TẠP CHÍ KHOA HỌC
TRƯỜNG ĐẠI HỌC QUY NHƠN

Thiết kế hệ thống điều khiển và giám sát theo hướng thông minh cho đô thị có hệ thống chiếu sáng phân tán

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TÓM TẮT

Hiện nay, các hệ thống chiếu sáng đô thị theo hướng thông minh có thể điều khiển và giám sát đến từng điểm trên nền tản IoT. Nhưng làm như vậy chưa thực sự phù hợp về chi phí với các nước đang phát triển. Bài báo đề xuất giải pháp điều khiển và giám sát cho các dãy đèn trên từng tuyến phố. Nghiên cứu này đã sử dụng cảm biến ánh sáng để phân biệt ngày và đêm, cảm biến hồng ngoại để đếm lưu lượng phương tiện đang lưu thông trên phố. Từ đó điều khiển đèn trên phố phù hợp với lưu lượng giao thông. Bên cạnh đó, tại phòng điều khiển trung tâm các kỹ sư và kỹ thuật viên có thể đặt lệnh điều khiển cụ thể cho các nhóm đèn trên các tuyến phố, nhằm đảm bảo lượng ánh sáng rực rỡ cho một số đường phố trong những ngày hội. Trạng thái của các dãy đèn trên phố, cùng các thông số đo lường được giám sát ở phòng điều khiển. Giải pháp đã đề xuất vẫn đảm bảo điều khiển linh hoạt, thích nghi với lưu lượng phương tiện giao thông và tiết kiệm năng lượng.

Từ khóa: *Chiếu sáng đô thị, chiếu sáng đường phố, điều khiển và giám sát hệ thống chiếu sáng đô thị, chiếu sáng thông minh.*

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Design of control and monitoring system for smart distributed urban lighting system

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ABSTRACT

Currently, smart city lighting systems can be controlled and monitored to each light source on an IoT platform. But those systems are not cost-effective for developing countries. This paper proposes a control and monitoring solution for lights on each street. In this research, light sensors are used to detect day or night, and infrared sensors are used to count the traffic volume on each street. On this basis, lights on the street are controlled in accordance with the traffic density. In addition, in order to ensure the high light intensity for some streets during festivals, engineers and technicians can set specific control commands to groups of lights on those streets at the central control room. The on or off state of groups of street lights, and measurement parameters are monitored in the control room. The proposed solution still ensures flexible control, adapts to traffic volume and saves energy.

Keywords: *City lighting, street lighting, control and monitoring of city lighting systems, smart lighting.*

1. INTRODUCTION

Economical and highly efficient use of energy sources, especially electricity are very importantbecause it both saves money and protects the environment through prevention of global warming, ozone depletion, environmental pollution, and natural disasters, etc.

The more developed cities become, the more complete the infrastructure of smart cities is. The public lighting system makes the city brilliant at night, and contributes to ensuring traffic safety, security and order. Hence, the smart public lighting system play an important role in city development.

Although a lighting system has an important role, it is distributed throughout the urban area. Therefore, lighting systems is not easy to manage, control and monitor. So far, only a few cities in Vietnam have applied technology to manage and control of public lighting systems, such as Hanoi, Ho Chi Minh City, etc. However, these systems also have certain limitations. Besides, some parts are not suitable for Industrial Revolution 4.0.[1] Presently, the lighting system is still manually managed in most cities and towns in Vietnam. For example, the public lighting system in Quy Nhon city is currently manually operated. Operators must go to many places, where the control cabinets are located, to set the time to turn on and off lights, monitor and manage the system. Therefore, this system is not operated flexibly, not promptly changed according to the weather, not followed actual needs, so its operation is not saving energy and not economical.

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Nowadays, in the world, the control technology for each light source that is suitable for the presence of vehicles on the road has been researched.[2-6] According to this control method, at each light source there is a control circuit which connects to infrared sensors, a light sensor and connects to a communication module. Moreover, in order to monitor all street lights at the control center, this center connects to each light group via a motherboard connected to all light sources in this group. However, it is not really cost-effective for developing countries like Vietnam in case this control and monitoring method is applied on a large scale.[1]

In Vietnam, Electric and Telecommunications Technologies Corporation has researched and designed a system to control public lighting from the center through a mobile communication network based on the web server, which is tried in Bac Giang in 2016.[7] The system consists of a control center integrated data monitoring software on computers, field cabinets measure the parameters of current, voltage, transmitter receiver devices transmit signals via the mobile communication network (with SIM card) to the control center. At the control center, operators can detect the problem, turn on and off street lights, and switch off alternating phases easily and conveniently. However, this system does not yet contain adaptive control for weather and traffic volume.

