An intermediate interpolation of VR glasses display animation based on hierarchical constraints

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Abstract: In order to solve the problem of long interpolation time in traditional methods, intermediate interpolation method of VR glasses display animation based on hierarchical constraints is proposed. Firstly, the corresponding relationship between the 3D objects of VR glasses display animation is analysed. Secondly, the swing posture of the user's head is obtained, the virtual scene in the user's VR glasses display animation is adjusted and the image parameters of the in between of VR glasses display animation are obtained; Finally, the visual feature points are obtained by using the automatic feature point extraction method, and the intermediate interpolation is realised according to the interpolation algorithm based on hierarchical constraints. The experimental results show that when the number of iterations is 80, the image region overlap rate of this method is only 1.9% and when the number of animations is 100, the time of intermediate interpolation is only 112 ms.

Keywords: hierarchical constraints; VR glasses; display animation; intermediate interpolation; visual feature points.

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1 Introduction

VR glasses is a complex new media vision device composed of shell, air bag, imaging optical lens, lens regulator and other components. It is a new technical medium for the real-world to enter the virtual world. The important direction of its technical intention lies in the shielding of the real-world and the bringing out of the virtual world (Chu and Yang, 2020). On the computer network, each picture is transmitted in a tiny unit, which stores all the information of the image in the form of data, which is called frame. Frame is actually a single picture during animation projection (Sushma and Aparna, 2020). The start and end pictures are respectively called the start in-between and the end in-between, which are collectively called the in-between. In-between are a series of pictures between the beginning and end in-between. Their existence makes the starting in-between transition smoothly and naturally to the end in-between, giving people a beautiful visual enjoyment. However, in-between alone cannot produce continuous animation effects. Interpolation must be carried out between adjacent in-between to generate more in-between pictures, the complete and vivid animation sequence can be formed only by making the motion posture of animated characters transition smoothly between in-between. Therefore, it is of great significance to study the intermediate interpolation method of VR glasses display animation (Li and Zhou, 2020; Rajkumar and Mahendran, 2021).

Wallis is put forward based on the feature matching of animation image in-between feature point interpolation method, using grey, gradient co-occurrence matrix model for animation image in the in-between feature point, build the active shape model for obtaining the best matching points, 3D animation image colour invariants are calculated by use of a Gaussian function, according to the 3D animation image scale space, the threshold vector of the in-between of the animation image is calculated, and the interpolation matching of the feature points of the in-between is realised according to the calculation results. This method has good matching effect of the in-between, but the interpolation matching time is relatively high. Feng (2019) is put forward based on the animation component analysis among 3D motion data intermediate interpolation method, using the 3D animation synthesis in-between are classified to 3D animation images, using the capture image segmentation method for in-between feature extraction, through sports redirect method to realise dynamic interpolation motion image in-between, this method can improve the intermediate interpolation effect, But the animated image areas overlap. Tang et al. (2019) is put forward the intermediate interpolation method of VR glasses display animation with secondary nesting. Use human facial micro-expressions intermediate interpolation on the 3D animation, secondary nested build database, micro-expression animation for animation in-between sequence, based on a true characters facial expressions of in-between in the animation image secondary nested inserted, implementation among the 3D animation frame interpolation, enhance the animation effects, but this method does not match the regional interpolation motion problems.

As traditional animation intermediate interpolation method in the design process is not given to the visual feature point analysis, animation intermediate interpolation gradation is poorer, so this article in order to solve the problems existing in the traditional method as the research target, put forward a intermediate interpolation method of VR glasses display animation based on hierarchical constraints, the specific research ideas are as follows:

Firstly, the corresponding relationship between 3D objects in the VR glasses display animation is analysed to obtain the swinging posture of the user's head, adjust the virtual view in the user's VR glasses display animation and obtain the image parameters of the in-between of the VR glasses display animation.

