Design And Implementation Of Intelligent Household Led Lighting Systemfor Energy Efficiency

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Abstract—Reducing energy consumption and saving energy in wireless communications has attracted increasing attention recently. Electric appliances consume electricity when they are in standby mode and sometimes even in off-mode. Particularly, a light accounts for a great part of the total energy consumption. Due to architectural limitations, the existing light control system cannot be successfully applied to home and office buildings. Therefore, this paper proposes an intelligent household LED lighting system considering energy efficiency by utilizing multi sensors to control LED light using wireless communication technology.

Keywords—LED, ZIGBEE, minimum light intensity control,adaptive middleware,complex environment.

I. Introduction

The environmental issues like climatic changes and global warming increases energy-saving solutions .The excessive usage of energy in ways of lights, computers, home appliances has contributed much in improving the carbon print in atmosphere.A survey denotes that a light has approximately occupies 20% of world total consumption of energy [5]. The proposed LED lighting system can autonomously adjust the minimum light intensity value to enhance both energy efficiency is expected to reduce the energy consumption of light.

II. Proposed Intelligent Household Lighting System

An intelligent lighting control system using various sensors and communication modules are actively studied and developed in both university and industry [6]. 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 where, 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. So they are mostly installed in the places such as the front door or the hallway. Because of the disadvantages in existing system in terms of cost rather than energy consumption a new intelligent lighting control system considering both energy efficiency and user satisfaction is designed.

The design goals of the new intelligent lighting control system are

- 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.*

A. Problem Description

Considering both energy efficiency and user satisfaction.Maintaining the Integrity of the Specifications

the design of intelligent household LED lighting system consists of a motion detection sensor, illumination sensor, and wireless communication interface.

Lmin minimum light intensity;
Lmax maximum light intensity;
Tr rise time period of the light intensity;
Tm time period between no movement detection and that the light intensity begins to falls;
Tf fall time period of the light intensity;

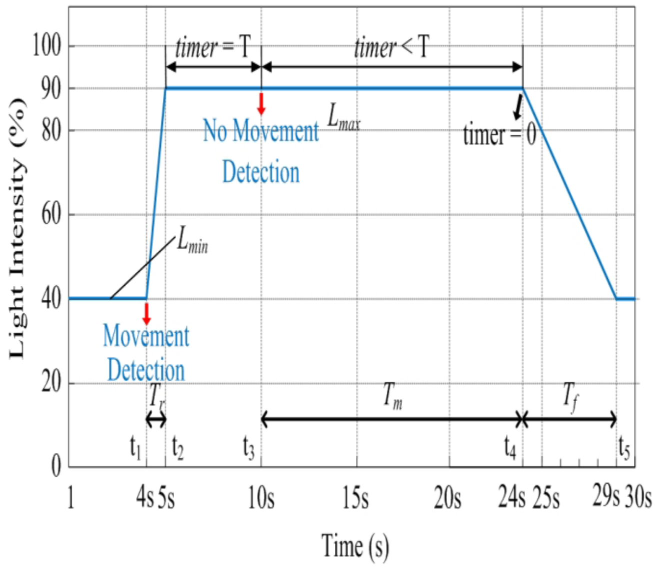


Fig. 1. Basic operating principles of the proposed system.

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 user movement is not detected for certain period time.

B. Overview of IHLS

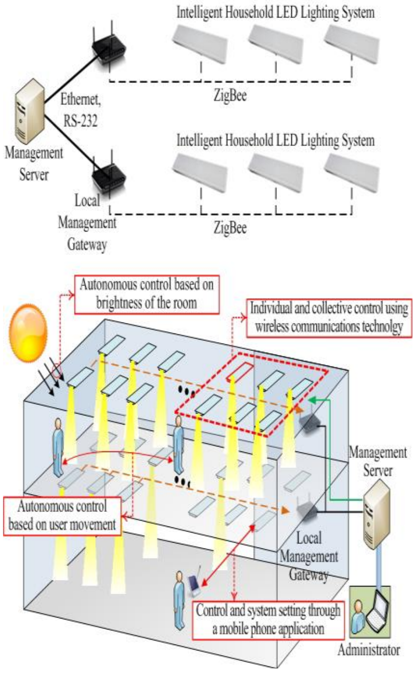


Fig. 2 An overview of the proposed lighting system.

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.

