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Intelligent LED Plant Lighting System based on Internet of Things

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Abstract

In modern plant lighting, the status of LED lighting continues to improve with the progress of its technology.At the same time, the development of Internet of Things technology provides the possibility for its integration with lighting technology. Aiming at the current intelligent lighting system based on Internet of Things, this paper introduces the application background and trend of LED plant lighting, Internet of Things and LED intelligent lighting system, some existing design schemes and two key issues in LED lighting --light decay compensation and color mixing matching.

Keywords

Internet of Things, LED plant lighting, Light decay compensation, Mixed color matching.

1. Introduction

Artificial light supplementation has become an important means of efficient production in modern plant production systems (such as greenhouse, plant factory, tissue culture workshop, seedling factory, etc.) [1]. Red orange light and blue violet light of traditional artificial light sources account for a small proportion and have poor controllability. Moreover, they are unable to regulate the light quality, light intensity and light cycle according to the requirements of plants. Moreover, they have large energy consumption and high operating cost, accounting for 50% ~ 60% of the total operating cost [2,3,4]. At the same time, plant lighting is characterized by multiple fields, complex biological principles and regulatory indicators, strong professional lighting, accurate control system, etc. [5]. Therefore, the traditional artificial light source is difficult to meet the practice of plant lighting and on demand lighting environmental protection concept.

LED with its energy-saving and environmental protection, on-demand dimming, good controllability, high efficiency, long life and diversified light source equipment and many other advantages, in line with the modern plant lighting safe and efficient concept and development direction. However, in the current market, most of the LED plant lamps have unsatisfactory performance parameters and fine design of light distribution, which cannot achieve dynamic control, and there are many problems such as poor lighting effect and large energy consumption. Therefore, it is very necessary to design efficient and reasonable LED plant lamps. At the same time, the combination of LED lighting and Internet of things is also the trend of smart agriculture development.

2. Internet of Things and LED smart lighting system

The emergence of the Internet of Things is called a new wave of information revolution. Essentially, the Internet of Things is an extension of the Internet. It strives to connect all things and perceive the world. General international concept of Internet of things is defined as: using information sensing devices, such as RFID, infrared sensors, global positioning system, laser scanner, etc., according to the contract agreement, to any item connected to the Internet, information exchange and

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communication, in order to realize intelligent identification, location, tracking and monitoring and management of a network concept [6].

At present, China's agriculture is gradually developing towards modernization, and the Internet of Things technology is more and more applied to agricultural production and life, which has a positive impact on improving the efficiency of agricultural production management, saving human and material resources, and transforming the traditional agricultural production mode. In 2010, the Ministry of Land and Resources and the Ministry of Agriculture successively issued the Notice on Issues Related to Improving the Management of Agricultural Land with Facilities and the Notice on Further Supporting the Healthy Development of Facility Agriculture. The circular made it clear that the construction of facility agriculture should be vigorously developed to meet the needs of the continuous development of modern agriculture and large-scale land management. The intelligent plant lighting system based on the Internet of things is a development direction of facility agriculture. It organically combines the entity of the intelligent LED plant lighting system with the platform of the Internet of Things by building a special platform of the Internet of Things. Intelligent LED lighting system based on Internet of things through the sensor detection control plant growth temperature, humidity, light, water, fertilizer consumption and other plant growth conditions, so as to quantitatively control the growth of plants, can effectively improve the added value of agricultural products, such as quantitative control flower growth period, to ensure that a certain period of time of flowering, avoid because of the change of environmental factors and make the flowering in advance or delay, to maximize production efficiency [7].

3. LED intelligent lighting system design based on the Internet of Things

Cen Yichao [8] et al. designed a new type of intelligent LED lighting system, see Figure 1. The system consists of red light (660 nm) and blue light (460 nm) LED light source, the ZigBee wireless communication, light sensor and MCU system composition, design to intelligent lighting plants, is the focus of the system are made valid by means of the photosynthetic quantum flux density as the control parameter, to solve the current optical measurement as the control parameters do not tally with the actual use photon measurement problem. The system is divided into four modules: 1. Centralized control module. 2.Zigbee wireless communication module. 3.LED light filling module. 4. Lighting detection module. The centralized control module is responsible for sending instructions to the LED lights through one-to-one Zigbee wireless communication, and receiving the illumination feedback from the illumination detection module for real-time processing and adjusting duty ratio to make the measured photosynthetically active quantum flux density close to the set value, so as to achieve the quantitative determination of light quality for the illumination of plants. The number ratio of red and blue leds in the light group is 4:1. The two kinds of lights are programmed by two PWM outputs and run under the constant current, and the output current changes with the change of duty ratio.

