Animation VR Motion Simulation Evaluation Based on Somatosensory Simulation Control Algorithm

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Keywords: somatosensory simulation control, animation, vr sports, simulation evaluation

Recieved: April 19, 2024

The animation business has developed steadily along with the social economy, becoming increasingly indispensable to people's everyday lives. Meanwhile, VR sports realize the simulation of various actions, such as indoor tennis, realistic somatosensory games, and so on. But to ensure the authenticity and experience of animation, VR sports are extremely important. The somatosensory simulation control algorithm is introduced to sort out the business flow of animation VR sports in this paper. Unlike the traditional simulation method, the somatosensory simulation control integrates the perception of the vestibule, provides extremely rapid feedback on the output error, and realizes the continuous correction and prediction of the input angular velocity and the corresponding acceleration to realize the prediction of undulations of the terrain in the animation VR movement. The results of the simulation experiment demonstrate the effectiveness of the somatosensory simulation control method and its ability to support phase delay to enhance the consistency of the associated VR motion simulation animation.

Povzetek: V članku je opisana izboljšana Otsu teorija za segmentacijo slik z več pragi in z vključitvijo algoritma kolonije mravelj za izboljšanje natančnosti in hitrosti procesiranja slik ter zmanjšanja šuma.

1 Introduction

People's need for leisure time has progressively increased as the social economy has continued to grow. In addition to traditional sports and games, there is also the pursuit of new scientific and technological achievements [1-2]. In recent years, interactive somatosensory sports such as drones, switches, and PS have gradually been favored by more and more people, especially VR technology, which lets the experiencer experience the first perspective as if they experience the game, path-finding in an experimental environment, barriers, etc. [3]. However, it should be noted that mobile devices with VR technology could bring certain motion sicknesses. The essence of this process is to systematically induce particular conflicts by utilizing information from the vestibular system, visual data perceived from a first-person perspective, and visual information regarding the external world. As a result, it presents symptoms associated with the corresponding state within the brain [4]. Especially in VR, the inconsistency of virtual and real motion often causes the corresponding vision to conflict with the corresponding virtual information, which causes VR motion sickness [5]. Corresponding scholars have researched this symptom, aiming to reduce or eliminate it. For example, in the process of wearing a VR terminal, a hard seat is used for ineffective exercise by trial. By comparing the monitoring of motion sickness symptoms before and after, it is proven that this method has certain effectiveness. Through the movement of a third party, such as the seat, the symptom can be reduced and eliminated [6]. Table 1 summarizes the literature review.

2 Related works

Table 1: Summary of literature survey

S.No	Method	Result	Limitation
Cheng et al. (2024)	The motor neuroscience was to comprehend how various nervous system components interact to produce coordinated motions. The fundamental methods used in physics-based character animation (PBCA) were examined, besides the fundamentals of human motor control and the functional anatomy.	The study of sensorimotor integration and human-character coordination may benefit greatly from greater cross-domain cooperation, according to their suggestions.	They only create interacting humanoids and humans using physics.
Kloiber et al. (2020)	Human movement cannot be separated from the specific environment and personnel, in the meantime, such movements mainly include the corresponding arms, head, traditional limb movement, facial and body posture, etc., such human movement can show personal personality and characteristics.	Technology for visual analysis was intended for the immersive visualization and investigation of human motion data.	They concentrated on the exploratory analysis of motion; going forward, we hope to include more automated elements for guiding and analysis.
Chen et al. (2019)	The omnidirectional movement of the human body can realize the ultimate human-machine movement, which can realize novel and natural interaction.	As a result, the students of animation dance cannot understand their learning status, let alone realize their simulation evaluation of animation VR sports.	Especially for students majoring in dancing, traditional video teaching was passive and single-type information transmission, without specific, effective, and timely information.
Fulvio et al. (2020)	The visual system used a variety of signals, including binocular and monocular cues, to interpret depth information about object motion. In the lab, observers' sensitivity to various three-dimensional (3D) motion cues varies, and binocular cues were frequently weaker than other cues.	The findings imply that when binocular cues were initially presented in a virtual reality setting, viewers might ignore them.	As is frequently the case with cue-combination studies, underestimating sensitivity to cue-isolating conditions or ceiling effects in estimations of sensitivity to combined cues can lead to differences between observed and expected sensitivities.
Li et al. (2019)	During the actual application and implementation, the algorithm of somatosensory simulation can mainly use a wash-out algorithm for research.	According to the targeted type or research focus, it mainly focused on the optimal wash-out, adaptive wash-out, and classic wash-out.	There were often low utilization efficiency and processing delays in the classic wash-out methods.

