Research on Animation VR System Scenario Considering High-Precision Line of Sight Tracking Algorithm

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At present, the utilization of eye tracking tech in the context analysis of the animation VR system can provide the best line of sight (LOS) effect from the current perspective to utilize the detection of the viewer's eye movement position, make the VR animation context more natural, have a higher sense of immersion, and greatly strengthen the interaction of the system. On account of this, this paper first analyzes the theoretical basis of LOS tracking tech represented by particle filter (PF) mechanism, and then studies the high-precision LOS tracking algorithm of self-organizing fusion of single feature, single target and multi-line of sight (MLOS) features, as well as the performance and performance amelioration strategies of different algorithms. Finally, this paper presents the implementation of animation VR situation considering high-precision LOS tracking algorithm, and in the comparison of PF and IPF animations within the VR system, IPF demonstrated superior performance.

Povzetek: Raziskava predstavi uporabo algoritma sledenja liniji pogleda v animacijskih VR sistemih, kar izboljša interakcijo, poveča kvaliteto sledenja in izboljša uporabniško izkušnjo.

1 Introduction

As one of the momentous forms of interaction, LOS realizes the perception and acquisition of multiple-info on account of the tracking of LOS direction. LOS tracking has momentous value for human-computer interaction with more intelligent LOS and more specific experience [1]. LOS tracking algorithm organically integrates camera tech, computer LOS, intelligent algorithm and image analysis. At present, the tracking tech mainly includes electrode measurement, image, pupil corneal reflection and invasive LOS tracking. Among them, the image LOS tracking algorithm is relatively simple, convenient and has high accuracy. The characteristics and principles of these different tracking methods are shown in Table 1 below.

Table 1: Characteristics and principles of different gaze trackia ng methods.

Category	Principle	Features
Image	Computer image LOS extraction and image info analysis	Simple, convenient and high precision
Electrode measuring	Eye tracking on account of electrode difference	The principle is simple and there are many restrictions
Intrusive	Measurement on account of eye movement information	Poor flexibility and high cost
3D model	Colour image and depth image fusion	High robustness to head motion
Headwear	Tracking of eye movement by equipment	Many restrictions, mostly used in VR scenes
Pupillary corneal mapping	Error analysis and parameter compensation	Poor robustness

Over the past 20 years, researchers have increasingly turned to virtual reality (VR) techniques to delve into human vision, leveraging computer-controlled environments where participants can navigate, exploring hypotheses that are challenging to replicate in real-world settings. The shift has significantly advanced our understanding of human behavior and perception. For instance, experiments contrasting the perceptions of stationary versus freely moving observers have illuminated variations in depth perception, object stability, structure from motion, and size constancy, underscoring potentially profound implications [2]. Advocates have thus urged a transition in vision and behavioral research from controlled laboratory settings to real-world scenarios involving mobile observers, with a primary focus on naturalistic perception. Essential to these investigations are tools such as position and orientation tracking systems and head-mounted displays (HMDs). However, the high costs associated with such equipment, ranging from tens of thousands to nearly a hundred thousand dollars, often limit access for researchers whose studies could benefit from VR technology. Interestingly, VR technology has begun permeating the consumer gaming market, with products like the High-Tech computer corporation (HTC) Vive and Oculus Rift now available for less than $1,000. The HTC Vive, equipped with a full HMD and robust position and orientation tracking system, offers a cost-effective alternative compared to the Oculus Rift [3]. The affordability enables more academics to leverage VR for realistic, unimpeded research into human vision and behavior. Designed originally for gaming, the HTC Vive proves promising for scientific inquiry due to its responsiveness and reliability. However, its effectiveness hinges on precise direction and location tracking to faithfully replicate an observer's movements in virtual environments [4]. Additionally, minimizing latency between physical head movements and corresponding display updates is crucial to prevent motion sickness and maintain stability in three-dimensional (3D) space. Utilizing a high-precision LOS tracking algorithm in context analysis of animation VR systems can enhance rendering, establish accurate eye movement models, and optimize interaction and immersion. On the other hand, in addition to LOS interaction, the acquisition of emotional immersion and interactivity of animation VR system also includes several types as shown in Figure 1 below, and the intelligent interaction form has become a momentous trend in the development of animation industry, which significantly improves the non-invasive, real-time and naturalness of interaction.

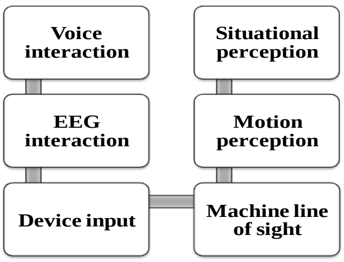

Figure 1: Several types of situations in animation VR system.

