

Research on the Technology and Method of Combining Virtual Reality with Eye Movement Tracking - Taking VR Vision Corrector as an Example

Ziyun Huang^{1,*}, Zengming Li²

¹ International College, Guangzhou College of Commerce, Guangzhou, China, 511363

² School of Modern Information Industry, Guangzhou College of Commerce, Guangzhou, China, 511363

* Corresponding author: 13826178150@163.com

Abstract. In response to the low efficiency and error prone human statistical recording in traditional vision testing and correction services, as well as the need for regular vision testing under the normalization of vision testing, which also brings more complex workload for testing personnel and higher professional technical requirements for correcting vision, this article takes VR vision correction equipment as an example to explore the significance and value of virtual reality combined with eye tracking technology in vision correction services. The article first introduces the basic concepts and characteristics of virtual reality, as well as the application of convolutional neural networks in eye tracking technology, and then constructs a research technical framework for VR vision correctors that combine virtual reality with eye tracking. Research has shown that virtual reality and eye tracking technology have great potential for application in the field of vision correction, and can effectively provide certain reference value for research and development in related fields.

Keywords: virtual reality, eye tracking, convolutional neural networks, vision correctors.

1. Introduction

Virtual Reality is a rapidly developing emerging field of computer science in recent years, which combines multiple disciplines and technologies, including but not limited to multimedia technology, simulation technology, computer graphics, artificial intelligence technology, parallel processing technology, human-computer interaction technology, stereoscopic display technology, system modeling and simulation, etc [1]. With the development of perception technology, the application of eye tracking technology has gradually matured. By capturing and analyzing eye behavior, we can further understand the subject's thinking mode and cognitive process, and rationally judge the subject's conscious behavior [2]. The intervention of eye tracking technology is conducive to demonstrating the immersive design of virtual environments and visual elements, promoting a more natural mutual stimulation in human-computer interaction processes [3]. At present, desktop eye tracking devices and glasses eye tracking devices are more common, and with the development of computer science, VR eye tracking devices are gradually beginning to appear in people's vision. VR technology can make users feel more immersed, thus better imitating the feelings given to people in real situations and improving the interactive experience [4].

With the development of deep learning, convolutional neural networks have become an important tool for processing complex data, solving key problems in fields such as computer vision and natural language processing. They have the ability to efficiently, accurately, and automatically learn features, promoting the widespread application of artificial intelligence in various fields. Compared to other neural networks, CNN can efficiently and quickly learn raw data, has the ability of representation learning, and is widely used in various fields such as computer vision and natural language processing [5]. Convolutional neural networks are actually feedforward neural networks composed of multi-layer convolutional structures, and can be trained in both supervised and unsupervised learning modes [6]. Convolutional neural networks consist of input layers, convolutional layers, computational layers, pooling layers, and fully connected layers, which together form a complete convolutional neural network [7]. Convolutional neural networks (CNNs) have advantages that traditional recognition

methods do not possess, such as the ability to train on their own, faster recognition speed, fewer features required, and higher classification accuracy. They have a wide range of applications in pattern classification and a pivotal position in deep learning [8].

Sun Yuxuan et al. used the method of visual tracking and backtracking based auditory thinking to collect real-time eye movement data when subjects experienced common virtual movements, and completed two scale evaluations before and after the experiment. The collected 11 parameter indicators were used for data analysis. Using entropy weighting method to improve EFA for comprehensive evaluation, first extracting factors to simplify the number of variables, and then correcting the weight of component factors under entropy weighting method [9]. Zhang Jingyu uses object detection methods to extract facial and human eyes, and designs a gaze estimation network to obtain gaze information based on facial and human eye related information. To improve the accuracy of gaze estimation networks, the model is further improved by combining mainstream lightweight networks and Generative Adversarial Networks (GANs) [10]. He Shishan proposed a design and implementation method for a strabismus measurement system based on virtual reality combined with eye tracking. Through investigation and comparison of relevant hardware devices and multiple virtual reality 3D engines available on the market, the HTC VIVE virtual head display, aSee VR eye tracker, and Unity3D engine were compared and determined to implement the strabismus measurement system. Detailed methods for connecting various hardware to Unity3D are provided, and conventional methods for measuring strabismus in hospital outpatient clinics are introduced [11].