C. Minimum Light Intensity Control Algorithm

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*, *Tr*, *Tm*, and *Tf* in order to enhance both energy efficiency and user satisfaction.

Fig. 3 illustrates a flowchart of a minimum light intensity control algorithm that requires a signal of inconvenience and a countdown timer. The signal of inconvenience is received from residents through a smart phone when they feel the brightness of the lighting with inconvenience. The countdown timer can interrupt the system after a given amount of time has expired.

The proposed minimum light intensity control algorithm automatically adjusts *Lmin* based on the signal of inconvenience of users, which are inputted via smart phones. The value of illumination intensity of the lighting that has been felt with inconvenience at the latest is *Lminincon*, whereas the value of illumination intensity that has not been felt with inconvenience for a certain period of time, T at the latest is *Lmincon*. The initial *Lmin0*, and *Lminincon* is set to zero, and the initial *Lmincon* is set to *Lmax*. The procedures are composed of five steps.

Step 1. First, check whether a signal of inconvenience has occurred. If a signal of inconvenience has occurred, then $Lminn = (Lmincon+Lminn\text{-}1)/2$, $Lminincon = Lminn\text{-}1$, $n = n + 1$, and $timer$ = T. And then check again whether a signal of inconvenience has occurred.

Step 2. Check whether a signal of inconvenience has occurred. If a signal of inconvenience has occurred, then $Lminn = (Lmincon+Lminn\text{-}1)/2$, $Lminincon = Lminn\text{-}1$, $n = n + 1$, and $timer$ = T as in Step 1. If a signal of inconvenience has not occurred, then check whether *timer* is equal to zero (i.e. the expiration of a given amount of time, T).

Step 3. Check whether *timer* is equal to zero, if *timer* is equal to zero, then $Lminn = (Lminincon+Lminn\text{-}1)/2$, $Lmincon = Lminn\text{-}1$, $n = n + 1$, and $timer$ = T. And then, check whether *Lmincon* minus *Lminincon* is less than 5 or not. If *timer* is not equal to zero, check again whether a signal of inconvenience has occurred.

Step 4-1. After check whether *Lmincon* minus *Lminincon* is less than 5, if *Lmincon* minus *Lminincon* is less than 5, then terminate this flowchart. If *Lmincon* minus *Lminincon* is not less than 5, then perform the process of Step 4-2.

Step 4-2. Check whether a signal of inconvenience has occurred. If a signal of inconvenience has occurred, then $Lminn = (Lmincon+Lminn\text{-}1)/2$, $Lminincon = Lminn\text{-}1$, $n = n + 1$, and $timer$ = T. If a signal of inconvenience has not occurred, then perform again from Step 3.

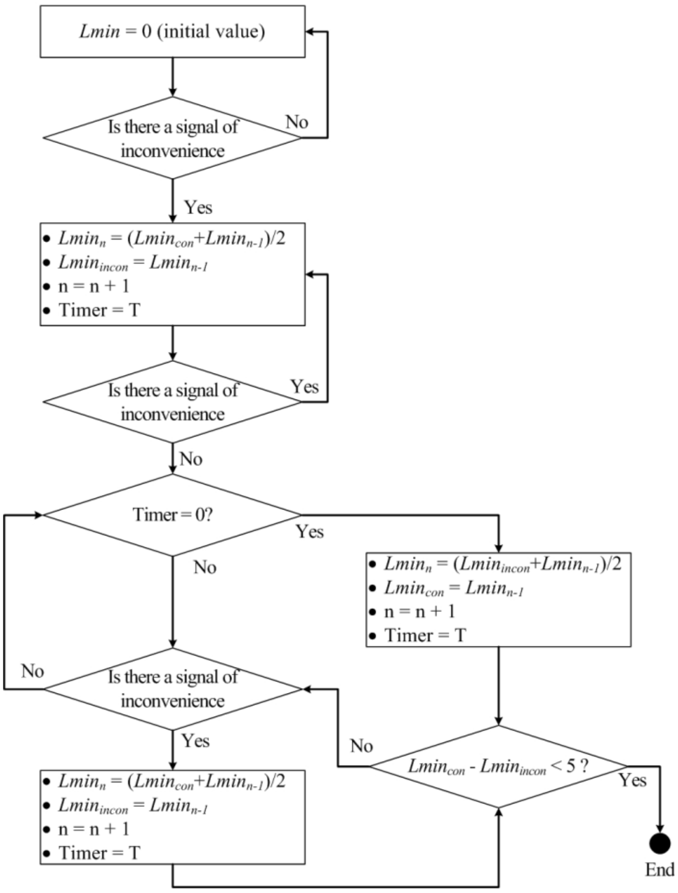


Fig. 3. Flowchart of a minimum light intensity control algorithm.