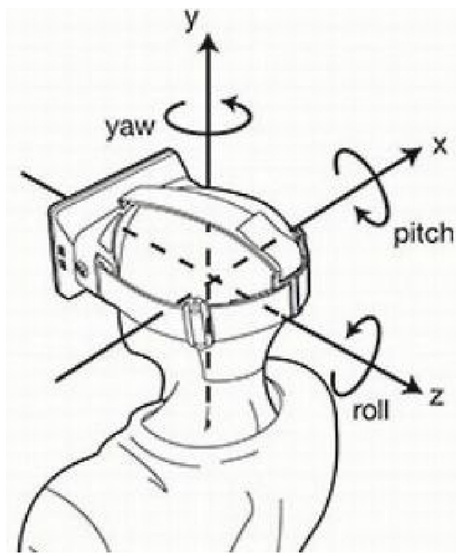
Secondly, the visual feature points in VR glasses display animation are obtained by automatic feature point extraction method. Finally, the monotone variation rule of in-between vector of VR glasses display animation is obtained, and the intermediate interpolation of VR glasses display animation is realised according to the interpolation algorithm based on hierarchical constraints.

Finally, the animation intermediate interpolation effect of the proposed method is verified by the image region overlap rate and the intermediate interpolation efficiency in VR glasses, and a conclusion is drawn.

2 Obtain the image parameters of the intermediate frame of VR glasses display animation

In order to realise the intermediate interpolation of VR glasses display animation, it is necessary to visually simulate the image of VR glasses display animation in order to obtain a more realistic user experience. Therefore, head tracking needs to be combined with VR glasses technology to obtain real-time 3D virtual scene to meet this feature. The head movement diagram of VR glasses is shown in Figure 1 (Aote and Potnurwar, 2019).

Figure 1 VR glasses head movement



For the interpolation compensation of VR glasses display animation in-between image, the intermediate image filled between the initial image and the target image is called in-between, and this supplementary process is called intermediate interpolation (Jiang and Shi, 2021). In this process, multiple position change points will be generated. These changeable points need to obtain the moving trajectory of human body or object through interpolation calculation to obtain relevant parameters. In 3D space, the calculation process of these location points is very complex. Therefore, this paper can convert this problem into points in 2D plane, use multi-level analysis for multi-dimensional combination, and realise 3D scene restoration according to hierarchical constraint rules (Prathiba and Kumari, 201). Then, the key problem is how to match the position relationship between 3D object and 2D plane. If we put multiple position change points generated in the intermediate interpolation process into one set, it is expressed as:

$$F = \{(P_i, N_i) | i = 1, \ldots, m\} \tag{1}$$

In formula (1), F represents the interpolation parameter set of in-between image, P_i represents the 2D plane transformed by VR glasses, and the normal vector of this 2D plane is represented by N_i (Pei, 2021). The 2D plane constituting the VR glasses display animation is represented as:

$$P_i = \{D_i | i = 1, \ldots, n\} \tag{2}$$

In formula (2), D_i represents each point in the 2D plane. Use F_s and F_e to represent the scene in the in-between of the animation displayed by two different VR glasses. Suppose there are N_s faces in scene F_s and N_e faces in scene F_e. When the image in the animation displayed by VR glasses changes from F_s to F_e, $\lambda(\alpha \leq \lambda \leq 1)$ intermediate images will appear, which is represented by F_1 in the article (Awan and Shin, 2021).

We can match the relationship of this change process into $P_{ei} = f(P_{si})$, and use $D_{ei} = \phi(D_{si})$ to represent the change of scene vertices in the middle picture. According to the difference calculation function, the change function of vertex parameter D_{Ei} of F_1 in the middle frame is:

$$D_{Ei} = D_{si} + \lambda(D_{si} - D_{ei}) \tag{3}$$

Based on the linear interpolation results of vertex parameters at this time, the intermediate interpolation of VR glasses display animation can be further performed.

