Development of Smart Illumination System with Fuzzy Logic Theory

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Abstract -This paper applies fuzzy logic theory to a smart home system in order to achieve artificial intelligence in the automated home. This would allow an automated home system to become a smart home system. In addition to enhancing the quality of life, it can also help to cut energy wasted and reduce overheads. It may not be a significant reduction of energy usage for a single family, yet the total energy saved globally will be significant. Therefore, how to enable families to adapt their homes to become a smart home is one area for development.

Keywords - fuzzy logic theory, smart home system, smart illumination system, artificial intelligence.

1. Introduction

Although the popularity of a wide range of home appliances has facilitated all aspects of people's daily life, it has also increased the electricity consumption year on year for most families. This has made the global energy shortage more severe. Before we enter a new era with alternative energy, energy saving is a great contribution to the Earth we live on.

The lamp is one of the homes most indispensable appliances. It can be used at any time. For traditional lighting systems a lamp only turns on or off, there is no other choice. It lacks flexibility and requires human control. Although dimmable lighting equipment is available, they are all manually controlled without applying artificial intelligence. This paper applies fuzzy control to the lighting system and allows it to have artificial intelligence. These lighting systems with fuzzy control are named as intelligent lighting systems.

Applying artificial intelligence to home appliances allows them to operate under different circumstances. This maximizes efficiency and reduces energy consumption, achieving the goal of carbon reduction. This technology can be applied not only in the home but also public places including hospitals, libraries, schools, etc. This can also advocate energy-saving ideas to the public and improve the energy utility rate of public places [1-2].

This paper uses fuzzy logic theory to achieve the purpose of energy saving. It uses the fuzzy toolbox in Matlab combined with Lab View software. Since Matlab is strong for computing, it is used as the computing center of the entire system. Lab View is mainly used as the user interface and as a bridge between the human operator and the computer. It is easy for the user to operate. It also allows the user to have a clear view over data information to improve the efficiency in analyzing the data [3-4].

2. Fuzzy Logic Theory

Fuzzy Logic Theory is a quantitative tool first proposed in 1965 by Lotfi. A. Zadeh; a U.S. scholar in the field of control theory. It can be used to express an ambiguous concept, and has been seen to work especially well with the ambiguity of human language. Thus, M. Sugeno, an engineer who was deeply attracted to this theory, began to launch research and founded applications using it in Japan. He then made the fuzzy logic controller (FLC), which attracted the world's attention [5].

An FLC's main advantage is that it can be applied in environments where the controlled body is too complex or difficult to use mathematical models. The design of the controller is expressed such that it can reflect the system with a few fuzzy rules. Thus, the FLC is both very smart and more human.

Generally speaking, FLC can be divided into four sections:

(A) Fuzzification,
(B) Decision Making Logic,
(C) Fuzzy Knowledge Base,
(D) Defuzzification.

This system would determine the level of illumination according to the recommended brightness and electricity usage. It can not only adjust the illumination automatically, but also minimize unnecessary electricity usage. For example, when there is sufficient sunlight and the electricity usage is moderate, the lighting system would reduce the output voltage and therefore reduce the indoor illumination and electricity usage. The indoor illumination would be sufficient while achieving the recommended brightness. The recommended brightness for a variety of scenarios can be seen in Table I. [6].

This system makes the specific value of illuminance and electricity fuzzy. The fuzzy value will then become the input value to the fuzzy logic theory. After the derivation of the fuzzy logic theory, the output voltage will be used to control the lamps brightness. The system flow chart is illustrated in Figure 1 [7-8].

Table I - Recommended brightness

Type	Place to be lit	Recommended brightness level (lx)
House	Baby room Study Living room	300~800 300~700 200~600
Office	Conference room Operating room	300~750 750~2000
Hotel	Conference room Toilet	50~300 70~150
Restaurant	Kitchen	150~300

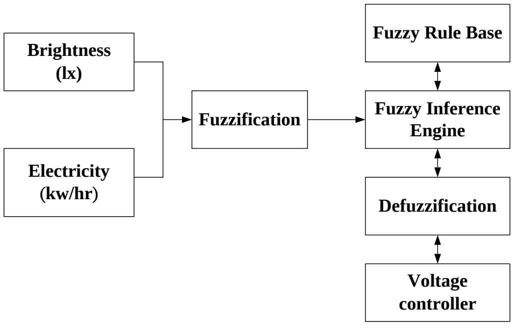

Fig. 1 Fuzzy Control Flow Chart

The next step is to establish the rule database for the fuzzy logic theory. The rules are determined by the relevant literature and an expert rule of thumb. They are listed in Table II.

Table II - Table of Fuzzy Rules

Brightness / Electricity	Dark	Medium	Bright
Low	High	Medium	Low
Medium	Medium	Medium	Low
High	Medium	Low	Off

After collecting the brightness and electricity consumption, the result of the fuzzy logic theory can be calculated. In Figure 2 the derivation chart for the fuzzy logic theory is given.

