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A Low Power Lighting Control System Considering Energy Efficiency and User Satisfaction

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Abstract

Saving energy has become one of the most important issues these days. The most waste of energy is caused by the inefficient use of the consumer electronics. Particularly, a light accounts for a great part of the total energy consumption. Various light control systems are introduced in current markets, because the installed lighting systems are outdated and energy-inefficient. However, due to architectural limitations, the existing light control systems cannot be successfully applied to home and office buildings. Therefore, this paper proposes an intelligent household LED lighting system considering energy efficiency and user satisfaction. The proposed system utilizes PIR-sensor-based lighting device. Generally although a PIR-sensor-based lighting device will turn on when motion is detected, and will turn off when the motion disappears, the device still consumes 1-3 W power when the lamp is off. In our design the device consumes 0. 007 W when the light is off, and is not only easy to set up but also inexpensive. The PIR-sensor-based lighting device is turned on only when motion is detected. When motion disappears, the time when the light is switched off, and the duration of the lighting can be adjustable. We designed and implemented the proposed system in the test bed and measured total power consumption to verify the performance. The proposed LED lighting system reduces total power consumption of the test bed up to 21. 9%[1].

Index Terms — household LED lighting system, situation awareness, minimum light intensity control, adaptive middleware.

I. INTRODUCTION

Energy-saving solutions have been becoming increasingly essential in recent years because of environmental issues such as climate change and global warming. Environmental problems are very important issues and these problems are largely caused by the excessive use of energy.

A light accounts for approximately 20 percent of the world's total energy consumption [5]; thus the related studies of an energy efficient lighting system have been done by various researchers around the world [7]-[14]. The invention of a light emitting diode (LED) is expected to significantly alleviate the energy consumption of a light, because the LED lighting device consumes 50 percent of the energy consumption compared to the fluorescent lighting device. Recently, an intelligent lighting control system using various sensors and communication modules are actively studied and developed in both university and industry. The intelligent lighting control system can reduce energy consumption as automatically controlling the intensity of illumination through situation awareness, such as awareness of user movement or brightness of surroundings. The technical report from the U. S. Department of Energy shows that about 15 percent of total energy consumption can be reduced through light control according to user's living pattern.

However, since the existing lighting control systems can support only simple on/off or dimming control according to user movement or brightness of surroundings, it is hard to be applied to complex environments such as house or office. The complex environment means that there is a variety of control requirements, because of the presence of a variety of users. Because of this limitation of existing systems, they are mostly installed in the places such as the front door or the hallway. Furthermore, since the existing systems are designed without considering user satisfaction, it is not appropriate to the places such as house and office where user satisfaction is more crucial factor than cost benefits due to energy saving; thus a new intelligent lighting control system should be designed considering both energy efficiency and user satisfaction.

All things considered, design goals of the new intelligent lighting control system are as follows:

- The new intelligent lighting control system should be designed to *maximize the utilization of an LED.*
- The new intelligent lighting control system should be designed to *have the communication capability.*
- The new intelligent lighting control system should be designed to *control based on the situation awareness.*
- The new intelligent lighting control system should be designed to *enhance both energy efficiency and user satisfaction.*

Therefore, this paper proposes an intelligent household LED lighting system considering energy efficiency and user satisfaction. The proposed system utilizes multi sensors and wireless communication technology in order to control an LED light according to the user's state and the surroundings. The proposed LED lighting system can autonomously adjust minimum light intensity value to enhance both energy efficiency and user satisfaction.

This paper is organized as follows: in Section II we discuss the works related to the existing intelligent lighting control system; in Section III we discuss the problems of the existing system; then we present the proposed intelligent household lighting control system along with system architecture and an important algorithm; in Section IV we present the system implementation and test bed; in Section V we discuss some case studies and experiment; finally we draw our conclusions in Section VI.

II. NETWORK BASED WIRELESS LIGHTING CONTROL

The lighting control is conventionally carried out in a cabled fashion. However, in many cases it is reasonable to use wireless connections to efficiently automate the whole system. For example, it is not acceptable to install new cabling for most renovation projects. In this case, it is suitable to perform control signal communication in a wireless manner. A typical home environment is depicted in Fig. 1 with switch modules and control unit.