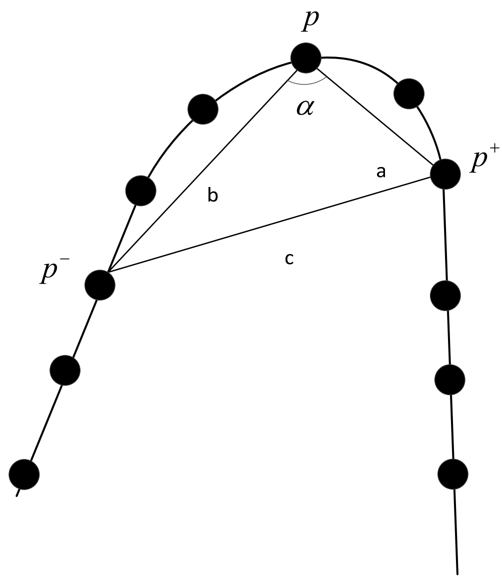
3 Intermediate interpolation based on hierarchical constraints

3.1 Automatic extraction of visual feature points

On the basis of obtaining the image parameters of the middle frame of VR glasses display animation, the automatic extraction method is used to extract visual feature points of VR glasses display animation (Bommisetty et al., 2021). This method is characterised by high speed, high accuracy and high intelligence. The specific process is as follows:

A is used to represent the middle frame image of VR glasses display animation, in which there are n sampling points, which are denoted as set $\{p_1, p_2, \ldots, \mathrm{p}_n\}$. First, scan the whole point set, search and calculate at each point. Among them, VR glasses display animation extracts feature points, as shown in Figure 2.

Figure 2 Schematic diagram of feature points extracted from VR glasses display animation



The built constraint is:

$$d_{\min}^2 \le \left|p - p^+\right|^2 \le d_{\max}^2 \tag{4}$$

$$d_{\min}^2 \le \left|p - p^-\right|^2 \le d_{\max}^2 \tag{5}$$

$$\alpha \le \alpha_{\max} \tag{6}$$

In formulas (4) to (6), p, p^+ and p^- are respectively used to represent three points in the VR glasses display animation, and $d_{\min}$, $d_{\max}$ and $\alpha_{\max}$ are used α to represent the average length, maximum length, and minimum length between points. Use $\left|p - p^+\right| = a$ to represent the length between two points. Similarly, $\left|p - p^-\right| = b$ is the length and angle of the line segment obtained by connecting vertex p and vertex p^-. α is the internal angle at vertex p in a triangle composed of vertices p, p^+ and p^-, and $\alpha \in [0, \pi]$, which can be calculated by the following inverse cosine formula α value of:

$$\alpha = \arccos \frac{a^2 + b^2 - c^2}{2ab} \tag{7}$$

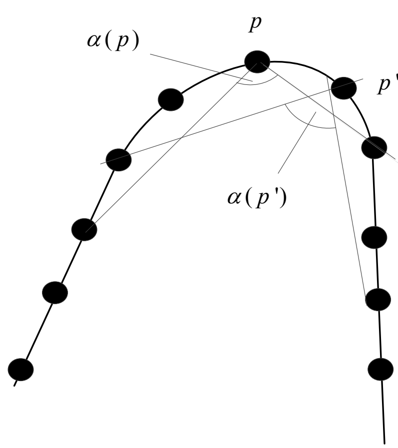
If a triangle takes vertex p as the reference point, then p can be regarded as an optional point. Among all triangles with p as the reference point and meeting the above conditions, select the one with the smallest $\alpha_{(p)}$ value, and then $\left|p - \alpha_{(p)}\right|$ it can be used as the sharpness of reference point p. If the reference point p that meets the above conditions cannot be found, it indicates that p has no sharpness, so p is not an optional point (Concha et al., 2019).

If a vertex exists near the reference point and satisfies the condition of $\alpha_{(p')} < \alpha_{(p)}$ (as shown in Figure 3), it indicates that p' is a sharper optional point than p. at this time, p will be abandoned and replaced by p' as a new feature point. Points near p refer to those vertices within a certain distance from p, which must meet the following conditions:

$$p - p'^2 \leq d^2 \tag{8}$$

The parameter of this condition is d, which needs to be manually assigned according to the actual situation. The values of these parameters are different for different graphs. The selection process of sharper feature points is shown in Figure 3.

Figure 3 Diagram of selecting sharper feature points



After the above operations, the in-between pattern A can be represented by some feature point sequence $\{p_1, p_2, \ldots, \mathrm{p}_m\}$ (Yousefi and Kuncheva, 2019).

