Light & Engineering
Vol. 26, No. 4, pp. 143–149, 2018

CLASSROOM LIGHTING ENERGY SAVING CONTROL SYSTEM BASED ON MACHINE VISION TECHNOLOGY

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ABSTRACT

In order to further improve the energy efficiency of classroom lighting, a classroom lighting energy saving control system based on machine vision technology is proposed. Firstly, according to the characteristics of machine vision design technology, a quantum image storage model algorithm is proposed, and the Back Propagation neural network algorithm is used to analyze the technology, and a multi-feedback model for energy-saving control of classroom lighting is constructed. Finally, the algorithm and lighting model are simulated. The test results show that the design of this paper can achieve the optimization of the classroom lighting control system, different number of signals can comprehensively control the light and dark degree of the classroom lights, reduce the waste of resources of classroom lighting, and achieve the purpose of energy saving and emission reduction. Technology is worth further popularizing in practice.

Keywords: machine vision technology, classroom lighting, energy saving, a control system**,** conventional lighting control (lc)

1. INTRODUCTION

School is a major power user, whose electricity consumption accounts for more than 30 % of the total electricity consumption of the society, while the classroom electricity consumption accounts for a large proportion of the total electricity consumption. To solve the problem of classroom lighting waste, the energy conservation measures adopted by the teaching unit mainly include: strengthening publicity on energy conservation, standardizing rules and regulations on classroom electricity consumption, reducing the number of open classrooms and arranging regular inspections [1]. Although the above measures save lighting energy consumption to a certain extent, it limits the number of available classrooms, which is not conducive to mobilizing students' enthusiasm for learning. Open classrooms usually turn on all lighting equipment, but lighting fixtures are not automatically controlled and intelligent based on the conditions of the room and the intensity of the light, resulting in severe power wastage. With the development of computer and image processing technology, machine vision and video detection technology has been applied in the field of traffic monitoring and fabric inspection [2]. Controlling energy conservation based upon existing video surveillance equipment is a new research direction emerging in recent years. The monitoring equipment automatically turns on or off the air conditioning, lighting, and ventilation equipment according to personnel conditions, light intensity, air temperature, humidity, and other information. Since this technology can improve the utilization rate of monitoring equipment and reduce energy consumption with small input, it was applied to air conditioning energy saving and city road lighting control [3]. Therefore, studies the energy-saving control system of classroom lighting based on machine vision technology was studied in this thesis, which has important practical significance.

2. STATE OF THE ART

Colleges and universities are a densely populated area which integrates teaching, scientific research and life. Therefore, it is inevitable that the power consumption of colleges and universities remains high. At present, most colleges and universities have begun to attach importance to energy conservation and environmental protection, and have taken corresponding actions and measures [4]. Many researchers have also turned to the research field of university lighting energy conservation and have achieved a lot of research results. Some scholars have conducted energy-saving experiments on different types of lamps used in college classrooms and found that replacing the existing classroom fluorescent lamps with energy-saving lamps can save 52.8 % of electricity. Besides, scholars have also adopted household metering and energy conservation in colleges and universities, centralized control through telephone lines, and limited power supply for the limited time and limited power supply [5]. University lighting power-saving technology has changed from the overall control of all lighting equipment in the classroom to the fine control of the classroom lighting equipment division; also, many new projects for energy-saving control in classrooms have expanded from lighting equipment to electrical products such as electric fans and air conditioners. Some scholars have proposed energy-saving schemes for classroom lighting: the classroom was divided into four areas, and light intensity detectors and pyroelectric infrared sensors were installed above different areas. The light intensity detector is used to detect the average light intensity in the corresponding partition, and the pyroelectric infrared sensor detects the corresponding segmentation personnel signal and then passes it to the single-chip microcomputer to independently control the illumination of each zone [6]. More importantly, using the existing monitoring camera network classroom, through the controller processing and decision-making to collect images in the classroom, determine the number of classroom staff, in order to control the classroom lighting equipment. This technology has broad application prospects in safety and monitoring [7].

