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Design of a light environment detection system in an artificial light-type plant factory

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ABSTRACT: *Along with technical rapid development, the world population has gradually increased, while agricultural land gradually has decreased. To ensure a stable supply of agricultural products and promote agricultural development, plant factories have emerged. An artificial light plant factory is an efficient agricultural system that achieves plant growth and development through high-precision environmental control inside the facility. The light environment inside a plant factory greatly affects plant growth and development. However,currently, there is no automatic detection system for light environments, and manual detection is generally adopted.This method cannot accurately and real-time control the changes in a light environment. Therefore, starting with illumination, which is an important factor affecting plant growth, this paper uses sensors to automatically and accurately detect illumination parameters such as illumination time, illumination intensity, and light quality. This provides a basis for the current internal illumination environment control of plant factories and offers a cloud platform for control management, ultimately constructing an artificial light plant factory light environment detection system.*
Keywords: *sensor; Agricultural Internet of Things; Data acquisition; Plant factory; Cloud platform; ZigBee technology.*

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I. INTRODUCTION

Chinese government departments attach great importance to the development of modern agriculture. As early as the "National Agricultural and rural information development" 13th Five-Year Plan ", it was pointed out that the Internet of Things and other technologies would be utilized to achieve high-tech intelligent agriculture [1]. As a new high-tech intelligent agriculture, plant factory has a good development prospect. Plant factory, as a new a revolutionary technological transformation for the plant production system that are greatly affected by climate, environment, and temperature. This innovation is poised to address challenges including agricultural production and food safety in the 21st century [2].

Plant factories are divided into two types according to their utilization of light energy: solar energy utilization and artificial light energy utilization [3]. Artificial light energy utilization, also known as artificial light plant factory,employs LED lighting systems, environmental regulation systems, and soilless cultivation techniques to produce the vast majority of crops [4]. All biological growth depends on the sunlight , as plants undergo photosynthesis in its presence. The suitability of light will directly affect the yield and quality of plants [5]. In nature, due to the weather, clouds, and plants, the light intensity of plants often changes dramatically in a short period of time, significantly affecting the growth and development of plants [6]. Therefore, the LED light-filling method adopted by the artificial light plant factory will effectively avoid these problems, offering the significant advantage of controlled and easily detectable regulation.

Research status:

It is found that for plants, the demand and distribution characteristics of the light environment have spatial and temporal differences, and there are also variety differences between plants [7]. At the same time, plants at different stages have different requirements for light. For example, the plant germination stage requires more infrared light and heat, while the plant growth stage requires more blue light. Therefore, designing an environmental monitoring system to detect the light environment of plants in real-time is necessary.

In the process of plant growth and development, light intensity and light-matter also have important effects on plant biological activity [8], metabolic activity [9-10], and photosynthesis [11-13]. In the experiment of Zhang Ruijie et al., regarding the influence of light intensity on the growth, development, and quality of apricot in the plant factory, it was found that the light intensity affected the quality [14]by impacting the absorption, accumulation, and transport of dry material in the plant. The exploration of the relationship between LED spectra and plant factory production improvement by Li Lintimes et al. suggested that the distribution and structural elements of plant growth spectra would play a crucial role in improving the yield of plant and product quality [15].

Therefore, taking artificial light plant factory as the object of exploration, referring to the domestic literature on plant factory light environment control technology, lighting control technology, and related environmental control system literature, an environmental detection system of artificial light plant factory is designed to detect the light time, light intensity and light quality.

II. System scheme design

2.1 System Framework

The artificial light plant factory's light environment detection system, during the process of building, data collection, and analysis of the light environment is necessary. The detection system needs to accurately acquire light data through light sensors. Subsequently, computer-based information processing and control instructions are employed to facilitate control over the artificial light plant factory's light environment [16]. The illumination environment detection system of artificial light plant factories mainly consists of three components: the sensor illumination data acquisition system, the wireless information transmission system, and the cloud platform system. The light sensor module detects the light time, light intensity, and light quality of the plant The acquired data is transmitted to the cloud platform via the ZigBee wireless communication system and then presented on the display after the summary and sorting of the cloud platform.

The architecture of the plant factory light detection system is depicted in Fig 1.