Besides, the control urban lighting system had been also researched and designed towards smart and energy saving based on the application of communication techniques via GSM/GPRS/3G wireless network combining microcontroller and electronic power.[8,9] The function of controlling the on/off of the lighting system automatically according to weather forecast or predetermined switching schedule are augmented into monitoring and control system. This urban lighting control system is commanded entirely from the control center. However, this system is not capable of detecting vehicular traffic on the street, where the lights are directly illuminated.

Moreover, the smart public lighting system using LEDs designed by a research team at Ho Chi Minh City University of Technology consists of 3 parts: LED light set, control cabinet combined with gateway, and control center. [10] At lights is also equipped a control circuit and a data transmission device with a connection to a control center, to control and measure the parameters of those lights. A lights group is controlled directly or automatically turns on and off remotely by a control cabinet, which also performs measurements of various parameters in the street lighting grid. At the supervisory - control center, the system allows monitoring overload, voltage, phase error, and the energy consumption during the day and night to be also reported in real time. This system is a type of control to each light source, so its installation cost is not suitable for large-scale deployment in Vietnam.[1]

In general, current studies in Vietnam still have some inappropriate points as mentioned above. Therefore, the goal of this paper is to build up a smart urban lighting system capable of automatically and appropriately with parameters collected such as traffic density, weather, etc. In addition, this system is connected to computers and smartphones through wireless communication. Operators can easily manage the system no matter where they are. Currently, there are many projects that are interested in investing in this field, such as Sapulico Company projects,[11] or Asian Development Bank (ADB) projects,[12] etc.

2. SOLVING PROBLEM

2.1. Research method

This research comes from the fact that the public lighting system in urban areas still have some inappropriate points and less flexibility. This study has analyzed the technical requirements of public lighting systems. Based on these requirements, this study has proposed the design of a control and monitoring structure for the public lighting system that is flexible and adaptable to actual conditions. The flexibility and adaptability of the proposed system have been verified through experiment.

2.1.1. Technical requirements

An urban lighting system must be automatically turned on and off, and it is able to reducethe number of lights illuminating or the capacity of each light in the off-peak hours when traffic density is low to save energy. This control is done according to preset scenarios applied in most cities today or adapted to the actual conditions just implemented in some cities of developed countries.

The method of alternately turning off lights to reduce the number of lights illuminating is still used mainly in the urban lighting systems. This is done in the lighting control cabinet by two contactors that are controlled by two timer relays (Figure 1). A control cabinet as shown in the diagram in Figure 1 allows turning on or off the lights according to two different branches, thereby the number of lights illuminating is reduced in two different ways.[13]

It is possible to adjust the on and off time of lights by changing the parameters of the timer relayas usually suggested in the following scenario:

+ In the evening from 18h00 to 23h00, and from 4h00 to 6h00: 100% of the lights are turned on;

+ In the late night, from 23h00 to 04h00: a third of the total lights are turned off, and two-thirds of the total lights are turned on;

+ During the day from 06h00 to 18h00: all are completely off.

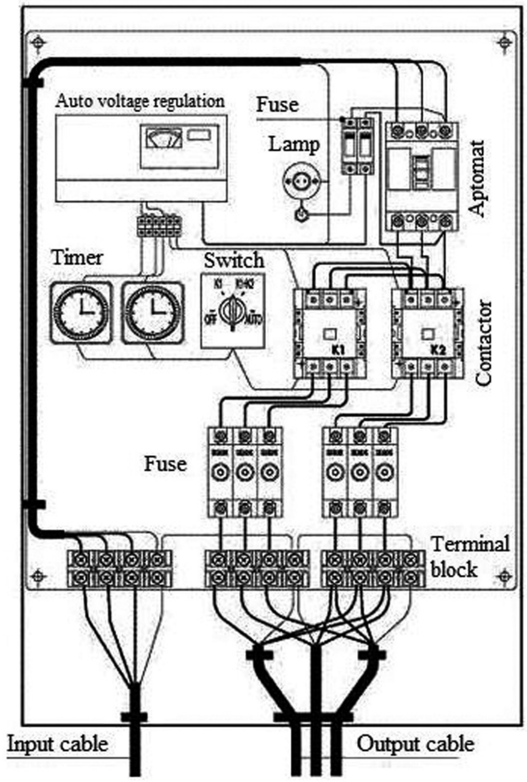

Figure 1. The structure of an ordinary lighting control cabinet.

