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A Study of Schoolroom Lighting Fuzzy Control System

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Abstract

In allusion to high electricity consumption and resource wasting of college schoolroom, this paper proposes a lighting fuzzy control system based on CC2430. The deviation and transformation rate comparing ideal illumination and the practical one has inferenced by Fuzzy Model Reference adaptive system (FMRAS), and it can compensate natural light illumination stabilizing schoolroom lighting through PWM code. The system core hardware structure and adaptive fuzzy control algorithm have been expressed. Simulation results show that the control system accords with government standard, and achieves the desired effect.

Keywords: *Illumination; CC2430; Model Reference; Adaptive Fuzzy Control; Matlab Simulation*

1. Introduction

Schoolrooms as an important place in college always adopt opening management pattern with eternal lighting, nobody lighting and few lighting. The number of lamp interior is numerous, and arrangement of wire is onerous.

To solve the problem above, this paper presents college schoolroom lighting fuzzy control system based on Zigbee. We choose CC2430 chip of TI as the core of data collection and terminal control, and adjust schoolroom lighting adopting and improved Fuzzy Model Reference Learning Control (FMRLC). It utilizes natural light reasonably, and creates favorable environment on the basis of energy conservation.

2. Core Hardware Design of Control System

The control system is been constituted with data collection, data processing and PWM drive control, as shown in Figure 1.

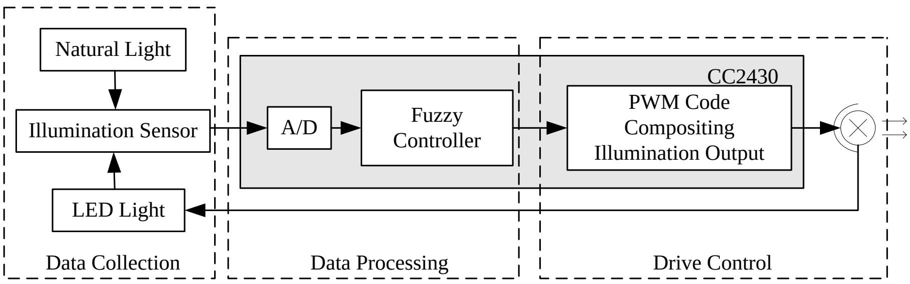

Figure 1. Control System Structure Chart

Where data processing and drive control have finished by CC2430.

The visible light illumination sensor—on9658 of ON which is a photoelectricity integration sensor is selected as illumination sensor, inlay double-sensitive element

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acceptor, and decay near infrared ray automatically. The range of visible light is sensitive, and the output current linear changes with illumination. The main role is collecting illumination signal of schoolroom environment, and sending to data processing unit during digital I/O pin P0.7 of CC2430. The circuit is shown as Figure 2.

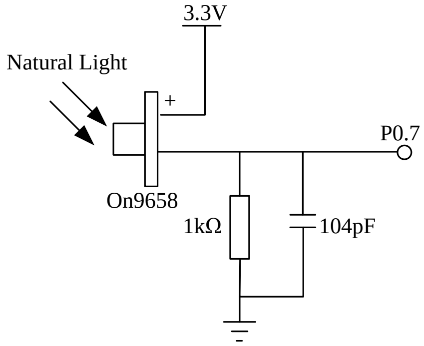


Figure 2. Circuit of llumination Sensor

The Zigbee chip as data processing and drive control of CC2430-F128 has a high-performance and low-power dissipation 8051 microcontroller core for depositing fuzzy control procedure [1-3]. ADC integrated inside chip supports 14 analog/digital transformation, and writes transform results to memory controller through DMA pattern. It not only makes detection result precise, but also improves system global efficiency.

To configure 16 timer—TIMER1 of CC2430, the PWM output aligning center. Firstly, we chooses TIMER1 positive counting/reverse counting pattern, and comparing pattern of gallery output chooses 5. Then the period of PWM signal deposits T1CCO, and controls variable quantity based on fuzzy inference finally. Computing PWM duty ratio to adjust effective value of output voltage, and compensating illumination of natural light [3-4].

2. System Application of Improved Adaptive FMRAS

In the illumination system at present, we employ control strategy of natural light and manpower one combined. It can’t build a precise model because of random, variable and interferential of natural light. This paper expresses an improved adaptive FMRAS as weak stability of traditional fuzzy control. For the improved one, no need for model of reference model and controlled system, it needs control rules on the basis of system fuzzy information to compensate disadvantage of traditional way.

The structure of adaptive FMRAS control system is shown as Figure 3 [4-9].

