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Design of an Intelligent Streetlight System in USN

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Abstract

In this paper, we propose an intelligent streetlight system that has a complex sensor module of temperature, humidity, luminance and motion detection and controlled by the fuzzy logic based central monitoring system in order to get flexible and precise manipulation of the streetlight system in USN environment. The proposed streetlight system provides low power consumption and high efficiency by using sensed data from the complex sensor module, which were collected, processed, and analyzed by the fuzzy logic based central monitoring system. The performance of the proposed streetlight system is to be evaluated by a simulation study in terms of power savings and safety at the fields constructed as a test-bed under several suggested scenarios. Finally, we know that the proposed intelligent streetlight system can maximize the energy savings efficiently with the fuzzy logic based central monitoring system and selective remote dimming control by connecting it to the wireless ubiquitous sensor network (USN) using a Zigbee module.

Keywords: *Streetlight, Fuzzy logic, Complex sensor, USN.*

1. Introduction

The eco-friendly Green-IT technologies, paid great attention recently, can minimize the Carbon discharge, maximize the efficiency of power consumption, and become promising new growth industry by fusing them with various similar technologies to create prospective new businesses in the future.[1] Especially, the high oil prices due to the exhaustion of energy resources and environmental pollution due to unplanned nature destruction intimidate our lives significantly. So, the eco-friendly and efficient Green-IT technologies become the center of public interest nowadays. Therefore, development of a high luminous LED module that can raise light efficiency dramatically for eco-friendly and future-oriented prospective industries to achieve the international energy competitiveness, and studies on human-friendly light temperature control techniques are actively carried out recently.[2] Development of technologies to substitute eco-friendly high power saving, high efficiency and high luminous LED luminous sources for existing luminous sources like low efficiency incandescent bulbs or fluorescent lights using toxic substances, patents dispute for the related technologies, and efforts for business affiliation among related business enterprises are progressed intensively. As a next generation illumination system, LEDs using new materials create high added value in the areas of the information technology, medical equipment system and related agricultural technology which have the characteristics of power savings and eco-friendly by integrating them with IT control techniques, and are positioned as prospective new growth dynamic industries.[3, 4] For low energy consuming industry structure, power saving, high luminous and human-friendly LED modules are developed as next generation luminous sources, and various researches were reported to achieve the maximum power savings by integrating a LED module with USN-IT technologies and using selective dimming and remote

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control according to their circumstances recently. They, however, are still on rudimentary stage in this field.[5, 6] With the rapid growth of the mobile computing and sensor technologies, various application techniques related to USN converged with other related technologies are actively disseminated recently. Most of these applications are aimed at the proper control and system monitoring using context information gathered through various sensors. But it is not easy to control and monitor the system precisely and flexibly since data generated by sensors are huge and variety. In this paper, we propose an intelligent streetlight system that has a complex sensor module of temperature, humidity, luminance and motion detection and controlled by the fuzzy logic based central monitoring system in order to get the flexible and precise manipulation of the streetlight system in USN environment. The proposed streetlight system can provide low power consumption and very high efficiency by using sensed data from the complex sensor module, which were collected, processed, and analyzed by the fuzzy logic based central monitoring system. The performance of the proposed streetlight system is evaluated by a simulation study in terms of consumed electric power and safety on the test fields constructed as a test-bed under several suggested scenarios.

The remainder of this paper is organized as follows. In section 2 and 3, we describe the system model and environmental model of a streetlight system. In section 4, we design the fuzzy logic based streetlight system proposed in this paper. In section 5, we evaluate the performance of the proposed streetlight system by a simulation study and compared with the ordinary streetlight system, and finally we conclude the paper in section 6.

2. System Model of a Streetlight System

The system model of the streetlight system considered in this paper is able to control remote dimming selectively and is developed to maximize power savings and LED lifespan. LED module is designed grid-shaped lighting method in order to maximize the LED lifespan, places the ceramic insulation layer on the heat sink to increase the efficiency of heat ejection, and uses all-in-one heat sink metal PCB without thermal interface materials by composing Copper wiring layer on a ceramic insulation layer. This technique improves the characteristics of heat ejection by minimizing the heat transfer path in LED module and gets technique and price competitiveness by reducing the number of components, processes and production costs.

