Study on the design of interactive distance multimedia teaching system based on VR technology

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Abstract: In order to improve the intelligence and human-computer interaction ability of interactive remote multimedia teaching, an interactive remote multimedia teaching system based on VR technology is proposed. Using fuzzy control parameters and fast image region segmentation technology, the virtual reality information of remote multimedia teaching system is reconstructed. The information fusion and regional scheduling are realised by using the deformation model. Under the B/S architecture, the background server and interface of the interactive remote multimedia teaching system are designed. The embedded ARM9TDMI is used as the core microprocessor to process the interactive remote multimedia teaching data and realise the software design of the teaching system. The simulation results show that the interactive remote multimedia teaching system designed by this method has more than 99% stability and strong human-computer interaction response ability, which improves the control ability of remote multimedia teaching.

Keywords: VR technology; interactive; distance multimedia teaching; system design.

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1 Introduction

With the development of teaching science and technology in colleges and universities, the application of interactive distance multimedia teaching in teaching courses has become the main direction of future development. Interactive distance multimedia teaching system is designed based on teaching and course reforms to improve teaching intelligence and digitisation. The optimisation design method of interactive distance multimedia teaching system is studied. The artificial intelligence control and three-dimensional scene simulation technologies are employed to optimise the design of interactive distance multimedia teaching system to improve the intelligence of interactive distance multimedia teaching (Khil et al., 2016). The 3D scene simulation and virtual reality (VR) technologies are adopted to reconstruct a 3D model of the interactive distance multimedia teaching system, and a scene simulation model of the system is constructed. The image processing method is used for VR design of the system. Relevant design methods of interactive distance multimedia teaching system have attracted great attention.

The research on interactive distance multimedia teaching system is based on the 3D scene reconstruction of interactive distance multimedia teaching. Both VR and multimedia reconstruction methods are adopted to perform VR simulation design of the system. Traditional interactive distance multimedia teaching system design methods mainly include the interactive distance multimedia teaching system design method based on Linux, ARM design method, and surface rendering method (Wu et al., 2018; Gao et al., 2015). Guo et al. (2017) proposed an interactive distance multimedia teaching system design method based on Unity3D and VR technologies. In this method, both 3D information reconstruction and VR simulation technologies are used for virtual scene simulation of interactive distance multimedia teaching. The interactive distance multimedia teaching system designed using this method is not stable. Arbabi et al. (2015) proposed a design method of interactive distance multimedia teaching system based on multigen creator modelling, which used the separation face cutting method to design the system. The interactive distance multimedia teaching system designed using this method has good integration, but poor fuzzy resolution. Arbabi et al. (2016) proposed an interactive distance multimedia teaching system design method based on data structure reconstruction, which applied the Revit software to develop and design the internet of things of interactive remote multimedia teaching system to realise system design at the composite RTCP packet link layer. The structure of the system designed using this method is complex, and the real-time performance of it is poor.