Wang et al. (2021)	One popular 3D user interface (UI) for virtual reality (VR) in hand-tracking applications was the Leap Motion Controller (LMC).	The system's ability to track two hands steadily was demonstrated by the results, which extend 164.43 degrees vertically and 202.16 degrees horizontally.	The measuring precision of a single LMC was the primary source of system accuracy constraints.

3 Methods and materials

Given these shortcomings and needs, a somatosensory simulation control algorithm is introduced by trial in this paper, through a comprehensive analysis of the space-related limitations of the motion simulator, somatosensory simulation algorithms, to achieve the unity of advantages and disadvantages, and more importantly, to effectively integrate the vestibular perception and somatosensory simulation control, to produce corresponding acceleration and angular velocity. Finally, according to the fuzzy logic method, the corresponding acceleration and angular velocity changes and updates are realized through the effective analysis of the output deviation, to realize the simulation evaluation of the animation VR movement, which aims to reduce the corresponding VR dizziness symptoms and enhance the effective experience feeling of VR.

3.1 Human perception system

In specific daily life, simple human sensory organs such as arms and eyes are frequently used, especially the visual system, which is complex and highly usable. Therefore, during effective perception of the external environment, more attention is paid to the changes in the environment, especially the difference in the state of the object and the color difference.

Vision system

For the visual system, the information directly received by vision occupies most of the information received, and meanwhile, the perception of movement can be realized through the occipitoparietal. Especially in the application process of VR human-computer interaction, the core corresponding processor can convert the image, and then transmit the converted information to the VR terminal device. People can realize the stimulation from the VR eye through the VR terminal device using the vision system to realize the spatial feedback of movement in the brain neurons.

Vestibular system

For the vestibular system, the human body's organs that directly sense movement include the vestibule and the corresponding otoliths. It is often only within a certain threshold range that it is possible to directly perceive it through the vestibular system. Especially for the perception of speed and angular velocity, it is impossible to distinguish accurately and effectively by relying solely on the otoliths of the human body. Therefore, the cooperation of the vestibule is required to effectively sense linear acceleration, specifically, as shown in formula (1):

$$f = a - g \qquad (1)$$

Among them, the perceptual specific force of the vestibular center is denoted by f, the acceleration of translation is denoted by a, and the acceleration of gravity is denoted by g.

On this basis, nonlinear tools can be introduced for fitting, and a motion perception model can be established to replace the nonlinear motion perception model. The specific transfer function is expressed by formula (2) and formula (3):

$$\frac{f}{f} = \frac{k\left(\tau_a s + 1\right)}{\left(\tau_L s + 1\right)\left(\tau_S s + 1\right)} \qquad 2)$$

Among them, the specific force input into the vestibular center in any one of the different directions is denoted by f.

$$\frac{\omega}{\omega} = \frac{T_L T_a s^2}{\left(T_L s + 1\right)\left(T_S s + 1\right)\left(T_a s + 1\right)} \qquad 3)$$

Somatosensory simulation control algorithm

For the somatosensory simulation, experts in the industry have also conducted in-depth research and analysis. Just as sorted out and analyzed in the previous article, traditional wash-out algorithms cannot directly conduct a somatosensory simulation. It often needs to be adapted or optimized to ensure that traditional simulations are fitter for the actual situation while reducing the complexity of the algorithm and improving the efficiency and accuracy of the calculation.

As a cultural characteristic output performance, the main audience of animation dancing is mainly young people, especially young girls, who often exercise relatively in a fixed period, either in a closed martial arts room or in a playground or community open space and other outdoor empty places, under the leadership of the corresponding organizer. There are still some inconsistencies in the way the animation dance organization is implemented, particularly for beginners who frequently reach the temporal learning curve and are unable to learn while practicing, making it difficult to share and update the dance resources.

Therefore, this article considers the principles and strategies of the corresponding animation and dance design, which mainly include:

(1) The first is the simplicity of the game, that is, by considering the user's understanding and acceptance of new things, the corresponding animation design is set to an easy level.

(2) In the actual reference of the game, the corresponding authenticity feedback needs to be obtained, so that the participants of the game can directly understand their state, lack of exercise, and corresponding defects, to make certain adjustments, and meanwhile increase the game's related fun, and achieve a certain satisfaction.