Based on this, the visual feature points of VR glasses animation scene are obtained, which lays a foundation for the acquisition of graphics vector law in the in-between later.

3.2 Vector change analysis of intermediate frames

On the basis of extracting visual feature points of VR glasses animation scene, the change rule of graphics vector of middle frame is analysed.

If the starting intermediate frame graph S is represented as $S = \{A_i \mid i = 0, 1, \ldots, n\}$, the target intermediate frame graph D is represented as $D = \{B_i \mid i = 0, 1, \ldots, n\}$, A_i, B_i are the feature points extracted from the beginning and end intermediate frame graph, then the initial image in the VR glasses display animation can be represented by S, and the contour position vector of the animated character can be represented by

$\vec{S} = \{a_i | i = 0,1,\ldots,n\}$. In the animation, the contour position of the virtual character is represented by $a_i = A_i - A_{i-1}$, and the target image of the character in the animation is represented by D at this time, the contour position vector of the animated character displayed by VR glasses is represented by $\vec{D} = \{b_i | i = 0,1,\ldots,n\}$. At this time, the contour position of the virtual character in the animation is represented by $b_i = B_i - B_{i-1}$, where, $A_n = A_0$, $B_n = B_0$.

For VR glasses display animation, both the virtual initial image and the final target image are completely closed curves. In this process, if the image changes gradually, an animated intermediate frame image will be generated during the change process. We use $C(t)$ to represent it, because the intermediate frame image always changes, so it is represented by the vector $\vec{C}(t) = \{c_i(t) | i = 0,1,\ldots,n\}$, $t \in [0,1]$. The vertices of the animation intermediate frame image are represented by $C(t) = \{C_i(t) | i = 0,1,\ldots,n\}$ and C $c_i(t) = C_i(t) - C_{i-1}(t)$ at this time, $C(t)$ needs to meet $\sum_{i=1}^{n} c_i(t) = 0$.

In order to process graphics more conveniently and make the middle frame graphics have strong presentation function and interactive modification ability, $c_i(t)$ is defined as the following form:

$$c_i(t) = \frac{w_1(1-t)^2 a_i + 2w_2 t(1-t) d_i + w_3 t^2 b_i}{w_1(1-t)^2 + 2w_2 t(1-t) + w_3 t^2} \tag{8}$$

where, $t \in [0,1], i = 1,2,\ldots,n$. In the above formula, w_1, w_2, w_3 are curve coefficients, all greater than 0. a_i is the vector representation of the starting in-between graph, b_i is the vector representation of the target in-between graph and d_i is calculated jointly by a_i and b_i. In order to more conveniently study the monotonic change and complex change law of graphics vector in the in-between during the gradient process, make:

$$M(t) = w_1(1-t)^2 a_i + 2w_2 t(1-t) d_i + w_3 t^2 b_i \tag{9}$$

$$N(t) = w_1(1-t)^2 + 2w_2 t(1-t) + w_3 t^2 \tag{10}$$

Normalise the monotonic change and complex change law of the graphics vector in the in-between, and the results are as follows:

$$M'(t) = (1-t)(2w_2 t d_i - 2w_1 a_i) + t(2w_3 b_i - 2w_2 d_i) \tag{11}$$

$$N'(t) = (1-t)(2w_2 - 2w_1) + t(2w_3 - 2w_2) \tag{12}$$

Thus, $c_i(t)$ can be expressed as:

$$c_i(t) = \frac{M(t)}{N(t)} \tag{13}$$

The derivative with respect to $c_i(t)$:

$$c_i'(t) = \frac{M'(t)N(t) - M(t)N'(t)}{N^2(t)} \tag{14}$$

After all the values of the boundary contour vector $\vec{C}(t) = \{c_i(t) | i = 0,1,\ldots,n\}$ of the intermediate frame graph are obtained, the coordinates of all vertices of the top point set $C(t) = \{C_i(t) | i = 0,1,\ldots,n\}$ can be obtained from $c_i(t) = C_i(t) - C_{i-1}(t)$. These vertex coordinates are the coordinates of the feature points on the intermediate frame graph contour. The next work is the same as the previous content, that is, the coordinates of the control points are inversely calculated according to the coordinates of these feature points. Then a series of pie shaped B-spline curves passing through feature points are generated through the coordinates of control points, that is, a DBBs model is established for the intermediate frame, which is the required intermediate frame graph.