Although more and more researchers are paying attention to the layout and application of eye tracking in VR/AR, there are still many problems in applying eye tracking technology to VR/AR due to its short application time [12].

This article takes VR vision correction equipment as a case study, aiming to study the application effect of virtual reality and eye tracking technology in the field of vision correction. Convolutional neural networks are introduced to achieve eye tracking, which can automatically extract features, have strong adaptability, good robustness, high data efficiency, and real-time performance, thereby improving the accuracy, efficiency, and applicability of eye tracking technology. Secondly, strategic analysis is based on the analysis of external opportunities, threats, and internal strengths and weaknesses that the internal and external environment of the enterprise has on its business activities, also known as SWOT analysis [13]. This article uses the SWOT analysis method to analyze the strategic environment of VR vision correctors. By using the SWOT analysis method to analyze the strategic environment of VR vision correctors, it can comprehensively understand the competitive environment of the product in the market and provide guidance for enterprises to make wise strategic decisions. This helps enterprises to fully utilize the advantages and opportunities of the product, while countering disadvantages and threats, achieving sustainable development and success. The significance of this study is to reveal the practical effects of virtual reality and eye tracking technology in commercial applications, providing strong support for enterprise and industry decision-making. In addition, the research results on VR vision correction technology will also verify its therapeutic effect and feasibility, promoting further development and application in this field.

2. Basic Principles of Eye Movement Tracking Technology Based on Convolutional Neural Networks

Eye tracking technology based on Convolutional Neural Network (CNN) is a common and effective method for estimating the position of human eye gaze points. The basic schematic diagram of this technology is shown in Figure 1:

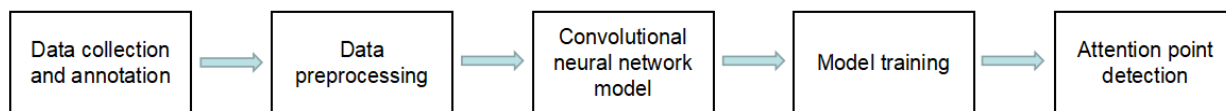


Figure 1. Basic schematic diagram of eye tracking technology based on convolutional neural networks

The convolutional neural network (CNN) model applied in eye tracking technology consists of the following five parts:

Input layer: The input layer receives input data from the eye tracking system, usually eye images or video frame sequences. These input data capture the eye position and movement during the observation process.

(2) Convolutional layer: Convolutional layer is one of the core components of convolutional neural networks. In eye tracking technology, convolutional layers extract important features in eye movement behavior through a series of convolutional operations. Each convolution operation uses convolution check input data for sliding calculation to obtain a Feature Activation Map, where each position of the feature map represents different high-level features.

(3) Pooling layer: Pooling layer follows convolutional layer closely, with the aim of downsampling and dimensionality reduction of feature activation maps. The commonly used pooling method is Max Pooling, which selects the maximum value within each region in the feature map as the output, reducing computational complexity while retaining important information.

(4) Fully connected layer: The fully connected layer connects the output of the pooling layer to one or more fully connected layers, converting features into predicted results of eye movement behavior. Each neuron is connected to all neurons in the previous layer, and the relationship between input features and eye movement behavior is established through weight adjustment and nonlinear activation functions.

(5) Output layer: The output layer produces the final eye tracking results. The specific output method depends on the task, such as predicting eye position, fixation point, or fixation duration. The design of the output layer usually involves selecting appropriate activation and loss functions to minimize the error between predicted results and true values.