(3) During the animation game, it is also necessary to evaluate the players of the game simultaneously. In particular, different evaluations shall be performed for different stages, e.g., "make persistent efforts"; ultimately, a final score must be assigned.

(4) The corresponding background music is used to rationalize the difficulty of the action responding to animation, and meanwhile, it can further target different audiences and players of different age levels.

(5) The dance movement teaching using mirrored VR operation enhances the actual sense of substitution and entry of the game.

(6) Increase the interactive integration of traditional methods and somatosensory to ensure that they are not controlled by somatosensory during the actual operation process, to reduce the probability of incorrect operation while reducing the threshold of access.

The animation dance is designed and developed based on Chinese-style music. Since, it allows more audiences to analyze the fun of animation dance; it also makes the audience understand the animation dance game analysis of somatosensory technology. In addition, it can also cover more audiences and different age levels. It has both the enthusiasm of youth dance music and the sweet and fluent ancient style. Compared with the relaxed and leisurely background music, the music is relatively leisurely with the slow rhythm and the rich types.

For classic somatosensory simulation, it is mainly realized through different channels, which are primarily separated into tilt coordination high-pass acceleration, and high-pass angular velocity. For high-pass acceleration, it has multiple components such as amplitude limit, coordinate transformation, filter, etc. It can also peel off the high frequency related to acceleration, simulate the linear acceleration, and analyze the displacement through the VR terminal. The low-pass acceleration, inclined portion, rate restriction, and other components make up the majority of the inclined coordinated channel. It can be stripped by inputting the low-frequency part of the straight line, and the straight line is converted into rotational motion through the inclined coordination, and the linear acceleration is analyzed using simulation of the component of gravity [13-14]. The high-pass angular velocity is realized through filters, coordinate transformation, integral, etc., which can strip the high-frequency part, and use the VR motion simulator to realize the rotation simulation. Specifically, as shown in formula (4), formula (5), formula (6), formula (7), formula (8), formula (9), etc.:

$$L_{IS} = \begin{bmatrix} c\theta c\psi & s\varphi\theta c\psi - c\varphi s\psi & c\varphi s\theta c\psi + s\varphi s\psi \\ c\theta s\psi & s\varphi s\theta s\psi + c\varphi c\psi & c\varphi s\theta s\psi - s\varphi c\psi \\ -s\theta & s\varphi c\theta & c\varphi c\theta \end{bmatrix} \tag{4}$$

$$H_{ah} = \frac{s^2}{s^2 + 2\xi_{ah}\omega_{ah}s + \omega_{ah}2} \cdot \frac{s}{s+\omega_0} \tag{5}$$

$$H_{al} = \frac{\omega_{al}^2}{s^2 + 2\xi_{al}\omega_{al}s + \omega_{al}^2} \tag{6}$$

$$\begin{cases} \varphi_{\beta L} = \tan^{-1}\left(-\dfrac{f_{Ly}}{g}\right) \approx -\dfrac{f_{Ly}}{g} \\ \theta_{\beta L} = \tan^{-1}\left(\dfrac{f_{Lx}}{g}\right) \approx \dfrac{f_{Lx}}{g} \end{cases} \tag{7}$$

$$T_S = \begin{bmatrix} 1 & s\varphi t\theta & c\varphi t\theta \\ 0 & c\varphi & -s\varphi \\ 0 & s\varphi/c\theta & c\varphi/c\theta \end{bmatrix} \quad (8)$$

$$H_{\omega h} = \frac{s^2}{s^2 + 2\xi_{\omega h}\omega_{\omega h}s + \omega_{\omega h}^2} \quad (9)$$

The controller of the VR terminal is realized using the requirements of the characters and the real-time feedback action of the motion platform, to simulate the specific state in the real environment for effective output of the operation signal, and realize the motion parameter conversion of the simulator through dynamic model calculation. It often includes acceleration, angular acceleration, attitude angle, etc. The motion parameters are translated through the transformation of the center of mass, which realizes the direct conversion of the parameters of the moving coordinate system into the motion conversion of the known reference system and realizes the collection and analysis of the human body's perceived motion state. The vestibular system of the human body can realize the transformation of the algorithm by sensing certain acceleration and angular velocity. This change can be transmitted to the motion instruction simulated by the VR, and the expansion motion of the specified action can be realized through cooperation with the platform, and finally the state of the motion is fed back to the controller. Such a closed loop forms the motion control system of the VR terminal. Figure 1 shows that the motion control system of the VR terminal is relatively complicated, which may involve the change of kinematics spatial position, the inverse calculation of the position, the analysis of the human sensory system, etc., which is the key part to the motion control system, the corresponding state of the motion simulator needs to be controlled to ensure the realization of the fidelity of the action controlled by the VR terminal [15-17]. Therefore, it is extremely important to establish a simulation of the motion state. The specific process is shown in Figure 1:

