Study on Learning Status Information in Education Based on Line-of-Sight Tracking in Artificial Intelligence Environment

Yang Lin*, Ping Zhang, Guoping Song
Jilin Distance Education Technology Innovation Center, Jilin, Changchun, 130022, China
*Corresponding Author

Abstract

Combining with education is one of the hot research directions of artificial intelligence, and acquiring learning state information is an all-important link in intelligent education. Vision changes can directly or indirectly reflect psychological and state changes, so eye gaze tracking plays a crucial role in intelligent education. First of all, the development of intelligent education is introduced. Secondly, the development, current research work, and research status of eye gaze tracking technologyare summarized and analyzed, and its related application and research work in the field of education in recent three years are summarized. Finally, the development trend of eye gaze tracking technology in the educational field is summarized and prospected.

Keywords: Intelligent education, Artificial intelligence(AR), Online education, Eye gaze tracking, Study analysis

I. Introduction

Eye gaze tracking is a way to record real, natural and objective user behavior, which uses eye gaze tracking technology to accurately record students' online learning focus and focus area, and detects color and texture information in images of Regions OfInterest (ROI) based on a data-driven approach. In the same scenario, different tasks will significantly change the ROI based on task-driven mode. Taking the simulated driving task in Figure 1 as an example, when driving at high speed, the driver should focus on the straight ahead of the driving direction, as shown in the box area in Figure 1 (a).In this task, the ROI detected by the above two methods is different, so the region in the figure cannot be used as the guiding ROI, and the ROI detected by the task-driven method is more accurate. In real task scenarios, the ROI detected by the data-driven approach cannot effectively reflect the real visual ROI. Eye movement is a rapid and subconscious movement behavior, which can reflect users' potential information, as shown in Figure 1. Facial expression can be camouflaged, while the eye state, especially the change of pupil size, cannot be controlled strongly. Therefore, eye movement tracking can provide support for teachers' personalized instruction in teaching. Moreover, eye-movement data, such as changes in pupil size, can also reveal emotional and physiological information during students' learning process.

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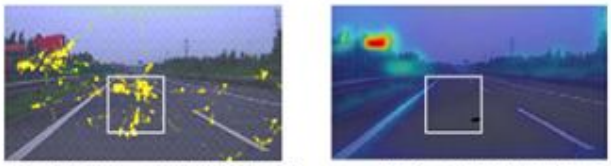

(a) Detection results of line-of-sight area (b) Region detection results of algorithm

(c) Schematic diagram of detection realization

Fig 1: Region detection results of eye gaze tracking method and algorithm

The research and analysis of the application of eye gaze tracking technology in the educational field include four parts: First of all, the origin and development of eye gaze tracking technology are introduced; Secondly, the principle and method of eye gaze tracking technology are analyzed; Thirdly, the application mode of eye gaze tracking technology in the educational field is summarized; Finally, the application of this technology in the educational field is prospected.

II. Eye Gaze Tracking Method

Human eye feature extraction and line of sight parameter detection are two key links of the eye gaze tracking system. The quality of human eye feature extraction directly affects the accuracy of eye gaze tracking. Eye gaze tracking methods can be divided into eye gaze estimation method based on 2D regression, eye gaze tracking method based on the 3D human visual system (HVS), eye gaze tracking method based on human eyeappearance features, and eye gaze estimation method based on deep learning.

(1) Gaze tracking method based on 2D regression

Eye gaze estimation methods based on 2D regression mainly include corneal pupil reflex method, pupil canthus feature point method, intersection ratio method, and homopic normalization method. The eye gaze detection diagram is shown in Figure 2. Qin Huabiao et al. used template matching and convex hull method to accurately locate the pupil center. The method is based on a monocular camera. First of all, four infrared light sources are used toproduce four light spots on the cornea.Secondly, the center of the light spot is calculated in accordance with the position of the four light spots, and the center position and the pupil center are used to establish the pupil corneal reflection vector. Finally, the quadratic polynomial is used to map the pupil corneal reflection vector to screen coordinates points.When the head moves in a space of 16 cm×10 cm×14 cm, the average accuracy can reach 1°. When detecting the line of sight based on a monocular camera under natural light, the estimation accuracy of the fixation point is low, and the head cannot move in a large range.