In the proposed systems, the communication between switches and control unit is performed in a wireless network environment. The control unit is assigned as the coordinator of the network whereas switch modules are assigned as end-devices. Typically, end-devices are battery powered and hence need to be designed by taking power consumption into account. It is also possible to configure switch modules as router when it is possible to have power near to the switch. When pressed, switches transmit data signals to the control unit. The control unit decodes the received signals and activates or deactivates lighting at the corresponding location so that it is not appropriate to be applied in various places. In addition, although the lighting control system using central management server or sensor networks was studied recently, it was not commercialized or industrialized, and even the commercialized products were excessively concentrated to the central management server.

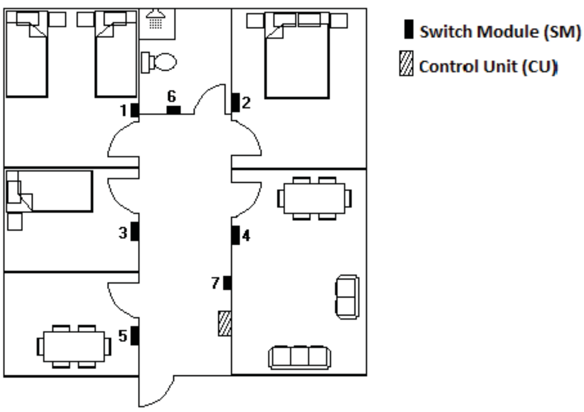


Fig. 1. Atypicalhomeinstallationforswitchmodulesandcontrolunit.

III. PROPOSED INTELLIGENT HOUSEHOLD LIGHTING SYSTEM

We design the intelligent household LED lighting system with a motion detection sensor, illumination sensor, and wireless communication interface. Before presenting the proposed system with system architecture and important scheme, we discuss the problem of the lighting system.

A. Problem Description

In day today life the small power is main fact of the world. So we introducing new method of power consumptions using PIR sensor to the commercial and industrial areas. we concentrate reduce the power in terms mW by using PIR.

EXISTING SYSTEM DISADVANTAGES

- Power consumption is more
- Manual operation

PROPSED SYSTEM ADVANTAGES

- Less power consumptions
- Automatic system for power saving

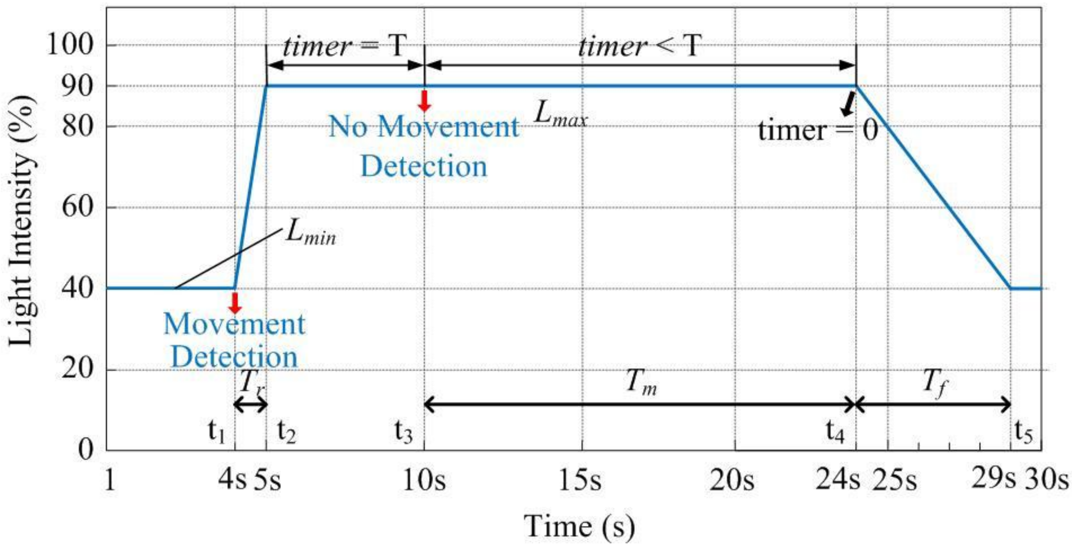


Fig. 1. Basic operating principles of the proposed system.