3.3 Intermediate interpolation algorithm with hierarchical constraints

Based on the monotony variation law of in-between graph vector in Sub-section 3.2, the in-between image is obtained by establishing DBBS model, and intermediate interpolation based on hierarchical constraints is carried out on this basis. In this paper, each VR glasses display animation can be interpolated separately and finally, multi-layer combination can be carried out according to the hierarchical constraint rules to achieve intermediate interpolation. The intermediate frame sequence generated by the general linear interpolation algorithm appears to break away from the left eye constraint at the left eye bead, because most of the existing shape deformation algorithms consider a single polygon, although they can generate smooth and characteristic matching results. But in the presence of regional nested relations, they did not consider regional relations between each other constraints, leading to a possible constraint violation, therefore on the basis of everybody can separate interpolation, but combine them up around the constraint relation between geometrical form, must be considered that constraint also called hierarchical constraint, using hierarchical constraints to interpolate intermediate frames can effectively improve interpolation accuracy and effect.

The specific process is as follows:

1) The outer contour nodes in the VR glasses display animation were obtained, and the 3D vector coordinate system was constructed. The interpolation calculation of in-between in the VR glasses display animation was calculated according to different coordinate values;

2) The centroid C of the parent node is calculated according to the coordinate position of the child node displayed by the VR glasses;

3) The coordinate positions of different child nodes and parent nodes are layered by principal component analysis method, and the regional spindles of each parent node are calculated. The centroid C in section 3 is taken as the centre origin of the 3D coordinate system to construct the local 3D coordinate system of the child nodes of the in-between of the animation;

4) The above coordinate system is matched with the child nodes of the in-between of each VR glasses display animation, and the position coordinates of the corresponding in-between are calculated to obtain the position coordinate value;

5) Interpolates the paths of the source and target bodies in relative coordinates;

6) The trajectory of the centre of mass is interpolated linearly;

7) The coordinate position of each in-between image is sorted, and a new centre origin coordinate position is constructed to realise the absolute coordinate transformation of VR glasses display animation;

8) Iterate until all nodes are accessed.

Since then, the intermediate interpolation of VR glasses display animation based on hierarchical constraints has been realised.

To sum up, this article through to VR glasses display animation three-dimensional objects is analysed, the corresponding relationship between VR glasses display animation intermediate interpolation of image parameters, automatic feature point extraction method is used to collect visual feature points, analysis of VR glasses show animation in the intermediate vectors monotone changing law, according to the intermediate interpolation algorithm based on hierarchical constraint the middle frame interpolation, therefore, this method has the characteristics of low overlap rate of image regions and short interpolation time, which can lay a solid foundation for research in related fields. The next step is to verify the application effect of this method.

4 Experiment

4.1 Experimental scheme design

In order to verify the effectiveness of the intermediate interpolation method of VR glasses display animation based on hierarchical constraints, experimental tests are carried out. The overall experimental scheme is as follows:

1) *Experimental data*: Several VR glasses animation scene animation designs are selected as experimental sample data, and the collected samples are denoised and enhanced to improve the accuracy of the simulation experiment. Owing the length of the sample data will cause certain influence to the experiment, so before experiment, experiment data have to be normalised processing, ensure the length of the sample data is less than to the maximum length of data simulation software can run, and choose the optimal experimental parameters by using the method of testing in advance as the initial parameters, ensure the smooth progress of the experiment.

2) *Evaluation index*: Take Wallis (2019) method, Feng (2019) method and Tang et al. (2019) method as experimental comparison methods and verify the application effect of different methods by comparing different indexes.