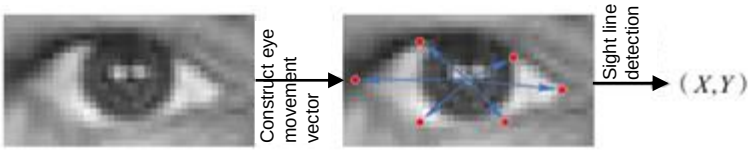

Fig 2: Line of sight detection method based on 2D regression

The sight line estimation method based on 2D regression can not handle the movement problem of the head. Kolakowski et al. introduced heuristic rules to detect the sight landing point more accurately in the case of head movement.

Zhu et al.[24] used two cameras to estimate the position of the head in 3D space based on regression in order to accurately detect the sight landing point when the head moved in a large space range, and then corrected the regression function by obtaining the position of the eyes in space, so as to compensate for the error caused by the head movement. This method has high detection accuracy but needs to calibrate the camera.

The movement of the pupil reflects the change of the line of sight, and accurate positioning of the pupil is the premise of accurately detecting the sight landing point. In the application environment of online education, wearing glasses and light changes will affect the positioning of the pupil. Zhang et al. proposed forward and backward oblique integral projection algorithms based on relative linear density. The polynomial mapping function f(x) was used to establish the corresponding relationship between eye movement V and coordinate points (X, Y). When the user was 60~80 cm away from the camera, the accuracy could reach 1.5°~2.2°.

The eye gaze tracking method based on 2D regression can accurately detect the sight landing point the head is relatively fixed. When the distance and angle between the head and the camera greatly deflect, the detection accuracy decreases.

(2) Eye gaze tracking method based on 3D HVS

The gaze tracking method based on 3D HVS can directly model the eye structure and calculate the eye direction. By defining the gaze direction vector and combining it with the screen, the intersection of the gaze direction vector and the screen is the fixation point. The exact position of the head in the space can be directly reflected by the position of the eyeball or cornea in the space. The gaze tracking method based on 3D HVS mainly includes the gaze tracking method based on a depth camera and the gaze tracking method based on an ordinary camera.

The gaze tracking method based on a depth camera has simple system configurationand can allow the head to move, but it needs to calculate the characteristics of the eyes very accurately, with relatively high requirements for the precision of hardware.

The gaze tracking method based on 3DHVS, as shown in Figure 3, usesa multi-view camera or depth camera to obtain 3D position information of eye f (x) and head h (x). When the distance between the user and the camera and the posture change, the head posture data g(x) can be used to compensate for the sight landing point, thus obtaining the sight landing point (X, Y).

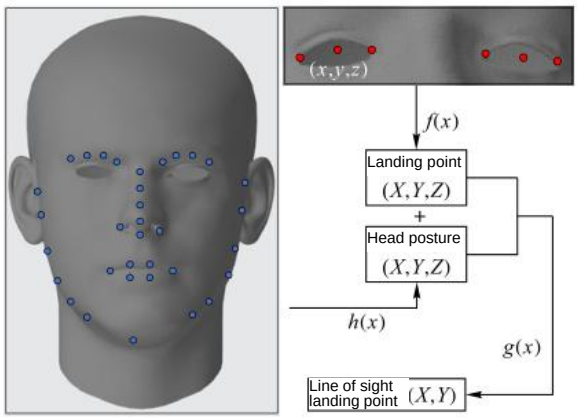

Fig 3: Sight landing point detection method based on 3D HVS

The gaze tracking method based on 3D HVS can effectively overcome the influence of head position and posture changes on the sight landing point and improve the accuracy of eye gaze tracking. However, when using a multi-view camera for gaze tracking, it needs a complex calibration process. The comparison results of the eye gaze tracking method based on 3D HVS and the eye gaze tracking method based on 2D regression are shown in Figure 4.