In short, the animation VR system uses the situational camera device to obtain the user's visual field image, so that the viewer can perceive the virtual and real-world information at the same time. The animation VR system integrating high-precision LOS tracking algorithm obtains the eye movement landing point by extracting the eye movement feature data, so as to realize the rapid response of non-invasive and natural interactive action. The high-precision gaze tracking algorithm uses feature point vector mapping to obtain the user's gaze. The utilization of this tech in animation VR can enhance the user's sense of situational experience. In the context analysis of animation VR system, eye tracking algorithm is integrated to interact with the system efficiently, real-time and naturally, and a real-time interactive vision animation VR system context is constructed.

2 Theoretical basis of LOS tracking tech

As the key tech of gaze tracking system, extracting eye motion features representing gaze direction could provide conditions and basis for subsequent gaze estimation. At present, there are many means to realize high-precision tracking, such as gradient algorithm, fast feature detection algorithm, Bayesian multiple logistic regression and methods on account of the overall appearance of the eyes. Among them, the eye motion features extracted by the head mounted LOS tracking system mainly focus on the pupil center, combined with the iris center, corneal reflection spot, inner and outer corners of the eye and so on. Secondly, there is a method to extract the inner and outer corners of the eyes, the corners of the mouth and the center of the nostrils as the feature parameters, and use the Gaussian learning algorithm to establish the relationship between these features and the fixation point. In addition, gradient algorithm and fast feature detection algorithm only locate the pupil center and inner and outer corners of the eye. Through the calculation of the SIFT features in the sample image, and using a voting mechanism to obtain the eye motion feature parameters, the feature vector of the whole eye figure is obtained, and the eye motion feature parameters are obtained by using this vector. Table 2 depicts the overview of the study literature and summary for the clear explanation.

Table 2: Overall summary of the following study

Study	Method	Principle	Advantages	Limitations	Performance Metrics
6	Doppler Radar for Concealed Object Detection	Temporal fusion of Doppler velocity and position measurements	Low-cost, series-produced radars; effective in dynamic settings	Noisy indirect reflections; complexity in separating direct and indirect reflections	Detection accuracy, tracking reliability
7	Outside-in Tracking System for AR/VR	Electromagnetic tracking using orthogonally wound receiver coils	Independent of LOS and occlusion; accurate 6-degree of freedom tracking	Requires precise coil calibration; potential interference in dense electromagnetic environments	Tracking accuracy, robustness against occlusion
8	IoRL VR System with Mobile VR Capabilities	Integration of mm Wave and Visible Light Communication for IPS	Mobile VR experiences comparable to PC systems; enhanced physical freedom	Relies on infrastructure deployment; potential latency issues	VR experience quality, mobility enhancements
9	LOS Guidance for AMV Route Following	Kinematic model-based LOS guiding laws	Precise route following for multiple AMVs; coordinated course navigation	Limited to line-of-sight scenarios; requires clear communication channels	Route following accuracy, coordination efficiency
10	UAV-Aided MEC Network for Mobile 360-Degree Video VR	UAV-based MEC for processing and communi cation	Enhances 360-degree video quality and real-time processing capabilities	UAV deployment logistics; potential airspace regulations	Video streaming quality, latency reduction
11	Dispersion-Threshold Identification Method with Eye-Tracking	Rules-based adjustment of dispersion thresholds	Accurate fixation identification; adapts to user characteristics	Dependent on eye-tracking device accuracy; algorithm complexity	Fixation detection accuracy, algorithm responsiveness
12	Eye-Tracking System for Virtual Control Tower	Utilization of Microsoft Kinect V2 for eye-tracking	Integration with AR content; Kinect's depth sensing capabilities	Requires binocular vision; limited to Kinect's field of view	Eye-tracking accuracy, AR content integration

3 Particle filter mechanism

The theoretical basis of LOS tracking tech includes Bayesian state estimation and particle filter, LOS tracking theoretical framework on account of particle filter, single feature and single target LOS tracking, MLOS feature fusion tracking, MLOS target tracking and infrared target tracking [5]. Among them, particle filter is on account of Monte Carlo random simulation theory, and the state posterior distribution is approximately represented by a group of weighted random samples. The new state distribution is estimated by Bayesian recursion of these random samples. The standard particle filter is on account of importance sampling, and the recommended importance distribution is the state prior distribution shown in equation 1 below.

$$p\left(\mathbf{X}_k^{(i)}\middle|\mathbf{X}_{k-1}^{(i)}\right) \quad (1)$$

The convergence premise of standard particle filter is relatively loose, as long as the likelihood function is continuous and bounded, and the convergence speed is independent of the dimension of the state. For other importance sampling particle filter, if the importance weight is continuously bounded and the re-sampling algorithm meets the following equation 2, the particle filter algorithm will converge in the sense of mean square error. In addition, particle filter sampling strategies include reject sampling method, importance sampling method on account of optimal importance distribution criterion, M-H algorithm and Gibbs sampling algorithm.

