The Analysis of the Artistic Innovation of LED Lighting in Gymnasiums Based on Intelligent Lighting Control Systems

Yan Huang, Sichuan Fine Arts Institute, China*
Zhihui Xiao, Sichuan Fine Arts Institute, China

ABSTRACT

With people’s attention to and participation in sports, large-scale and comprehensive gymnasiums have sprung up nationwide. Unlike previous small gymnasiums, large modern gymnasiums have more robust functions, more intelligent control, and humanization. However, some shortcomings remain, such as too centralized control and inflexible control. Therefore, intelligent control and energy saving of lighting will become the development direction of lighting systems. To ensure the normal progress of sports events and the quality of TV broadcast, the requirements of gym lighting are increasingly stringent, so the lighting control system of gyms has higher requirements accordingly. To solve these problems, this paper designs a gym intelligent control lighting system based on LED bus, which can adapt to the corresponding lighting scenes of different venues. The experimental results show that the intelligent lighting control system designed in this paper can run normally and stably, and can complete the detection of crucial working parameters. This system can automatically control the light and dark and switch off according to the indoor lighting brightness, achieving a sound energy saving effect, improving the lighting environment, and achieving the desired goal.

KEYWORDS

Intelligent Lighting Control, LED Lighting, Stadium

1. INTRODUCTION

With the improvement of people’s living standards, people have higher and higher requirements for lighting quality. From the initial need to provide essential brightness to the current requirements, lighting is required to provide appropriate brightness and create an elegant and comfortable atmosphere and more energy saving (Peng D, 2018). In addition to providing essential venues for various sports activities, modern comprehensive gymnasiums can also host meetings, literary and artistic activities, exhibitions, etc (Wang Yi, 2021). To achieve this goal, the industry has developed many energy-saving lighting appliances, but still can not meet the requirements of “green lighting”. Born in the s of the
th century, it only emitted red light at that time, and its energy conversion was much worse than that of incandescent lamps used at that time (Xiao YH, 2013). With the continuous progress of science, scientists have become more and more familiar with the primary colors, and have begun to explore the materials in depth to create lamps that can meet various colors. With scientists’ understanding of materials getting deeper and deeper, the processing and production of materials have witnessed rapid development. The brightness has also been improved many times, and various colors can be made (Caicedo D, 2015). Therefore, high brightness is another important innovation after the discovery of the bulb in the history of lighting. Vertical illuminance, illuminance uniformity, color rendering index and other parameters, meet the specified standards, which is an essential requirement for the modern comprehensive gym and gymnasium (Hong I, 2013).

Due to the versatility, in addition to holding different sports events, the venues will also host entertainment activities such as evening performances. Therefore, the venue lighting needs to meet various usage requirements, and in most cases, the competition venues will be divided into several sub-venues for simultaneous activities (Siddiqui AA, 2012). The control of venue lighting in sports venue lighting control system is often a great challenge for lighting designers because of the complex lighting patterns and complicated design. Lighting design should not only meet the requirements of various sports events to the greatest extent, but also create a comfortable competition environment for athletes, referees and spectators, so everyone in the venue can enjoy the competition heartily (Kandasamynk, 2018). In particular, when the game is broadcast in real-time through high-definition broadcast signals, it is necessary to ensure good broadcast quality and clear picture, which requires higher rationality and comfort of the lighting design of (Liu J, 2016). As a place to hold sports events and cultural and sports activities, gyms and gymnasiuems also use many intelligent systems (Tan YK, 2012). As an essential part of the intelligent system of gyms and gymnasiuems, so it is widely used in gyms and gymnasiuems (Shahzad G, 2016).

The intelligent control gymnasium studied in this paper can provide multiple functional services. The gymnasium is composed of the main competition area and the auxiliary area. Among them, the main competition area includes the badminton hall, the soldiers’ gym, the basketball hall, the billiards hall, the volleyball hall and other venues, which can hold various events. The auxiliary area includes office and entertainment spaces, which can hold meetings and concerts. Its intelligent lighting control system is based on bus technology to establish the entire communication network of the gym lighting. With the embedded server as the control center of the whole of intelligent lighting system, users can realize various control of the gym lighting through the image page on the developed server. Its innovation lies in:

(1) Design lamps with rotating function and introduce them into sports lighting system. The designed rotating lamp shall be able to rotate in the horizontal and vertical directions so that the lamp can rotate freely within a specific angle range. (2) The control data of the motor is transmitted to the motor drive end through radio frequency technology to control the rotation angle of the lamp.