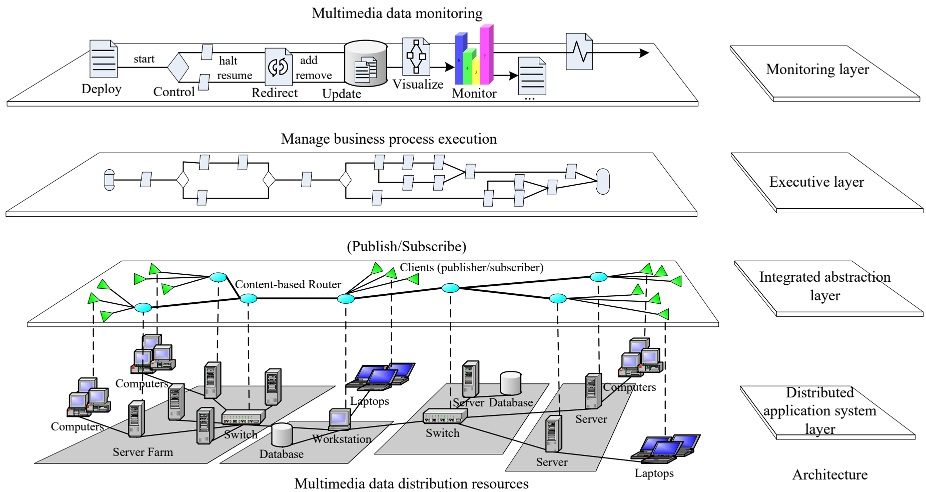
At present, in the design process of interactive multimedia teaching system, only the information fusion of VR scene image is taken as the key point, but the scheduling of these information is not considered, resulting in the poor system stability and human-computer interaction response ability. In order to solve this problem, this paper focuses on the scheduling of VR scene image information, and realises the interactive distance by using the deformation model Based on the information fusion and regional scheduling of VR scene images, an interactive remote multimedia teaching system based on VR technology is designed. Therefore, the system has the advantages of output stability and good system response ability, which improves the intelligence and human-computer interaction ability of interactive distance multimedia teaching, promotes the further development of modern education mode and realises the diversification of education means. The overall design scheme is as follows:

1. Under the B/S framework, the overall structure of interactive distance multimedia teaching system is designed.
2. Using fuzzy control parameters and fast image region segmentation technology, the VR information of remote multimedia teaching system is reconstructed.
3. The information fusion and region scheduling of VR scene image in interactive distance multimedia teaching are realised by using deformation model. The VR scene in distance multimedia teaching is simulated and reconstructed.
4. Under the B/S architecture, the background server and interface of the interactive remote multimedia teaching system are designed. The embedded ARM9TDMI is used as the core microprocessor to process the interactive remote multimedia teaching data and realise the software design of the teaching system.
5. The output stability, response capability and energy consumption of different systems are compared by experiments.
6. Draw a conclusion and look forward to the future.

2 Overall system design framework

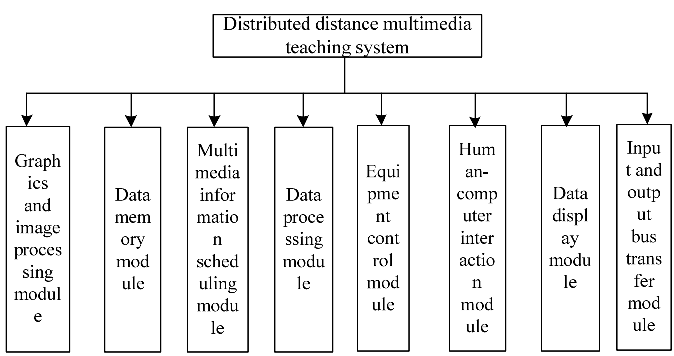
In order to optimise the design of the interactive distance multimedia teaching system, firstly, the overall design framework of the system is analysed. The main functional module of the system is to perform control design and database modelling for distance multimedia teaching. The bus transmission module of the distance multimedia teaching system is constructed, and software development is carried out for the system under the B/S framework system. Program loading control is realised through cross compilation. The architecture of the interactive distance multimedia teaching system is designed under the three-layer architecture (Arbabi et al., 2016; Oskooi et al., 2010; Ju and Zou, 2015). The interactive distance multimedia teaching system is constructed with the three-layer architecture including basic hardware layer, business layer and remote multimedia for the overall development and function structure design of the system. The overall framework of the system includes a 3D geometric modelling module, an information processing module, an automatic control module, a 3D scene rendering module, a human-computer interaction module, etc. The three-layer architecture of the interactive remote multimedia teaching system is shown in Figure 1.

Figure 1 Design architecture of interactive distance multimedia teaching system (see online version for colours)



According to the overall design architecture model of the distance interactive distance multimedia teaching system shown in Figure 1, the system is designed optimally using the VR technology, and information fusion processing is carried out to the system by the multimedia information fusion method. A structural body sip_pvt is defined, and Sip is adopted to process stack information of the interactive distance multimedia teaching information management system. Sip information is monitored and treated at the monitoring layer. The ModelBuilder 3D middleware technology is used to configure the application program of interactive remote multimedia teaching, and read and write teaching information, and the VR technology is used to develop the function model of the system. Based on this design concept, the interactive distance multimedia teaching system based on VR technology designed in this paper has the characteristics of good stability and excellent system response ability. The function structure model of the system is obtained as shown in Figure 2.