An intelligent streetlight system is implemented with a complex sensor module of temperature, humidity, luminance and motion detection to minimize power consumptions. The complex sensor module aggregates sensed data in every moment, transfers them to the fuzzy logic based central monitoring system in real time, and exploits them as preliminary data to activate the selective remote dimming control according to their circumstances. These streetlight systems are composed local area wireless communication network, so called Ubiquitous Sensor Network, and Zigbee module built-in the streetlight is used. LED has short On/Off switch time and does not generate additional power consumption so it can control the amount of lighting easily.

Streetlight systems are connected in USN and USN is also connected to the ordinary wired network via wired/wireless frequency demultiplier to transfer sensed date to the fuzzy logic based central monitoring system. At this moment, it is not easy to control and monitor the streetlight system precisely and flexibly with the sensed data from the complex sensor module because the sensed data generated from sensors are huge and variety. The central monitoring system stores these data in its database and analyzes them with the fuzzy logic to realize current state of environmental circumstances precisely and flexibly. It issues control signals to the LED streetlight systems if sensed data arrives at certain predetermined threshold value. Therefore, it can control streetlight systems intellectually according to their environmental circumstances and maximize the power savings through remote dimming control selectively. Furthermore, these control operations are performed remotely in real time so the effect of all controls is efficient and correct.

3. Environmental Model of a Streetlight System

We assumed the practical environmental model of the intelligent streetlight system considering the environmental factors which can affect to streetlight placement and sensors in this paper. The proposed environmental model is divided into 3 regions according to their characteristics for practical installation region of the streetlight systems as a test-bed for performance evaluation. The first zone is very bright and thickly inhabited area so there are lightings like electric signs around the streetlight. We call this zone as a high-density shopping zone. (Zone 1) The second zone is not much bright and thickly inhabited area but this zone is a little bit dangerous area because it is adjacent to the main roadway and many cars and pedestrians go by. So, extra lightings are required when the weather is bad and we call this zone as a low-density shopping zone. (Zone 2) Finally, the third zone is dark and sparsely inhabited area. So, lightings from midnight to dawn are not needed when no pedestrian goes by during these times. We call this zone as mountainous zone. (Zone 3) We installed 7 intelligent streetlight systems around these region, 2 in zone 1, 3 in zone 2, and 2 in zone 3 respectively, to construct the test-bed for the power saving simulations of the proposed streetlight systems.[7]

4. Design of the Intelligent Streetlight System

In this section, we design the fuzzy logic based intelligent streetlight system that collects the environmental context data sensed from the complex sensor module of temperature, humidity, luminance and motion detection, processes and analyzes these data with fuzzy logic, and performs the precise and flexible control in real time with these sensed environmental context data to the streetlight system. At this moment, huge data generated from various sensors in real time may have lots of anomalies due to the system failures, errors, and noises and these data can cause the inappropriate control and monitoring of the streetlight system. Therefore, we design the fuzzy logic based intelligent street light system to filtering these anomalies from the sensed data to provide the precise and flexible control of the street light system.

The major factors that influence the current context for the local environmental change are local temperature, humidity and luminance and these data determine the change of local context information. Fig. 2, 3, and 4 below shows the basic fuzzy set for the change rates of each local temperature, humidity, and luminance, which represent the local context information of each sensor node respectively. These are mapping 3 different fuzzy set: Low, Medium, High by each membership function according to the degree of temperature, humidity and luminance.

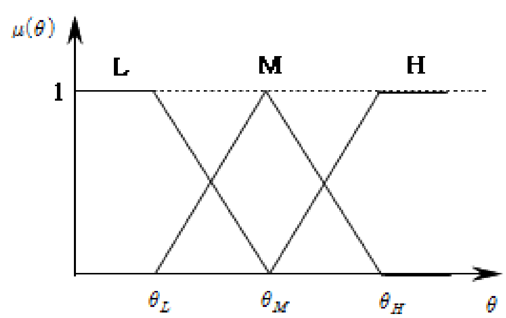

Figure 1. Basic Fuzzy Set for Change Rates of Temperature.