$$E\left[\left|\sum_{i=1}^{N}\left(N_k^{(i)}-Nw_k^{(i)}\right)r^{(i)}\right|^2\right]\leq C_k N\max_{i=1\cdots N}\left|r^{(i)}\right|^2 \quad (2)$$

3.1 The principle of high-precision LOS tracking

High precision LOS tracing is to tracing the LOS landing point of the human eye, and seek the settlement of the LOS landing point of the human eye according to the human eye characteristics extracted from the human eye figure. However, the feature data extracted from the human eye image often contains the faults data of head or eye motion. In this case, the LOS landing point will have unacceptable faults. In order to refrain from the motion of the head and reduce the generation of errors, the pupil center and pulchin spot center are extracted by relevant methods. The LOS tracing system is calibrated according to the LOS model, the LOS mapping model is solved, and the LOS landing point is calculated. The corresponding eye motion data and the coordinate data of the LOS point in the screen are recorded in real time to obtain the LOS landing point and complete LOS tracing.

3.2 Definition of LOS tracking on account of significance of bayesian state estimation

The essence of LOS tracking is to recursively estimate the target position with significant image features represented by color, shape, texture and motion in video sequence. As a recursive state estimation, LOS tracking can be divided into single feature, single target LOS tracking, MLOS feature fusion tracking, MLOS target tracking, etc., and LOS tracking in complex situations represented by animation VR system has typical non-Gaussian and nonlinear characteristics.

3.3 Mechanism of LOS tracking algorithm considering particle filter

The implementation of LOS tracking algorithm considering particle filter is first the LOS target state sampling and transfer, followed by the weighting of state samples and the output of state estimation, and then the re-sampling step [6]. As a description of the motion characteristics of LOS target between two frames, the accuracy of state transition model has a direct impact on the difficulty of LOS tracking. Because it is difficult to establish an accurate state transition model, we usually learn from a specific training image sequence, select a specific statistical model, and then establish an approximate state transition model.

In addition, as the key to the calculation of particle weight, the observation probability distribution and observation probability distribution of LOS target are established, so as to realize the effective statistics and description of specific LOS characteristics. In LOS tracking on account of standard particle filter, firstly, the LOS target state is sampled and transferred. Secondly, the kernel density probability method is used to realize the statistical description of color features, and the sampled particles are directly weighted by color probability distribution.

3.4 Performance of LOS tracking algorithm considering particle filter

In the framework of particle filter theory, the factors affecting the robustness of LOS tracking include the accuracy of state transition model, the effectiveness of sampling strategy, and the discrimination and stability of LOS features [7]. Among them, in the accuracy level of state transition model, the state transition of LOS target can be unified with state sampling, and the accuracy of state transition model can be partly attributed to the effectiveness of sampling strategy. Secondly, in terms of the effectiveness of the sampling strategy, if the sampling strategy should make the newly sampled particles more representatives, then the sampling strategy is effective. For the sampling strategy of the same estimation problem, when the importance weight variance of the two particle sets meets the following equation 3, the LOS tracking sampling measurement of the standard particle filter is more accurate.

$$\operatorname{var}\left(w_1^{(i)}\right) < \operatorname{var}\left(w_2^{(i)}\right) \tag{3}$$

In addition, in terms of the discrimination and stability of LOS features, the former refers to whether the LOS feature can significantly distinguish the tracked LOS target from the background, the tracked LOS target from other similar LOS targets; the latter focuses on whether the LOS feature can maintain good discrimination in the whole tracking process. In different scenes, different LOS features have different distinctiveness and robustness.

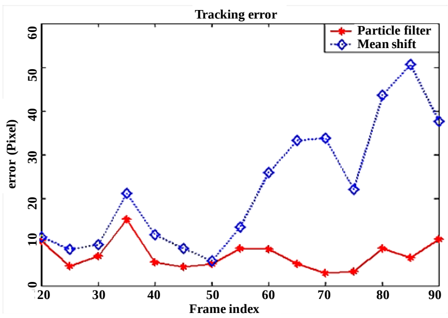

Figure 2: Advantages of standard particle filter in LOS tracking

Break away from visible-wavelength techniques and demonstrate the use of low-cost, series-produced. Doppler radars for the detection, classification, and tracking of concealed objects in large-scale dynamic settings. They employed temporal sequences of Doppler velocity and position measurements, which they fused in hybrid Non-Line of Sight (NLOS) detection and tracking network over time, to learn how to separate noisy indirect and direct reflections. Considering that the standard particle filter LOS tracking has higher precision and accuracy than the traditional LOS tracking algorithm (mean shift LOS tracking), as shown in Figure 2 above.