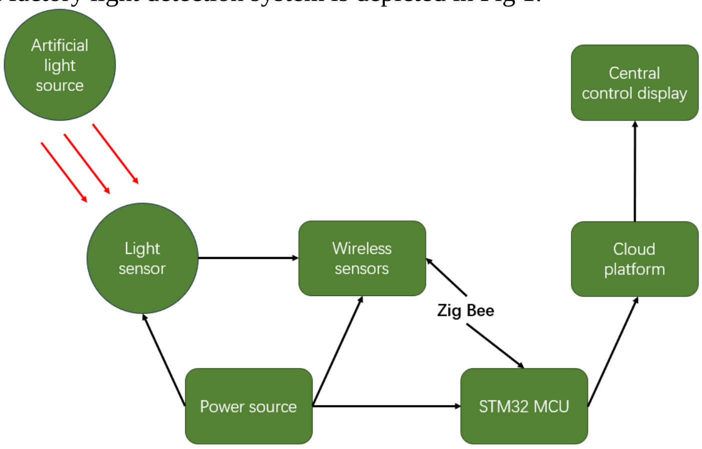

Fig. 1 System framework diagram

2.2 Functional module design

2.2.1 Sensor system

Sensor technology [17] involves the measurement and control of modern systems through the collection, conversion, and processing of information. The light sensor is a specific type of sensor capable of detecting various light parameters. For effective use in artificial light plant environments, light sensors require strong light sensitivity, precise linear amplification circuits, and the capability to output accurate linear electrical signals based on diverse light measurements. The system integrates a sensitive sensor capable of converting optical signals into electrical outputs. This sensor[18] is characterized by its affordability, small size, high durability, resistance to damage, simple interface and ease of use and learning. The light sensor employed within the artificial light plant factory is shown in Fig 2.

Fig. 2 The light sensor inside the plant factory

2.2.2 Wireless transmission system

The system employs the ZigBee wireless sensor network to gather pertinent environmental parameters and forward the corresponding data. It achieves data transmission both among the sensor nodes and between the sensor nodes and the platforms through the [19] ZigBee wireless communication mode. ZigBee, grounded in attributes such as low power consumption, cost-effectiveness, modest data rates, and suitability for short-range transmissions, proves well-suited [20] for deployment in the realm of intelligent agricultural automation. The core of the system relies on the STM32 microcontroller, with data communication executed via the cc2530 module to transmit detection data to the cloud platform. Subsequent data processing and presentation transpire on the primary display. The outline of the host device is illustrated in Fig 3.

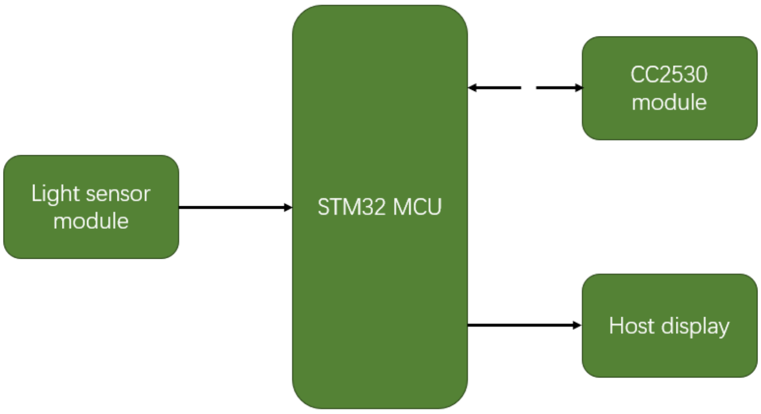

Fig. 3 Schematic diagram of the MCU

The STM 32 series microcontroller has high performance, low cost, and low power consumption [ ]. Take STM32F103ZE as an example[ ], which has the characteristics shown in Table 1 below:

Table(1). Functional characteristics of STM32F103

kernel	ARM 32 bit Cortex-M3 CPU, the highest operating frequency 72MHz,1.25DMIPSMHz
store	512 KB Flash memory. And 6-64 KB of the SRAM memory
source	2.0-3.6V Power supply and drive supply voltage of the IO interface
DMA	The 12-channel DMA controller
watchdog timers	Independent watchdog and the Window watchdog
keyer	24-bit inverted counter. Two 16-bit base timers are used to drive the DAC
Communication interfaces	2 IIC interfaces (SMBusPMBus) and .5 USART interfaces (ISO7816 interface, LIN, IrDA compatible, debugging control). Three SPI interfaces (18 Mbits), two, and IIS reuse. CAN interface (2.0B). The USB 2.0 full-speed interface. SDIO joggle

Furthermore, opting for the STM32 MCU in the experimental context offers several advantages, including its cost-effectiveness, extensive range of peripherals, impressive real-time performance, diverse model availability, and a low developmental cost.