2.1.2. Proposal of a control and monitoring structure of urban lighting system

Today, with the strong development of automation technology, and combined achievements of microelectronics and information technology, it is possible to create an automation solution in all fields. Automation has become an inevitable trend for all fields in any country and territory. Automation of smart urban lighting system is definitely an inevitable issue.

From the requirement techniques, a smart urban lighting control and monitoring system structure is proposed as can be seen in Figure 2.

At field level, values from the light sensor (the photoresistor sensor used in this study) and the infrared sensor are regularly read by a control circuit (an Arduino UNO circuit is used in this study). Light sensors are used in control cabinets to turn on lights when it is dark, and turn off lights at dawn. Infrared sensors are placed

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at the entrance points of streets. These sensors provide signals to control cabinets to reduce the number of lights illuminating when there are few people on the street. When the time between two detections of a passing person is far apart:

+ In case there is no traffic in more than 15 minutes, the number of lights illuminating will be reduced by a third;

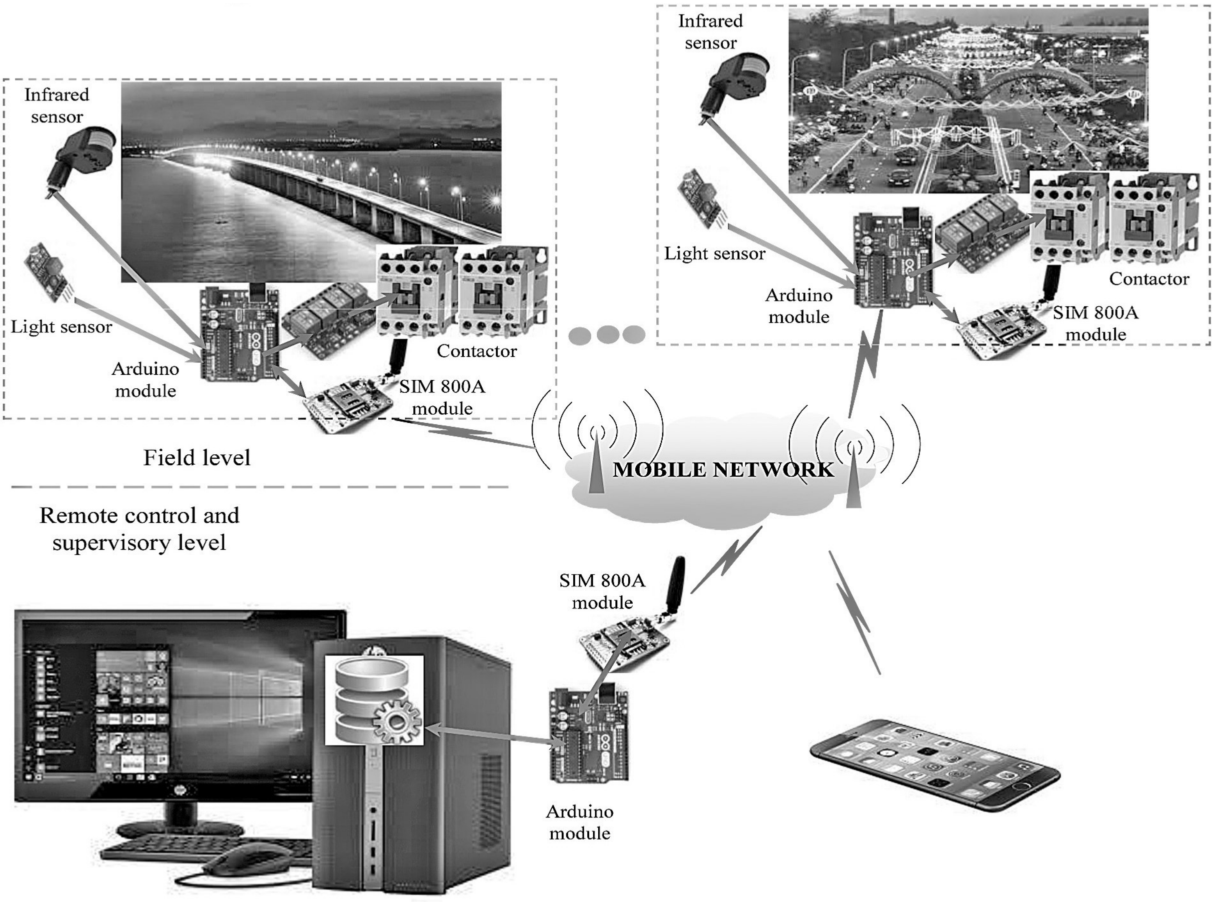

Figure 2. Structure of control and monitoring system for smart distributed urban lighting system.

+ In case this street is with vehicle in the next 15 minutes, the number of lights illuminating will be increased by a third;

+ In case there is no passerby in the next 15 minutes, then two thirds of the total of lights will be turned off.

All control commands and data monitoring of urban lighting system are saved on a server computer. Urban lighting system can be remotely controlled and monitored by smartphones or computers that are connected to data in the server via mobile network or internet. Control commands are set up on a software in smart-phones and computers. Then these commands are sent to control cabinets at the field level. The on or off state of lights and other parameters are collected by control cabinets. Then these signals are transmitted to the control center via the mobile network. Because sending commands and receiving parameters do not need to respond in real time (a delay is still an accepted). Consequently, SIM modules are used to connect wireless communication between the control center and control cabinets at the field level by sending and receiving messages. As a result, communication costs are reduced to a very low rate. The low cost of communication combined with the low cost of equipment in the control system are advantages of the system, making it easily applied on a large scale.

2.2. Research tools