3. METHODOLOGY

3.1. Quantum Image Storage Model Algorithm Based on Machine Vision Design Technology

To further improve the design of the classroom lighting energy-saving system, machine vision design technology is applied to achieve accurate system design, while this technology is the main system image processing part, usually adopting the method of frame difference and background difference superposition to separate the background and identify the indoor personnel [8]. The frame difference method uses the previous frame image as the background model of the current frame. It has the advantages of short interval between adjacent frames, strong real-time performance, no background accumulation, fast update speed, simple algorithm and small calculation [9]. However, the disadvantage of the frame difference method was that it was sensitive to the choice of ambient noise and noise. For example, for a more uniform moving target, the frame difference method was likely to create gaps in the target and affect the effect of background separation. Background subtraction method uses the parametric model of the background to approximate the background image, and compares the current frame with the background image to realize the detection of the target area. The pixel region with large difference was regarded as the target region, and a pixel region with small difference was regarded as the background region. The key to the background difference method is background reconstruction and its real-time update algorithm with changes in illumination or external environment; therefore, the quantum image storage model algorithm is used to analyze machine vision technology. The quantum matrix model was proposed by S.E. Venegas Anemia in the literature, in which each pixel in the image was represented by a qubit, so when the size of the classical digital image is N×M, its representation is as in Equation (1):

$$I = \phi_{ij}, i \in \{0,1,\dots,N-1\}, j \in \{0,1,\dots,M-1\}. \quad (1)$$

When performing quantum image processing, improvement cannot be achieved. Moreover, the colour information of the image pixels we noted in this model was preserved in the quantum amplitude of the ground state of the qubit. And we have no way to obtain this kind of probability information by quantum measurement, which means that when we save the image information in the quantum model, there is no way to recover the classic digital image. For images with a size of N * N, the model will iteratively divide the image into 1/4. This state is equivalent to the ground state of the n-bit 4-dimensional quantum bit sequence representing each image pixel, and the colour information of the pixel is stored in the quantum amplitude of the ground state I. N the entire quantum superposition state, where n = 21 OG 4 N. The representation of the model is shown in equation (3).

$$I = \sum_{i_1,\ldots i_n = 0,1,2,3} c_{i_n,\ldots i_1}. \tag{2}$$

For an image of size 2n×2n, the representation of the two-dimensional superposition state model is as follow:

$$I = \frac{1}{2}\sum_{Y=0}^{2^n-1}\sum_{X=0}^{2^n-1}(\cos\theta_{YX} + \sin\theta_{YX}). \tag{3}$$

This model can maintain the adjacent relationship between the pixels of the classic image; meanwhile, the performance of the quantum image processing can also be improved by using the quantum superposition state to store the pixels. The two-dimensional coordinates of the image pixels were still determined by two quantum sequences of Y and X, and the colour information of the corresponding pixels was determined by the quantum amplitude θ_{YX} of a single qubit entangled with YX. In the superposition state of the quantum image, the base vector terms corresponding to all the pixels are equally weighted. Fig. 1 shows a schematic diagram of a quantum image based on a two-dimensional superposition state model with a size of 4 × 4. It could be known that for image of size, the model needs to use 2logN+1 2D qubits to store the complete image information by analyzing the expression of the model.

3.2. Design of Classroom Lighting Energy-saving Control System Based on Back Propagation Neural Network Algorithm

Combining the analysis above, the classroom lighting energy-saving control system is mainly composed of the image acquisition module, monitoring computer, and electrical control module and classroom circuit. The image acquisition module is a camera monitoring device and a video transmission line installed in the classroom, and the monitoring computer was located in the teaching building or the main monitoring room of the school. In addition to the traditional video surveillance and recording functions, the monitoring computer of the system also completes the personnel identification and electrical control decision tasks in the classroom. The electrical control module is designed based on a microcontroller that can receive control information from the monitoring computer and turn the lighting on or off in the classroom. The classroom electrical circuit can be controlled by the electronic control module and manually. The working process of the system determines the working status and goals of the system. A correct and reasonable workflow is also very important for the normal and stable operation of the system. The work flow chart clearly reflects the designer's design ideas and objectives for entity operation. According to the sequence of the system flow chart, the working mode and process of the system software can be determined. The design of this paper explores and chooses the hardware of the system in detail, which requires that the design of the workflow diagram should be as accurate as possible. Only if these hardware functions can be played, the smooth operation of the hardware can be guaranteed, or can the intelligent control requirements of the lighting system be realized.

