aided Design & Graphics, no. 04, 2003, pp. 449-453.