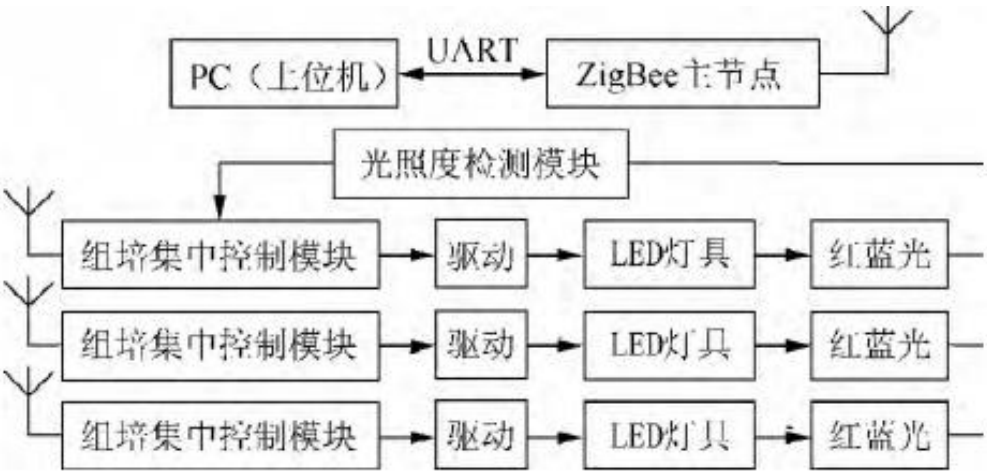

Figure 1. Overall architecture of the system [8]

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Xu Xiuzhi [9] et al. proposed an all-digital intelligent control system for LED plant light supplementation, aiming at the problems existing in existing LED plant light supplementation devices, such as fixed ratio of red and blue lamp beads, environmental temperature and lighting conditions of plant growth, etc. without considering, see Figure 2. This system is based on CPLD design, under the premise of not changing the ratio of red and blue beads, output PWM duty ratio according to the change of the external environment, so as to reach the preset temperature, illumination and other supplementary light information, so as to realize the lighting requirements for different plants and the same plant at different growth stages. The system consists of three parts, namely control box, smart driver and LED supplementary light. The control box controls up to 28 LED supplementary light lamps. The smart driver integrates red and blue brightness sensors and temperature sensors to transmit the perceived environmental data to the control box. Meanwhile, the control box can also access the parameters in the lamp holder for real-time adjustment of red and blue brightness and other parameters.

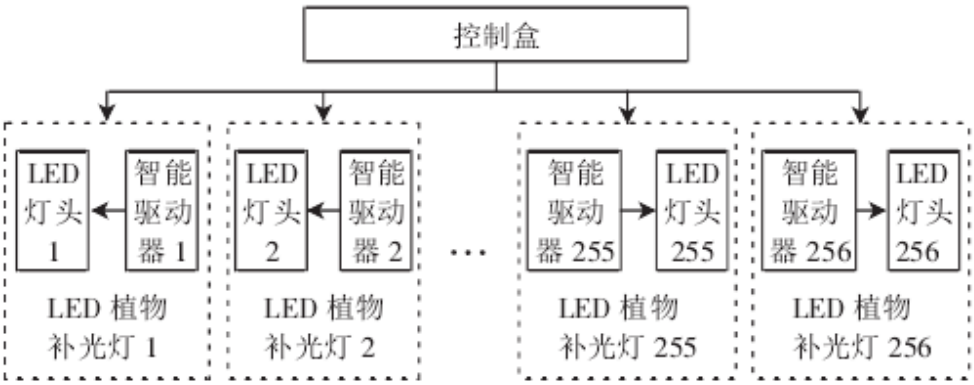

Figure 2. All-digital intelligent control system [9]

Huang Gang [10] et al. designed an intelligent LED lighting digital control system based on intelligent control by analyzing the advantages of LED lighting system and the problems such as uneven illumination degree and overlapping irradiation areas, which lead to the deterioration of plant growth quality, etc, see Figure 3. The system adopts manual control and automatic control to realize adaptive intelligent control, considering temperature, humidity, light demand and so on. The embedded unit and digital interface make up the overall architecture of the system. In order to satisfy the information input, output and control of sensors and LED dimming drivers, the operation is carried out through the control bus. Remote communication interface provides data transmission and communication function, and facilitates exception handling. The 32-bit DSP technology is adopted in the microcomputer processing unit, which can not only meet the need of information transmission control, but also solve the system control algorithm.