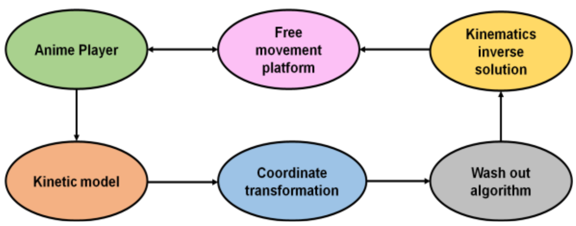

Figure 1: The model of the motion control system of the motion simulator.

Motion platform modeling and coordinate transformation

To further realize the dynamic simulation of the terminal in the VR motion state, it is necessary to establish a corresponding mapping relationship in the reference system to realize the effective conversion of the real signal into the driving signal of the VR simulation and realize the washing-out process of the motion platform. First, static and dynamic coordinate systems are established according to the corresponding motion platform to determine the position, constraint relationship, and motion amplitude value of each calibration point in the upper and lower platforms [18-20]. Meanwhile, the corresponding software is used to construct the model to realize the calculation and acquisition of numerical value.

The position relationship and angular velocity relationship of the coordinate system of VR motion simulation can be calculated by the formula (10) and formula (11):

$$\begin{bmatrix} x & y & z \end{bmatrix} = L_{IS}\begin{bmatrix} x' & y' & z' \end{bmatrix} \quad (10)$$

$$\begin{bmatrix} \dot{\varphi} & \dot{\theta} & \dot{\phi} \end{bmatrix} = T_{IS}\begin{bmatrix} p & q & r \end{bmatrix} \quad (11)$$

Inverse solution of kinematics

For the inverse solution of position, the essence is to inversely solve the corresponding expansion and contraction quantity through the posture of the moving platform [21-23].

Among them, the specific calculation of the initial length of the hydraulic cylinder is shown in formula 12:

$$l_i = \|A - B\| \quad (12)$$

The specific calculation of the length of the hydraulic cylinder is shown in formula (13):

$$l_i' = \|C - B\| \quad (13)$$

The specific calculation of the expansion and contraction of the hydraulic cylinder is shown in formula (14):

$$\Delta l_i = l_i' - l_i \quad (14)$$

Of which: $C = L_{IS}A\left(i = 1, 2, 3, \cdots, 6\right)$

Wash-out algorithm

The conventional wash-out algorithm uses the motion simulator to achieve a unified simulation of the angular velocity channel, the inclined cooperative channel, and the high-pass acceleration channel, as seen in Figure 2. The motion simulation's acceleration loading can be realized via the high-pass acceleration channel, ensuring that the acceleration effect occurs in animation VR simulation, and the specific displacement of the platform is calculated according to the washed-out algorithm; the motion platform's partial angular position movement can be realized using the inclined channel, which can also produce the flight's acceleration effect; the motion simulation's high-pass angular velocity can achieve a particular acceleration comparison [24]. Through the washout algorithm, it can be used as an important component of displacement, which can realize the calculation and simulation of the vector and the corresponding attitude angle.

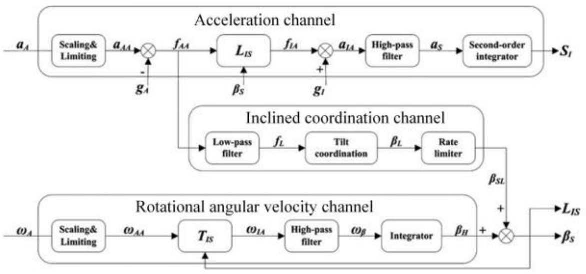

Figure 2: Schematic diagram of classic wash-out algorithm.

Vestibular model

Since the human body's motion sensory system is relatively complex, as mentioned above, it includes the perceptual system of angle and the sensory system of acceleration, which can be simulated through specific vestibular models, as shown in Figure 3:

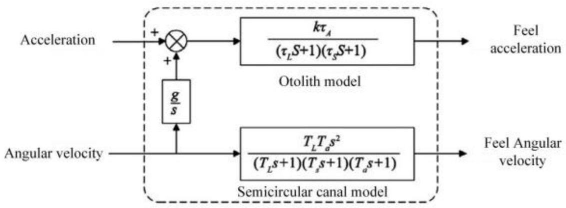

Figure 3: Human vestibular model.