2. RELATED WORK

With the rise of the Internet of Things, smart home and other concepts, intelligent lighting is also developing rapidly. Intelligent lighting is still primarily used in high-end meeting rooms, hotels and other places, while ordinary home and office applications are less. An important reason that affects the promotion of intelligent lighting is the wide variety of protocol standards in the market and the lack of unity.

To solve these problems, Magno (2014) needs sports lighting control system not only to absorb the advantages of various bus systems at present, but also to learn from the relatively mature building control system, and also to infiltrate and integrate with other lighting control systems, and to become a standardized, humanized and intelligent sports lighting control system with its better flexibility, economy and reliability, which is an inevitable development trend. Escolar (2012) has taken measures
to promote the use of LED light sources, vigorously and intelligent lighting control has entered a brand-new development upsurge. Various lighting manufacturers at home and abroad have taken this as a business opportunity to enter the intelligent field, and directly attack LED lighting system solutions. Elejostep= (2013) introduced the application of bus in intelligent building, especially the interface design between controller and computer in hardware. The highlight of this document in software lies in redefining the bus application layer protocol and studying the information scheduling scheme of priority promotion. Nagy (2015) has done a lot of research on fire monitoring, hardware research on temperature and smoke information collection, software research on system algorithm, further improved the fuzzy control algorithm, and improved the accuracy of fire alarm. Amor (2016) describes the distributed temperature acquisition system based on bus technology, which fully uses the resources of extended devices. This device has simple configuration and good performance, and has been widely used in distributed temperature measurement and control systems. Lee (2011) introduced that the bus unit node temperature acquisition module is transmitted to the upper computer through the bus. The user interface is written by software to realize unified monitoring, parameter setting of resource nodes, unified data management and data report printing. Gancarz (2013) introduced the bus technology, which is the bus node of the microcontroller. The peripheral circuit includes the execution module (lighting control circuit and dimming control circuit) and the data acquisition module (illumination detection module and infrared detector module), which provides a hardware technical reference for scholars. This system realizes the integration automation of intelligent lighting and achieves the purpose of energy saving. Gorgulu (2020) has also appeared in many promotion schemes. Through the government’s vigorous publicity and demonstration projects, the shadow can be seen everywhere, from industry to agriculture, from military to civilian use. The state has also provided many “green lights” for its production and sales, to vigorously promote this low-carbon and environmentally-friendly product in various industries across the country. Shi Hai (2015) changes the lighting effect by adjusting the direction and speed of the lighting, changing the stroboscopic speed, the size of the aperture, and the focal length. The stepping motors with different functions in the computer head-shaking lamp help the computer lamp achieve so many varied stage effects. When designing the control program, it is only necessary to obtain the operating parameters of the stepping motor, understand the functional characteristics of the stepping motor, and define and program it to realize the control of the computer lamp. Eddie (2020) Cheung is represented by DALI agreement based on open agreement, which major lighting equipment manufacturers usually initiate. Members in the industry participate extensively, and the agreement is modified and certified by a third-party organization. The openness of the agreement and the compatibility of products make the open agreement have certain advantages in shopping malls.

3. METHODOLOGY

3.1 Planning and Design of Intelligent Lighting Control System for Gymnasium

The lighting system has the characteristics of a large number of lamps, high power, scattered distribution, many loops and complicated lighting patterns (Reynoso, 2020). The traditional lighting control system is from the control room, from the circuit breaker to the switch, and then from the switch to the lamp. Due to the large number of lamps and lanterns, the number of cables returning to the control room is huge, resulting in the excessive size of the cable tray and the excessive use of wires (Sukte, 2022). The overall design scheme of the major sports lighting system is shown in Figure 1, the schematic diagram of the new sports lighting system.

Introduce rotating lamps into the existing sports lighting system, and add input unit control panel with radio frequency remote control, output unit lamp rotating driver. The input unit and output unit together constitute a small lamp turning control system, which can also be called lamp rotating controller. The control panel with radio frequency remote control is installed on the wall according
to the venue’s situation. The radio frequency remote control can be detachable and hand-held, and the rotary driver of the lamp is installed inside the rotary lamp.