Firstly, the intermediate interpolation effect of VR glasses display animation in this method is verified, and then the image area overlap rate in VR glasses of the four methods is compared. The image area overlap rate refers to the intersection ratio of two images often encountered in image processing. The lower the overlap rate, the better the intermediate interpolation effect. Finally, the interpolation time of display animation in-between is compared. The interpolation time of display animation in-between refers to the time taken to complete the interpolation of VR glasses display animation in-between. The shorter the interpolation time, the higher is the efficiency.

4.2 Interpolation effect test

In order to analyse the design effect of this method, the process of linear interpolation and intermediate interpolation in this paper can be compared and analysed. VR glasses animation scene design for sign language 'lament', related to the process of movement known as the in-between, regardless of is called virtual in-between, among each frame to add the same amount of logo position, then VR glasses animation scene in the in-between, to obtain the linear interpolation method and the intermediate interpolation method of step effect, as shown in Figure 4.

Figure 4 Comparison of interpolation effect of sign language 'Lament'. (a) Linear interpolation (b) Paper method

(a)

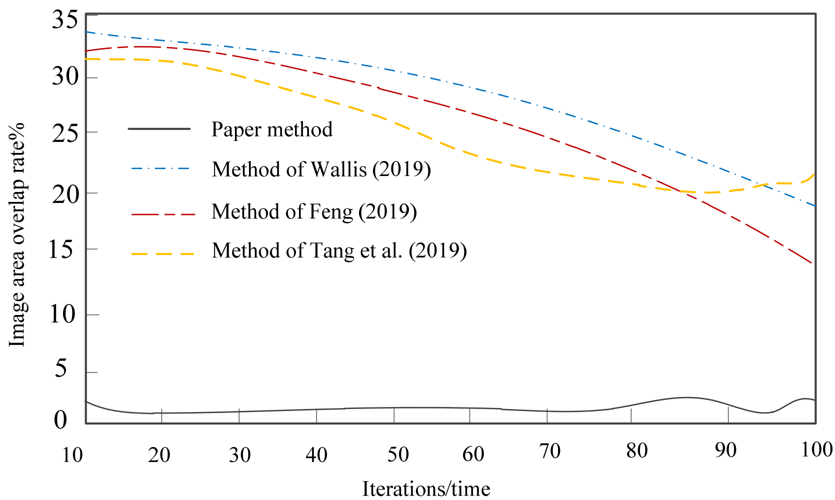
(b)

According to the analysis of Figure 4, compared with the two groups of sign language 'Lament' animation change processes, the limbs of the linear interpolation method are obviously stiff, and the gestures almost pass in a straight line. However, the sign language 'Lament' animation change process of this method has obvious ups and downs, which is more like the human action of the actual scene, which shows that the interpolation effect of this method is obviously better.

4.3 Image area overlap rate monitoring

In order to verify the interpolation effect of this method on the in-between in VR glasses display animation, this paper uses the Wallis (2019) method, Feng (2019) method, Tang et al. (2019) method and this method to detect the image area overlap rate and the results are shown in Figure 5.