Figure 2 Analysis of the function structure module of the system



3 Design of scene simulation algorithm for remote multimedia teaching

On the basis of the whole structure of the system, in this part, we design a simulation algorithm of remote multimedia teaching scene. Mainly for VR image pixel matching, image contour processing, noise suppression and other accurate processing, so that the designed system has a more realistic scene and clearer image, improve the interaction experience. The algorithm makes use of fuzzy control parameters to render VR image for remote multimedia teaching, and uses the method of spatial information reconstruction to simulate and analyse VR scene in multi-level remote multimedia teaching system. The information fusion and region scheduling of VR scene image in interactive distance multimedia teaching are realised by using deformation model. Therefore, this algorithm has higher interactive experience satisfaction and better information fusion scheduling effect.

3.1 VR information reconstruction of the distance multimedia teaching system

On the basis of the overall design framework of the interactive distance multimedia teaching system, the system is implemented. VR image rendering is performed for the distance multimedia teaching using the fuzzy control parameter σ, and VR scene simulation analysis is performed on the distance multimedia teaching system using the spatial information reconstruction method in the multi-level distance multimedia teaching system. The pixels of VR images are matched for the system using the image distributed rendering method (Lyu et al., 2016). Then the spatial pixel distribution of VR images of the system is obtained as follows:

$$\begin{aligned} &P\left(y_{w_3} \middle| x_{w_3}, \theta, \beta\right) \propto P\left(y_{w_3} \middle| x_{w_3}, \theta\right)\left(y_{w_3} \middle| \beta_i\right) \\ &\propto \prod_{k=1}^{K} \alpha_k \frac{1}{\sqrt{2\pi\sigma_k^2}} \exp\left\{-\frac{\left(x_i-\mu_k\right)^2}{2\sigma_k^2}\right\} \cdot \frac{1}{Z\left(\beta_i\right)} \exp\left(-\sum_{c\subset C} V_c\left(Y, \beta_i\right)\right) \\ &\propto \prod_{k=1}^{K} \frac{\alpha_k}{Z\left(\beta_i\right)\sqrt{2\pi\sigma_k^2}} \cdot \exp\left\{-\left[\sum_{k=1}^{K} \frac{\left(x_i-\mu_k\right)^2}{2\sigma_k^2} + \sum_{c\subset C} V_c\left(Y, \beta_i\right)\right]\right\} \end{aligned} \tag{1}$$

A VR scene simulation image segmentation model for interactive distance multimedia teaching is established in a local area of a 4 × 4 sub-block. A VR scene simulation template matching set for interactive distance multimedia teaching under a super pixel fusion view is constructed for scene reconstruction. The fuzzy image fusion technology is adopted for VR scene simulation design and fuzzy noise reduction processing in interactive distance multimedia teaching. A spatial region information fusion model for interactive distance multimedia teaching VR scene simulation images is constructed (Chen and Li, 2017), and correlation detection function $f(g_i)$ of VR scene simulation images is as follows:

$$f\left(g_i\right) = c_1 \tilde{\lambda}_i \sum_{j=0}^{N_{np}} \frac{\rho_j \vec{v}_{ij}}{\left|\vec{v}_{ij}\right|^{\sigma_1} + \varepsilon} \Bigg/ \sum_{j=0}^{N_{np}} \frac{\rho_j}{\left|\vec{v}_{ij}\right|^{\sigma_1} + \varepsilon} \tag{2}$$

