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Research on Collaborative Method of Road Smart Lighting

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Abstract. Road Smart Lighting uses networked street lights and smart models for research and application, enabling them to meet the different needs of urban road lighting dynamically. The article goes deep into the understanding of the concept of smart lighting and clarifies the difference between intelligent lighting and smart lighting, which is of great significance for the application optimization of smart lighting. According to the road lighting standard, this paper proposes a street lamp terminal coordination scheme based on the perception layer to solve the problem of insufficient linkage of street lamp terminals. In addition, the energy consumption caused by the "Constant light mode" in road lighting and the lack of coordination and coordination of streetlight terminals in the lighting control system is improved.

1.   Introduction

In the development process of smart lighting, the embarrassing situation of "information island" is the first bottleneck encountered in the growth of related industries [1]. The "information island" originated from the fact that there is no standard for the integration of the concept of smart lighting in China, which leads to the existence of separate industries. The concept of smart lighting and smart lighting in the country is mixed in academic journals, and there is no clear distinction. In the face of intelligent lighting, basic concept research plays a pivotal role in development and application. Therefore, the paper gives a clear definition of lighting from traditional to intelligent and plays a supporting role in the optimization of subsequent road applications.

For road lighting, domestic and international research focuses on intelligent lighting control systems at present. There are mature application systems and architecture systems for street lighting control, and less research on regional linkage control [2], and the coordination of road lighting is better. low. In this paper, the idea of "lighting + information" is used to optimize the coordination between single lamps in lighting control, and a sensitive sensing layer control strategy is proposed to solve the problem of insufficient linkage of street lamps to improve lighting management efficiency.

2.   Analysis of lighting concept

2.1.   Traditional lighting concept

Illumination refers to the use of natural light or artificial light to provide sufficient illumination for the service object to complete the display or navigation function. The display illuminates, illuminates the target to reflect the human eye, and achieves the target positioning; guides the person to advance toward the target, removes obstacles, and contributes to advance.

Traditional lighting applications use light to achieve aesthetic effects, and as a medium to connect people and the world through display and navigation, to achieve deeper connections and awareness of the world. Traditional lighting is therefore defined as the stage of "lighting is lighting".

2.2. *Intelligent lighting concept*

In traditional lighting, the concept of intelligence is introduced. The intelligent means that functions such as sensibility, controllability, judgment, and memory can be developed into the basic things, thereby realizing the upgrading of product functions. On the basis of light illumination, intelligent lighting uses sensors, control systems and other technologies to make lighting with intelligent and intelligent functions such as colour temperature, brightness, timing control, etc., to meet the individualized functional requirements of people in the basic lighting standards. The core is to provide the right lighting at the right time and place, including the right colour temperature, lighting duration, and lighting dimming. Intelligent lighting incorporates considerable sensible and controllable functions, surpassing the display illumination in traditional lighting, extending the guiding navigation of traditional lighting and defining it as the stage of "lighting is not just lighting". According to the European Lighting Association's 2025 strategic roadmap, as shown in Figure 1, people-oriented lighting is the ultimate development goal of intelligent lighting.
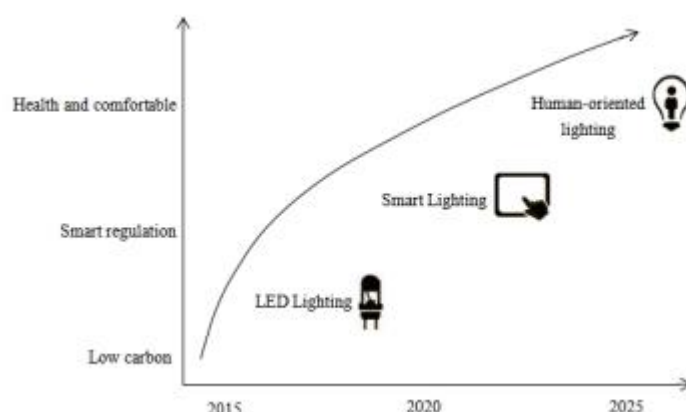

Figure 1. Intelligent lighting development prospects

2.3. *Smart lighting concept*

Smart lighting is an ecological model that is realized after the intelligent lighting system is applied to the environment, and is a more advanced stage of intelligent lighting. The aim is to create an ecological model of "light", "domain" and "cloud", with light as the core, as a terminal for sensing demand and intelligent operation; focusing on the domain, using sensors and protocols to build a local area network for data processing and transmission. The final data is uploaded to the background supervision system through the cloud server, analysed and then fed back to the terminal for intelligent operation. Smart Lighting continues to improve and upgrade the standards and communication protocols in previous lighting, gradually forming its own architecture, returning to the stage of "lighting is lighting", completing a new upgrade cycle and leading the industry forward.