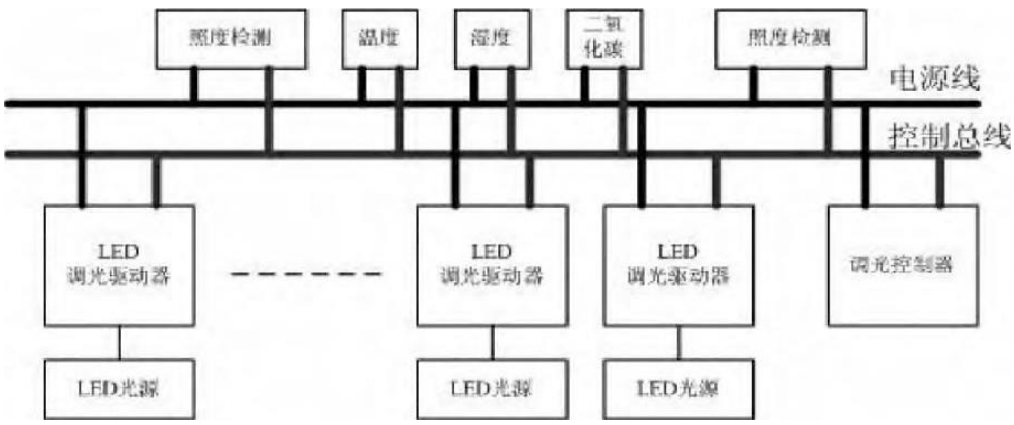

Figure 3. Structure diagram of Intelligent digital control system [10]

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4. Key issues

4.1 Optical attenuation compensation

The problem of light decay is one of the important factors that prevent LED lighting from replacing traditional lighting. The so-called light decay problem simply refers to that the LED core will gradually age with the use of time, and the light intensity will also decrease. The reduced part is called light decay. Research shows that heat is the most important factor affecting the life of LED, and the source of heat is mainly generated by LED. Nearly 70% of the electric energy is converted into heat, and with the accumulation of heat, the temperature of LED will rise, thereby reducing the chip performance and material aging [11].

Inventronics [12] proposed a LED light decay compensation scheme, which firstly obtained the LED light decay characteristic curve, and then calculated the LED drive output current curve gradually increasing with time through the control chip. In this way, the LED driver can dynamically change the output current, so that the output light flux of LED light source increases with the passage of time, ensuring that the output light flux is always consistent with the amount needed in the irradiated area, and thus realizing the optical attenuation compensation.

Wang Qi [13] et al. designed a SEPIC single-stage drive circuit as the main topological structure and adopted L6562 and TSM101 chip at the same time, which is different from the Scheme of Infet changing the output current. The former realizes the constant current output of LED and can stabilize the brightness of LED, thus playing the role of automatic dimming and light decay compensation. When the input voltage is between 175 and 265V, the SEPIC single-stage drive circuit is in the critical current mode, so that the PF and power conversion efficiency of the circuit are kept above 90%, which ensures the constant current output of LED and reduces the optical attenuation to a great extent.

4.2 Mixed color matching

Unlike traditional lighting design, LED color blending allows LED products to maximize their performance. LED color mixing technology can achieve the consistency and repeatability of LED lamps. Color blending also allows the use of a large color range, while reducing LED unit costs and providing consistent color point results. The light with a wavelength of 390nm-700nm is within the range that can be detected by human eyes. However, at first, LED lamps only used red (about 630nm), green (about 540nm) and blue (about 470nm), resulting in limited application range and the inability to mix every color visible to the naked eye.

The LED Color mixing design scheme based on Cypress EZ-Color controller [14] is a fast and simple method. In this scheme, the EZ-Color controller is composed of three parts (input, output driver and transfer function relation). At the same time, PSoC exprESS software is needed. This software runs at the system level and adopts special functions (such as sensor, LED driver, thermistor, etc.). Ez-color Color mixing scheme USES (x, Y, y) as the input (according to the characterization method of CIE 1931 chromaticity diagram), that is, X and Y represent tone and Color saturation, reflecting Color chromaticity information. Y stands for luminous flux, reflecting the brightness information of the color; RGB trichromatic LED as output. This method can be used to mix the desired Color, which is easy to operate, requires no programming, and can easily handle multiple pixels with the same EZ-Color device, saving the cost of multiple microcontrollers for a wide range of RGB pixels.

5. Conclusion

This paper introduces the development status and future trend of LED lighting in plant lighting. With the development of the Internet of Things in modern agriculture, the demand for smart agricultural lighting system combined with the Internet of Things has become increasingly prominent. This paper summarizes the design of smart lighting system based on the Internet of Things by some scholars, and summarizes some solutions for the light decay and color mixing matching problems of LED lights themselves.

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