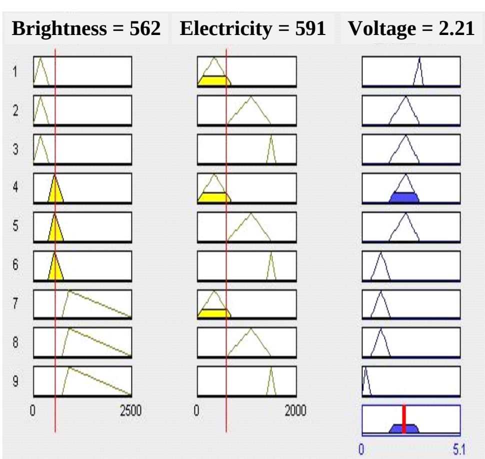

Fig. 2 Fuzzy Logic Theory Derivations

3. Framework of the intelligent system

ZigBee is a personal wireless area network standard based on the open IEEE802.15.4 agreement. The layer uses the Media Access Control specification, applying the IEEE802.15.4 agreement, and a Physical Layer with speeds less than 250kbps. This is able to achieve low power consumption, short range, support a large number of nodes, user safe, and is also easy to develop on.

Figure 3 shows the block diagram of the system circuit used to retrieve the brightness. The external light signal is first transmitted through the light sensor to the A/D conversion circuit, which feeds the analog signal into a digital signal and transmits it to the controller. The controller controls the output signal sent to the D/A conversion circuit, the signal is then transmitted to a digital to analog amplifier, and finally transmitted to the LED, in order to control its brightness.

Figure 4 shows the ZigBee optical sensing module. The module transfers the data for the measured brightness level, converted by the ADC, to the database. The system formula will apply fuzzy logic theory to the data in the database. After calculation, the result reaches the ZigBee wireless control module to output the desired voltage and change the brightness of the LED.

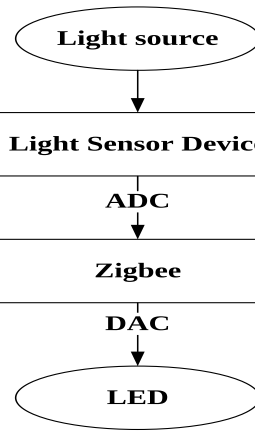

Fig. 3 Light Controlling System

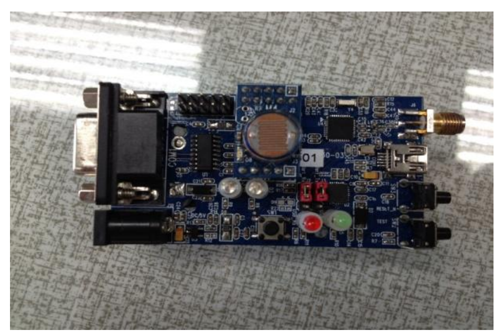

Fig. 4 ZigBee Optical Sensing Module**References**

4. System result and analysis

Figure 5 shows the model house which our system is tested on. There are two floors and three rooms. The room on the left of the second floor is 2F-1 and the one on the right is 2F-2. Each room is equipped with a light sensor. Three groups of current amplifiers are stored in the attic. The current amplifiers are used to supply power to the LEDs.

An infrared sensor used as an automatic switch is installed in level one. It can be turned on by a man-machine interface when someone is present to control the lights. The sensing device to control the first floor lamps turns off automatically when no one activates the infrared sensor. In the following we describe the test steps.

Fig. 5 House Module

Figure 6 shows the test result with fuzzy control applied. The electricity consumption for room 1F is 1963W. In room 2F-1 consumption is 784W, while 2F-2 is 540W. The total electricity consumption is 3287W. It can be seen from this data that after applying fuzzy control, the electricity consumption of each room is significantly decreased. This has achieved our goal of energy saving.

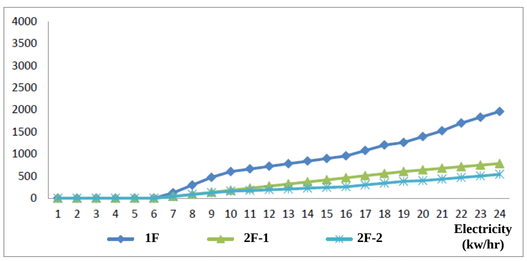

Fig. 6 Test Result with Fuzzy Control

5. Conclusion

When fuzzy control is not applied, lamps can be automatically turned off only sometimes. After running a test for 24 hours with the lamps all turned on under the testing environment without fuzzy control, it can be found that that even though the lights can be turned off sometimes, the electricity consumption is still higher than the test with fuzzy control. Therefore using the fuzzy control energy-saving mode can reduce electricity consumption and automatically adjust the brightness without requiring user input.

6. Reference

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