



Design of Human-Computer Interactive Fire Extinguishing Training System Based on Virtual Reality Technology

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Abstract. In order to improve the ability of human-computer interactive fire extinguishing training, a visual simulation model of man-machine interactive fire extinguishing training based on virtual reality technology is proposed. Taking the large-scale emergency scene fire drill as the research object, the virtual scene image reconstruction model of human-computer interaction fire fighting training is constructed, the boundary feature detection and particle tracking filter processing are carried out for the scene image of human-computer interaction fire fighting training, the dynamic structure of the scene image of human-computer interaction fire fighting training is reorganized with fuzzy edge feature extraction method, and the virtual reality simulation model of human-computer interactive fire fighting training scene image is established. The multi-person cooperative control method is used to simulate the virtual reality in the process of human-computer interactive fire fighting training, and the 3D simulation image of virtual scene fire drill in large-scale emergency scene is followed and rendered, and the optimization design of virtual reality VR simulation model of human-computer interactive fire fighting training is realized. The test results show that the virtual scene simulation of human-computer interaction fire fighting training using this method has good cooperation, high image fusion performance and strong reconstruction ability of fire fighting training scene simulation.

Keywords: Virtual reality technology · Human-computer interaction · Fire fighting · Training system

1 Introduction

With the development of the virtual reality technology, the virtual scene reconstruction is carried out in combination with the image processing technology, the virtual simulation method is adopted, the model of the environment system is built, and the cost of the drill is reduced while the cost of the drill is reduced, and the efficiency of the training exercise is improved. The three-dimensional solid model design is carried out by adopting the image information processing technology [1], a human-computer interaction fire-fighting training system is established in a virtual scene simulation environment, a three-dimensional visual analysis method is adopted, the human-computer interaction fire-fighting training optimization design is carried out, The model of

human-computer interaction fire-fighting training system based on virtual reality is studied, and it is of great significance in the optimization of emergency drill training [2].

A virtual scene three-dimensional simulation model of a large-scale emergency scene fire drill training is constructed, a three-dimensional visual reconstruction technology is adopted, and the optimization structure of a large-scale emergency scene fire drill training system is carried out [3]. The invention adopts the digital information processing technology to carry out a large-scale emergency scene fire drill training virtual scene three-dimensional simulation design, and combines the VR framework of the virtual reality to carry out a large-scale emergency scene fire drill training virtual scene three-dimensional simulation design, Three DStudio MAX and Multigen Creator are adopted for the design of the virtual scene model of the emergency drill of the main transformer of the fire main transformer [4]. The virtual scene reconstruction of the emergency drill of the main transformer of the fire is carried out by using the texture mapping technology, and the better visual reconstruction efficiency is achieved. But the above-mentioned method is not good in human-computer interaction and fire-fighting training, and the human-computer interaction capability is not strong [5]. In view of the above problems, this paper presents a visual simulation model of human-computer interaction fire-fighting training based on virtual reality technology. taking a large-scale emergency scene fire drill as a research object, building a virtual scene image reconstruction model for human-computer interaction fire-fighting training, and performing boundary feature detection and particle tracking filtering processing on a visual image of the human-computer interaction fire-extinguishing training, The multi-person cooperative control method is adopted to carry out the virtual reality simulation in the human-computer interaction fire-fighting training process, and the tracking and rendering of a large-scale emergency scene fire drill virtual scene three-dimensional simulation image is carried out, and the optimization design of the virtual reality VR simulation model for human-computer interaction fire-fighting training is realized. Finally, the simulation experiment is carried out to show the superiority of the method in improving the virtual reality simulation and visual simulation ability of man-machine interactive fire-fighting training [6].