D.Middleware Architecture

As for the conventional LED lighting products, they should be developed using the low-cost MCU in order to reduce the production unit price; thus, they have a disadvantage of having the limited availability of the computing resources or storage resources. To solve this problem, we design the platform of adaptive middleware that can update an internal program through the automatic control or the remote control by an administrator in accordance with the external environmental changes. The adaptive middleware platform is composed of *the LED control module group*, which performs the role of controlling LED, *the adaptive middleware group*, which can change through the external environment or the remote command of the administrator, and *the table group*, which manages a variety of data used for context awareness and LED control. Fig. 5 shows an adaptive middleware platform of the proposed system.

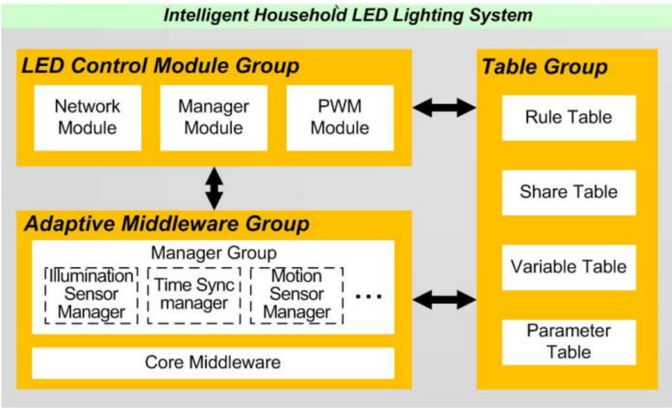


Fig. 4. Adaptive middleware platform of the proposed system.

1) LED Control Module Group

- ***Network Module***: It is the module related to the ZigBee and RS485 serial for communication with the external control system. This module processes interrupts and message for communications.
- ***Manager Module***: It internally processes the control command, which is transferred from the manager of the adaptive middleware group and converts it into a form for communications and control, and has the role of managing the conflict or loss of the transferred messages.
- ***PWM Module***: It performs the role of generating and stabilizing the PWM signal for LED control. It also performs the role of generating the signal to control an actual LED based on the data transferred from the adaptive middleware and retrieved from the table group.

2) Adaptive Middleware Group

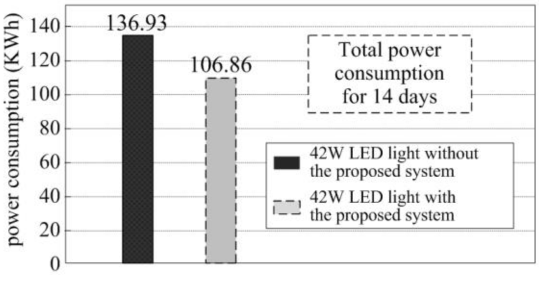
- ***Core Middleware***: It is the module to possess the core function of the adaptive middleware. Basically, it is mainly used for the manager management, scheduling for managers, and access control of the table used by the managers. It registers and activates the managers upon receiving the control messages from the external management server. It also performs the role of deleting the existing managers in accordance with the commands transferred from the management server. In addition, it performs the role related to authentication for external management server.

- ***Manager Group***: This group can registers and deletes the managers in the adaptive middleware group in real time. *The illumination sensor manager* performs the roles of gathering the value of intensity of illumination from the sensor or making the rule table for control upon receiving the data sensed from the sensor module, the neighboring lighting system, or the management server. In addition, this group is used for managing the value of illumination intensity of the internal parameter table. *The time sync manager* is the manager related to the time-based control. It plays a role in time synchronization with the external control system and making the rule table for time-based control or updating time information in the share table. *The motion sensor manager* plays the role in managing the information collected from the motion sensor in the same way as the illumination sensor.

a.

III CONCLUSION

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. 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. Therefore, we propose an intelligent household LED lighting system considering energy efficiency and user satisfaction. This utilizes multi sensors and wireless communication to control an LED light according to the user's state and the surroundings for adjust the minimum light intensity value to enhance both energy efficiency and user satisfaction .



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