Adjustable Irradiance Prototype of Smart Street Lighting System by Using Simple Optical Components

Jiann-Hwa Lue[1], Ting-Jou Ding[2], Rong Seng Chang[1], Shen Cherng[3], Tai-Chuan Ko[4*], Shuan-Yu Huang[5,6*], Wen-Ming Cheng[7]

[1] Department of Optics and Photonics, National Central University, Chung-Li, Taiwan 320, R.O.C.
[2] Department of Electro-Optical and Energy Engineering, Ming Dao University, Chang-Hua, Taiwan, R.O.C.
[3] Department of Computer Science and Information Engineering, Chengshiu University, Kaohsiung, Taiwan, R.O.C.
[4] Department of Optometry, Jen-Teh Junior College of Medicine, Nursing and Management, Miaoli 356, Taiwan, R.O.C.
[5] Department of Ophthalmology, Chung Shan Medical University Hospital, Taichung 402, Taiwan, R.O.C.
[6] School of Optometry, Chung Shan Medical University, Taichung 402, Taiwan, R.O.C.
[7] Metal Industries Research & Development Centre, Kaohsiung, Taiwan, R.O.C.
kcc33546@gmail.com, syhuang@csmu.edu.tw

Abstract: In this study, an adjustable irradiance prototype of street lighting system with several optical components and simple control circuit interface are demonstrated. By using several photoresistor sensors and data acquisition (DAQ) card, the control center of system can adjust suitable irradiance of street lamps automatically. The system will respectively supply 50% or 100% of irradiance of the street lamps depending on its detection of the insufficient environment light or sensing vehicles and pedestrians. Therefore, this street lighting system can provide sufficient irradiance to vehicles and pedestrians whenever needed. As a result, when we use LEDs street lamps and smart street lighting system simultaneously, both of the electric energy wasted by traditional street lamps and cost could be saved as well.

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1. Introduction

Nowadays, the advancing smart street lighting system has improved a waste of the electric energy. According to statistic studies, most of the electric energy in the world is consumed by street lamps. [1] By use of the automatic switch systems, street lamps are turned on at night and turned off in the daytime. This huge waste of electric power in the world can be solved by the smart street lighting system. [2]

In recent articles, many researchers have paid more and more attention to three solutions. For a smart street lighting system, most researchers use LEDs light source and remote management center to control and manage the turn on/off and brightness of cluster of street lamps [3] to reach the goal of electric energy and cost saving. [4,5]

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In this study, we propose a prototype of smart street lighting system that has extension capability in the future. This system uses several optical sensors to monitor the environmental status and accords the received data to adjust the irradiance status of lamps.

2. Concept of the system

The design concept of smart street lighting system is setting up two optical photoresistor detectors (remarked as sensor A and sensor B) respectively at the street model. Sensor A is used as environment irradiance detector and sensor B is used as vehicle or pedestrian detector. When the sensor A detects the decrease of irradiance of the natural illumination, it will send an insufficient irradiance signal to the system control center by DAQ card and then the system will feedback a command signal to switch on all street lamps with 50% irradiance. The percentage of irradiance can be adjusted by the user setting. When vehicles or pedestrians are passing through the branch street, the sensor B will immediately transmit a trigger signal to the control center by DAQ card and then the system will feedback a command signal to successively increase the irradiance of the lamps up to 80% or 100%. As vehicles or pedestrians are leaving the outlet of the street after a period of time, the control center will reduce and return the irradiance back to the initial condition with 50% irradiance.

3. Devices and methods

(a) Devices

In this experiment setup, LEDs and photoresistors are the key optoelectronic components.

High brightness LEDs are used to replace the street lamps.

The photoresistors (CDS) are small optical sensors. As their squiggly surface is illuminated by light, the resistance goes down and it is about 5-10KΩ. When it is dark, the resistance goes up to 200KΩ. Normally, resistors are common parts in all types of electric circuits and their function is to block the flow of electricity through a circuit. Especially, a photoresistor can also be used as a switch to regulate the flow of electricity according to the illumination. In this study, we also adopt the optical switch function of a photoresistor.

(b) Software and hardware

The controlled program is developed by LabVIEW software (National instrument), which is the most popular and powerful commercial tool for engineering and science. This program possesses the capability of integrating all control communication, for example, GPIB, VXI, PXI, RS-232, RS-485 interfaces and so on. Also, it supports the Data Acquisition (DAQ) and Image Acquisition. Figure 1 is the picture of DAQ card and its model number is NI USB-6008 multifunction (LED-based). Data acquisition card and LabVIEW program are used to design the smart street lighting systems of this study. The LabVIEW program of this system is shown as figure 1(b).

Figure 1 (a) The hardware of the control interface, DAQ card.

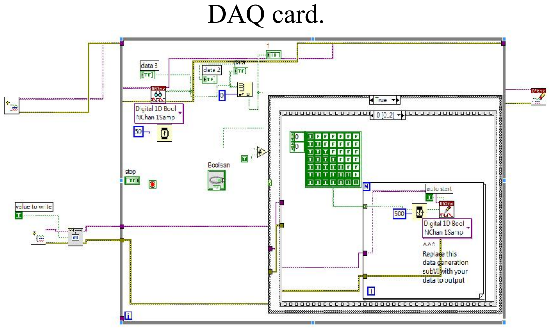

Figure 1 (b) The program of the control software in LabVIEW.