By combining these five levels, eye tracking technology based on convolutional neural networks can automatically extract high-level features, and achieve analysis and prediction of observer attention allocation and cognitive processes by learning and predicting eye position and movement. The convolutional neural network (CNN) model applied in eye tracking technology is shown in Figure 2:

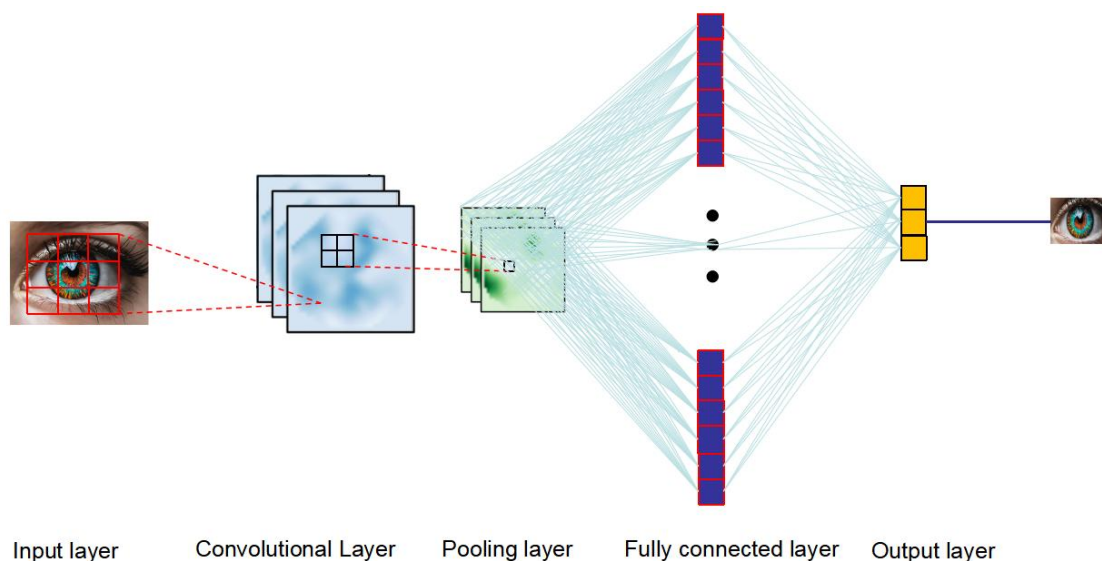


Figure 2. Convolutional neural network model applied in eye tracking technology

3. Results

VR vision correction device, as an innovative product combining virtual reality and eye-tracking technology, is gradually gaining attention in the market and showing vast market potential. Nowadays, vision problems have become a common issue globally, especially with the increasing number of myopia patients, and traditional methods of vision correction often lack personalization and attractiveness. With its unique advantages, the VR vision correction device meets the new demands for vision correction.

Firstly, the VR vision correction device satisfies users' need for personalized correction solutions. By utilizing virtual reality and eye-tracking technology, the VR vision correction device offers a novel and personalized approach to vision correction. It generates customized vision correction plans based on individual eye-tracking data, thus better meeting users' unique needs. This personalized experience enhances user engagement and satisfaction, making the VR vision correction device their preferred choice for vision correction.

Secondly, the VR vision correction device combines immersive virtual reality experience, attracting the interest and curiosity of a wide range of users. By providing a virtual environment backdrop, users can undergo vision correction in an immersive and captivating experience, making the process more vivid, enjoyable, and engaging. This immersive experience not only enhances the effectiveness of correction but also increases user involvement and persistence, encouraging users to actively utilize the VR vision correction device.

Thirdly, with the continuous development of virtual reality technology, the VR market is expanding, providing opportunities for the market development of VR vision correction devices. More and more companies and investors are focusing on VR technology and its application market, gradually recognizing the potential of VR vision correction devices as innovative products in the healthcare field. It is expected that the VR market scale will continue to grow in the coming years, offering greater market space and development opportunities for VR vision correction devices.