2 Virtual Scene Model and Feature Extraction of Man-Machine Interactive Fire-Fighting Training

2.1 Virtual Scene Model of Man-Machine Interactive Fire-Fighting Training

The three-dimensional simulation software such as MAYA, 3DStudio MAX, SoftImage and LightWave 3D is used to design the solid model of the virtual reality emergency training model. the three-dimensional visual simulation and the characteristic reconstruction of the human-computer interaction fire-extinguishing training are carried out, the AMCC is the main control chip, the overall design framework of the human-computer interaction fire-fighting training system is carried out [7], the SPI interface is constructed, and the peripheral equipment of the virtual reality simulation model for human-computer interaction and fire-fighting training is constructed. In SD

mode, the bus control is carried out to obtain the modular design of the virtual reality simulation model, and the general structure of the virtual reality system with human-computer interaction and fire-fighting training is shown in Fig. 1.

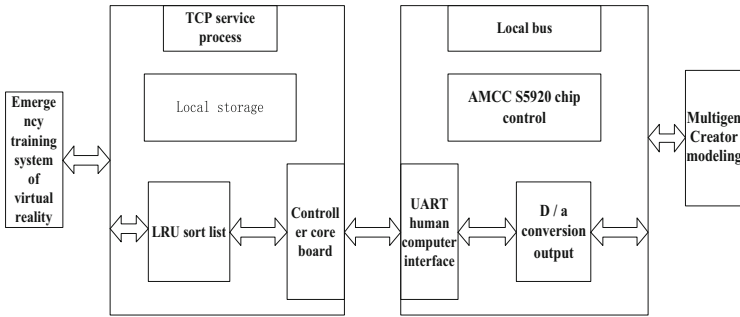


Fig. 1. Overall structure of virtual reality system for human-computer interactive fire fighting training

The Haar-like rectangular feature template matching method is used to segment the virtual visual image block of human-computer interactive fire extinguishing training. Combined with the dynamic weight registration method, the scene image reconstruction of human-computer interactive fire extinguishing training is carried out, the detection ability of scene reconstruction of human-computer interactive fire extinguishing training is improved, the overall framework of human-computer interactive fire extinguishing training system is carried out in square subregions, and the static visual model is established [8]. The distributed reconstruction model of human-computer interaction fire extinguishing training is obtained. In the Jakobi matrix $J(x, y, \sigma)$, the imaging area model of human-computer interaction fire extinguishing training can be expressed as follows:

$$J(x, y, \sigma) = \begin{pmatrix} \frac{\partial P}{\partial x} \\ \frac{\partial P}{\partial y} \end{pmatrix} = \begin{pmatrix} 1 & 0 & L_x(x, y, \sigma) \\ 0 & 1 & L_y(x, y, \sigma) \end{pmatrix} \quad (1)$$

Wherein, $L(x, y, \sigma) = G(x, y, \sigma) * I(x, y)$, $G(x, y, \sigma)$ is the seed point of the visual image of the human-computer fire extinguishing training, and $I(x, y)$ is the gray scale feature of the fusion of the visual image area of the human-computer fire extinguishing training, \vec{N} represents matrix vector, ∂ is the adjustment coefficient. According to the gray scale histogram model [9], the visual reconstruction of the human-computer interactive fire extinguishing training is carried out, and the square template matching matrix is expressed as follows:

$$\begin{aligned}
 M &= \begin{pmatrix} \frac{\partial^2 P}{\partial x^2} \vec{N} & \frac{\partial^2 P}{\partial x \partial y} \vec{N} \\ \frac{\partial^2 P}{\partial x \partial y} \vec{N} & \frac{\partial^2 P}{\partial y^2} \vec{N} \end{pmatrix} = \begin{pmatrix} (0, 0, L_{xx}(x, y, \sigma)) \cdot \vec{N} & (0, 0, L_{xy}(x, y, \sigma)) \cdot \vec{N} \\ (0, 0, L_{xy}(x, y, \sigma)) \cdot \vec{N} & (0, 0, L_{yy}(x, y, \sigma)) \cdot \vec{N} \end{pmatrix} \\
 &= \begin{pmatrix} L_{xx}(x, y, \sigma) & L_{xy}(x, y, \sigma) \\ L_{xy}(x, y, \sigma) & L_{yy}(x, y, \sigma) \end{pmatrix}
 \end{aligned} \quad (2)$$

A visual reconstruction model of human-computer interaction fire-fighting training is constructed by a continuous 3D reconstruction method, and a boundary characteristic detection method is adopted to carry out the feature extraction of the visual image of the human-computer interaction fire-extinguishing training, and the virtual scene model design of the human-computer interaction fire-extinguishing training is realized.