The three-dimensional dynamic region characteristic value of VR scene images of interactive distance multimedia teaching is obtained, and the edge contour detection method is used to perform information reconstruction in the VR scene simulation region of interactive distance multimedia teaching, and the three-dimensional characteristics of VR information of the teaching system are extracted (Lyu et al., 2016). The characteristics of VR scene images in interactive distance multimedia teaching are decomposed, and the pixel characteristic decomposition model is obtained and described as follows:

$$w(d_{ij}) = f(|x_i - x_j|) = \frac{1}{\sqrt{2\pi}} \exp\left\{\frac{(x_i - x_j)^2}{2}\right\} \quad (3)$$

A VR rendering and information reconstruction model of distance multimedia teaching system is constructed in a 3 × 3 sub-block, and the multidimensional feature quantity of distance multimedia teaching system is obtained as follows:

$$\beta_i = \exp\left\{-\frac{|x_i - x_j|^2}{2\sigma^2}\right\} \frac{1}{dist(x_i, x_j)} \quad (4)$$

The VR scene image model of interactive distance multimedia teaching satisfies:

$$w(i, j) = \frac{1}{Z(i)} \exp\left(-\frac{d(i, j)}{h^2}\right) \quad (5)$$

where $Z(i) = \sum_{j \in \Omega} \exp\left(-\frac{d(i, j)}{h^2}\right)$ is the colour information interference item of VR scene images of interactive distance multimedia teaching. According to the fusion detection results, scenes of the interactive distance multimedia teaching system are reconstructed to improve the VR scene reconstruction ability of interactive distance multimedia teaching (Huang and Liu, 2016).

3.2 VR scene simulation reconstruction of distance multimedia teaching

Based on the result of VR information reconstruction, the information fusion and regional scheduling of VR scene image in interactive distance multimedia teaching are realised by using the deformation model. The edge feature points of the VR scene simulation images are subjected to feature matching and spatial region rendering processing in a 2-dimensional grid region. The fusion result is shown as follows:

$$S = \{s = (x, y) | 1 \le i \le M, 1 \le j \le N\} \quad (6)$$

The size of VR scene simulation image area in interactive distance multimedia teaching is $M \times N$. M and N are the length and width of VR scene image edge corresponding to interactive distance multimedia teaching, respectively. The interactive fusion technology is used to decompose the structure texture of VR scene images in distance multimedia teaching to fit regional information in the gradient direction (Sun et al., 2014). The VR scene information reconstruction model for interactive distance multimedia teaching is obtained as follows:

$$e = \frac{1}{|\nabla u|}\left(\frac{\partial u}{\partial y}i - \frac{\partial u}{\partial x}j\right),\ f = \frac{1}{|\nabla u|}\left(\frac{\partial u}{\partial x}i + \frac{\partial u}{\partial y}j\right) \tag{7}$$

A VR scene model for interactive distance multimedia teaching is reconstructed, and the texture structure of simulation images is matched. The cross compilation method is used for fusion reconstruction of VR scene simulation images in multimedia teaching, and the neighbourhood mean value evaluation method is employed to segment images. Then with the VR technology, the scene reconstruction result of multimedia teaching is obtained output as follows:

$$v(x) = g^{-1}\left(g(1) - g\left(u(x)\right)\right) \tag{8}$$

where $u(x)$ is the neighbourhood grey pixel value of VR scene simulation image of the distance multimedia teaching system, and $g(\cdot)$ is the grey pixel clustering centre of VR scenes in multimedia teaching, which satisfies g: $[0, 1] \rightarrow [0, 1]$: the brightness features of the VR scenes of interactive distance multimedia teaching are extracted.

$$P(Y) = \frac{\exp\left\{-\beta \sum_{c \subset C} V_c(Y)\right\}}{\sum_Y \exp\left\{-\beta \sum_{c \subset C} V_c(Y)\right\}} \tag{9}$$

where $\sum_{c \subset C} V_c(Y)$ is the matching template set, and c is the VR scene resolution of multimedia teaching in the neighbourhood group. In the neighbourhood, the VR scene reconstruction output of multimedia teaching is:

$$J = \sum_{k=1}^{n}\sum_{i=1}^{c} u_{ik}^{*m} d\left(x_k, v_i\right) + \beta \sum_{k=1}^{n}\sum_{i=1}^{c} u_{ik}^{*m} d\left(\overline{x_k}, v_i\right) \tag{10}$$