The proposed system basically controls illumination intensity of a lighting device according to user movement and brightness of surroundings. That is, when the maximum value of illumination intensity of a lighting device is *Lmax* and the minimum value is *Lmin*, the illumination intensity becomes *Lmax,* if user movement is detected and becomes*Lmin,* if usermovement is not detected for certain period time. As shown in Fig. 2, it can be confirmed that as T_r is longer, T_m and T_f are shorter, and

Lmax and *Lmin* are smaller, the energy saving effect becomes larger. However, it implies the possibility that inconvenience of users can be bigger because of frequent light on/off, and dark indoor environment, etc. whereas the energy saving effect becomes larger. Therefore, it is necessary to properly set the value according to space environmental characteristics (frequent or rare user movement, work type, etc.

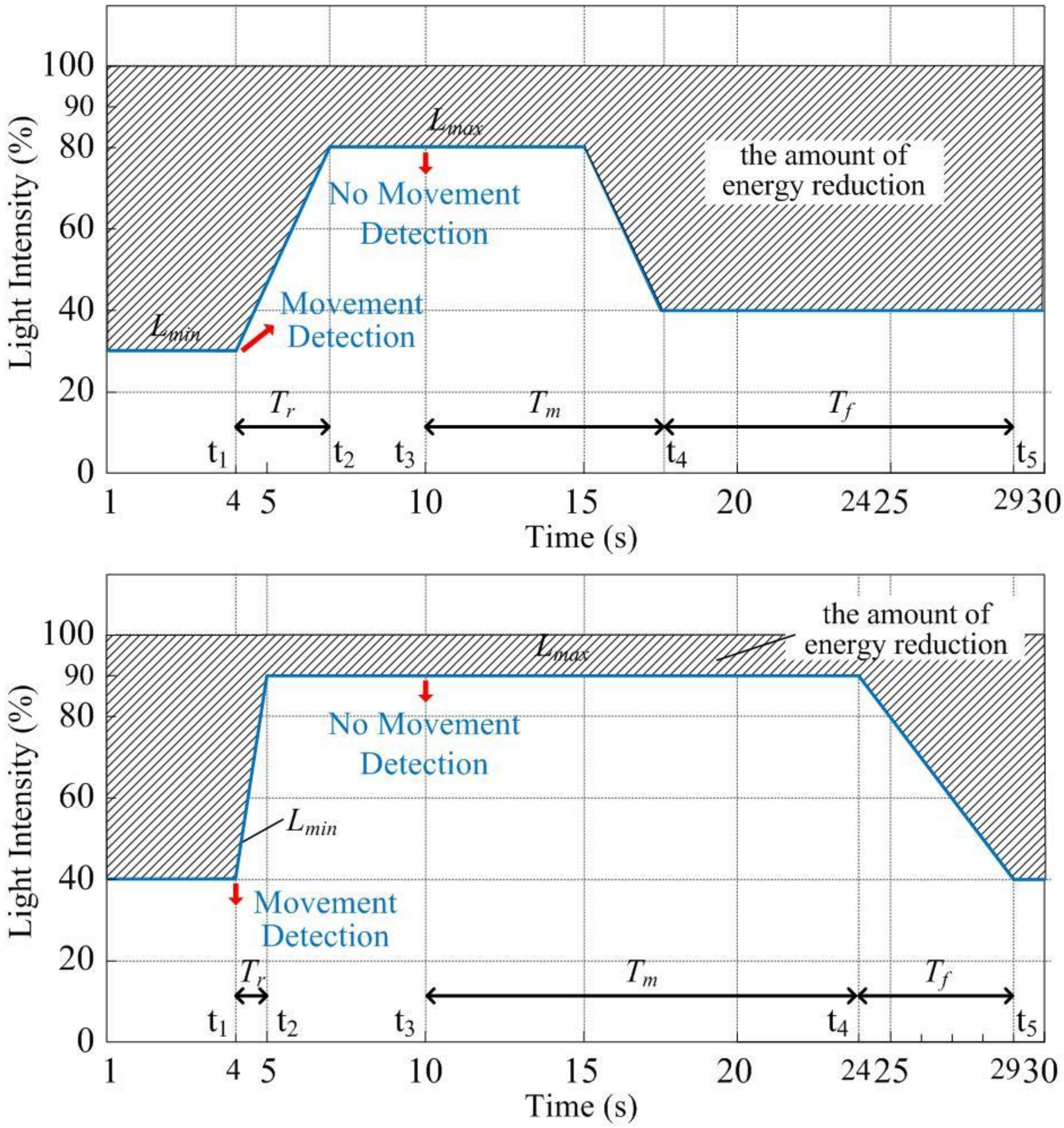


Fig. 2. Comparison of the amount of energy reduction according to Lmax, Lmin, T_r, T_m, andT_f.