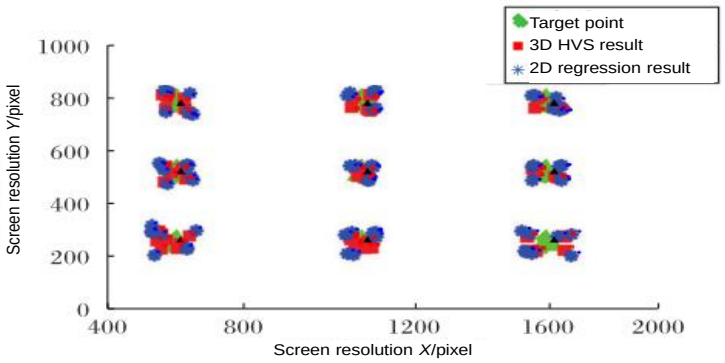

Fig 4: Comparison results of the eye gaze tracking method based on 3D HVS and the eye gaze tracking method based on 2D regression

Fig 5: Image acquisition schematic diagram of sight landing point detection method based on appearance

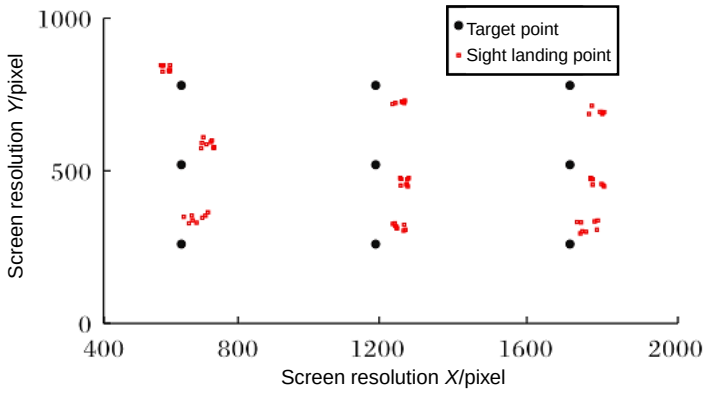

Fig 6: Sight landing point detection resultsbased on appearance

(3) Gaze tracking method based on deep learning

Deep learning-based fixation detection is also widely used in mobile devices. Naqvi et al. used infrared sensors to collect facial images of drivers while driving, and extracted the Purkinje spots of left and right eyesin the images. Combined with facial images as input of convolutional neural network, the gaze tracking was carried out.Wong et al.used ResNet-18 (Residual Neural Network) for training to detect the sight landing point when using mobile devices. Wu et al. proposed the multi-task deep network EyeNet, which can be used to complete multiple tasks simultaneously, including fixation point detection, eye region segmentation, Purkinje spot detection, and pupil and corneal center point detection.

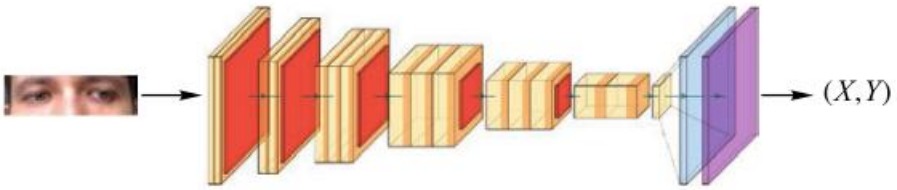

Fig 7: Sight landing point detection based on deep learning

Currently, gaze tracking needs to limit the use environment and uses professional equipment to collect facial images. The accuracy of the sight landing point detection is affected by image resolution. The sight landing point detection method based on deep learning does not require complex calibration of the camera and can accurately detect the sight landing point when the training data is sufficient. However, the training of the model needs to collect a large amount of image data in different environments, but the lack of relevant data sets restricts its developmentd.