4 Performance of high precision LOS tracking algorithm

4.1 Robustness of high-precision LOS tracking algorithm

The robustness of high-precision LOS tracking algorithm includes the effectiveness of sampling strategy and the discrimination and stability of LOS features. Among them, in the aspect of improving the effectiveness of the sampling strategy, it mainly aims at the LOS tracking of single feature and single target to improve the robustness of tracking. Secondly, in the complex situations represented by animation VR, there are great differences in the discrimination and stability of LOS features. Therefore, MLOS feature fusion needs to be used to better meet the requirements of robust LOS tracking.

In addition, in the aspect of improving the real-time performance of LOS tracking algorithm, the computational complexity of particle filter algorithm is linearly corresponding to the number of sampled particles [8]. An outside-in tracking system that uses electromagnetic to enable 6-degree of freedom tracking that is independent of LOS and occlusion for augmented reality and virtual reality devices. A collection of orthogonally wound receiver coils placed in the head-mounted display and a center coil coiled in three orthogonal directions make up the tracking mechanism. Therefore, it is necessary to comprehensively balance the correlation between the number of sampling particles, the real-time performance of the algorithm and the robustness of LOS tracking. The adaptive determination methods of sampling particle number include likelihood ratio method and KLD method. The former can reflect the estimation ability of sampling particle set to state posterior distribution; the latter is on account of probability estimation.

4.2 The overall process of high-precision los tracking algorithm

The high-precision LOS tracking system estimates the position of human eye focus by establishing the relationship between eye motion features in two-dimensional human eye image and screen fixation points. After the input image is eliminated by image preprocessing tech, the effective eye motion features are extracted from the human eye feature, and the LOS mapping model is established to obtain the LOS direction and fixation position of the human eye. Therefore, the whole LOS tracking algorithm mainly includes the extraction of eye motion features, the establishment of LOS mapping model and so on. For eye motion feature extraction, it mainly extracts the pupil and iris center, purchin spots, corner points and the contour of upper and lower eyelids under infrared light; the establishment of LOS mapping model mainly refers to the establishment of the relationship between two-dimensional eye motion features and screen gaze to obtain the position of the final human eye focus.

4.3 Single feature and single target LOS tracking algorithm

The robustness amelioration of high-precision LOS tracking algorithm is inseparable from the amelioration of sampling effectiveness. Therefore, the usual means include establishing an effective importance recommendation distribution, as shown in equation 4 below, and MCMC sampling method.

$$q\left(\mathbf{X}_k^{(i)} \middle| \mathbf{X}_{k-1}^{(i)}, \mathbf{Z}_k\right) \sim N\left(\bar{\mathbf{X}}_k^{(i)}, \mathbf{P}_k^{(i)}\right) \quad (4)$$

The methods of constructing the proposed distribution of importance include EKF prediction method and UKF prediction method with local linearization. Among them, the construction of LOS tracking algorithm on account of EKF predictive sampling particle filter first needs to establish the state transition model, and then carry out the sampling suggestion distribution, LOS characteristics and their statistical description. The robustness of EKF LOS tracking algorithm can be significantly improved when the number of sampling particles is small, and the robustness of EKF LOS tracking algorithm can be further improved, but the real-time performance of the algorithm has a large room for amelioration.

In addition, for the importance sampling strategy, the amelioration of sampling performance needs to reduce the influence of degradation and sample poverty as much as possible, and the robustness of LOS tracking can be effectively improved by constructing an invariant distribution as a state a posteriori distribution in the state space, which is also the key of MCMC sampling algorithm [9]. The IoRL created a single IoRL VR system that offers mobile VR experiences comparable to PC-operated systems, combining processing power with physical freedoms. The project focuses on creating an Indoor Positioning System (IPS) that could revolutionize VR tracking by integrating mm Wave and Visible Light Communication technologies, as demonstrated in previous publications. The key step of MCMC sampling is to accept probability calculation. As shown in equation 5 below, the sampling algorithm can significantly improve the robustness of single feature and single target LOS tracking.

$$p_a\left(\mathbf{X}, \tilde{\mathbf{X}}\right) = \min\left\{1, \frac{w'\left(\tilde{\mathbf{X}}\right)}{w'\left(\mathbf{X}\right)}\right\} \quad (5)$$

4.4 MLOS Feature fusion tracking algorithm

For complex situations such as animation VR system, the dynamic change of the discrimination of single LOS characteristics makes its stable discrimination difficult to last, and then reduces its LOS tracking performance. For the LOS tracking target, its LOS features are redundant, and the typical LOS features are complementary to the dynamic changes of the scene, which makes the LOS target can be described by some implementation features with typical stable discrimination ability. It can be seen that the MLOS feature fusion tracking algorithm can effectively improve the robustness of tracking. LOS feature elements include color features, shape features, texture and motion features. The advantages and disadvantages of statistical description of these different features are shown in Table 3 below.