Given the varying sizes of artificial light plant factories for cultivating different crops, the establishment of a ZigBee wireless transmission network becomes essential. This network involves distributing light sensor acquisition nodes across various plant detection points. Subsequently, communication takes place between these nodes and the main control center via the ZigBee wireless transmission network. This interaction is facilitated through the use of the cc2530 module, which communicates with the upper computer. The upper computer undertakes information processing and integration before transmitting the compiled data to the cloud platform. The specific structural framework is depicted in Fig 4.

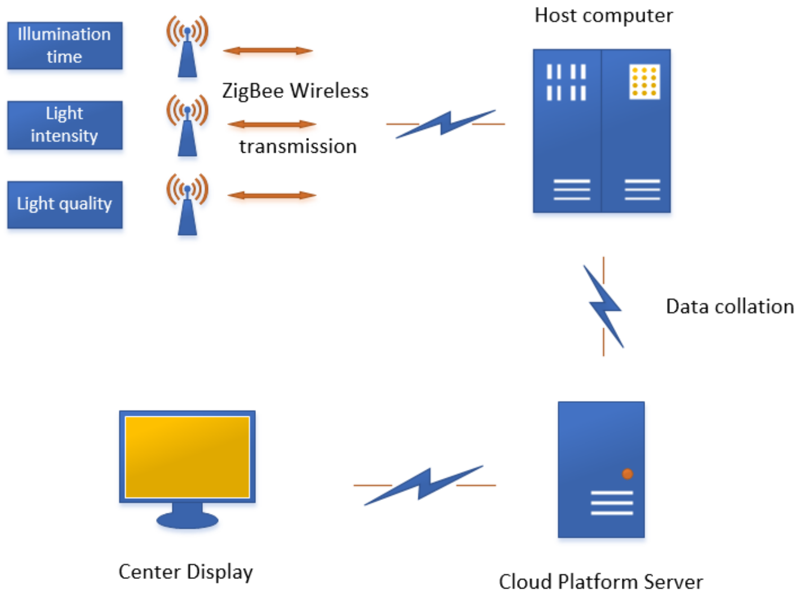

Fig. 4 ZigBee Wireless communication network framework

2.2.3 Cloud platform

Amidst the evolution of the Internet and the Internet of Things technology and the wide application of smart mobile devices, cloud platform technology (also known as cloud computing technology) has found increasing application in an expanding number of [21] development scenarios with its advantages of high efficiency, high availability, high flexibility, and easy maintenance. In the domain of agricultural Internet of Things, cloud platforms are widely used for the real-time detection of environmental parameters.

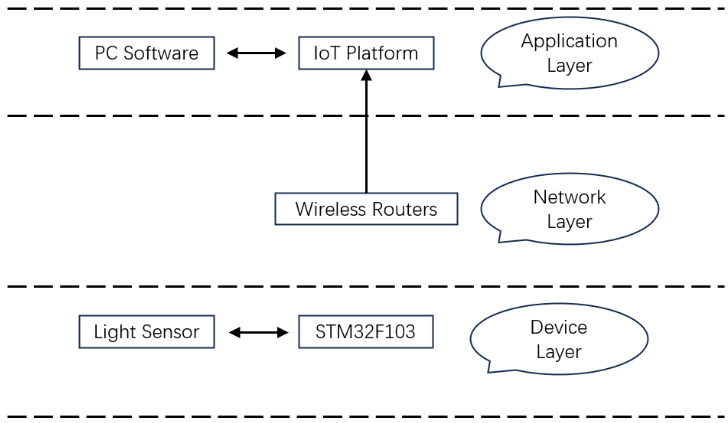

Fig. 5 Framework diagram of the cloud platform system

The cloud platform within the system includes the application layer, network layer, and device layer [22]. The equipment layer is installed inside the plant factory, and the STM32F103 is the main control chip, and the real-time light data is collected through the light sensor. STM32F103 Link to WIFI to communicate with the cloud platform through a wireless router. The application layer embodies the Internet of Things detection platform. The framework is visualized in Fig 5.