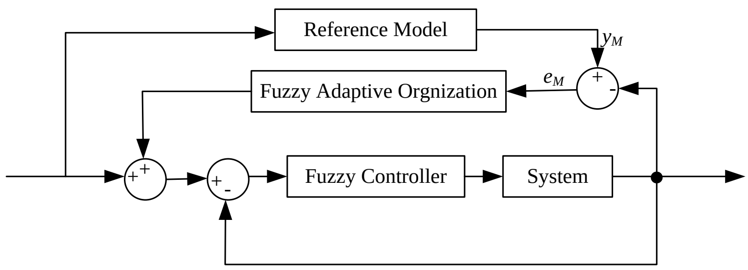


Figure 3. Adaptive FMRAS Structure

Where U_r is reference illumination value, y_M is output of reference model, y_f is output of controlled system, and e_M is difference between y_M and y_f.

The rules of fuzzy controller is: when deviation is large, the choosing is for eliminating error as soon as possible; when it is little, the choosing is for stabling system.

2.1. Design of Fuzzy Feedback Controller

On the basis of illumination standard, we make 450 Lux as standard illumination value, and set range [300,500]. After illumination stable, set deviation range [-20,20].

Feedback controller is two-dimensional fuzzy controller, and input value is illumination deviation *e* and deviation rate *ec*, output value is rise of controlled system *u*. Fuzzy set of *e* and *u* defines {NB, NM, NS, Z, PS, PM, PB}, and set of *ec* is { NB, NS, Z, PS, PB}. The fuzzy rules are shown in Table 1.

Table 1. LUT for Fuzzy Feedback Control

U		*EC*						
		-3	-2	-1	0	1	2	3
	-5	3.58	3.54	3.49	3.53	3.39	2.88	2.58
	-4	3.53	3.53	2.97	2.78	1.97	1.49	1.14
	-3	3.15	3.12	2.54	2.33	1.47	0.82	-1.15
	-2	2.7	2.7	2.2	1.6	0.84	0.31	-0.20
	-1	2.67	2.09	1.56	0.75	-0.08	-1.1	-1.15
E	0	2.67	1.79	0.82	0.19	-0.85	-1.82	-2.67
	1	1.15	1.1	0.05	-0.77	-1.57	-2.11	-2.67
	2	-0.20	-0.34	-0.87	-1.65	-2.18	-2.67	-2.67
	3	-0.20	-0.85	-1.49	-2.35	-2.32	-2.67	-2.67
	4	-1.15	-1.5	-2	-2.78	-2.78	-2.78	-2.78
	5	-2.67	-2.99	-3.54	-3.58	-3.54	-3.54	-3.58

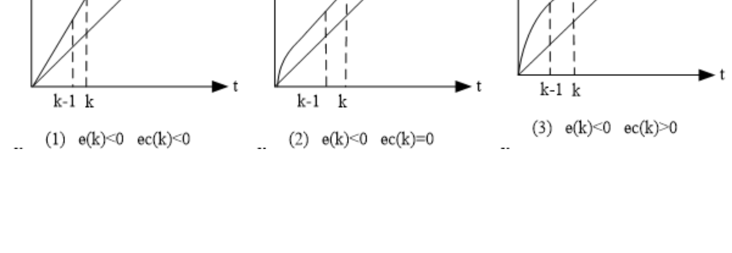
Where *E*, *EC*, *U* are linguistic variables of illumination deviation *e*, deviation rate *ec* and output rise *u* respectively.

2.2. Design of Fuzzy Adaptive Organization

For the system, fuzzy adaptive organization creates a fuzzy adaptive signal in accordance with the difference between y_M and y_f., and makes the output tend to reference model [10-12]. As a matter of fact, there will be a object parameters change, state interference, and so on. This makes the relationship between the reference model and transient response object will appear 9 kinds of relations, as shown in Figure 4 [13-14].There is Takagi and Sugeno (T-S) fuzzy model, that is:

$$\text{If } e = \text{A and } ec = \text{B then } u = g(e) \quad (1)$$

Where A, B are fuzzy sub-set, and $g(e)$ is continuous function of e.