2.2 Visual Image Feature Extraction of Human-Computer Interactive Fire Fighting Training

On the basis of constructing the virtual visual image reconstruction model of human-computer interactive fire extinguishing training, the fuzzy feature extraction of the visual image of human-computer interactive fire extinguishing training is carried out, such as the boundary feature quantity of each visual image is fuzzy mining, and the matching feature quantity of the constructed template is as follows:

$$d_j^a(s, t) = \text{sqr}t \left[\sum_{i=1}^n (s_j^a[i] - t[i])^2 \right] \quad (3)$$

Where j is the current Haaris feature set, $a[i]$ is the covariance value of the virtual view image pixel sequence of the current man-machine interaction fire-fighting training, and $d_j^a(s, t)$ represents the distance between the j -th characteristic values of the first pixel sample. calculating the boundary feature quantity of the virtual visual image of the human-computer interaction fire-extinguishing training to obtain an average value $d_j^a(s, t)$ of the edge contour feature distribution, and taking the $\mu(j)$ as a characteristic distribution threshold value of the virtual reality imaging, and the following:

$$\mu(j) = \frac{1}{k} \sum_{a=1}^k d_j^a(s, t) \quad (4)$$

Wherein, k is the total number of samples for scene reconstruction of human-computer interactive fire fighting training [10]. The fuzzy feature reconstruction of the visual imaging edge feature j of human-computer interactive fire extinguishing training is carried out. The fuzzy boundary coefficient $C(x, y)$ and x, y represent the i and j matrices respectively in the virtual space. The number of pixel points in the virtual

parameter panel and the main interface is n , where $\mu(i)$ represents the first matrix sample weight:

$$\mu(i) = \frac{1}{n} \sum_{k=1}^n p_k(i) \quad (5)$$

The virtual image acquisition of human-computer interactive fire extinguishing training is carried out by using optical sensor, and a two-dimensional random variable is outputted to find out the dynamic weight coefficient of the visual image of human-computer interactive fire extinguishing training:

$$C(i,j) = \frac{1}{n-1} \sum_{k=1}^n ((p_k(i) - \mu(i))(p_k(j) - \mu(j))) \quad (6)$$

In that whole virtual reality visual distribution system, the visual reconstruction of man-machine interaction fire-extinguishing training is carried out, and the covariance of the sub-region and the human-machine interaction can be represented by an $d \times d$ -dimension matrix to obtain an 8×8 grid with the $[(d^4 + d^2)/2] - d^2$ useful characteristics of a human-computer interaction fire-extinguishing training vista, The best matching block area of the three-dimensional simulation design image of the fire main transformer emergency drill training virtual scene is as follows:

$$\{\tau_k(t_i) : |\tau_k| \geq 4, i = 2, \dots, |\tau_k| - 2, k = 1, \dots, K\} \quad (7)$$

The gray-scale pixel decomposition method is adopted to obtain the grid block function of the three-dimensional simulation design of the fire main transformer emergency drill training virtual scene:

$$F(B, X) = B * X = ax^2 + bxy + cy^2 + dx + ey + f \quad (8)$$

Wherein, $B = [a, b, c, d, e, f]^T$, $X = [x^2, xy, y^2, x, y, 1]^T$, $F(B, X_i)$. The virtual scene reconstruction of the emergency drill of the main transformer is carried out under the framework of the virtual reality [11].