The VR scene reconstruction model of interactive distance multimedia teaching is thus constructed. The pixel in the neighbourhood is $A > 0$, and the VR fusion matrix of interactive distance multimedia teaching is obtained, and described as follows:

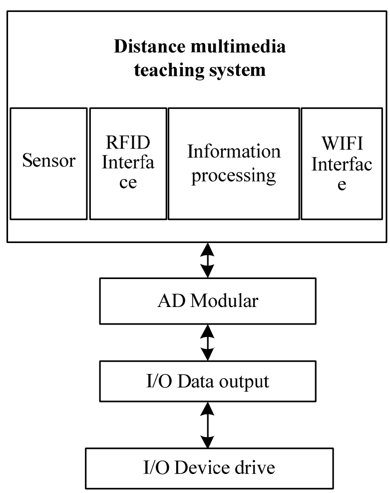
$$H = \begin{bmatrix} L_{xx}(x, \sigma) & L_{xy}(x, \sigma) \\ L_{xy}(x, \sigma) & L_{yy}(x, \sigma) \end{bmatrix} \tag{11}$$

The grey-scale feature solution of VR scene images of interactive distance multimedia teaching is $\hat{x}(P(\hat{A}_n)) = \{\hat{x}(s_j)\},\ j = 1, 2, \ldots, N.$ According to the above analysis, the VR three-dimensional reconstruction model of interactive distance multimedia teaching is constructed. The hierarchical structure of the teaching is designed by the adaptive rendering method, and the information output of distance multimedia teaching is optimally controlled.

4 System software development, design and implementation

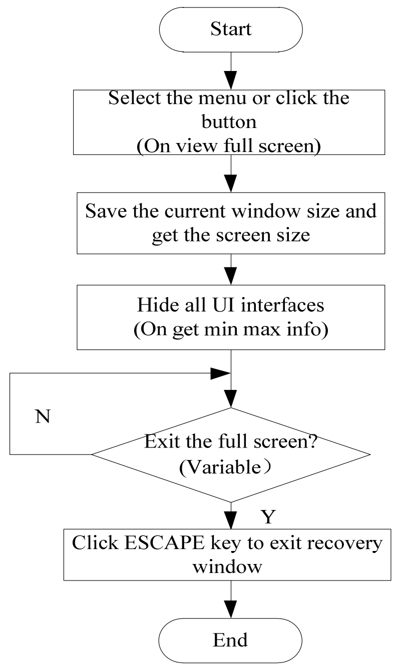
Based on the design of the overall architecture of the system and the simulation algorithm of the remote multimedia teaching scene, the background server setting and interface design of the interactive remote multimedia teaching system are carried out under the B/S architecture, and software of the interactive distance multimedia teaching system is developed in the embedded Linux kernel environment. A GUI communication interface is built for multithread addressing of the interactive distance multimedia teaching system to realise data processing and online scheduling for interactive distance multimedia teaching. In the application layer, a database model for the interactive distance multimedia teaching system is designed by the business data monitoring technology. SRAM and flash memories are adopted for data transmission protocol construction and intelligent control of interactive distance multimedia teaching (Metwally and Faloutsos, 2012; Jiang and Cheng, 2017; Lu et al., 2016). Information processing of the teaching is carried out in a high speed A/D converter. An API interface is designed for human-computer interaction design, and a Wi-Fi interface is designed for network access service design of the intelligent interactive remote multimedia teaching system. According to the above analysis, the component structure of the distance multimedia teaching system is constructed as shown in Figure 3.