(1) Otolith model

For the otolith model, it is an important acceleration sensing system, which can sense specific relative acceleration specific force, and realize the calculation of gravitational acceleration through translational acceleration [25]. To realize the simulation and analysis of the human body motion sensory system, and to realize the linear simulation, simulated springs, standard mass blocks, dampers, etc. are used, as shown in Figure 4:

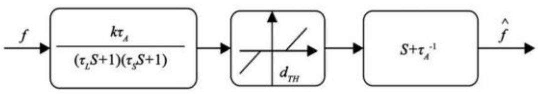

Figure 4: Otolith model.

Formula (15) displays the precise computation of the otolith model's transfer function:

$$H_{OTO}(S)=\frac{L[f]}{L[f]}=\frac{k(\tau_A s+1)}{(\tau_L s+1)(\tau_S s+1)} \qquad (15)$$

(2) Semicircular canal model

Regarding the semicircular canal, it is the analysis of the perception of rotational angular velocity. Through the angular velocity sensing system of the vestibular system, the angular velocity of three angles such as roll and pitch is realized. The specific model is shown in Figure 5.

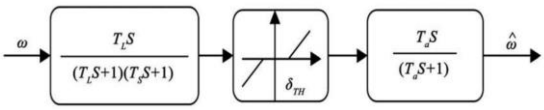

Figure 5: Semicircular canal model.

The specific calculation of the transfer function of the semicircular canal model is shown in formula (16):

$$H_{ROT}(S)=\frac{L[\omega]}{L[\omega]}=\frac{T_L T_s s^2}{(T_L s+1)(T_S s+1)(T_a s+1)} \qquad (16)$$

Improved somatosensory simulation algorithm

The vestibular structure representation is integrated into the somatosensory model approach using the conventional somatosensory simulation methodology as a foundation. The angular velocity and acceleration are used as the input reference [26]. There is a certain perception error between the former and the real sensing signal that existed actually, which can cause dizziness during movement.

VR terminals often have a certain sense of immersion and a way to read data, realize the angle compensation of the model to supplement the terrain undulations and realize the re-correction of the change of the gravity component. For high-frequency motions, such virtual reality collisions, analysis and modeling can be done using the breakdown of acceleration and angular velocity.

Low-frequency angular velocity simulation is lacking in the classic somatosensory simulation system. The specific angular velocity can realize the simulation of the gravity component, as shown in formula (17).

$$\varphi_{\beta\omega} \approx \frac{\omega^2 r}{g} \quad (17)$$

The rolling angle is represented by $\varphi_{\beta\omega}$ among others, the angular velocity of turning is represented by ω, and the finite radius of circular motion is represented by r.

Fuzzy logic controller

A fuzzy logic controller is a computational method for simulating human thought and decision-making processes using linguistic variables and fuzzy rules while working with systems that have complicated and unpredictable inputs. When evaluating VR motion simulation animations, a fuzzy logic controller can be utilized to dynamically modify parameters and settings in response to real-time user feedback. The fuzzy logic controller can adjust to different physiological states and user preferences. It permits instantaneous user experience modifications to simulation parameters in real-time. It improves the impression of presence and realism in virtual reality simulations by timing sensory feedback with visual movements.

The input variables, denoted by VN, N, Z, VP, and P, are categorized into five stages of fuzzification based on the related fuzzy logic control: negative small, negative large, moderate, positive large, and positive small.

The input angular velocity is calculated using the membership function as shown in formula (18).

$$\begin{cases} \mu_{VN}(x;-5,3) = \max\left(\min\left(\frac{-x-3}{2},1\right),0\right) \\ \mu_{N}(x;-5,-3,-1) = \max\left(\min\left(\frac{x+5}{2},\frac{-x-1}{2}\right),0\right) \\ \mu_{Z}(x;-2,0,2) = \max\left(\min\left(\frac{x+2}{2},\frac{-x+2}{2}\right),0\right) \\ \mu_{P}(x;1,3,5) = \max\left(\min\left(\frac{x-1}{2},\frac{-x+5}{2}\right),0\right) \\ \mu_{VP}(x;3,5) = \max\left(\min\left(\frac{x-3}{2},1\right),0\right) \end{cases} \quad (18)$$

When there is a significant negative output error for fuzzy rules, it suggests that the intake is decreasing too quickly and the output is too huge, causing the output error to gradually increase. To achieve the value of change of the controlling quantity, the error must be rapidly reduced (Table 2).