3 Optimization of Visual Simulation Model for Human - Machine Interactive Fire Extinguishing Training

3.1 Dynamic Structure Recombination of Visual Image of Man-Machine Interactive Fire-Fighting Training

The virtual scene image reconstruction model of human-machine interactive fire-extinguishing training is constructed [12], the boundary feature detection and particle tracking filter processing of the visual image of human-machine interactive fire-extinguishing training are carried out. Given the fire main transformer emergency drill

training virtual scene 3D simulation design image pixel sequence sample $(x_1, y_1), (x_2, y_2), \dots (x_N, y_N)$, $y_i = 1$ or 0 respectively represent the fire main transformer emergency drill training virtual scene model design edge pixel set, take the edge pixel point as the information localization center, extract the fire main transformer emergency drill training virtual scene 3D simulation $h_t(x)$, carry on the feature matching in the block to get the emergency training feature extraction: virtual description:

$$h(x) = \begin{cases} 1 & TH = \sum_{t=1}^T a_t h_t(x) - \frac{1}{2} \sum_{t=1}^T a_t \geq 0 \\ 0 & \text{others} \end{cases} \quad (9)$$

Wherein, $a_t = \log \frac{1}{\beta_t}$, which represents the state information of the emergency drill training of the fire main transformer, adopts a template matching method in the color space of the distributed man-machine interaction fire-extinguishing training, and the matching function of the virtual scene template of the emergency drill training of the fire main transformer is as follows:

$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \frac{\delta * \sin \alpha}{\sin(\alpha + \theta)} & \frac{n}{2 \cos \alpha} - \frac{\delta * nose * \sin \alpha}{\sin(\alpha + \theta)} \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} \quad (10)$$

In the formula, θ is the pixel point of pixel region segmentation, y represents the color difference drift of virtual reality, $nose$ represents the transparency of virtual scene design in fire main transformer emergency drill training, and δ is the rendering intensity of visual surface [13].

The self-correlation matching feature of the distributed man-machine interactive fire-fighting training is obtained by combining the self-adaptive feature matching method:

$$R(x, y) = ax^2 + by^2 + cxy + dx + ey + f \quad (11)$$

Wherein

$$\begin{cases} \frac{\partial R}{\partial x} = 2ax + cy = 0 \\ \frac{\partial R}{\partial y} = 2by + cx + e = 0 \end{cases} \quad (12)$$

By using sparse linear feature decomposition method and RGB color reconstruction [14], c represents the number of color components, R represented by three primary colors, the homomorphic feature transformation of human-computer interactive fire fighting training is as follows:

$$l(X, Y) = (2u_x u_y) / (u_x^2 + u_y^2) \quad (13)$$

Using the color contrast method, the scene reconstruction of man-machine interactive fire extinguishing training is carried out. The virtual scene seed point matching expression of man-machine interactive fire extinguishing training is as follows:

$$H = \sum_{r=1}^t \sum_{p=1}^{k_1} (x_{ir} - x'_{irp})(x_{ir} - x'_{irp})^T \quad (14)$$

Based on the edge pixel point matching formula, the region segmentation model of distributed human-computer interaction fire fighting training scene image is obtained as follows:

$$\begin{aligned} G &= tr(W_i^T [\sum_{r=1}^t \sum_{q=1}^{k_2} (x_{ir} - x_{irq})(x_{ir} - x_{irq})^T] W_i) \\ &= tr(W_i^T H_2 W_i) \end{aligned} \quad (15)$$

Wherein

$$H_2 = \sum_{r=1}^t \sum_{q=1}^{k_2} (x_{ir} - x_{irq})(x_{ir} - x_{irq})^T \quad (16)$$

In the different three-dimensional visual reconstruction model, the dynamic structural reorganization of the visual image of human-computer interaction fire-fighting training is carried out [15].

3.2 Virtual Reality VR Simulation Design of Man-Machine Interactive Fire-Fighting Training

In combination with a fuzzy edge feature extraction method, a dynamic structure recombination of a human-machine interaction fire-extinguishing training visual image is carried out, a virtual reality simulation model of a man-machine interaction fire-extinguishing training visual image is established, and a process for designing a virtual reality simulation model algorithm for man-machine interaction fire-extinguishing training is established [16]:

1) Input the training sample $S_1 = \{(x_1, y_1) \cdots (x_n, y_n)\}$ of the virtual scene image pixel sequence of human-computer interaction fire fighting training, in which the edge pixel feature matching points on the grid model corresponding to $y_i = \{0, 1\}$ are obtained. Under the known principal transformer emergency training, the statistical eigenvalues of the virtual samples of human-computer interaction fire fighting training are obtained. At m feature matching points, Qm pixel regions are divided into feature points, and a total of n training samples are obtained.