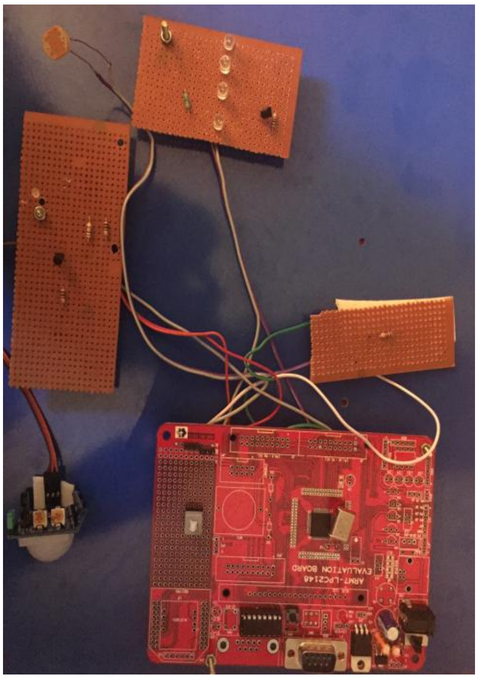


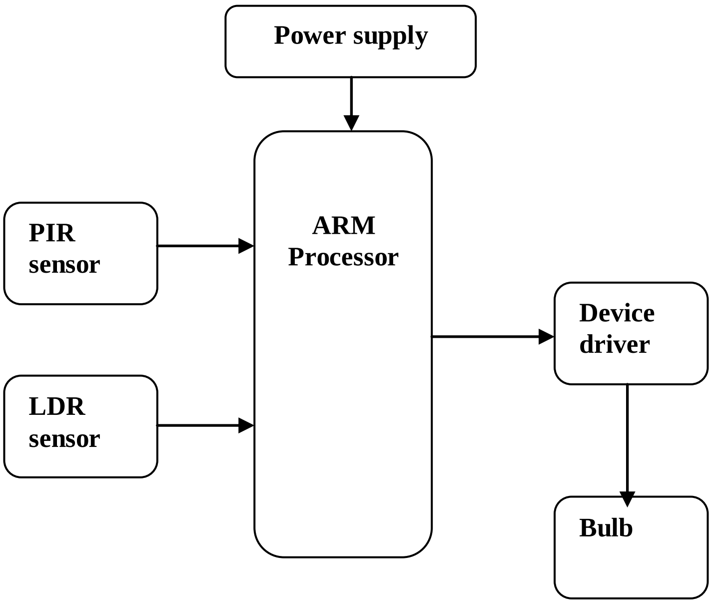
Fig. 3. Overview of the proposed system.

B. Overview of IHLS

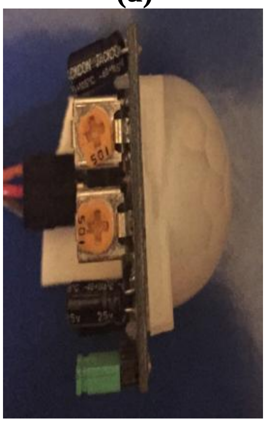
We propose an intelligent household LED lighting system using various sensors and wireless communication technology. Fig. 3 shows an overview of the proposed lighting system. The main features are as follows:

- Autonomous control based on user movement
- Autonomous control based on brightness of the room
- Autonomous optimization of system control and state variables.
- Collective control using a wireless technology
- Control and system setting through a wireless controller and a mobile phone application

The proposed system can reduce energy consumption via interaction with the information about user's state and surroundings (e. g. brightness of a room). The autonomous control could lead to disturbance to residents. Thus, the proposed system autonomously optimizes the system control and state variables, especially *Lmax*, *Lmin*, T_r, T_m, and T_f in order to enhance both energy efficiency and user satisfaction.



(a)



(b)

Fig. 5. Implementation of the proposed system (a) hardware block diagram (b)PIR Sensor.