Table 2: Table of fuzzy control rules

Specify the angular velocity difference and acceleration	Perceptual deviation				
	P	VP	Z	VN	N
N	Z	P	N	VN	N
VP	VP	VP	P	Z	Z
P	P	VP	P	N	Z
VN	Z	Z	N	VN	VN
Z	P	VP	Z	VN	N

Beat control

For animation dancing, music is an extremely important background component, and it is extremely important for the definition of style, the grasp, and the development of rhythm. How users can analyze and develop animation actions through VR terminals is extremely effective. The corresponding animation actions are oriented to a wider audience. To ensure the component analysis of the corresponding music beats is sent in the module time at the right time, realizing the "one-to-many" characteristic analysis. The observer mode can be used to perform an analysis of the control of music beats, as shown in Figure 6.

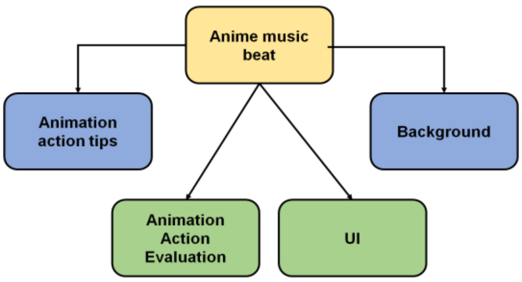

Figure 6: Observer mode of music beat control.

The changes in the observer data can be used to realize data processing for observer mode, especially the need to divide each module to improve the overall reusability and maintainability.

Action evaluation algorithm

For developing an animation action evaluation method, several procedures are involved in VR motion simulation that is based on a somatosensory simulation control algorithm to evaluate and enhance user experiences. Researchers may design VR experiences that are not only immersive but also optimized to lessen motion sickness, improve user comfort, and increase overall happiness by putting into practice an action assessment algorithm based on a somatosensory simulation control algorithm.

(1) Research on action evaluation algorithms

The two primary traditional dance training methods are "one-to-one" live demonstration and video instruction. Better learning outcomes can be achieved with in-person training, but it requires more time and materials than online learning. For individuals with little or no experience, the video teaching method moves too quickly, offers insufficient reference and comparison, and has large amplitude of movement deviation, making it difficult to achieve sufficient learning results.

For a successful learning effect, real-time feedback to the corresponding action learning is therefore required.

In the evaluation of the action similarity, the computer can automatically perceive the person's position, and can effectively judge the person's state, that is, "What are you doing"?

Efficiently estimating posture is the first step in evaluating the similarity of actions. For posture evaluation, it is mainly to identify the posture parameter analysis of each part of the human body through a specific input image sequence. The location and orientation of every body part in the entire three-dimensional space are typically interpreted as a collection of a set of posture parameters. This part needs to be completed by a VR motion capture device. Since the evaluation of action similarity depends to a large extent on the results of posture estimation, accurate estimation of posture can ensure an effective evaluation of similarity. However, the basis of these evaluations is to have clear input data. Meanwhile, effective processing of motion data is needed, such as data noise reduction and motion similarity evaluation.

(2) Implementation of action evaluation algorithm

The following describes the precise steps involved in implementing the adaptive joint weights and interpolated wavelet action evaluation algorithm:

1. Data noise reduction

The motion data is subjected to a mean filtering and Faber-Schauder interpolation wavelet technique to minimize noise.

2. Method for evaluating adaptive joint weight.

The motion characteristics are the starting point for breaking down the action sequence into many sub-segments. The action's joint weight is calculated and compared, as it is the cascaded joint direction feature. The distance between any two frames can be determined using the data.

The calculation method of adaptive joint weight is as follows:

1) Make features out of cascaded joint orientation data.

2) Calculation of adaptive joint weight.

The procedure that follows is the process for calculating adaptive joint weights:

①The number of segments (N) that make up the action sequence P depends on the distance end to end of each time segment.

②Determine the energy of the relative motion $f\left(p_n^i\right)$ of the action segment p_n^i.

③Determine how many times every combined ID appears in the vector T^H, the ratio of the segment S_i with greater energy of joint I to all segments can be obtained.