Table 3: Statistical description of LOS feature elements.

Characteristic elements	Statistical description	Advantages	Disadvantages
Colours	Colour histogram	Stable for rotation and scale change	The discrimination of target colour is high
Shape contour	Contour discrete observation probability	LOS target contour can be obtained	Complex calculation, low applicability
Texture	SSD method	Simple and easy	Description capability, easy to be disturbed
Motion	Inter frame difference histogram	Strong discrimination	Easily disturbed

The realization methods of MLOS feature fusion and tracking usually includes MLOS feature synthesis observation probability fusion and MLOS feature fusion on account of sampling strategy [10]. The former directly solves the synthetic observation probability of MLOS feature to realize the probability weighting of sampling particles under MLOS feature; the latter combines the MLOS feature information into MLOS tracking through a specific sampling strategy to realize the fusion and tracking of MLOS features. Initially, a control goal is defined for an AMV's route following using a kinematic model. The main LOS guiding laws for route following are then thoroughly examined. Next, the detailed rules for LOS guidance that apply to several AMVs pursuing a coordinated course are presented.

MLOS feature fusion on account of sampling strategy can effectively realize MLOS feature fusion and tracking through hierarchical sampling in hierarchical state space. In order to further improve the efficiency of hierarchical sampling, the sampling sequence should be carried out from course to fine. In addition, the adaptive and self-organizing weight dynamic correction mechanism of MLOS feature synthesis observation probability fusion algorithm makes it more flexible.

4.5 MLOS feature self-organizing fusion tracking

The MLOS feature tracking algorithm still has great room for amelioration in the aspects of self-organization, discrimination and reliability [11]. Secondly, the algorithm also has great amelioration potential in strengthening the dynamic and adaptive change of the contribution rate of LOS features to LOS tracking. Therefore, it is necessary to further explore and construct an efficient MLOS feature self-organizing fusion mechanism the proposal proposes a novel UAV-aided mobile edge computing network for high-quality mobile 360-degree video VR applications, focusing on joint UAV placement, MEC and radio resource allocation, and 360-degree video content layer assignment.

4.6 MLOS feature self-organizing fusion mechanism

The key of MLOS feature fusion and tracking on account of democratic synthesis is to make adaptive correction according to the support results, so as to obtain and maintain the maximum support in all information. The index $A_m\left(\mathbf{X}_k\right)$ is defined to describe the effectiveness of the LOS target state $\mathbf{X}_k$ under the LOS feature *m*. its fusion mechanism is shown in equations 6 and 7 below. Although democratic synthesis provides a good MLOS feature self-organizing fusion mechanism, the algorithm needs to be combined with an effective LOS tracking framework, otherwise the efficiency of the algorithm will be reduced. Secondly, discontinuous motion will significantly reduce the tracking performance of the algorithm. In addition, the anti-jamming ability of the tracking algorithm is poor, and it is easy to adapt to the jamming target, resulting in tracking failure.

$$R\left(\mathbf{X}_k\right)=\sum\nolimits_{m=1}^{M} r_k^m A_m\left(\mathbf{X}_k\right) \tag{6}$$

$$\hat{\mathbf{X}}_k=\arg\max_{\mathbf{X}}\left\{R\left(\mathbf{X}_k\right)\right\} \tag{7}$$

As an effective theoretical framework for MLOS feature fusion and tracking, the organic fusion of particle filter and democratic synthesis algorithm can significantly improve the efficiency of the algorithm. The creation of a dispersion-threshold identification method is presented in paper [12], which uses data from an eye-tracking device that is embedded into a head-mounted display. It is suggested to use rules-based criteria to adjust the algorithm's thresholds depending on several characteristics, such the quantity of fixations and the proportion of points that are part of a fixation. The calculation of MLOS feature synthesis observation probability on account of the theoretical framework of particle filter is shown in equation 8 below. The quality measurement of LOS feature can describe the discrimination of the LOS feature to the tracked LOS target, reflect the contribution of the LOS feature to LOS target tracking, and solve the LOS feature quality measurement through two-level state filter estimation deviation.

$$p\left(\mathbf{Z}_k^{(i)}\middle|\mathbf{X}_k^{(i)}\right)=\sum_{m=1,\cdots,M}\pi_k^m\,p\left(\mathbf{Z}_k^{(i),m}\middle|\mathbf{X}_k^{(i)}\right) \tag{8}$$

The self-organizing correction algorithm of MLOS feature synthesis weight on account of LOS feature quality measurement can effectively realize the online adaptive and self-organizing fusion of MLOS features, and significantly improve the robustness of LOS tracking in complex scenes. In the framework of particle filter theory, the MLOS

feature fusion tracking algorithm is not sensitive to the discontinuous motion of LOS target, and can realize the robust tracking of discontinuous moving LOS target. The MLOS feature fusion tracking algorithm is not sensitive to the interference of similar false targets.