In, lamps and lanterns used for lighting are essential equipment. The existing lamps and lanterns are usually lamps with adjustable illumination angles. Although these lamps and lanterns are fixed, their illumination areas are variable. The rotary lamp comprises a base, a lamp body, a lamp holder, a first driving device and a second driving device, wherein the lamp body is rotatably connected to the lamp holder, the lamp holder is rotatably connected to the base, the first driving device can drive the lamp holder to rotate around a first axis, and the second driving device can drive the lamp body to rotate around a second axis, and the first axis and the second axis form a predetermined included angle. In addition, the rotary lamp also includes a turntable, which is connected with the second gear through a transmission shaft, and the lamp holder is fixed on the turntable. The second driving device comprises a second motor, a third gear and a fourth gear which are meshed with each other, the output shaft of the second motor is connected with the third gear, the fourth gear is associated with the lamp body through a connecting shaft, and the second axis is collinear with the axis of the connecting shaft. The third gear and the fourth gear are mutually matched bevel gears. In addition, a plurality of rollers are arranged on the turntable’s surface opposite the base, and the rollers are in contact with the base; when the turntable rotates, the rollers roll on the base. Of course, it also includes a control device, which can control the first driving device to rotate or stop the lamp holder, and the control device can also control the second driving device to rotate or stop the lamp body.

The structure diagram of LED lighting control system based on DALI is shown in Figure 2. The system consists of an upper computer, a master control system and a slave control system.

The master control system communicates with the upper computer through RS-232 communication protocol. Each DALI system can control up to 64 slave control systems through DALI bus. In addition to communicating with the upper computer, the main control system can also expand the keyboard, sensor, and remote control modules. The slave control system controls the dimming, switching, lighting scene setting and other LED light functions through the LED drive circuit. This paper focuses on the hardware and software design of master control system and slave control system.
3.2 Dimming Algorithm Based on Average Split Pulse

In the traditional PWM dimming algorithm, the high weight bits of grayscale data greatly influence grayscale uniformity. To reduce this influence, this paper adopts bit separation of grayscale data, that is, the whole grayscale data is divided into high-weight bits (MSB) and low-weight bits (LSB) for processing. At the same time, the conduction time in the whole PWM cycle is evenly divided into several short conduction times, equivalent to improving the visual refresh rate. For M-bit grayscale data, assuming that the number of LSB is N, the number of MSB is (M-N). At this time, the weight of MSB is not the original weight of each bit, but the weight of each bit when it is regarded as an independent binary number. The weight of the lowest bit in the original MSB is $2^{N}$, but now it is changed to $2^0 = 1$, while the weight of the highest bit in the original MSB is $2^{M-1}$, but now it is changed to $2^{M-N}$. The number of valid high levels generated by the MSB data is:

$$L_M = S_M \cdot 2^{M-N-1} + S_{M-1} \cdot 2^{M-N-2} + \ldots + S_{N+2} \cdot 2^1 + S_{N+1} \cdot 2^0$$  \hspace{1cm} (1)$$

The number of effective high levels generated by LSB data is:

$$L_L = S_N \cdot 2^{N-1} + S_{N-1} \cdot 2^{N-2} + \ldots + S_2 \cdot 2^1 + S_1$$  \hspace{1cm} (2)$$

According to Formula (1) and (2), the effective high level generated by gray data is:

$$L = 2^N L_M + L_L$$  \hspace{1cm} (3)$$

It can be seen from formula (3) that the display time of high-level gray values is evenly divided into $2^N$ time periods, and each period is $L_M$, $L_L$, which is inserted into the end of each segment of $2^{N-1}$ according to the principle of average matching, so it does not change the overall duty ratio.
The differential input voltage of the receiving node of CAN bus is affected by the following factors: the total dielectric resistance $R_w$, the node resistance $R_{\text{diff}}$ and the voltage output of the sending node $V_1$. Calculate the maximum number of nodes in the network distribution. Considering the most unfavorable condition, that is, when the sending unit node is at one section of the bus, and the receiving node is at the other end of the bus, the input voltage of the receiving node is calculated as follows:

$$R_# = \frac{R_{\text{diff}}}{n-2} / R_{\text{diff}} / R_T$$  

(4)

$$R = R_w + 2R_w$$  

(5)

$$V_2 = \frac{R_{#}}{R} \times V_1$$  

(6)