MPIIGaze database can be used to evaluate the accuracy of sight landing point detection, and it contains the image data of 15 subjects in a real laptop environment. Different subjects collected the data in different camera positions, and head posture, sight direction, and light changes are diversified, so it is often used to evaluate the accuracy of sight landing points. The test results of the

model using MPIIGaze database are shown in Table 1.

Tab 1: Average error rate unit of gaze tracking model :(°)

Model name	Average error rate
iTracker(ResNet-34)	5. 300
iTracker	6. 030
Multi-modal CNN	6. 600
Spatial wights CNN	6. 055
UnityEyes	9. 580
DeepVOG(Video-Oculography)	0. 500

(4) Comparison of gaze tracking methods

The existing gaze tracking methods are shown in Table 4. Through the analysis of Table 4, it can be found that the sight estimation method based on 2D regression can extract the features of human eyes, such as pupil position, iris center point, inner, and outer canthus. When there is an auxiliary light source, the Purkinje spot reflected by the light source on the cornea can be extracted, and the changes of the line of sight can be represented by the movement of the feature points in the eye region.Polynomial mapping function, neural network, and support vector regression are used to establish the mapping relationship between eye movement and screen area. The head must remain still when there is no auxiliary light source. When two or more light sources are used to form Purkinje spot in the cornea, the relationship between pupil and Purkinje spot can be established. Taking head movement into account makes the head move in a small scope of space.The sight estimation method based on 2D regression has a simple system configuration and does not require additional calibration operations, but the head movement range is greatly limited.

Convolutional neural networks are widely used in gaze tracking tasks. The gaze tracking method based on deep learning does not require complex camera calibration and can adapt to the changes of illumination. However, this method needs to collect a large amount of training data, and there are few relevant data sets. The advantages and disadvantages of the existing algorithms are shown in Table 5.

Tab 2: Comparison of gaze tracking algorithms

Methods	Advantages	Disadvantages
Gaze tracking method based on 2D regression	The system is simple and does not require calibration	Reduced accuracy of head movement over a wide range
Gaze tracking method based on 3D HVS	Allow the head to move	Complex calibration, and the precision of sight landing point detection is affected by the precision of hardware
Gaze tracking method based on appearance features	Have relatively low requirements for the precision of camera hardware	Sensitive to changes in light and posture
		A large amount of data needs to be

Gaze tracking method based on deep learning	Strong robustness, adapt to light and environmental changes	collected to train the model

III. Application of Gaze Tracking Technology in Educational Field

Under the strong support of national policies and relevant enterprises, online education provides support for traditional education and has been vigorously developed and popularized. Especially during the pandemic, online education presents unique advantages. Thegaze tracking technology is used to collect students' sight landing point, pupil size change, fixation duration, fixation times, fixation point sequence, saccade distance, facial expression change and physiological information during online learning, thus obtainingstudents'relevant state data in class.Relevant state data, including concentration, mood change and reading habits, can not only provide support for teachers' personalized guidance but also make personalized learning plans for students, so as to realize the idea that teaching benefits teachers as well as students. The application process of gaze tracking technology in the educational field is shown in Figure 8.

When students study online, a monocular camera, binocular camera, depth camera, or professional equipment will be used to collect images of students' faces. By analyzing the collected images, we can not only get the heart rate change and facial expression change of students during learning but also obtain their sight landing point by using gaze tracking technology. The sight landing point is an important data source for analyzing students'real-time ROI. The collected data are summarized and analyzed to feedback students' learning status.

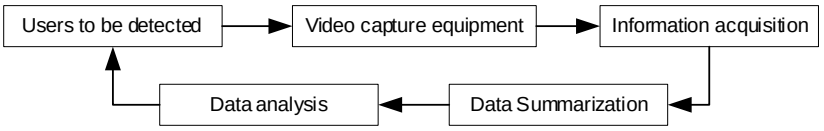

Fig 8: Application process of gaze tracking technology in educational field

In recent years, with the continuous development and improvement of artificial intelligence technology, image processing technology and related algorithms, researchers at home and abroad have carried out in-depth research on the application of gaze tracking technology in the educational field. According to the research purposes, the application of gaze tracking technology in the educational field can be divided into the following four categories: 1) The application of gaze tracking technology in the change of teaching methods; 2) The application of gaze tracking technology in improving academic performance; 3) The application of gaze tracking technology in optimizing workflow; 4) Other applications of gaze tracking technology.