2) Initialization sample weight: the dynamic weight segmentation method is used to carry out multi-person cooperative control, and the initialization weight is $\omega_{t,1} = 1/2m$; for the vector initialization characteristic value of $\omega_{t,0} = 1/2q$, fire main transformer emergency drill training.

3) The virtual scene image samples of man-machine interactive fire-extinguishing training are cut into 8×8 grids, and the multi-person cooperative control method is used to take two different sub-areas for state feature matching. if 8×8 , the $S_{t+1} = S_t$, human-machine interactive fire-extinguishing training process is stopped; when the water and electricity fee is full, the iterative process of man-machine interactive fire-extinguishing training jumps to step (2).

4) The matching point weight of multiplayer collaborative virtual reality: $\omega_{t+1} = \omega_{t,i} \beta_t^{1-e_i}$, according to the emergency mode of human-computer interactive fire fighting training system. Initialize $e_i = 0$, get $e_i = 1$, $\beta_t = \varepsilon_t / (1 - \varepsilon_t)$;

5) According to the maximum distance p between the virtual scene image point cloud of the human-computer interaction fire-fighting training, cutting off the edge contour imaging error, and performing virtual reconstruction by adopting a plurality of cooperative methods;

6) Set $t = t + 1$, if t is not greater than the threshold, return to step 3.

7) the virtual reality simulation model of the human-computer interaction fire-extinguishing training visual image is established, and the output optimization control of the virtual visual image of the human-computer interaction fire-extinguishing training is realized, and the imaging output is obtained as follows:

$$h(x) = \begin{cases} 1, & \sum_{t=1}^T \alpha_t h(x) \geq \frac{1}{2} \sum_{t=1}^T \alpha_t \\ 0, & \text{otherwise} \end{cases} \quad (17)$$

Wherein $\alpha_t = \ln \frac{1-\varepsilon_t}{\varepsilon_t}$.

8) for $t = 1, \dots, T$. he main transformer emergency target function $\varepsilon_j = \sum_{j=1}^n \omega_{t,j} |h_j(x_i) - y_i|$ with multi-people cooperative virtual reality is the smallest, and the G of each feature is sorted according to the size. And the control frame is continuously sent, so as to realize the optimization of the multi-people collaborative virtual reality emergency training and output the final result.

The implementation process is shown in Fig. 2.

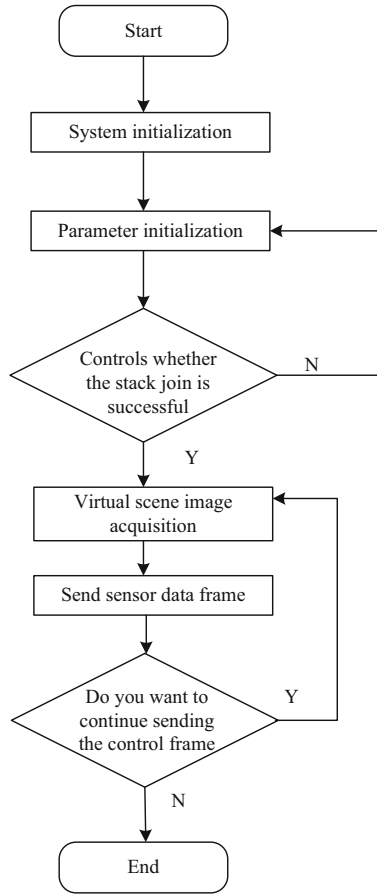


Fig. 2. Model development design process

4 Simulation Experiment and Result Analysis

In order to test the application performance of this method in the visual simulation of human-computer interaction fire fighting training, the experimental test and analysis are carried out. The development environment CPU is Inter Pentium 43000 MHz, memory 1.5 GB, the sample set of visual image of man-machine interaction fire extinguishing training image is 800, the size of 3D visual block area is $256 \times 256 \times 224$, fuzzy feature matching coefficient 1.26, the feature resolution of virtual scene image imaging of human-computer interaction fire extinguishing training is $300 * 500$, and the parameter writing interface is shown in Fig. 3.