The smart urban lighting control and monitoring system is designed on the basis of using commercially available devices and modules to ensure reliability in use.

The devices for interacting with users are computers and phoneswhich are popular today. Moreover, Arduino UNO R3 circuits, SIM 800A modules, infrared sensor modules, light sensor modules, intermediate relay modules, etc. are used this system. Besides, electrical power equipments are also used in lighting control cabinets, such as electricity meters, aptomat, contactor, etc.

2.2.1. Arduino UNO R3 module

An Arduino board consists of an AVR microcontroller with add-on components that make programming easy. An important feature of the Arduino is its standard connections, which allow users to connect the board's CPU to other modules. So, it is easy to change function and use target item. Expansion modules can communicate with the Arduino board directly via pins, or via serial communication I2C. Multiple modules can be stacked and used in parallel. ATmega series of AVR microcontrollers, especially ATmega8, ATmega168, ATmega328, ATmega1280, and ATmega2560 are usually used for Arduino.

Arduino allows to load program directly from the computer to the module through the USB port without using any other external module. Arduino circuits are programmed via USB thanks to built-in converter such as the FTDI FT232. In addition, some Arduino modules have other ways of connection, such as RS-232, or a detachable serial communication cable, or Bluetooth.

2.2.2. SIM module

GSM/GPRS SIM800A module (upgraded from SIM900A) integrated pulse source with compact design. But, this module still retains the necessary elements for the circuit to operate stably, including: high-current pulse source circuit, RS232 MAX232 communication IC, standard SIM slot and signal LEDs, GSM antenna. The SIM module is used for the purposes of calling, texting SMS GSM, and GPRS.

GSM/GPRS SIM800A modules communicate with the microcontroller circuits via UART serial communication. It is noted that microcontrollers using 5VDC need to add a logic level converter or voltage divider to 3.3VDC to avoid damage SIM modules.

2.2.3. Infrared sensor module

Infrared sensors use PIR technology to detect human movement. When a human movement is detected, its output is immediately activated. This module is connected to the Arduino circuit at the field level.

In particular, the sensitivity and the delay time to keep output’s state of infrared sensor modules can be adjusted. Moreover, users can also adjust the sensor to work only at night or all day and night.

2.2.4. Light sensor module

Photoresistor that is used to detect light intensity is a type of light sensor. The value of DO output of the sensor module depends on the light intensity of the environment. When it is bright, the DO output is 0. If it is dark, the DO output is 1. On the sensor module, there is a potentiometer to adjust the sensitivity to light intensity.