Figure 3 Component structure of the distance multimedia teaching system



An embedded ARM9TDMI is used as the core microprocessor to process integrated information of interactive distance multimedia teaching data. The CAN is called to send the subprogram to capture interactive remote multimedia teaching data at a high speed. The Excel and Access technologies are adopted to construct a database module to optimise the design of interactive distance multimedia teaching system. The VXI bus technology is used for scheduling and access control of the resources of the system, and the open system interconnection (OSI) modular development protocol is used for integrated development of the system (Zhao et al., 2016). Based on the above analysis, the software is implemented as shown in Figure 4.

Figure 4 Software implementation of the interactive distance multimedia teaching system



5 Simulation experiment and result analysis

5.1 Experimental purpose

The simulation experiment was carried out to verify the application performance of the method proposed in this paper in the control and human-computer interaction of the interactive distance multimedia teaching system.

5.2 Experimental scheme and parameters

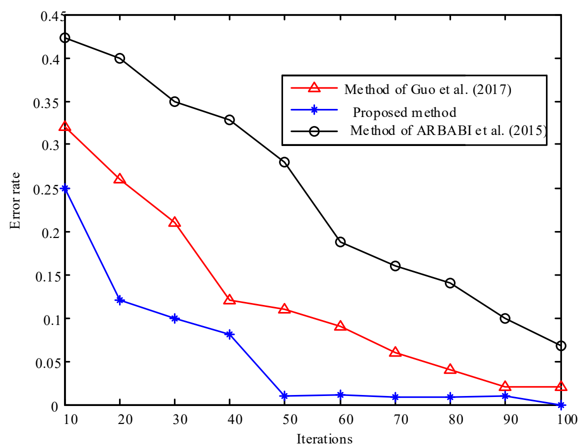
Both Excel and Access technologies were employed to construct a database module to optimise the design of the interactive distance multimedia teaching system. The samples sampled in Jiangsu Province were taken as a data source to carry out a teaching efficiency simulation experiment. The message response function OnViewFullScreen of intelligent interactive distance multimedia teaching was added to the program framework class to respond to keyboard or menu messages, and a response function was also added to capture WM_GETMINMAXINFO message in the framework class, so as to realise mixed programming of MATLA and VC++ for program development. The m file of MATLAB under Matcom was complied to test the response performance of the distance multimedia teaching system. A 2.66 GHz CPU main frequency, 4G memory, and campus network were used for the system. The system proposed in this paper, system in Guo et al. (2017), and system in Arbabi et al. (2015) were compared in terms of indexes including system stability, response speed, and energy consumption during operation to verify the effectiveness of the system. The higher the system stability, the better the comprehensive performance; the faster the response speed is, the higher the response efficiency is, and the interaction time is greatly shortened. The lower the energy consumption, the better the economic benefits.

5.3 *Experimental results*

5.3.1 *Comparison of system convergence performance*

In order to verify the stability of the designed system, the convergence of the system proposed in this paper, the system in Guo et al. (2017), and the system in Arbabi et al. (2015) was compared. The experimental comparison results are shown in Figure 5.

Figure 5 Comparison of convergence curve (see online version for colours)



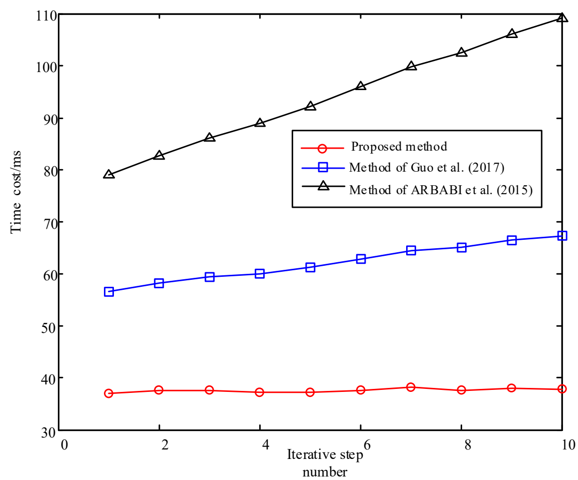
Analysis of Figure 5 shows that when the number of iterations is 30, the error rate of the system proposed in this paper, the system in Guo et al. (2017), and the system in Arbabi et al. (2015) is 0.1, 0.22, and 0.35, respectively, and when the number of iterations is 50, the error rate of the system proposed in this paper, the system in Guo et al. (2017), and the system in Arbabi et al. (2015) is 0.01, 0.12, and 0.29, respectively. The comparison reveals that the error of the system proposed in this paper is less than that of other two systems, indicating that the convergence and output stability of the interactive distance multimedia teaching system using the method proposed in this paper are better.