The basic Back Propagation algorithm contains two processes of forwarding propagation of signals and back propagation of errors. That is, the calculation of the error output is performed in the direction from the input to the output, and the adjustment weight and the threshold were performed from the

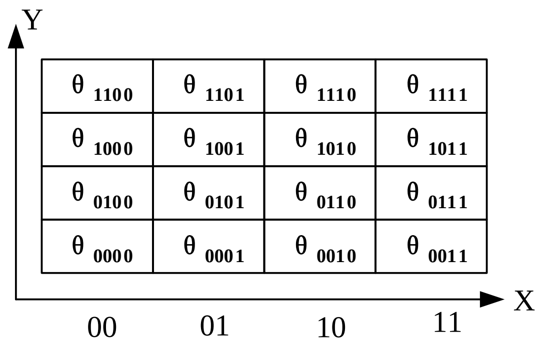

Fig.1. Schematic diagram of 4×4 pixel two-dimensional superposition quantum image model

output to the input. In the case of forwarding propagation, the input signal acts on the output node through the hidden layer and undergoes a nonlinear transformation to generate an output signal. But if the actual output does not match the expected output, it is transferred to the back propagation process of the error. Error back propagation is to pass the output error back to the input layer through the hidden layer one by one and distribute the error to all the units in each layer, and then use the error signal obtained from each layer as the basis for adjusting the weight of each unit. By adjusting the connection strength between the input node and the hidden layer node, and the connection strength between the hidden layer node and the threshold value of the output node, and reducing the error along the gradient direction, after repeated training, the final network parameters to the minimum response error is determined (weight and threshold), the training will stop. Therefore, Back Propagation neural network algorithm is applied to analyze and evaluate the effectiveness of its design. The basic learning algorithm of Back Propagation neural network is called gradient steepest descent method, which is defined as adjusting weights to minimize the total error of the network. Using the gradient search technique, the mean square error of the actual output value of the network is minimizing. The network learning process can be seen as a correction of weight coefficients and a process of error propagation. In the Back Propagation neural network structure, the three-layer network structure is made up of the input layer, the hidden layer and the output layer, among which there is no direct connection between the hidden layer (middle layer) and the outside world, but the neuron state of the hidden layer can influence and change the input and output. The idea of the algorithm is to continuously correct the network weight (ω_{ij}, T_{li}) and the enthalpy (θ), so that the error can continue to decline along the direction of the negative gradient, thus finally we get the satisfactory results. The learning formula of Back Propagation neural network has designations as follows: ω_{ij} is the network weight between the input node and the hidden layer node, T_{li} is the network weight between the hidden node and the output node, t_1 is the expected value of the input node, t_1 is the input node, and the output node is O_l. Where x_1—x_n represents the input signal of the neuron, ω_{ij} represents the connection weight between the neuron j and the neuron i, and e represents the threshold, also called the bias, and the input and output relational expression of the neuron i is:

$$net_i = \sum_{j=1}^{n} w_{ij} x_j - \theta \qquad y_i = f\left(net_i\right). \tag{4}$$

The output of neuron i is y_1, the net is called net activation, and function f is called activation function. If the threshold has been used as the weight w_{i0} of certain input x_0 of neuron i, then Equation 1 can be simplified as:

$$net_i = \sum_{j=1}^{n} w_{ij} x_j \qquad y_i = f\left(net_i\right). \tag{5}$$

If X has been defined as the input vector and W as the weight vector, then:

$$X = \left[x_0, x_1, x_2, ..., x_n\right]. \tag{6}$$

$$\omega = \begin{bmatrix} \omega_{i0} \\ \omega_{i1} \\ \omega_{i2} \\ \cdot \\ \cdot \\ \cdot \\ \omega_{in} \end{bmatrix}. \tag{7}$$

Then the output of the neuron can be converted into the product of the vector:

$$net_i = X\omega \qquad y_i = f\left(net_i\right) = f\left(X\omega\right). \tag{8}$$

If the net value of the neuron is positive, it could be defined that the neuron is in an active state or an excited state; but if the neuron net value is negative, it can be defined that the neuron in a suppressed state. Such a neuron model embodied in the form of a “threshold weighted sum” is called McCulloch-Pitts Model, which is also known as the processing unit in the neural network. The network topology was divided into two types of feedforward type network and feedback type network in the neural network, including the structure of the network and the connection mode between the neurons. The feedforward type network means that when there is no feedback in the middle, each neuron outputs the input operation of the previous layer to the next layer; the feedback network refers to the feedback loop