2.2.5. Relay module

Output power of Arduino UNO modules are not enough to drive contactors in the dynamic circuit. For this reason, it is necessary to use an intermediate relay as a control bridge.

Relay modules are suitable to convert from DC current to AC current. These modules are used for devices that consume high intensity current. These modules are compact design, with opto and transistor isolation, low level trigger (0V) suitable for all types of microcontrollers.

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2.3. Design and programming

2.3.1. Hardware design

The hardware of the urban lighting control and monitoring system is designed according to the system structure proposed above (as shown in Figure 2).

The controller and monitor at the field level is designed as demonstrated in Figure 3. Here, an Arduino circuit does the main task, including control, monitoring and communication. The other modules are responsible for supporting this circuit. Specifically, the light sensor module is used to detect whether it is bright or dark; infrared sensor module is used to detect traffic volume; relay module is a control bridge to contactors, that turn on or off lights; the SIM module is used to communicate with control and monitoring center; the DC module supplies power to the modules in this cabinet.

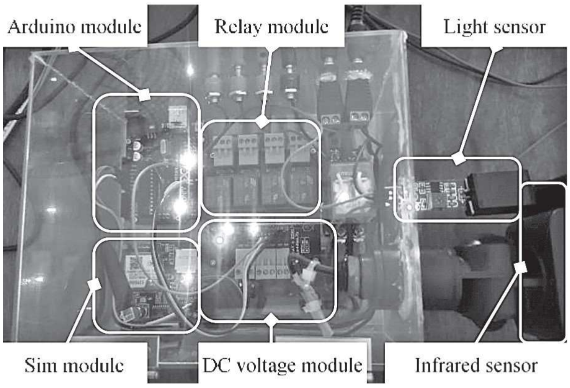

Figure 3. Controller, data collection and communication at field level.

In the control and monitoring center, a data and communication processor system is designed (as shown in Figure 4) to connect wirelessly to control cabinets at the field level. Here, the control commands from the computer are transmitted through an Arduino module, and then they are sent as messages by a SIM module. The data from the field levelsent in the form of messages - is received by the SIM moduleand then is forwarded through the Arduino module to the computer for monitoring.

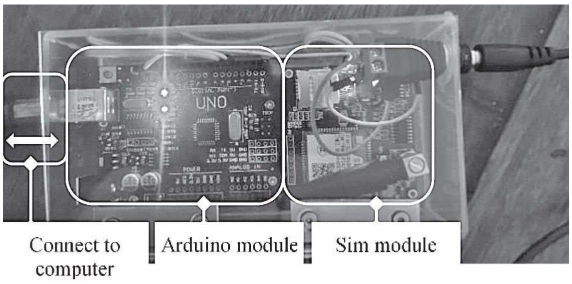

Figure 4. Data processing and communication in the control and monitoring center.

The designed urban lighting control and monitoring system was tested with a road that is a scale model with inside median lights (Figure 5).

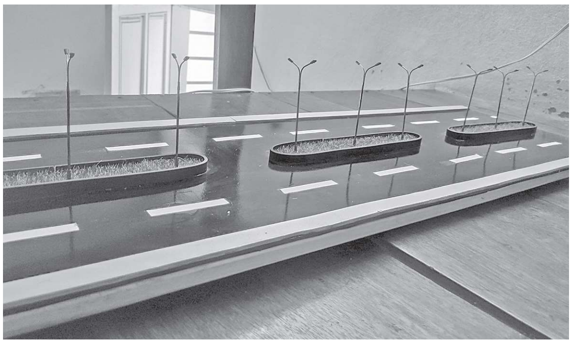

Figure 5. Experimental street light model.