4.7 Performance optimization of multi-LOS self-organizing fusion tracking

For high-dimensional LOS feature space, the difficulty of MLOS feature fusion tracking calculation will be significantly improved, which will affect the real-time performance of the algorithm. The framework of multi-target tracking system is shown in Figure 3 below. MLOS target tracking essentially uses gating tech and data association to realize the processing of multi-target joint state estimation [13]. The theoretical framework of particle filter directly constructs a multi-target tracking algorithm, which can only track MLOS targets in a relatively simple scene. If similar or non independent LOS targets appear in the scene, the performance, efficiency and real-time performance of target processing will be seriously reduced. Combining joint probabilistic data association with multi-target LOS tracking can effectively improve the above problems. Firstly, the target state is predicted according to the target motion model. Secondly, the association probability of joint data is calculated, and the target state is estimated. Finally, the association filtering of joint probability data is realized. The joint probabilistic data association filter on account of particle filter organically combines independent sampling and joint probabilistic data association, which simplifies the sampling and data association process, improves the efficiency of MLOS target tracking, and achieves good results in multi-target tracking in complex situations represented by animation VR system. The design of a particular eye-tracking system for the virtual control tower application utilizing Microsoft Kinect V2 is elaborated. To verify the accuracy of the measurements identified by the suggested solution, the requirement for binocular vision to use AR content is evaluated, and the interface has been tested on a small number of people.

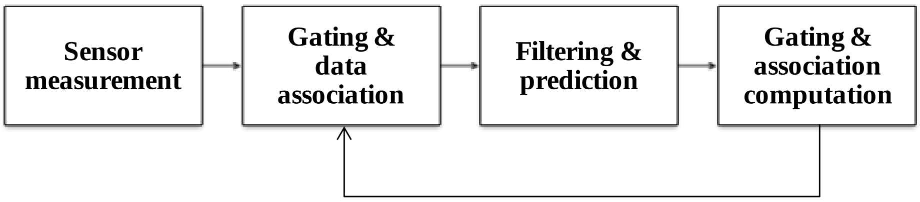

Figure 3: Multi target tracking system framework

5 Animation VR situation considering high-precision LOS tracking algorithm

5.1 System requirements of high-precision VR-LOS tracking algorithm

Firstly, the animation VR system on account of high-precision tracking algorithm needs to be able to calculate the user's gaze on the screen according to the captured figure. Secondly, the system needs to build a 3D scene, and users can interact with the content of the scene through their eyes. In addition, the system includes control module, figure reading module, LOS tracking module and scene module. The scene module includes calibration scene and 3D LOS tracking interaction scene. The user enters the calibration interface by pressing the key on the VR handle. Meanwhile, the user needs to look at the calibration points on the screen in turn. After the calibration, the user can interact with the 3D scene through the LOS. After calibration, the calibration scene will exit automatically and enter the LOS interaction scene.

5.2 Key technologies of animation VR situation construction

The key technologies of animation VR situation construction include but not limited to stereo display, environment modeling, geometric modeling, physical modeling, behavior modeling and realistic real-time rendering [14]. Stereoscopic display is on account of the parallax generated by human physiological structure to fuse the figures to produce a spatial situation. Two different figures corresponding to the left and right eyes are generated for the same situation to produce parallax. Secondly, environment modeling can build a simulation environment through system simulation; especially realize scientific visualization by 3D modeling means such as geometry, physics and behavior. In addition, at the realistic real-time rendering level of animation VR context construction, the authenticity simulation is mainly carried out according to the shape, optical properties and occlusion relationship of objects in animation context. In the animation VR situation, the scene should change in time with the change of user's viewpoint, so as to ensure the real-time performance of the situation.

The key to the construction of animation VR situation is to ensure the fidelity of the display and strengthen the authenticity. It needs to focus on the design of texture mapping, environment mapping and anti aliasing. Environment mapping uses texture figure to represent the effect of specular reflection and regular perspective of object surface. The animation VR virtual situation is rendered by texture mapping, illumination and other models, and the figure of unknown perspective is generated in the face change according to the pre generated situation figure. Transform, interpolate and deform the picture close to the viewpoint or LOS direction, so as to quickly obtain the scene picture at the LOS point.