④Determine the joint weights. The specific calculation of joint weight ω_i is shown in formula (19).

$$\omega_i = S_i \cdot \alpha \Big/ \sum_{j=1}^{m} S_j' \qquad (19)$$

The remaining joints split the remaining weight equally; the weight's precise computation is displayed in the formula (20).

$$\omega_i = \begin{cases} S_i \cdot \alpha \Big/ \sum_{j=1}^{m} S'_j, i \in C \\ (T-m)/(1-\alpha), i \notin C \end{cases} \quad (20)$$

The specific calculation of the metric is shown in the formula (21).

$$dist(p_r, q_{r'}) = \sum_{i=1}^{T} \frac{\omega_i + \omega'_i}{2} \cdot \left| d\left(p_r^i, q_{r'}^i\right) \right| \quad (21)$$

When the split time segment reaches 0.8 seconds in the test set experiment, the best decision is made with H=6 and α=0.7.

Determine how the action sequence is mapped out.

The unique correspondence in between the action sequence P that is referenced and the contrast action sequence Q is found using the DTW action sequence matching technique. Note the two's matching relationship in the records.

The explanation of the DTW-based action sequence matching method is as follows:

1) The distance on the pathway is computed at regular intervals, beginning at the first node, using the inter-frame distance measurement formula and the three requirements of the DTW regulation. To get the path's minimum distance, the one chosen for matching is the least of these, to which the current distance is added.

2) To achieve a fully regular path, repeat the preceding step.

3) To record the distinct mapping relationship between each frame in the action sequence in reference P and the contrasting action sequence Q, create an array map frame. Follow the prescribed path and document the mapping relationship in a Map Frame.

Take out the multi-dimensional action sequence's crucial frames.

Conduct a similarity analysis.

Calculate the distances of all keyframes in the two sequences and average them, as shown in formula (22):

$$DIST(P,Q) = \frac{\sum_{r=1}^{R} dist(Kp_r, Kq_{r'})}{R} \quad (22)$$

Formula (22), which is displayed in formula (23) states that the similarity evaluation is obtained following normalization:

$$Similarity(P,Q) = \frac{1}{DIST(P,Q)+1} \quad (23)$$

4 Simulation results and analysis

This study conducts a simulation experiment to confirm the somatosensory simulation control method's accuracy, consistency, and dependability. From the results of Figure 7, Figure 7(a) is the human body's sensory acceleration, indicating that the vestibular perception curve can directly introduce the signals of angular velocity and acceleration in the VR scene as a certain response curve to achieve an analysis of curve comparison. The somatosensory simulation method of the VR scene is applied to build the enhanced curve; it is required to provide the signal required to run the virtual reality motion simulator and to improve the signal so that it may be compared to the reference curve and the classic curve. The speeding up mistake in Figure 7(b) is caused by the reference curve's delay, which makes it easier to provide misleading clues.