Therefore, according to Formula (4), (5) and (6), the input of the receiving node is:

$$V_2 = \frac{V_1}{1 + 2R_w(-\frac{n-1}{R_{\text{diff}}+\frac{1}{R_T}})}$$  

(7)

Among them, $R_w = \rho \times L$ is the total resistance of transmission medium, $R_{\text{diff}}$ is the differential input resistance of nodes, $R_T$ terminal matching resistance, $V_1$ sending node differential output response, $V_2$ receiving node differential input voltage, and $n$ is the total number of CAN bus network nodes.

The dominant potential voltage value depends on the dominant threshold voltage and user-defined voltage, so the detected dominant differential input voltage is:

$$V_{#} = V_{\text{th}} + ksm \times (V_1 - V_{\text{th}})$$  

(8)

Among them, $V_{#}$ is the detected dominant bit differential input voltage, $ksm$ differential coefficient (0~1), and $V_{\text{th}}$ is the threshold voltage of receiving dominant bit.

The transceiver driving resistor determines the maximum number of nodes connected to the bus $R_{\text{1.min}}$. The minimum driving resistance of transceiver PCA82C250 is $R_{\text{1.min}} = 45\Omega$. In the worst case, the total line impedance can be approximately considered as $R_w = 0\Omega$, and the maximum number of nodes is:

$$n_{\text{max}} \leq R_{\text{diff.min}} \times \left[ \frac{1}{R_{\text{L.min}}} - \frac{2}{R_{T.min}} \right]$$  

(9)

Among them, when $R_{\text{diff.min}} = 20k\Omega$, $R_{T.min} = 120\Omega$, the maximum number of bus nodes is:
\[ n_{\text{max}} \leq 20 \times 10^3 \times \left[ \frac{1}{45} - \frac{2}{120} \right] \approx 111 \] (10)

The maximum number of bus nodes is 111. The maximum number of nodes in the bus is not only related to the transceiver’s drive ability, but also the bus length.

The system software consists of upper management system software programming and intelligent lighting control system programming. The program design of the lighting control system includes the external actuator program controlled by the microcontroller, and the data exchange program between the microcontroller and the controller. The resource node code bit is mainly used to indicate the internal units of the operating equipment. They are road intelligent control relay, temperature sensor, humidity sensor, infrared sensor, illumination sensor, and other resource node codes as spare parts for future expansion. In addition to the function code continuous write port and status change transmission command corresponding to the intelligent control relay, other resource nodes correspond to the continuous read port and status change transmission command, as shown in Table 1.

Among them, the state of intelligent control relay supports reading and writing of master control node; Each sensor resource node only supports the master node to read commands. When the master node sends a command message, the unit node receives the message to read the value of the corresponding sensor or the status value of the intelligent control relay. It transmits it to the master node in a response mode. The sensor value and the real-time status of the switch controlled by the intelligent relay are displayed on the user interface, so that personnel can understand the real-time status of each venue.

4. RESULT ANALYSIS AND DISCUSSION

In this paper, after the hardware and software design of intelligent lighting control system is completed, the control system is debugged. First, it is the test of the system hardware. The hardware design of the system is modular, so each module is debugged during debugging. After the system is powered on, the voltage of relevant points is carefully checked by multimeter, and the results show that all test points meet the designed requirements. First, create a project, then load files in the project, complete the compilation and connection of the program, and eliminate the errors in the program one by one according to the information prompted by the software. After debugging the software and hardware of the control system, the generated source code is loaded into the single-chip microcomputer for software and hardware debugging. To test the reliability of the system, several groups of experiments were carried out under different conditions, and the measured results are shown in Table 2.