5.3 Key technologies to realize high-precision LOS tracking system

The key technology to realize high-precision LOS tracking is the extraction of eye motion features and the establishment of LOS mapping model. At the level of eye motion feature extraction, it should not only meet the strict requirements of high precision and real-time, but also eliminate the difference of figure clarity. The implementation of eye motion feature extraction algorithm is complex; especially the real-time feature extraction is difficult. In addition, at the level of establishing the LOS mapping model, the position data of fixation points are obtained mainly by using the extracted eye motion features. Most 2D LOS mapping model algorithms are relatively simple, but need the help of infrared light source or more screen calibration points. The algorithm of 3D mapping model is complex, which not only depends on complex hardware system to realize graphics acquisition, but also it is very difficult to establish a LOS mapping model with simple calibration process.

5.4 LOS Tracking and motion capture in animation VR system

The motion capture of animation VR system includes spatial positioning, linear motion capture and angular motion capture [15]. It mainly focuses on optical motion capture, and uses computer vision and multiple high-speed camera systems to monitor and track the target feature points from different angles to realize motion capture. Generally speaking, only a few target feature points are needed to obtain the angle action data of larger feature points. In the context of animation VR system, the experimenter usually interacts with other content from the first perspective to realize three-dimensional interactive experience. The animation VR scene realizes the dynamic simulation of the scene in the real world with a fixed reference system, and the size of the objects in the virtual scene are equal to those in the actual scene, so as to refrain from impression distortion.

5.5 The modules of high-precision LOS tracking system

With the utilization of sight tracking tech in monitoring field, it can intuitively understand the status of relevant personnel. The system is mainly divided into LOS tracking data extraction module, LOS tracking data calculation module and LOS tracking data monitoring module. The LOS tracking data extraction module uses the centroid method to solve the pulchin spot center coordinates, then uses the star ray model and high connected region to extract the pupil contour, and then obtains the pupil center, and finally uses the Harris algorithm to solve the inner corner of the eye. The LOS tracking data calculation module uses the points in the screen to calibrate, obtains the mapping relationship between the LOS landing point in the screen and the pupil corneal reflection vector, uses their relationship to solve the LOS landing point in real time, and calculates the area where the LOS landing point is located. The LOS tracking data monitoring module applies the method of human eye LOS tracking to monitor the concentration of users.

5.6 Principle of LOS tracking in animation VR Context

The visual display of animation VR situation system should have high authenticity in terms of quality, modification rate and scope compared with the scenes in daily experience. The evaluation index of visual display effect and characteristics of animation VR situation system shall include several aspects as shown in Figure 4 below, and realize the animation VR situation according to the principles of engineering, safety, reliability and cost, which can provide three-dimensional vision reality.

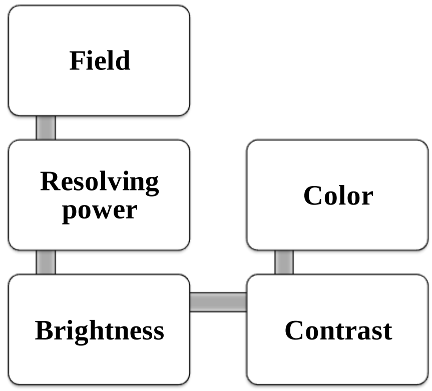

Figure 4: Visual display effect index of animation VR situational system

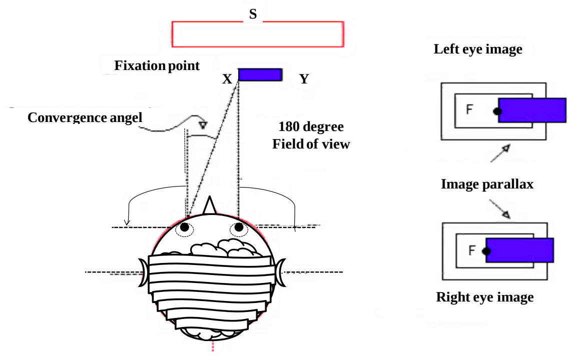

Figure 5: LOS tracking device in animation VR situation

The principle of realizing stereo vision effect in the process of LOS tracking in animation VR situation is shown in Figure 5 below. Where the optical axes of two eyes are parallel, it is equivalent to looking at the distance of the two eyes. IPD is the distance between the pupils of two eyes. The different spatial position of two eyes is the reason for stereo vision. X is a fixed point on object Y close to the human eye. In the animation VR system, it is necessary to generate the sense of distance in terms of distance and depth of objects according to the principle of stereo parallax generated by the physiological structure of human eyes, so as to establish the 3D LOS information of the environment.

5.7 Realization of animation VR situation considering LOS tracking

The facial curve of the animation VR system considering high-precision LOS tracking is close to the eyes to eliminate the LOS gap of the eyes, increase the realism, and ensure the display of clear virtual 3D figures. At the same time, the advanced figure wide-angle device will imitate the ultra wide field of view effect of human eyes to the greatest extent. The LOS tracking device in the animation VR system analyzes the direction the eyes are looking at by observing the small motions of the eye muscles, and generates a corresponding digital signal as feedback information and sends it to the feedback information processing equipment. After processing, the VR processor sends the figure that the eyes should see at this time from the real existence processing equipment.