2.3.2. Programming

a. Programming for Arduino at field level

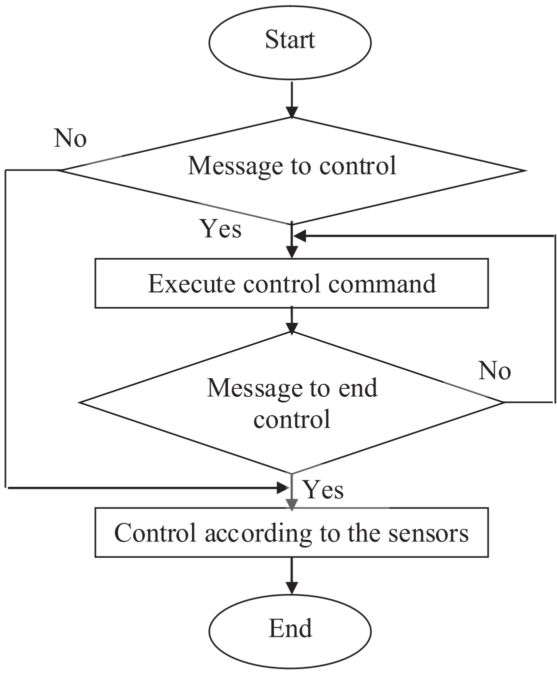

Figure 6. Algorithm flowchart of a program in a loop in Arduino at field level.

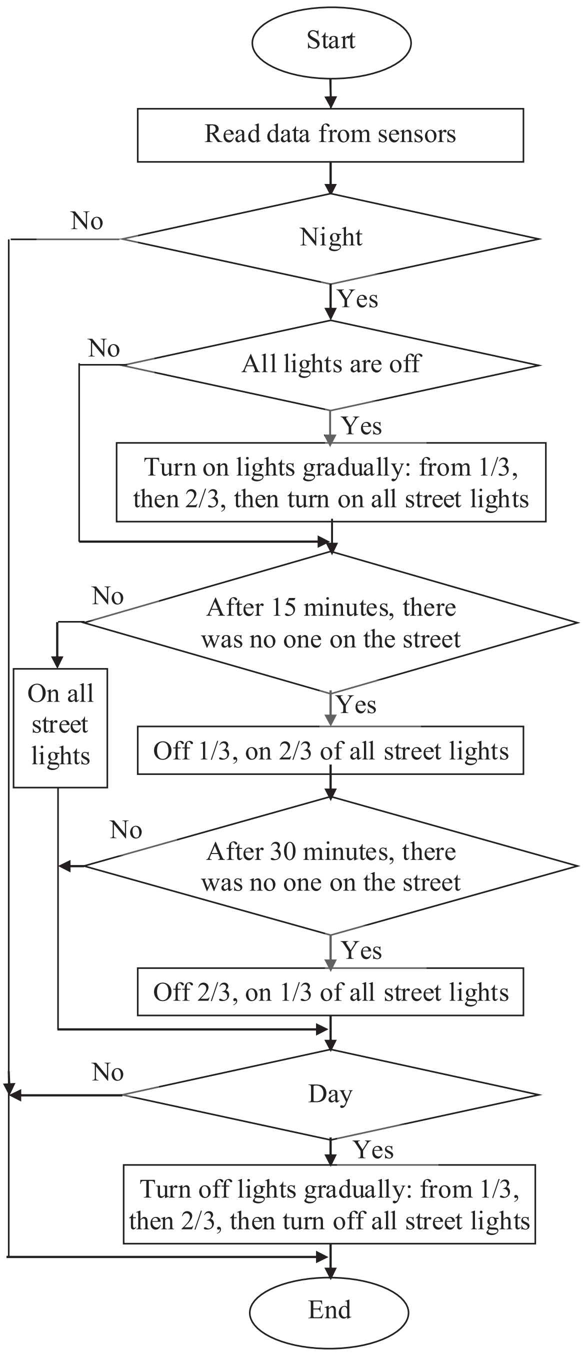

Figure 7. Algorithm flowchart of control program according to sensors in a loop in Arduino at field level.

At the field level, Arduino modules receive the control commands in the form of a message from the control and monitoring center and executes them (as flowchart in Figure 6). The control of the center is only done during holidays and festivals. If there is no control command from the center, the Arduino modules at field level collect information from the streets to control lights (like Figure 6 and Figure 7). The control method according to the collected information from the streets makes the system adaptable to changes of traffic volume and weather.

The Arduino modules at the field level control street lights according to sensors as the algorithm diagram shown in Figure 7. This diagram shows the principle of operation details of this system, which is presented in Section 2.1.2.

b. Programming interfaces for smartphones

The software that allow operators to control and monitor the urban lighting system on the smartphone is programed following the steps below:

Step 1: Create a project: File → New → Default. Then, choose a path to save the file.