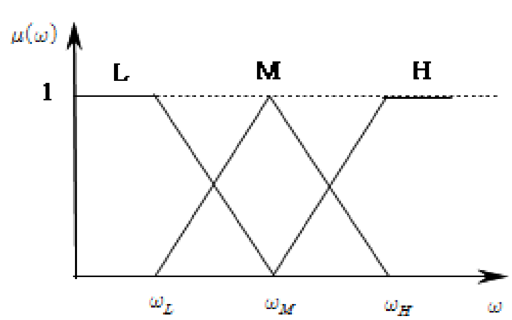

Figure 2. Basic Fuzzy Set for Change Rates of Humidity.

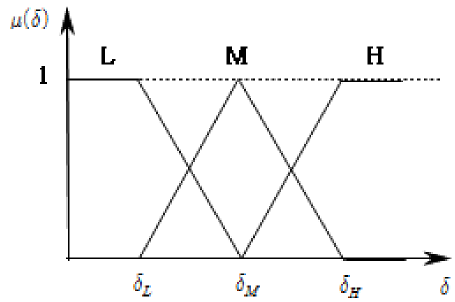

Figure 3. Basic Fuzzy Set for Change Rates of Luminance.

Table 1 below shows the fuzzy control rule for the change rates of temperature and humidity which represent the local context information on the sensor node. Table 2 also shows the fuzzy control rule for the change rates of relative luminance that represents the local context information on the sensor node respectively.

Table 1. Fuzzy Control Rule 1

Tem \ Hum	Low	Medium	High
Low	Safe	Mid Danger	Danger
Medium	Safe	Safe	Mid Danger
High	Safe	Mid Danger	Danger

(Input variables)
Hum : Change rates of Humidity,
- High, Medium, Low
Tem : Change rates of Temperature
- High, Medium, Low
(Output variables)
- Safe, Medium danger, Danger

Table 2. Fuzzy Control Rule 2

H/T \ Lum	High	Medium	Low
Safe	LO	SL	MT
Mid Danger	SL	MT	SH
Danger	MT	SH	HI

(Input variables)
Lum : Change rates of Luminance,
- High, Medium, Low
H/T : Danger rates of Humidity/Temperature
- Safe, Medium Danger, Danger
(Output variables)
LO - Lower or off, MT - Maintain, HI - Higher
SH - Slight higher, SL - Slight lower

5. Performance Evaluation

In this section, we evaluate the performance of the proposed intelligent streetlight system by a simulation study in terms of power savings and safety under the given 3 different scenarios at the fields constructed as a test-bed. In order to get the maximum efficiency of power savings and maximum safety in a proposed streetlight system, the temperature, humidity, luminance and motion detection sensors are used with the following scenarios.

Scenario 1: In zone 1, additional lightings from LED streetlights are required restrictively since there are so many bright luminous sources around the streetlight system. Therefore, the luminance sensor measures the current luminance and transfers to the central monitoring system. Then, central monitoring system calculates the additional luminance needed at this site and sends back control signals to streetlights for dimming control selectively.

Scenario 2: In zone 3, the maximum lightings from LED streetlights are required since there are no luminous sources around the streetlight system. This region, however, is a mountainous zone and does not need lightings during night time if there is no one goes by. The intelligent streetlight system will be turned off from 12:00 a.m. to 6:00 a.m. to save the electric power and motion detection sensor is also working to detect any movements around the streetlight system during those times. If the motion detection sensor detects any movements the central monitoring system recognizes it immediately and sends back control signals to streetlights through USN. Finally, LED streetlights will be turned on while pedestrians go by.

Scenario 3: In zone 2, extra lightings are required when the weather is bad. Temperature and humidity sensors are used to determine the state of the current weather condition. If a temperature sensor detects some degree of low temperature and the humidity sensor detects some degree of high relative humidity then the central monitoring system decides it is bad weather day and sends the control signals to streetlights to raise lightings by one or more step higher for safety of this region.