Secondly, several output waveforms with different duty cycles are sampled through the oscilloscope, as shown in Figure 3, Figure 4 and Figure 5. The duty cycle in Figure 3 is 33%, that in

<table>
<thead>
<tr>
<th>Resource Node Code</th>
<th>Function Description</th>
</tr>
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<tbody>
<tr>
<td>0x00</td>
<td>8-way intelligent control relay</td>
</tr>
<tr>
<td>0x01</td>
<td>Temperature sensor</td>
</tr>
<tr>
<td>0x02</td>
<td>Humidity sensor</td>
</tr>
<tr>
<td>0x03</td>
<td>Infrared sensor</td>
</tr>
<tr>
<td>0x04</td>
<td>Illumination sensor</td>
</tr>
<tr>
<td>0x05-0xF</td>
<td>Retain</td>
</tr>
</tbody>
</table>
Figure 4 is 95%, and that in Figure 5 is 0.4%. It can be seen from the figure that there is no burr in the waveform, the harmonic content is relatively low, and the loss of constant current drive is small.

According to the data obtained from the above modules, the error between the measured results and the expected goals is small, which indicates that the intelligent control system designed in this paper can reach the desired goals, run stably and reliably, and can be applied to different occasions to meet the initial design requirements.

To avoid the rapid change of brightness causing a visual impact on people and affecting the visual effect, the dimming of the whole system is achieved through gradual brightness adjustment, which requires the high dimming performance of LED. Therefore, the linearity of the dimming curve of the system is tested. The test environment illumination is 49Lux, and the test tool is the illuminometer Guard FX-101Lux METER. During the test, keep the relative position of the illuminometer and the lamp fixed, set the brightness level of the lamp on the tablet computer to make it transition from 10% to 100% in turn, then use the illuminometer to record the illuminance under each brightness level, and draw the illuminance curve according to the measured data. The illuminance curve is shown in Figure 6.

Table 2. Test results of light intensity

<table>
<thead>
<tr>
<th>Testing Environment</th>
<th>Illumination Value (1X)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Night</td>
<td>0</td>
</tr>
<tr>
<td>Indoor cloudy day (lights off)</td>
<td>25</td>
</tr>
<tr>
<td>Indoor (turn on the light)</td>
<td>194</td>
</tr>
<tr>
<td>Outdoor cloudy day</td>
<td>150</td>
</tr>
<tr>
<td>Indoor in sunny days (lights off)</td>
<td>192</td>
</tr>
<tr>
<td>Indoor in sunny days (lights on)</td>
<td>239</td>
</tr>
<tr>
<td>Outdoor sunny day</td>
<td>358</td>
</tr>
</tbody>
</table>

Figure 3. Test waveform (a)
Measure the communication signals with different communication cable lengths. During the test, 50 meters of communication cable is selected between the controllers of the first group, and 300 meters of communication cable is selected between the controllers of the second group. Then, the communication waveform and bit error rate are tested. The test waveform includes the data waveform of the bus port and the waveform at the receiving pin of the single-chip microcomputer, as shown in Figure 7.
More accurate neural network models can be obtained when there are many gym and gymnasium sample data. Of course, by analogy, other types of gym and gymnasium sample data can also be collected, such as multi-functional comprehensive gym and gymnasium, and neural network models can be established. The sample data can be further subdivided if the collected data volume is relatively rich. For example, the multi-functional comprehensive gyms can be classified into municipal comprehensive gyms, provincial comprehensive gyms and national comprehensive gyms according to the size of the venues. Neural network models are established for the three types of complete
to estimate the recommended values of p in the comprehensive different sizes. In this way, when designing a new comprehensive gym, the recommended value of the corresponding rotating lamps can be selected according to the scale of the gym. On this basis, the lighting design of the gym will certainly provide convenience to the lighting designers.

5. CONCLUSION

With the continuous development of science and technology and the continuous improvement of people’s living standards, people have higher and higher requirements for the management of lighting equipment. The application prospect of intelligent lighting with energy saving, safety, centralization and humanized management is increasingly broad. At present, manual switch is widely used in the lighting system. In the gymnasium, turning off the lights is often not timely, which shortens the service life of the lamps and causes unnecessary energy waste. Through the method analysis and application exploration of the above-mentioned intelligent lighting control system based on the network bus, the planning and design of intelligent lighting control system adapted to relative ghost towels and multiple buildings have been realized, reaching the goal of distributed control of large-scale lighting for buildings. The system has realized the intellectualization, networking and scientific management of building lighting. The research results align with the development direction of bad green protection and the national policy of bamboo energy emission reduction, and have determined popularization value.

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