4. System buildup and test

The system buildup flowchart is shown as figure 2. For the consideration of practical applications, each part of the system is inspected and debug by the control center, which is program in LabVIEW. The main tests include environment sensor test, vehicle or pedestrian sensor test, LEDs light up test and LEDs modulation test. Figure 3 is the lighting modulation test of the LEDs connected with DAQ card.

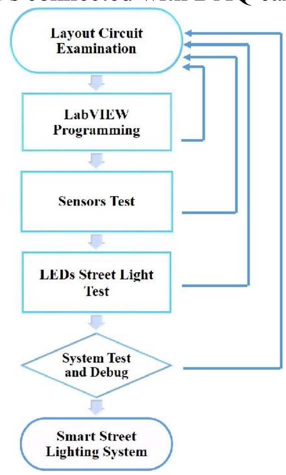

Figure 2. Tests and debug flowchart of smart street lighting system.

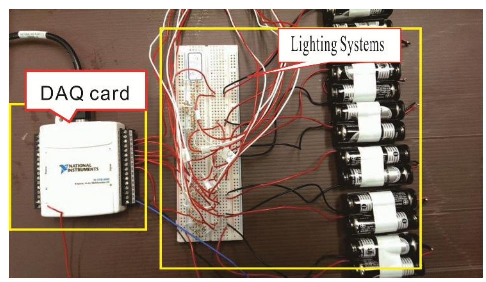

Figure 3 (a)

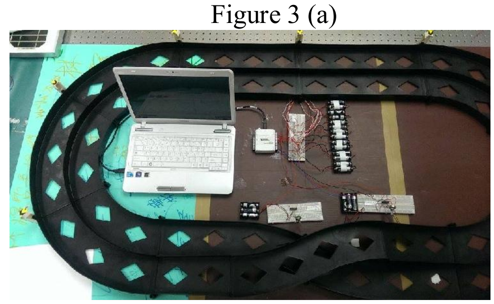

Figure 3 (b)

Figure 3. Lighting modulation test of LEDs. (a) Assembled LEDs connected with DAQ card. (b) The lighting modulation control centor is based on the laptop and DAQ card.

The smart street lighting system is shown as figure 4. Figure 4(a) shows that when the sensor A detects insufficient environment irradiance, all the LEDs have been turned on with 50% irradiance. Figure 4(b) illustrates the irradiance of LEDs have been increased to 80% or 100% when the sensor B detects the test car passing through the branch street. Moreover, the system will return back to the initial lighting state, which the irradiance of each LED is 50% after the car is leaving the outlet of this branch street for a period of time. The period can be adjusted in the control center.

Considering the safety for the pedestrians and the vehicle drivers, it is better to keep all street lamps in the irradiance of 50% at least in general situation. As long as vehicles and pedestrians are going to pass through the street, the smart street lighting system will increase the irradiance in advance. Therefore, the efficiency of energy saving is obvious.

Figure 4(a) Lamps are turned on by smart street system when the sensor A detects the insufficient irradiance of environment.

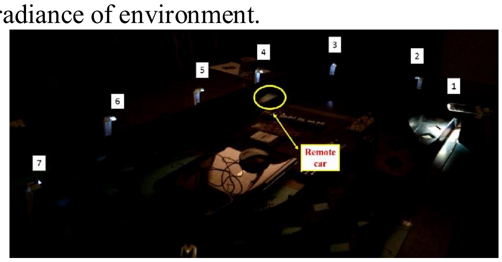

Figure 4(b) Smart street system increases the irradiance of lamps when the sensor B detects the remote car is passing through the street.

5. Conclusion

In this article, a proposal prototype of smart street lighting system with several simple optical components and DAQ card is demonstrated. By using several photoresistors to detect the irradiance of the environment, the system can successfully adjust the irradiance of street lamps automatically. As the environment irradiance is insufficient, this system will turn on lamps to reach 50% of irradiance. It will also turn on lamps to reach 80% or 100% irradiance while sensing vehicles and pedestrians. Therefore, this street lighting system is able to avoid the disadvantage of traditional street lamps, which always keep 100% irradiance in certain period and it can provide vehicles and pedestrians sufficient irradiance whenever needed. As a result, if we use LEDs street lamps and smart street lighting system at the same time, the electric energy and cost can be greatly saved as well.

Corresponding Authors:
Shuan-Yu Huang
Department of Ophthalmology, Chung Shan Medical University Hospital, Taichung 402, Taiwan, R.O.C.
School of Optometry, Chung Shan Medical University, Taichung 402, Taiwan, R.O.C.
E-mail: syhuang@csmu.edu.tw

Tai-Chuan Ko
Department of Optometry, Jen-Teh Junior College of Medicine, Nursing and Management, Miaoli 356, Taiwan, R.O.C.
E-mail：kcc33546@gmail.com

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