Secondly, in terms of head sensory orientation tracking in animation VR context, it is necessary to accurately determine the user's eye position. Determining the position of the eyes plays a direct role in the high-precision tracking of the LOS of the animation VR system. It will not only have a direct impact on the data retrieval of the processor from the database in the animation VR system, but also ensure that the objects in the virtual situation can be adjusted and changed in real time during the motion of the eyes, so as to ensure the interactivity of the situation.

In addition, the immersion of the animation VR system considering LOS tracking can make the audience feel more immersive, so as to enhance the immersive feeling, enhance the on-the-spot effect of the animation VR system, and produce the ability of on-the-spot response and real-time response with the user's motion. With the iterative progress of AI tech and intelligent algorithm, the realization of animation VR situation in the future will further integrate ANN, voice recognition, natural interaction and other technologies to ensure that VR situation can continuously record, analyze and track users' actions.

The performance metrics of accuracy, precision, recall are compared with PF, IPF and proposed LOS+IPF is shown in table 4 and Figure 6. PF obtained an accuracy of 86%, whereas LOS+IPF increased this measure to 90.3%. In a similar vein, PF (92%) and IPF (94%) precision demonstrated, whereas LOS+IPF scored 93.9%. In terms of recall, PF (90.2%) and IPF (94%) achieved, whereas LOS+IPF (96.5%) shows higher improvement.

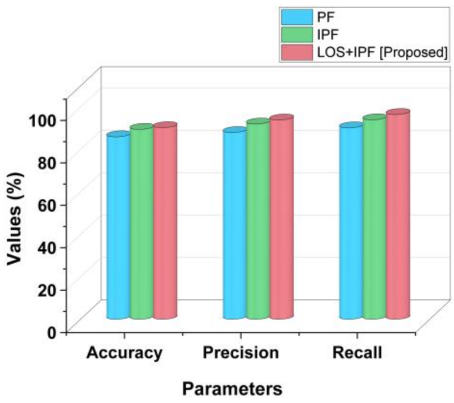

Figure 6: Comparison of the proposed approach

Table 4: Numerical evaluation of accuracy, precision and recall.

Parameters	Values (%)		
	PF	IPF	LOS+IPF [Proposed]
Accuracy	86	89.5	90.3
Precision	88	92	93.9
Recall	90.2	94	96.5

5 Discussion

The High-Precision LOS Tracking Algorithm for Animation VR Systems offers several advantages over existing methods like Doppler Radar, Outside-in Tracking System, IoRL VR System, LOS Guidance for AMV Route Following, UAV-Aided MEC Network, Dispersion-Threshold Identification Method with Eye-Tracking, and Eye-Tracking System for Virtual Control Tower. The proposed algorithm uses self-organizing fusion of multiple features to reduce noise and enhance accuracy, addressing noise and reflection challenges. It is also independent of electromagnetic interference. The algorithm enhances the VR experience without heavy infrastructure, focusing on user eye movements, unlike the IoRL VR System. It is effective in both LOS and NLOS scenarios. Logistically, the algorithm reduces complexity by focusing on software-based improvements rather than extensive hardware setups. The adaptive algorithm efficiency allows it to adjust thresholds based on user characteristics, enhancing performance and accuracy. The algorithm offers broader applicability beyond specific hardware requirements, making it a more effective and versatile solution for creating immersive VR experiences.

6 Conclusions

High precision gaze tracking algorithm can know the real fixation point of human eyes, improve the authenticity of virtual situation, refrain from the visual discomfort caused by unreal feeling, improve the user's sense of real experience of animation VR situation, create a free mobile mixed reality experience, let users perceive animation situation and bring a good experience beyond peripherals. Through the analysis of the theoretical basis of LOS tracking tech, this paper studies the mechanism of LOS tracking algorithm considering particle filter and the performance amelioration strategy of the algorithm, and further analyzes the LOS tracking algorithms with single feature, single target and MLOS features. The study finding shows that LOS+IPF achieved 90.3% accuracy, achieved 93.9% precision, and achieved 96.5% recall. The practical implications of our research are considerable. The improved LOS tracking enhances user immersion and interactivity in VR animation systems, making these systems more effective for applications in entertainment, education, and training. The ability to track eye movements precisely allows for more intuitive user interfaces and can lead to more engaging and personalized VR experiences. Target state prediction, association probability calculation, and target state estimation may all be accomplished efficiently by combining joint probabilistic data association with multi-target LOS monitoring. Finally, through the research on the animation VR situation of high-precision LOS tracking algorithm, the implementation strategy of animation VR situation considering LOS tracking is given.

Data availability

The data used to support the findings of this study are available from the corresponding author upon request.

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