However, market competition and technological advancements also pose challenges to VR vision correction devices. Although there are relatively few competitors in the field of eye-tracking technology, other VR manufacturers and traditional vision correction methods may become rivals. Therefore, VR vision correction devices need to continually innovate and enhance their technology to maintain a competitive edge. Furthermore, increasing consumer focus on health, comfort, and personalization requires VR vision correction devices to adapt to changing market demands and offer more diverse and comfortable products.

This study conducted a strategic environmental analysis of the VR vision correction device using the SWOT analysis method. By analyzing internal factors, the strengths of the VR vision correction device can be identified, such as technological innovation, improved product quality, and unique feature design. Recognizing and utilizing these strengths can help companies stand out and establish differentiation advantages in the market competition. The weaknesses of the VR vision correction device can also be identified, such as inadequate product design, high prices, and inconvenience in user experience. Recognizing existing weaknesses can drive companies to make improvements and enhancements to enhance product competitiveness.

By analyzing external environmental opportunities, potential opportunities in the VR market can be discovered. These may include market growth, emerging upgrade demands, and partnership opportunities. Seizing these opportunities can help companies expand market share and achieve growth. Furthermore, potential threats can be revealed, such as the emergence of competitors, technological shifts, and the implementation of disruptive regulations. Being aware of and prepared for these potential threats can help companies take proactive measures to maintain competitive advantages and market position.

Finally, by conducting a comprehensive assessment of the internal and external environment, companies can formulate strategies that adapt to market changes. By combining strengths with opportunities, addressing weaknesses, and mitigating threats, effective guidance for company development can be provided.

Using the SWOT analysis method, the strategic environmental analysis of the VR vision correction device is as follows:

Strengths:

(1) Technological innovation: Based on eye-tracking technology, the product demonstrates technological innovation and provides high-precision vision correction and training effects.

(2) After-sales service: Excellent customer support and after-sales service including technical training, problem-solving, and maintenance enhance user satisfaction and build brand reputation.

(3) Personalized customization: Offering personalized vision correction plans based on users' eye-tracking data and needs enhances the product's customization and personalization.

Weaknesses:

(1) High price: VR vision correction devices based on eye-tracking technology often have a relatively high price, which may limit the purchase intention of some potential customers.

(2) Technological complexity: Eye-tracking technology requires certain technical knowledge and operational skills, which may act as a barrier for some potential users.

Opportunities:

(1) Market demand growth: With an increasing awareness of eye health and the prevalence of vision issues, the market demand for VR vision correction devices is expected to grow.

(2) Technological advancements: Continuous innovation and improvement in eye-tracking technology and VR technology provide more advanced and accurate eye movement measurement and correction capabilities.

Threats:

(1) Intensified market competition: With the entrance of competitors and the emergence of similar VR vision correction devices, market competition may intensify.

(2) Regulatory limitations: Specific regions or countries may have regulations and restrictions on eye-tracking technology or VR technology.

Through the SWOT analysis, we have identified the competitive advantages, weaknesses, opportunities, and threats of VR vision correction devices based on eye-tracking technology in the market. This provides guidance for companies to develop strategies, thereby enhancing product competitiveness and market position, to meet user demands while addressing requirements or restrictions.

4. Conclusion

Through this study, we have conducted an in-depth discussion on the effectiveness of virtual reality (VR) and eye tracking technology in commercial applications, using VR vision correction devices as an example. We have also conducted a comprehensive assessment using convolutional neural networks (CNNs) and the SWOT analysis method.

Firstly, the application of CNNs enables us to better process the rich data provided by eye tracking technology. This allows us to accurately analyze users' fixation points and eye movements, providing more precise data support for vision correction. The advantage of CNNs lies in their ability to process images and visual data, which is closely related to the eye movement data generated by eye tracking technology. This can further enhance the effectiveness of vision correction solutions.