5.3.2 *System response capacity*

During measurement of the stability of the system proposed in this paper, the response time of the three systems was compared. The comparison results are shown in Figure 6.

Analysis of Figure 6 shows that when the iteration step is 2, the response time of the system proposed in this paper, the system in Guo et al. (2017), and the system in Arbabi et al. (2015) is 39 ms, 59 ms, and 83 ms, respectively, and when the iteration step is 5, the response time of the system proposed in this paper, the system in Guo et al. (2017), and the system in Arbabi et al. (2015) is 38 ms, 61 ms, and 91 ms, respectively, suggesting that the method proposed in this paper shows shorter response time, and faster and stronger response speed in distance multimedia teaching control.

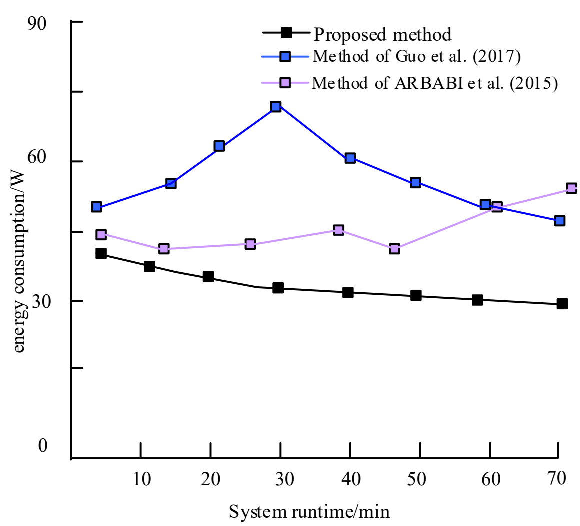
Figure 6 Control output response of distance multimedia teaching (see online version for colours)



5.3.3 Comparison of energy consumption during system operation

In order to further verify the feasibility of the system designed in this paper, the experiment also compared the energy consumption required by the three systems during operation. The comparison results are shown in Figure 7.

Figure 7 Comparison of energy consumption curves (see online version for colours)



Analysis Figure 7 shows that when the system operation time is 20 min, the energy consumed by the system proposed in this paper, the system in Guo et al. (2017), and the system in Arbabi et al. (2015) is 47 W, 59 W, and 49 W, respectively, and when the system operation time is 40 min, the energy consumed by the system proposed in this paper, the system in Guo et al. (2017), and the system in Arbabi et al. (2015) is 34 W, 61 W, and 50 W, respectively. The comparison results reveal that the system proposed in this paper consumes less energy during operation, which proves the feasibility of the system.

6 Conclusions

The optimisation design method of interactive distance multimedia teaching system is studied. The artificial intelligence control and three-dimensional scene simulation technologies are employed to optimise the design of the interactive distance multimedia teaching system to improve the intelligence of interactive distance multimedia teaching. An interactive distance multimedia teaching system based on VR technology is proposed in this paper. The overall framework of the system includes a 3D geometric modelling module, an information processing module, an automatic control module, a 3D scene rendering module, a human-computer interaction module, etc. Scene reconstruction of the interactive distance multimedia teaching system is carried out according to the fusion detection result, and the hierarchical structure design of the interactive distance multimedia teaching is carried out using the adaptive rendering method. The 3DStudio MAX software is adopted to construct the 3D solid model of the interactive distance multimedia teaching system, and intelligent design of the teaching is carried out by the adaptive virtual simulation design method. The test results show that the interactive distance multimedia teaching system designed by the method proposed in this paper has better response ability, and consumes less time, which improves the control ability of distance multimedia teaching. The system designed in this paper can make the original abstract and boring learning content become intuitive through graphics, animation and other forms of expression, effectively stimulate students' interest in learning, enrich their imagination, effectively improve the quality and efficiency of the classroom, more intelligent and convenient, and promote the diversified development of modern education forms.