III. System test

This system built a light detection system in the artificial light plant research laboratory to verify the feasibility and rationality of the system. Experimental results are shown in Fig 6:

At the two detection points within the plant factory, the detection system precisely captured red, blue, and white light, along with their corresponding intensities. This confirmed the system's capability to accurately detect light intensity and quality.

Plant Fill Lighting μmol/m²/s	Red Light	Blue Light	White Light
Light Sensor 1	92	51	172
Light Sensor 2	96	44	140
Operating State	Interplanting normal		

Fig. 6 Light data of plant factories

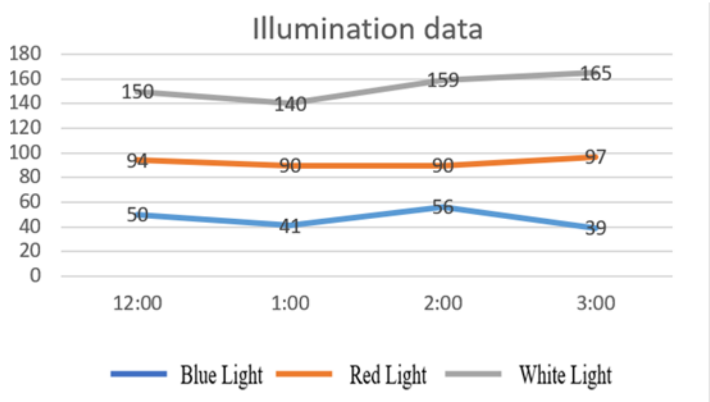

Fig. 6 Line graph of light data

Simultaneously, the system conducts real-time illumination data monitoring, logging illumination times, and categorizing the gathered data. This data is then visualized in a line chart for convenient experimental observation, as depicted in Fig 7.

The The system detects illumination data from red, blue, and white spectra during distinct time periods, uploading the collected data to the database for storage. This facilitates the retrieval of light environment data over specific time intervals.

Following validation, the system is capable of real-time detection of light duration, light intensity, and light quality, making it suitable for monitoring the light environment of artificial light plant cultivation.

IV. CONCLUSION AND PROSPECTS

The artificial light plant factory represents an efficient production mode with a highly controllable environment and double capacity. It experiences little to no restriction from natural resources [ ]. It can produce crops throughout the year, which is the key to solving food problems in the future. As a core technology in artificial light plant factories, light technology has complex procedures and implementation processes. Thus, to streamline the regulation of the artificial light plant factory's light environment, this paper devises an artificial light plant factory light environment detection system. It leverages sensor technology, ZigBee technology, and agricultural Internet of Things technology to achieve real-time monitoring of the internal light environment within the plant factory. This, in turn, assists in the management and exploration of the artificial light plant factory's light environment.

In paralle with the innovation of artificial light plant factory technology, light technology also presents an increasingly miniature and gradual change [ ]. To advance the automation of agricultural product cultivation and production within artificial light plant factories, the evolution and enhancement of light environment detection technology will continue.

REFRENCES

[1]. Lu , T. G, Wang , Y. F, Lu, H.N male. Design and implementation of the dynamic regulation function of the artificial light-type plant factory lighting system [J]. China Lighting Appliances, 2022 (07): 20-25.

[2]. Dong , J. R, "Internet + Agriculture" reshaping the agricultural industrial chain —— diagram "The 13th Five-Year Plan" National Agricultural and Rural Informatization Development Plan " [J]. Agricultural Economy, 2016 (10): 14-15.

[3]. Liu , W. K, Analysis of the definition and classification methods of plant factories [J]. Journal of Lighting Engineering, 2016,27 (05): 83-86.