Table 1. Classroom Lighting Monitoring Data

Input quantity		Output	
Standard of illumination (h)	**Luminaire power (W)**	**X axis coordinates (cm)**	**Y axis coordinates (cm)**
150	40	282	225
	30	233	280
	20	200	250
	25	92	82
300	40	282	229
	30	200	229
	20	80	200
	25	50	82

between the neurons. The training algorithm (also called learning algorithm) refers to the method of adjusting the weight during the training process determining the initial weight of each connected neuron and satisfying the performance of the network, which could be broadly divided into supervised and unsupervised learning methods. Supervised learning provides input mode and desired output mode to the network while training; by continuously inputting different training modes to adjust the weight, the output mode gradually approaches the expected pattern. Unsupervised learning is to adjust the parameters according to the input value, and the output value can accurately reflect the characteristics of the input training samples.

4. RESULT ANALYSIS AND DISCUSSION

When the light is turned on and off, the difference between the current frame and the previous frame is large. At this time, the model will improve the convergence speed of the reconstructed background, so that the image acquisition system can get better background adaptability. At the same time, the convergence speed of background reconstruction will also be adjusted adaptively according to the difference. For designing the most energy-saving luminaire installation scheme under the premise of meeting the standard illuminance value, the simulation experiment can be carried out through the Back Propagation neural network. Generally, in different environments, the installation position and power of the luminaire have a certain influence on the lighting effect establishing the model by the Back Propagation neural network, and defining the illuminance standard and the luminaire power as the input quantity, and the installation position of the luminaire as the output quantity, and training it. The experiment selects a classroom in the teaching building as the experimental object and normalizes the input data of the Back Propagation algorithm to determine the input and output parameters of the network, which were selected according to the actual situation. The distribution and measured data of the lamps in the classroom are shown in Tables 1, 2.

First, a composite dataset is generated consisting of two graphs: the Delaunay Triangulation Graph and the Random Join Graph. Graph Differential thermal gravity is commonly used in the field of computer vision and pattern recognition because of some quite good properties, such as sparseness, locality, and no singular angles. When generating the data set, the nodes of the graph can be randomly generated in a two-dimensional space by using a literature method, and then the Differential thermal gravity graph is constructed. Scale from 5 to 50,

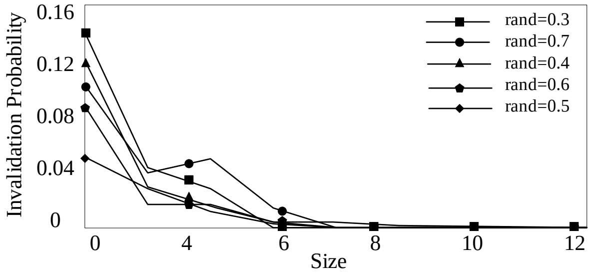

Fig.2. Failure probability distribution for random connection graph data set in running Qwalk algorithm

Table 2. The Sample Data Table

Input sample									Output sample	
H(10m)	φ (1041m)	A(102m^2)	η	K	P_c	P_f	P_w	E_{av} (103lx)	N(10)	E_{av} (103lx)
0.36	0.3112	1.08	0.7	1.3	0.55	0.26	0.35	0.35	28	0.304
0.36	0.2865	1.08	0.7	1.3	0.36	0.33	0.36	0.39	35	0.350
0.36	0.2553	1.08	0.7	1.3	0.39	0.36	0.37	0.299	36	0.318
0.36	0.2006	1.08	0.7	1.3	0.12	0.41	0.61	0.15	28	0.196

randomly generating 100 sets of test chart pairs for each scale. Fig. 2 shows the accuracy comparison of these approximate quantum model algorithms for different scale Differential thermal gravity plots. Lu is an algorithm designed specifically for Differential thermal gravity diagrams, but it can be found that when the scale of the graph is large, the accuracy of the algorithm is poor. Also, from the results, it can be implied that as the scale of the graph increases, the quantum model algorithm has a smaller standard deviation and better accuracy.