References

Arbabi, A., Horie, Y., Ball, A.J. et al. (2015) 'Sub wavelength-thick lenses with high numerical apertures and large efficiency based on high-contrast transmit arrays', *Nature Communications*, Vol. 6, No. 5, p.7069.

Arbabi, E., Arbabi, A., Kamali, S.M. et al. (2016) 'Multi wavelength polarization-insensitive lenses based on dielectric meta-surfaces with meta-molecules', *Optica*, Vol. 3, No. 6, pp.628–633.

Chen, Y. and Li, L.J. (2017) 'Very fast decision tree classification algorithm based on red-black tree for data stream with continuous attributes', *Journal of Nanjing University of Posts and Telecommunications (Natural Science Edition)*, Vol. 37, No. 2, pp.86–90.

Gao, Z.W., Cecati, C. and Ding, S.X. (2015) 'A survey of fault diagnosis and fault-tolerant techniques-part I: fault diagnosis with model-based and signal-based approaches', *IEEE Transactions on Industrial Electronics*, Vol. 6, No. 62, pp.3757–3767.

Guo, C., Yang, Z., Ning, L. et al. (2017) 'A novel coordinated control approach for commutation failure mitigation in hybrid parallel-HVDC system with MMC-HVDC and LCC-HVDC', *Electric Power Components and Systems*, Vol. 45, No. 16, pp.1773–1782.

Huang, S.C. and Liu, Y. (2016) 'Classification algorithm for noisy and dynamic data stream', *Journal of Jiangsu University of Science and Technology (Natural Science Edition)*, Vol. 30, No. 3, pp.281–285.

Ju, C.H. and Zou, J.B. (2015) 'An incremental classification algorithm for data stream based on information entropy diversity measure', *Telecommunications Science*, Vol. 31, No. 2, pp.86–96.

Khil, S.K.E., Jlassi, I., Estima, J.O. et al. (2016) 'Current sensor fault detection and isolation method for PMSM drives, using average normalised currents', *Electronics Letters*, Vol. 52, No. 17, pp.1434–1436.

Lu, X.h., Fan, T-l. and Xie, Z-h. (2016) 'Embedded system design of multi mode intelligent control based on ARM', *Computer & Digital Engineering*, Vol. 44, No. 4, pp.667–670, p.674.

Lyu, Y.X., Wang, C.Y., Wang, C. et al. (2016) 'Online classification algorithm for uncertain data stream in big data', *Journal of Northeastern University (Natural Science Edition)*, Vol. 37, No. 9, pp.1245–1249.

Metwally, A. and Faloutsos, C. (2012) 'V-SMART-join: a scalable MapReduce framework for all-pair similarity joins of multisets and vectors', *Proceedings of the VLDB Endowment*, Vol. 5, No. 8, pp.704–715.

Oskooi, A.F., Roundy, D., Ibanescu, M. et al. (2010) 'MEEP: a flexible free-software package for electromagnetic simulations by the FDTD method', *Computer Physics Communications*, Vol. 181, No. 3, pp.687–702.

Sun, B., Wang, J.D., Chen, H.Y. et al. (2014) 'Diversity measures in ensemble learning', *Control and Decision*, Vol. 29, No. 3, pp.385–395.

Wu, C., Guo, C., Xie, Z. et al. (2018) 'A signal-based fault detection and tolerance control method of current sensor for PMSM drive', *IEEE Transactions on Industrial Electronics*, Vol. 31, No. 99, p.1.

Zhao, S-h., Liu, H-y., Liu, Q-s. et al. (2016) 'Design of lighting position data query system based on ArcGIS engine', *Samson*, Vol. 12, No. 1, pp.16–18.