Step 2: Create Layout: Click Designer → Open Designer. Code of the objects on the Designer interface are written in the main window.

Step 3: Connect to Leapdroid: Click WYSIWIG → Designer Connect.

c. Programming interfaces for computer

The monitoring console on the computer is programed in Visual C# language.

3. RESULTS AND DISCUSSION

At each control cabinet, the signal of a light sensor is read by an Arduino module. Then, lights are turned on when it is dark and turned off at dawn. Based on signals of infrared sensors, all lights are turned on when the street is crowded, or some lights are turned off when there are few people on the street. When the time between two detections of passing people is far apart, the lights are turned off or turned on according to the principle proposed in Section 2.1.2. The results are shown in Figure 8.

During festivals, operators can use an application written for smartphones and computers to send control commands to the control cabinets at the field level (Figure 9, Figure 10). At the control cabinet, the SIM

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module receives control commands in message form and transmits it to an Arduino module, then the lights are turned on or off according to these control commands by contactors. Here, data from the sensors are read by an Arduino module, which transfers this data to a SIM module, then it is sent to the server computer in the control center. As a result, the status values of the lights, and many other parameters are monitored on smartphones and computers that access to the server computer (Figure 9, Figure 10).

(a)

(b)

(c)

Figure 8. (a) All street lights are turned on, (b) 2/3 street lights are turned on, (c) 1/3 street lights are turned on.

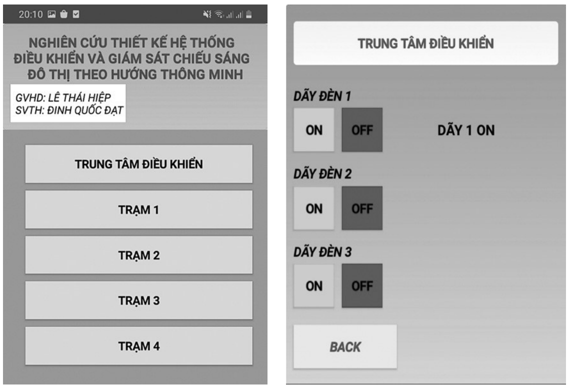

Figure 9. Control and monitoring application in smartphones.

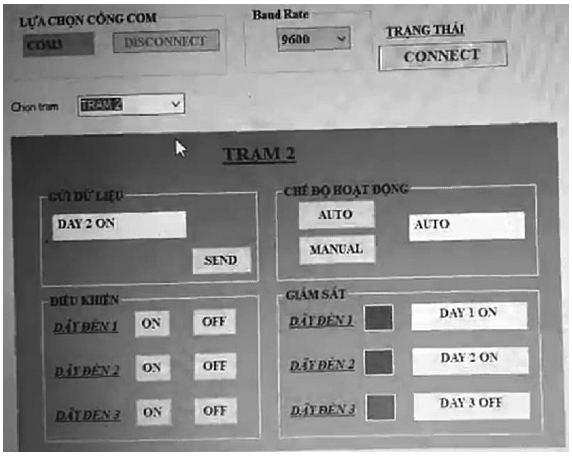

Figure 10. Control and monitoring application in computer.

4. CONCLUSIONS

This study has designed a smart urban lighting control and monitoring system. The designed system has some following features:

i) Operators can control and monitor the urban lighting system by computers and smartphones connected to the server computer in the control center;

ii) The lights on the streets are automatically turned on when it gets dark, and turned off when the sun shines;

iii) In the evening, the number of street lights turning on and off depends on the traffic volume on each street.

This study is not aimed at controlling each light source because it requires a very large initial investment cost. In terms of lighting quality, the proposed method in this study is not as good as the control method for each light source. But in terms of flexibility and adaptability, the test results of this study have shown that the urban lighting system is operated adaptively according to the actual traffic volume in each street.

Therefore, the proposed method in this study should be applied to secondary roads in urban areas, where there are control cabinets to turn on and off street lightings. Nevertheless, main roads and national highways need lighting quality even if street lights turn on with power-saving mode, these roads should be invested the control technology for each light source or auto-dimming street lights. This combination not only ensures good lighting quality where needed, but also saves electrical energy, making it suitable for investment because the total length of secondary roads in urban areas is usually much longer than that of main roads and national highways passing through the city.

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