Fig. 2 displays the probability distribution of the algorithm failures caused by the random connection graph generated for us leading to two trends in the results. Firstly, the larger the scale of the graph is, the more the probability of failure can be. When the scale of the graph exceeds 10, basically no more failures occur. Secondly, the data used in the test shows that the input is the illumination brightness (lc) and the lamp power (W), and the output is the minimum horizontal and vertical interval (in cm) of the installed fixtures in a given classroom, and the size is 12m × 9m, which can be tested by modifying the data for classrooms of different sizes. The fluorescent lamp is used as the test luminaire in the test since the 16 W LED tube selected in this design is the same as for 40 W fluorescent lamp, so the simulation result of the 40W luminaire under test can be used as the basis for the installation position of the luminaire in the design. The total error of the training obtained by running multiple times is shown in Fig. 3. The error of the algorithm is graphically displayed and displayed every ten iterations.

Furthermore, it can be calculated through the test results that to meet the illumination requirements, 40W lamps can be chosen in the 12m × 9m classroom, for five lamps in the X-axis range, six lamps within the Y-axis range, and 30 lamps throughout the whole classroom. In order to achieve better background difference, this research proposes a background reconstruction algorithm for segmentation convergence: the video image processing program uses the pre-acquired empty classroom image as the first frame of background reconstruction, and the first 10 frames converge at 1 % rate to make the initial reconstruction background similar to the real-time background.

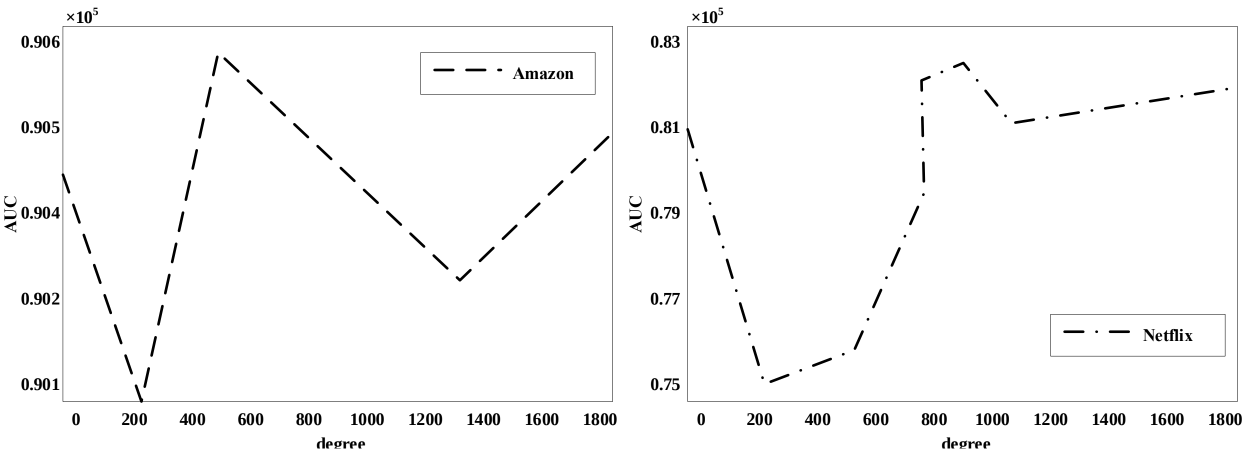

Fig.3. Back Propagation neural network algorithm

5. CONCLUSION

To solve the problem of energy waste in classroom lighting, this paper studies the energy-saving control system of classroom lighting based on machine vision. The system captures indoor surveillance video by monitoring equipment installed in the classroom, and uses frame difference and BA technology, neural network algorithm Back Propagation and quantum image storage technology to segment and identify indoor personnel in surveillance video. On this basis, the opening and closing of lighting in the classroom is controlled according to the personnel situation. The model algorithm is used to analyze and simulate the experiment. The system can perform real-time indoor personnel identification of the illumination video, and the detection accuracy of the frame containing no and including indoor personnel is 100 % and 93 % respectively. With the increasing popularity of public space monitoring equipment, machine vision-based energy consumption control applies its monitoring system to improve the utilization of monitoring equipment while reducing energy consumption, which has a popular application prospect.

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