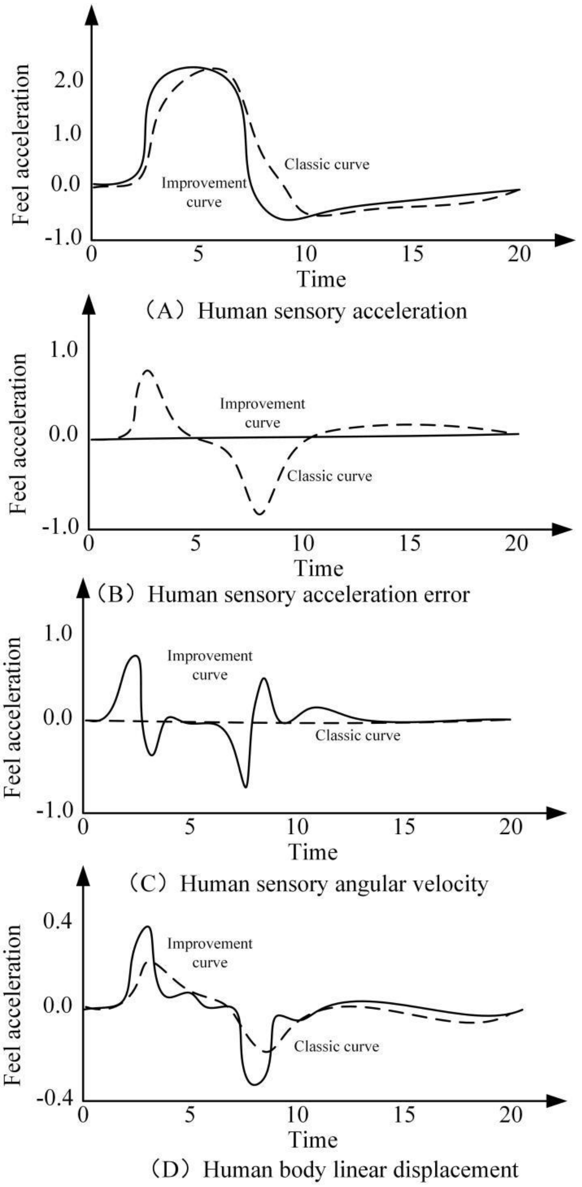

Figure 7: Response curve of step signal.

Figure 7(c) illustrates that the modified curve and the reference curve can both be directly recognized. Approximately 80% more platform utilization has been achieved with the improved method in comparison to the conventional somatosensory simulation approach.

Figure 8 displays the reaction curves for both the standard somatosensory simulation approach and the enhanced algorithm, which uses Gaussian white noise to simulate continuous acceleration variations like braking, deceleration, and acceleration.

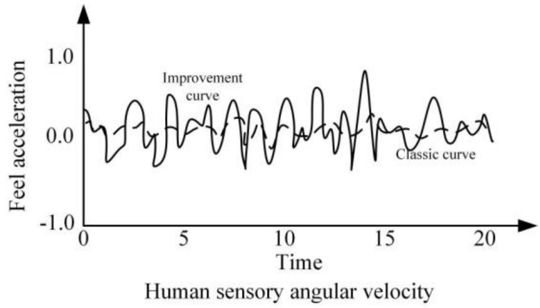

Figure 8: White noise response curve.

In terms of platform utilization rate, the results in Figure 8 demonstrate that the enhanced somatosensory simulation technique outperforms the traditional somatosensory simulation methodology.

Movement Time (MT) for different movement orientations was found to exhibit two completely different patterns, i.e., approaching and retreating target speed. MT increased as the target travelled away from the participant more quickly, as shown in Figure 9.

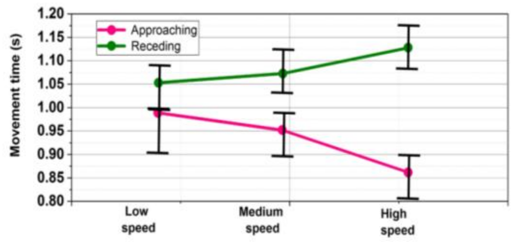

Figure 9: Direction and speed on MT error bars and the 95% confidence interval

5 Discussion

The primary techniques employed in physics-based character animation (PBCA) are demonstrated, along with the functional principles and functional anatomy of human motor control. The purpose of the motor neuroscience is to comprehend how various nervous system components interact to produce coordinated motions (Cheng et al. (2024)). The visual system uses a variety of signals, including binocular and monocular cues, to interpret the depth information about object motion. In the lab, observers' sensitivity to various three-dimensional (3D) motion cues varies, and binocular cues are frequently weaker than other cues (Fulvio et al. (2020)). One popular 3D UI for virtual reality (VR) in hand-tracking applications is the Leap Motion Controller (LMC). According to the findings, the system can follow two hands steadily throughout a 202.16 degree horizontal and 164.43 degree vertical range (Wang et al. (2021)). In this research, the somatosensory simulation control technique was introduced to organize the business flow of VR sports animation. In contrast to the conventional simulation approach, the somatosensory simulation control incorporates vestibule perception and offers incredibly quick feedback on output mistakes. The enhanced somatosensory simulation technology performs better than the classic somatosensory simulation methodology in terms of platform utilization rate.

6 Conclusions

The social economy continues to grow; people, especially young people, are growing more and more interested in animation and VR acts. To clarify the evaluation of animation VR action simulation and to realize the authenticity and experience of animation VR movement, a somatosensory simulation control algorithm is introduced through combining the business flow of animation VR action. Fuzzy control provides extremely fast feedback on the output error, realizes continuous correction and prediction of input angular velocity and the corresponding acceleration, as well as realizes the reflection of the ups and downs of terrain changes in animation VR sports. Fuzzy control controls input and somatosensory faults in real-time, decreasing vertigo, improving motion perception's stability and realism while giving very quick feedback on output errors. The simulation experiment's outcomes demonstrate the efficacy of the somatosensory simulation control technique, which can also accommodate phase delays to enhance the consistency of the related VR motion simulation animation.

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