Figure 5 Analysis of image region overlap rate under different methods

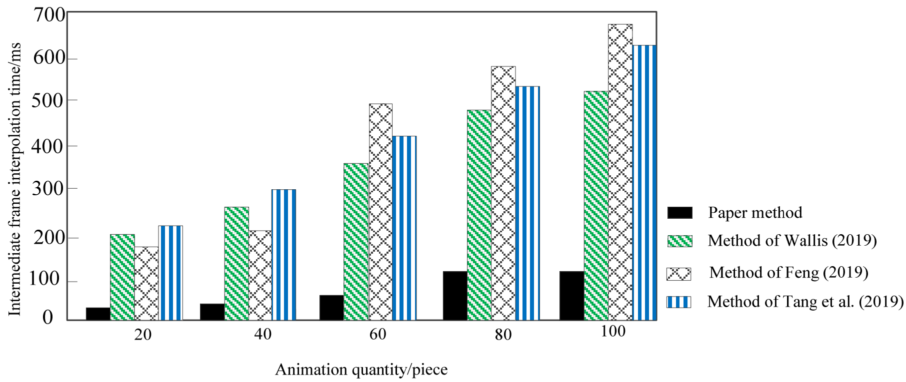


For display animation, the interpolation effect of in-between can be reflected by the overlap rate of image area. When the intermediate interpolation effect is better, the image area overlap rate will be lower. According to Figure 5, the image region overlap rate is different under different methods. When the number of iterations is 10, the image region overlap rate of VR glasses in Wallis (2019) method is 34%, the image region overlap rate of VR glasses in Feng (2019) method is 32.5%, the image region overlap rate of VR glasses in Tang et al. (2019) method is 31.8% and the image region overlap rate of VR glasses in the method of this paper is 2.5%. When the number of iterations is 80, the image region overlap rate of VR glasses in Wallis (2019) method is 25.2%, the image region overlap rate of VR glasses in Feng (2019) method is 23%, the image region overlap rate of VR glasses Tang et al. (2019) method is 22% and the image region overlap rate of VR glasses in the method of this paper is 1.9%. The image region overlap rate of VR glasses in this method is significantly lower than that of the other three traditional methods, because this paper constructs the DBBs model of in-between and interpolates the in-between in animation by using hierarchical constraints, which effectively reduces the image region overlap rate.

4.4 Show animation intermediate interpolation time

In order to verify the interpolation efficiency of this method on the in-between of display animation, Wallis (2019) method, Feng (2019) method, Tang et al. (2019) method and this method are used to detect the interpolation time of in-between of display animation and the detection results are shown in Figure 6.

Figure 6 Shows the interpolation time of animation in-between



By analysing Figure 6, it can be seen that the interpolation time of in-between displaying animation in VR glasses increases with the number of animation. When the number of animations is 20, the intermediate interpolation time of the display animation of Wallis (2019) method is 206 ms, the intermediate interpolation time of the display animation of Feng (2019) method is 188 ms, the intermediate interpolation time of the display animation of Tang et al. (2019) method is 229 ms and the intermediate interpolation time of the display animation of the method of this paper is 32 ms. When the number of animations is 60, the intermediate interpolation time of the display animation in Wallis (2019) method is 392 ms, the intermediate interpolation time of the display animation in Feng (2019) method is 500 ms, the intermediate interpolation time of the display animation in Tang et al. (2019) method is 439 ms and the intermediate interpolation time of the display animation in the method of this paper is 72 ms. When the number of animations is 100, the intermediate interpolation time of the display animation in Wallis (2019) method is 551 ms, the intermediate interpolation time of the display animation of Feng (2019) method is 682 ms, the intermediate interpolation time of the display animation of Tang et al. (2019) method is 635 ms and the intermediate interpolation time of the display animation of the method of this paper is 112 ms. The intermediate interpolation time of the method of this paper is far less than that of other methods, indicating that the intermediate interpolation efficiency of the method of this paper is high, this is because this method uses the hierarchical constraint method to extract the visual feature points of animation images, which obviously speeds up the intermediate interpolation.

5 Conclusions

1) In-between generation technology is a very important link in the field of computer animation. The quality of gradient graphics directly affects the implementation effect of the whole animation. Therefore, based on the in-depth analysis of visual feature points, this paper proposes an intermediate interpolation method of VR glasses display animation based on hierarchical constraints.

2) The experimental results show that when the number of iterations is 80, the image region overlap rate in VR glasses is 1.9%. This method uses hierarchical constraints to interpolate the in-between in animation, which effectively reduces the image region overlap rate. When the number of animations is 100, the intermediate interpolation time of the display animation in this method is 112 ms, which shows that the intermediate interpolation efficiency of this method is high. Therefore, this method has many characteristics, such as low image area overlap rate and short interpolation time.

3) The method proposed in this paper improves the abnormal phenomena such as selling and shrinkage of VR glasses display animation. The experimental effect is good and has a wide application prospect, but further research is still needed in the following aspects. For example, the premise of the interpolation algorithm given in this paper is to construct vector edges for the beginning and end in-between contours, which affects the monotonic change of the edge length of the in-between to a certain extent. Although the generated in-between graphics are more accurate and vivid, whether a more accurate processing method can be found still needs further research.

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