(1) Application of eye-tracking technology in teaching method change

The different way of knowledge presentation makes students' acceptance of knowledge inconsistent. As for the same learning content, students will adopt different learning methodsdue to individual differences. The gaze tracking technology can be used to dynamically analyze learners' behaviors

and formulate targeted learning methods and content presentation forms according to different learners' learning preferences.The researchers designed the following three experiments, respectively: 1) the teacher's face did not appear in the video; 2) The teacher's face appeared in the video and guided the students through sight; 3) The teacher's face appeared in the video but did not guide students through sight. The researchers collected the sight landing point in each of the three conditions.The experimental results showed that the presence of the teacher's face didn't affect the learning effect, and students can reasonably allocate their sight to the teacher's face and the content taught. Not only the presentation way of learning content will have a great impact on students' learning effect, but also the cognitive level will have a great impact on
students' knowledge acceptance ability.

(2) Application of gaze tracking technology in improving academic performance

There may be differences in learning styles of students with high scores and low scores. Students' sight landing point in the learning process is collected by the gaze tracking technology, and the sight landing point of students with excellent performance is analyzed, so as to provide corresponding learning guidance for students with poor performance, and change their learning style.

(3) Application of gaze tracking technology in optimizing workflow

Gaze tracking technology is also widely used in industrial and medical fields to improve students' professional skills. Students and professional workers have different educational backgrounds and work experience. Therefore, by comparing the areas that students and professional workers pay attention to the production process and improving the production process from different perspectives, the production time of each product can be reduced by 20-180 s and the production efficiency can be improved[77].During surgery, the ROI changes, and the ROI of an expert differs from that of an inexperienced surgeon. The SMI REDn non-contact eye tracker is used to collect the ROI of the expert during surgery to provide support for young doctors, so as to reduce the occurrence of medical accidents.

(4)Application of gaze tracking technology in other aspects

The gaze tracking technology is used to analyze students'sight landing points during learning. Relevant studies have shown that fixation time, fixation frequency, fixation point sequence, saccade distance, back-glance frequency and pupil diameter are generally taken as important parameters of thinking activities and psychological changes. When students study online, the changes in learning state and psychological state can be reflected in the changes of eye state and sight landing point. Therefore, real-time observation of students' eye movement information during online learning can be used as a basis for analyzing and guiding their learning.A lot of important information can be obtained by analyzing the eye movement pattern, eye landing point and related eye movement parameters. For example, the eye landing point can reflect students' ROI and the content they are interested in. The fatigue degree of students is judged according to saccade speed, blink speed and eye-opening degree. Meanwhile, relevant literature has shown that saccade speed is related to the difficulty of learning content. Therefore, according to relevant parameters,students' mental states can be determined and the learning process can be analyzed, and then corresponding learning strategies

and intervention measures can be adopted to adapt to different learning needs.

IV.Conclusion

Gaze tracking has played an important role in the educational field. Due to the demand for intelligent education, the decrease of hardware costs, and the improvement of image processing algorithms, the application of gaze tracking technology has been more and more extensive in the educational field. In the future, more attention should be paid to the following aspects. First of all, a robust sight landing point detection algorithm based on common cameras should be developed.Secondly, the gaze tracking data in the learning process should be established and improved, and the group features and individual features of students'sight landing points that reflect their learning status should be extracted based on big data. Finally, the sight landing point should be combined with physiological signals, expressions, micro-expressions, and teaching situations, and the multi-dimensional data is used for accurate learning process state analysis, thus providing data support for personalized learning guidance and formative evaluation of students' learning process.

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