Table 3. Results of a Simulation Study

Zone No.	1		2			3		
# of lights	1	2	3	4	5	6	7	(kw/h)
Ordinary Streetlight System	159.6	161.3	219.8	220.7	219.7	140.2	140.3	
Intelligent Streetlight System	160.3	158.7	199.8	198.7	199.6	140.1	140.2	

Table 3 shows the results of a simulation study in terms of the power consumptions of each streetlight under the given 3 different scenarios at the fields constructed as a test-bed for the performance evaluation. As shown on the table, the amount of total power savings in three zones are various according to their environmental characteristics. The LED streetlights 1 and 2 installed in the high density shopping area (zone 1) can save electric power exceptionally high rather than other areas because zone 1 is very bright and thickly inhabited area so there are many lightings like electric signs around streetlight systems and a streetlight supplies only additional illumination required by measuring the amount of current lightings using a luminance sensor. Therefore, the amount of power savings in this zone is much greater than other relatively dark areas. On the other hand, the mountainous area like zone 3 is very dark and sparsely inhabited area. So, the lightings from midnight to dawn are not needed when no pedestrians go by during those times. The LED streetlight systems are allowed to be turned off during these times. The motion detection sensor is used to determine the lights-out time of the streetlight systems. The simulation results of the average probability of lighting-up for each time zone by using motion detection sensors in night time represent 0.2 in zone 1, 0.3 in zone 2, and 0.1 in zone 3 after the time allowed to lights-out(i.e. after 12:00 a.m.) respectively. That means the probability of lighting-up in a sparsely inhabited mountainous area is lower than other areas. In table 3, the case using luminance and motion detection sensor shows the biggest amount of power savings in zone 1 as expected, the second in zone 3, and the third in zone 2. The amount of power consumption in mountainous zone (i.e. zone 3) is expected very big since this area is very dark at night time. But, it is proved that the amount of power consumption is relatively small because this area is allowed to turn off the streetlights if there are no pedestrians go by at night time. The differences between ordinary and our intelligent streetlights are getting bigger in zone 2 because this region needs more luminance when the weather is bad condition for the safety of this region. The LED streetlight system in zone 2 raises one or two levels up the luminous flux in bad weather conditions like rainy, snowy, foggy, and freezing weather. The average luminous flux in zone 1 is lower than other areas because there is much lighting like electric signs around the streetlight. The required luminous flux, however, drastically increased because these electric signs are turned off after 12:00 a.m. The required luminous flux in zone 3 is relatively high because this area is dark and sparsely inhabited area. According to the simulation results of a performance evaluation for the proposed intelligent streetlight systems under given scenarios, we know that the maximum power savings is about 38% in zone 1 and zone 3. In zone 2, the power consumptions of our intelligent streetlight system is much more decreased about 19.8% compared with those of the ordinary streetlight system because the luminous flux of our intelligent streetlights in this area may decrease one or two levels down in the case of bad weather but safe condition of the road for pedestrians and vehicles in this region.

6. Conclusion

In this paper, we propose an intelligent streetlight system that has a complex sensor module of temperature, humidity, luminance and motion detection and controlled by the fuzzy logic based central monitoring system in order to get flexible and precise manipulation of the streetlight system in USN environment. The proposed streetlight system provides low power consumption and high efficiency by using sensed data from the complex sensor module, which were collected, processed, and analyzed by the fuzzy logic based central monitoring system. The performance of the proposed streetlight system is evaluated by a simulation study in terms of electric power savings and safety of the road at the fields constructed as a test-bed under several suggested scenarios. According to the results of the simulation study, our intelligent streetlight system can reduce the power consumption about 19.8% compared with those of the ordinary streetlight system especially in zone 2. Furthermore, we know that the proposed intelligent streetlight system can maximize the electric energy savings efficiently with the fuzzy logic based central monitoring system and selective remote dimming control by connecting it to the wireless ubiquitous sensor network.

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