IV. IMPLEMENTATION AND TESTBED

A. Implementation

Fig. 5 shows the prototype and hardware block diagram of the proposed system. The main processor part uses ARM7 microprocessor. This part plays a role in situation analysis, event processing, and learning. This part optimizes the control and state variables to adapt itself to the various environments. The sensor part is composed of various sensors. To provide energy saving services mentioned above, two kinds of sensors, that is a motion detection sensor and illumination sensor are needed basically.

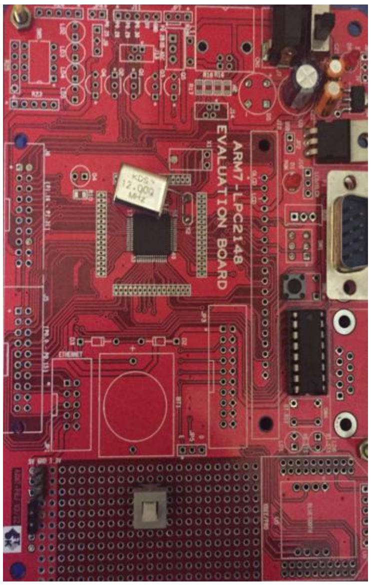


Fig. 6. PCB layout of the proposed system.

The proposed intelligent LED lighting system is shown in Fig. 6, and it is possible to adjust the variable system control parameters, i. e. *Lmax*, *Lmin*, T_r, T_m, T_f, and countdown timer to adjust the maximum value of illumination intensity (*Lmax*), and to adjust the setting of the minimum value ofillumination intensity (*Lmin*)..

B. Testbed

Fig. 7 shows aillumination simulation result. There are 4 LED lights with the proposed system. When a motion is detected and when the room light intensity is below threshold then the simulation results are as shown.

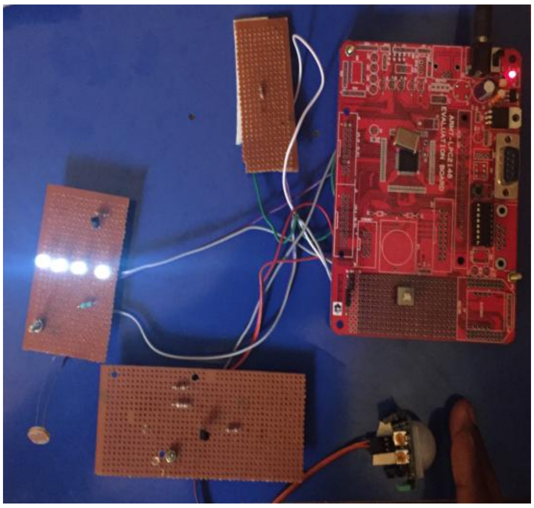


Fig. 7. Simulation results.

V. CASE STUDY AND EXPERIMENT

A. Case Study

1) Home and office building

There are many people in a home and office building; thus, user satisfaction is an important factor in the light evaluationIn these places, *Lmin* is set according to the proposed minimum light intensity control algorithm. Generally, *Lmin* is set to the high value in these places.

2) Warehouse

There are a few people in a warehouse; thus, user satisfaction is a less important factor than the case of a home or office building. Generally, in the warehouse, *Lmin* is set to the low value. In this case, a significant amount of energy consumption can be reduced.

3) Parking lot

Like the warehouse, in the parking lot, user satisfaction is an less important factor than the case of a home or office building as in a warehouse. A car that enters the parking lot will move a vacant parking space; thus, when a car enters the parking lot, *Lmin* is set to the high value only from the entrance of the parking lot to a vacant parking space. Then, when a user gets out of a car, *Lmin* is set to the high value only from user's current position to the entrance of the building.

VI. CONCLUSIONS AND FUTURE WORKS

Saving energy has become one of the most important issues these days. A light accounts for approximately 20 percent of the world's total energy consumption; thus, a lot of studies and development related to energy saving of a light have been done by various researchers all over the world. However, since there are no products considering both energy efficiency and user satisfaction, the existing systems cannot be successfully applied to home and office buildings. Therefore, we propose an intelligent household LED lighting system considering energy efficiency and user satisfaction. The proposed system utilizes multi sensors and wireless communication technology in order to control an LED light according to the user's state and the surroundings. The proposed system can autonomously adjust the minimum lightintensity value to enhance both energy efficiency and user satisfaction We designed and implemented the proposed system in the test bed and measured total power consumption. The proposed lighting system reduces total power consumption of the test bed up to 21. 9%.

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