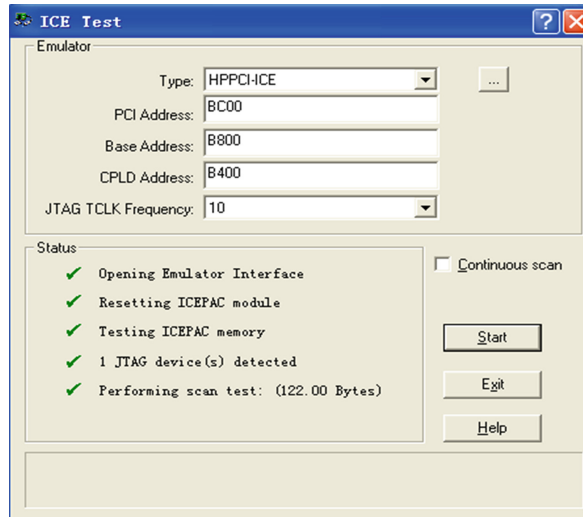


Fig. 3. Parameter write interface

The multi-person cooperative control method is used to simulate the virtual reality in the process of human-computer interactive fire fighting training, and the 3D simulation image of virtual fire drill in large-scale emergency scene is followed and rendered. The visual simulation output of human-computer interactive fire fighting training is shown in Fig. 4.



Fig. 4. Visual simulation output of man-machine interactive fire-fighting training

The analysis of Fig. 4 shows that the performance of visual simulation is good, and the image fusion performance is high. The output resolution of different systems is tested, and the results are shown in Table 1.

Table 1. Comparison of the resolution of the virtual scene of man-machine interactive fire-fighting training

Frame	Texture contrast detection method	Proposed method
100	567	935
120	435	1356
140	689	1456
160	545	2100
180	578	2241
200	547	2313

The analysis Table 1 shows that the resolution of the visual simulation of man-machine interactive fire-fighting training is better, and the parameters such as the mean square error and the output signal-to-noise ratio of the human-computer interaction fire-fighting training are tested by the method, and the results of the comparison are shown in Table 2.

Table 2. Performance Comparison Test

Method	MSE	Time overhead/ms	Output SNR/dB
Proposed method	0.032	26.4	43
Traditional manual design method	0.412	105.6	21

The results of the analysis in Table 2 show that the virtual visual simulation of human-computer interaction and fire-fighting training has good coordination, high image fusion performance, strong visual simulation and reconstruction capability of fire-fighting training, and good output performance.

5 Conclusions

In this paper, the image information processing technology is used to design the 3D solid model, and the human-computer interactive fire extinguishing training system is established in the virtual visual simulation environment. In this paper, a visual simulation model of human-computer interactive fire extinguishing training based on virtual reality technology is proposed. The virtual reality simulation model of human-computer interaction fire extinguishing training scene image is established by using continuous 3D reconstruction method. The virtual reality simulation in the process of human-computer interaction fire fighting training is carried out by using multi-person

cooperative control method, and the tracking and rendering of virtual scene three-dimensional simulation image of large-scale emergency scene fire drill is carried out, and the optimization design of virtual reality VR simulation model of human-computer interaction fire fighting training is realized. It is found that the cooperation of virtual scene simulation with human-computer interaction fire fighting training is better, and the tracking and rendering ability of 3D simulation image is strong, and it has a good ability to reconstruct fire fighting training scene simulation. This method has good application value in visual simulation of machine cross fire fighting training.

6 Fund Projects

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