3. Lighting quality indicator

The fundamental purpose of road lighting is to achieve harmony and balance between people (car drivers) and the environment and to provide drivers with comfortable and safe visual conditions always ranked first [3]. Therefore, all quality indicators of a road are evaluated, taking into account two aspects of human visual function and visual comfort. Including the average brightness of the road, brightness uniformity, glare control level and visual guidance.

The average brightness of the road surface is the arithmetic mean of the brightness of all calculated points on the whole road surface, expressed as:

$$L_{av} = \sum_{i=1}^{n} L i \cdot (n)^{-1} \qquad (1)$$

L_{av} is the average brightness of the road surface; Li is the brightness of the first calculation point; n is the total number of calculation points.

Brightness uniformity is defined as the ratio of the minimum brightness to the average brightness on the road surface.

$$U_0 = L_{min} \cdot (L_{av})^{-1} \qquad (2)$$

L_{av} and L_{min} are the average brightness and minimum brightness of the road respectively.

The threshold increment (TI) refers to the disability glare in the glare control level, meaning that to compensate for the decrease in the viewer's visual resolution due to the glare source, what percentage of the brightness level should be increased accordingly.

The percentages of objects set on the road surface are called display capability. The concept of display capability is proposed to study the influence of average brightness on visual function. The relationship between average brightness, brightness uniformity, and display capability is shown in Fig. 2 and Fig. 3
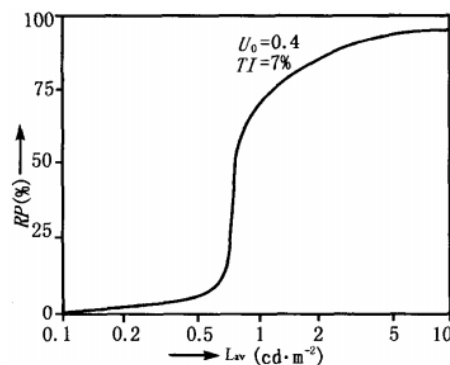

Figure 2. Relationship between average brightness and display ability
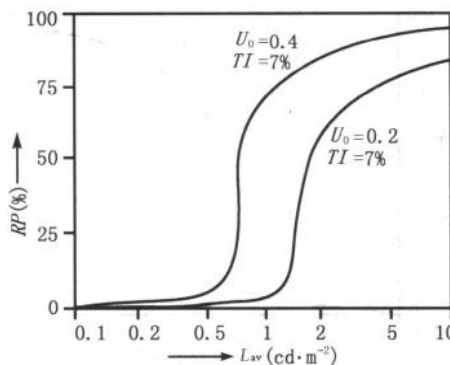

Figure 3. Relationship between display capability and brightness uniformity

According to the standard value of road lighting in China, the overall uniformity U0 of the road surface is 0.4, the maximum threshold increment is 7%, and the display capacity index increases when the average brightness of the road surface is 0.5cd·m^{-2} to 1cd·m^{-2}. When the average brightness reaches 2cd·m^{-2}, the display capacity reaches the highest; after more than 2cd·m^{-2}, the display ability gradually becomes flat [3]. The road surface brightness uniformity in the road lighting standard shall not be less than 0.4. In the same threshold increment in Figure 3, the average road surface brightness is the same. If the road surface uniformity is lower, the display capability is smaller [3].