[4]. Liu, W. K, Application strategy of LED short-time strong light irradiation to enhance the quality of leaf vegetables in plant factories [J]. China Lighting Appliances, 2021, No.437 (08): 11-14.

[5]. Yang , Y. T , Wei , L. L, Wei ,Q, Yang , Q. C, Application of LED in facility Horticulture Series (V) Application of LED in greenhouse light supplement [J]. Agricultural Engineering Technology (greenhouse gardening), 2009 (09): 15-16.

[6]. He, X. Y, Liu, H. C, Progress in the application of light intensity fluctuation illumination in plant factories [J]. Agricultural Engineering Technology, 2022,42 (16): 49-56.

[7]. Wu, R.J, Ji, Q, Cheng, M, etc. Optimal design method of light uniformity of LED plants based on multilight lamp beads [J]. Journal of Lighting Engineering, 2022,33 (06): 52-60.

[8]. Duan, Y.L, Effect of different light matter on the enzyme activities of glutamate synthetase and calmodulo system in wheat seedlings [J]. Journal of Huazhong Agricultural University, 1999 (05): 409-412.

[9]. Liu ,W.H, Gao, D.S, Zhao, H.L, Yang ,R. Effect of different light intensity on reactive oxygen species metabolism in facility peach trees [J]. Journal of Fruit Tree, 2006 (02): 186-190.

[10]. Du ,J.F, Liao,X.G, Ye, B.Q, Li ,M. Effect of light matter on rapeseed seedling growth and antioxidant enzyme activity [J]. Botanical Bulletin, 2002 (06): 743-745.

[11]. Hong ,Y, Tong ,Z. Role of phytochromes in plant ontogeny [J]. Plant Physiology Communications, 1998 (06): 417-422.

[12]. Liu, W.H, Gao ,D.S, Shu, H.R. Effects of different light intensity treatments on photosynthesis and fluorescence characteristics of peach trees in facilities [J]. Agricultural Science of China, 2006 (10): 2069-2075.

[13]. Ai ,X.Z, Guo ,Y.K, Ma ,X.Z, Xing, Y.X. Light demand characteristics and chloroplast ultrastructure of cucumber in solar greenhouse under low-light conditions [J]. Agricultural Science of China, 2004 (02): 268-273.

[14]. Zhang, R.J, He, Z.Q, Liu, Y.H, etc. Effect of light intensity on the growth and quality of apricot in plant factories [J]. Journal of Northwest Agriculture, 2022,31 (07): 886-892.

[15]. Li ,L.B, Hu, Z.H, Wang, G.L, etc. Exploration of the relationship between LED spectra and plant factory production promotion [J]. Journal of Lighting Engineering, 2021,32 (02): 6-9.

[16]. Zhu, B. Research on the monitoring system of the smart agricultural greenhouse based on the Internet of Things Technology [J]. Southern Agricultural Machinery, 2023,54 (06): 84-86.

[17]. Wang, K.Q. Application and development trend of light sensor principle [J]. Sensor World, 2021,27(02):1-5.DOI2021.02.001.

[18]. Huang, H.X. Intelligent farmland monitoring system based on sensing and detection technology [J]. Electronic production, 2022,30 (01): 31-33.

[19]. Zhou, Y.H. Effective realization of SCM in agricultural intelligent irrigation system [J]. Computer Products and Circulation, 2020 (11): 276.

[20]. Yan, J.H, etc. Intelligent water-saving drip irrigation system based on STM 32 SCM [J]. Internet of Things Technology, 2022,12 (01): 55-56.

[21]. Qu, X.Y,etc. Design and implementation of plant factory intelligent control system based on cloud platform [J]. Foreign electronic measurement technology, 2020,39 (07): 115-120.

[22]. Xiao, C.B, Wei, Y.L, etc. Design of environmental monitoring system for agricultural greenhouses based on Aliyun [J]. Internet of Things Technology, 2023,13 (04): 26-30.

[23]. Yang, Q.C, Chen, X.L, Li, K. Design points of artificial light plant factory system [J]. Agricultural Engineering Technology, 2018,38 (19): 14-19.

[24]. Zhang, S.F. The development status and future technology development trend of artificial light plant factory [J]. Agricultural Engineering Technology, 2020,40 (16): 64-67.