Secondly, through the SWOT analysis method, we have delved into the strengths, weaknesses, opportunities, and threats of VR vision correction devices in commercial applications. This analysis provides us with a clear understanding, guiding us to better grasp the business environment and market opportunities. It also helps us recognize the challenges and risks faced by VR vision correction devices. This analytical framework enables us to have a comprehensive understanding of the commercial potential of VR vision correction devices and provides guidance for their further development and application.

However, we also need to acknowledge the limitations and challenges of the technologies and applications involved in this study. Virtual reality technology is still relatively expensive, and the

prevalence of devices needs to be improved. In addition, the use of virtual reality technology may cause comfort issues, such as dizziness and discomfort. Furthermore, there is currently a lack of sufficient legal regulations and policy support for virtual reality and eye tracking technology.

Nevertheless, we believe that with the continuous advancement of technology and the increasing demand for personalized health services in society, VR vision correction devices have tremendous potential for commercial development. We can seize market opportunities by continuously improving technology, reducing costs, enhancing product comfort and user experience. Moreover, seeking partnerships and policy support will further drive the commercialization of VR vision correction devices.

In conclusion, this study highlights the effectiveness of VR and eye tracking technology in commercial applications, specifically in the context of VR vision correction devices. The application of CNNs enhances data analysis capabilities, while the SWOT analysis provides insights into the commercial potential and challenges. Despite limitations and challenges, the development and application of VR vision correction devices have promising prospects. Future efforts should focus on technological advancements, cost reduction, comfort improvement, user experience enhancement, and collaboration with partners and policy-makers.

Acknowledgment

The authors gratefully acknowledge the financial support from Fund project: 2023 College Student Innovation and Entrepreneurship Training Program Project

References

- [1] He Shishan Design and implementation of a strabismus measurement system based on virtual reality combined with eye tracking [D]. Huazhong University of Science and Technology, 2020.
- [2] Zhao Wenxuan, Zhang Li Research on User Experience of Eye Movement Tracking in Virtual Reality [J] Beauty and Times (Part 1), 2023, (04): 138 - 140.
- [3] Ding Ni, Zhao Tian the application and progress of VR eye tracking technology [J] Modern Film Technology, 2023, (02): 43 - 49.
- [4] Wu Rongrong Research on Eye Movement Tracking System and Its Application in VR Environment [D]. Tianjin University of Finance and Economics, 2019.
- [5] Li Qibing Research on clothing recognition and classification model based on convolutional neural networks [J] Journal of Hunan University of Engineering (Natural Science Edition), 2022, 32 (03): 69 - 73+87.
- [6] Li Xiaoning Research on Acceleration Methods for Convolutional Neural Network Models [D]. Shandong Normal University, 2023.
- [7] Tong Chaodi, Meng Qiuyun Process analysis of dual row license plate recognition based on convolutional neural networks [J] Changjiang Information and Communication, 2022, 35 (12): 104 - 106.
- [8] Shi Tengfei, Shang Jiaxiu, Wu Zonghang Research on Image Classification Improvement Method Based on Convolutional Neural Networks [J] Modern Information Technology, 2023,7 (05): 109 - 112.
- [9] Sun Yuxuan, Wang Shuyi, Liang Juhong, Wei Qiangsheng Research on Eye Movement Model of Virtual Reality Motion Design Mechanism Based on EFA Entropy Weight Method [J] Packaging Engineering, 2022, 43 (22): 79 - 86+94.
- [10] Zhang Jingyu Research and application of deep learning-based eye tracking methods [D] Xi'an University of Petroleum, 2023.
- [11] He Shishan Design and implementation of a strabismus measurement system based on virtual reality combined with eye tracking [D] Huazhong University of Science and Technology, 2020.
- [12] Deng Leling Eye tracking object detection method for VR/AR field [D]. Northwestern University, 2022.
- [13] Wen Xueqin Research on the Financial Strategy of Guizhou Qianjiu Based on SWOT Analysis [J] Quality and Market, 2022, (07): 193 - 195.