4.   Current status of intelligent street lighting systems
Urban street lighting intelligent lighting system design is the most widely used case of smart lighting in the road. Through the transformation of street lamps, the high-power high-pressure sodium lamp is

transformed into an energy-saving LED lamp, and a single-lamp controller is added to the LED street lamp, and all the street lamps are information-managed and managed by PLC (power line carrier) or ZigBee protocol. Monitoring, inspection and other functions [4]. The current intelligent lighting control system framework is mainly divided into the sensing layer, the data transmission layer and the data processing application layer [5]. Its system framework is shown in Figure 4. The sensing layer forms a local area network with a node controller to form a local area network, and the centralized controller uses wireless transmission to communicate with the sensing layer and the data transmission layer. After receiving the data of the node, the centralized controller transmits the data to the cloud server for backup through GPRS. The cloud server sends data to the background management system. After the background management system analyses the data, the processing result is fed back to the street lamp node through the centralized controller. And dimming the street light, so the centralized controller acts as a "communicator" in the system, which can upload the data of the street light node to the cloud server and the background management system, and can also send the background management system dimming command to the street light terminal [6].
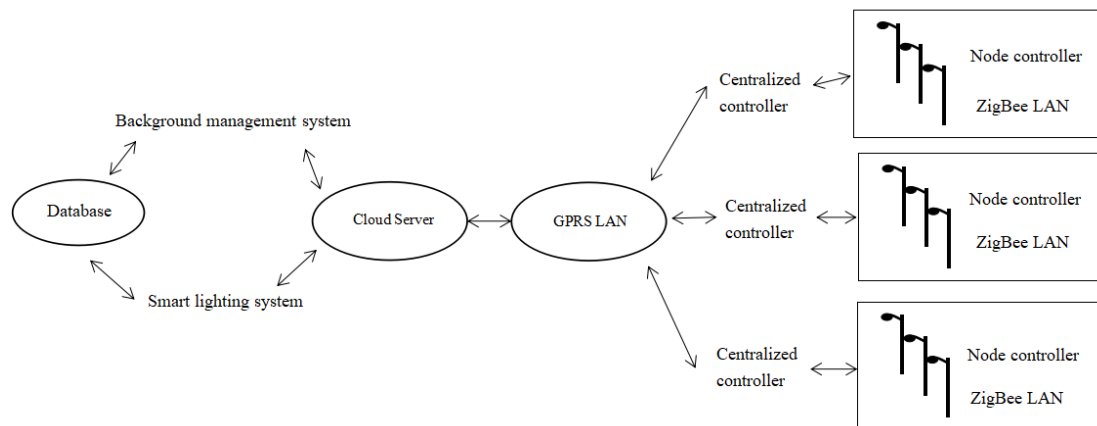

Figure 4. Urban street light intelligent lighting control system framework

At present, the street lighting control system has been perfected and has the prototype of intelligent lighting, but there are also some problems. For example, the different emphasis of various control schemes leads to the problem of the imperfect system; in the solution, the functionality, reliability, interoperability, especially security of various IoT devices are not perfect enough [7]. The most important part of the terminal perception layer is the coordination problem between multiple lights. At present, the intelligent lighting control system has little research on the multi-lamp linkage coordination for the terminal. Linkage collaboration means that the street light collects various information through the sensor, and through the linkage with each other, judges and filters the information, and finally uploads the information of the function demand to the regional coordinator, thereby increasing the efficiency of the street lamp information collection, thereby improving the lighting management efficiency [8].

5.   Sensor layer-based street lamp terminal coordination scheme

5.1.   Terminal node and coordinator introduction

The collaborative scheme divides the entire streetlight network into different areas, and one area includes a three-node terminal and a zone coordinator of the road separation zone [9]. The node terminal refers to the environmental sensor which is included in a single street light, and the regional coordinator is the "team leader" of the node terminal, which is responsible for uploading data and issuing instructions. The node terminal integrates functions such as environmental information collection, vehicle information detection, and street light control. It is mainly divided into two parts: information collection and lighting control. The node terminal is responsible for information collection and uploading data. The coordinator is responsible for collecting and comparing information and issuing control commands.

5.2. *Linkage distribution control strategy*

The environmental information obtained by a single street light terminal is relatively independent and the accuracy is relatively low, so single lamp control has certain limitations in practical lighting control applications [10]. Aiming at this problem, the urban secondary road is selected as the environment application object, and the linkage distribution control structure based on the perception layer is proposed. The distribution control structure is shown in Figure 5. The method of joint decision between multiple node terminals and the coordinator is used to improve the accuracy of lighting control. The specific steps of the entire linkage process are as follows:

The direction of coordinated control of the area is determined by the driving direction. When the vehicle passes through the area 1, the node terminal recognizes the traffic volume and the vehicle speed. The area coordinator collects the traffic volume and the vehicle speed recognized by the node terminal and calculates the average value. After the analysis, the signal is sent to the node terminal [11]. The instructions for brightness control are strictly controlled according to the standard values of motorway lighting in China, as shown in Table 1. When the traffic volume is low, the average brightness of each node terminal is controlled at about 0.5 cd·m^{-2}, so that the RP percentage reaches 15%. When the traffic volume is high, the street lamp of the node terminal controls the average brightness to 1~2 cd·m^{-2}. The percentage of RP is above 75%. The regional coordinator sends the traffic flow average information to the coordinator of the next region at the same time as the command to the node terminal is issued, as a reference for the next region information collection and comparison.

Table 1. China's motorway lighting standard value.

level	Road type [b]	Brightness		Illuminance	
		Average brightness L_{av}/(cd•m^{-2})	Total uniformity U_0 minimum	average illumination E_{av}/lx	Total uniformity U_e minimum
I	Highway	1.5/2.0[a]	0.4	20/30[a]	0.4
II	Main road	1.0/2.0[a]	0.4	20/30[a]	0.4
III	Secondary road	1.0/0.5[a]	0.4	15/20[a]	0.4
IV	Branch road	0.5/0.75[a]	0.4	8/10[a]	0.3

[a] Table gives two standard values for the average brightness and average illuminance of each level of road, the left side of the "/" is the low value, and the right side is the high value.
[b] Values in the table are only for dry roads.

When the vehicle passes through the area 2, the node terminal continues to identify the traffic volume and the vehicle speed and uploads the data to the coordinator. The coordinator compares the information received in the previous area with the information uploaded by the node terminal [12]. If the traffic information is not significantly different, then According to the average brightness standard of the previous area node, if the difference is obvious, the node command is given, and the average brightness is increased or decreased accordingly so that the RP value meets the requirements of the current environmental information.
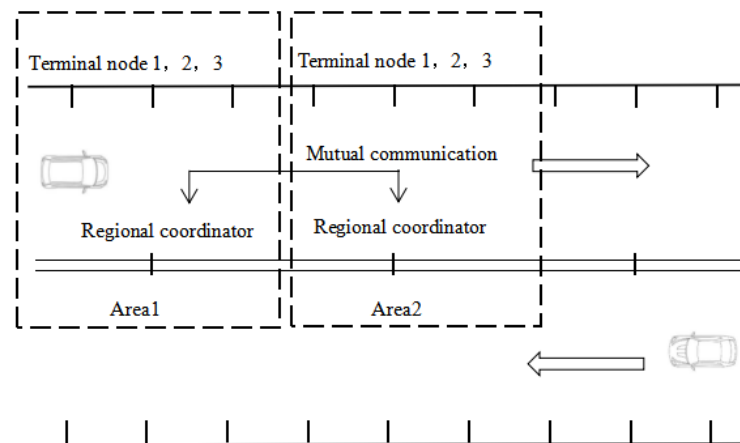
Figure 5. Distributed control structure

The street lamp terminal cooperation scheme is uploaded to the coordinator through the node terminal, and then the information is compared by the coordinator to improve the judgment efficiency of the street lamp on the road information [13]. Enhancing sensory ability is the most basic function to achieve intelligent lighting. The synergistic scheme combines the single lights of the road into a linkage distribution control structure. By constructing the structure, the node terminals can realize mutual communication and mutual linkage effects, thereby solving the problem of insufficient linkage of the streetlight terminals of the sensing layer, and improving Lighting management efficiency.

6.   Conclusion

The article takes the basic concept research as an entry point and summarizes the different concepts and functions involved in the process of lighting from traditional to intelligent. It proposes that "lighting is lighting" - "lighting is not just lighting" - "lighting is lighting" Upgrade development cycle. The study of basic concepts helps to promote the establishment of a smart lighting standard system, and establishes a theoretical basis for the healthy development of the smart lighting industry. The current situation of the intelligent street lamp control system is analysed, and the problem of poor linkage of the terminal streetlight control part of the current perception layer is summarized. A linkage distribution control strategy for intelligent lighting is proposed. According to the traffic density, road lighting is strictly followed. The quality index is controlled by brightness, which improves the management efficiency of lighting control and reduces the lighting energy consumption, reduces the waste of lighting resources, and improves the efficiency of lighting management.

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