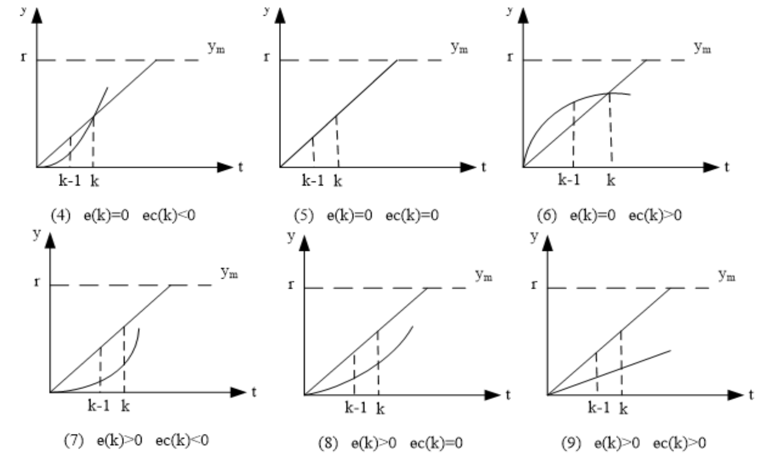


Figure 4. Relationship between the Reference Model and Transient Response Object

It gets adaptive fuzzy control rules based on the relationship of reference model and controlled object, as shown in Table 2.

Table 2. Fuzzy Rules

	U	*EC* PB	PM	PS	Z	NS	NM	NB
	PB	$g_1(e)$	$g_1(e)$	$g_2(e)$	$g_3(e)$	0	0	0
	PM	$g_1(e)$	$g_1(e)$	$g_2(e)$	$g_3(e)$	0	0	$g_3(e)$
	PS	$g_1(e)$	$g_2(e)$	$g_3(e)$	0	0	$g_3(e)$	$g_2(e)$
E	Z	$g_1(e)$	$g_3(e)$	0	0	0	$g_3(e)$	$g_1(e)$
	NS	$g_2(e)$	$g_3(e)$	0	0	$g_3(e)$	$g_2(e)$	$g_1(e)$
	NM	$g_3(e)$	0	0	$g_3(e)$	$g_2(e)$	$g_1(e)$	$g_1(e)$
	NB	0	0	0	$g_3(e)$	$g_2(e)$	$g_1(e)$	$g_1(e)$

Where $g_1(e)$, $g_2(e)$, $g_3(e)$are K_0e, $0.6K_0e$, $0.3K_0e$ respectively, and K_0 is ratio coefficient.

According to fuzzy rules, we can get adaptive fuzzy look-up table, as shown in Table 3.

Table 3. Fuzzy Adaptive Organization Fuzzy Look-up Table

	f	Ec -6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6
	-6	1	1	0.93	0.82	0.66	0.46	0.38	0	0	0.3	0.3	0.3	0.3
	-5	1	1	0.9	0.81	0.65	0.45	0.37	0	0	0.3	0.3	0.3	0.3
	-4	0.97	0.95	0.87	0.77	0.62	0.44	0.36	0	0.1	0.32	0.35	0.38	0.4
	-3	0.96	0.91	0.85	0.67	0.53	0.41	0.35	0	0.1	0.34	0.38	0.4	0.43
	-2	0.92	0.83	0.71	0.58	0.5	0.36	0.34	0	0.3	0.36	0.41	0.46	0.53
	-1	0.86	0.77	0.66	0.48	0.35	0.3	0.3	0	0.3	0.38	0.47	0.51	0.6
	0	0.8	0.67	0.5	0.4	0.3	0	0	0	0.3	0.4	0.5	0.67	0.8
e	1	0.6	0.51	0.47	0.38	0.3	0	0.3	0.3	0.35	0.48	0.66	0.77	0.86
	2	0.53	0.46	0.41	0.36	0.3	0	0.34	0.36	0.5	0.58	0.71	0.83	0.92
	3	0.43	0.4	0.38	0.34	0.1	0	0.35	0.41	0.53	0.67	0.85	0.91	0.96
	4	0.4	0.38	0.35	0.32	0.1	0	0.36	0.44	0.62	0.77	0.87	0.95	0.97
	5	0.3	0.3	0.3	0.3	0	0	0.37	0.45	0.65	0.81	0.9	1	1
	6	0.3	0.3	0.3	0.3	0	0	0.38	0.46	0.66	0.82	0.93	1	1

The product of arbitrarily element in table and K_0e is the output u_f of fuzzy adaptive organization in relevant system state, and

$$u_f = f(e,\ ec) K_0 e \tag{2}$$

2.3. Simulation

2.3.1. Set up Simulink model: Fuzzy logic tools of Matlab affords seamless connection with Simulink. After establishing fuzzy system in fuzzy logic tools, we can conduct simulation in Simulink environment. The fuzzy logic control block diagram in Simulink should be copied to simulation model established by user, and the name of its fuzzy inference matrix should be same to fuzzy inference system in Matlab working space. Finally, the connection of fuzzy inference system and Simulink will be accomplished.

We build Simulink model in Matlab 6.5 with adaptive FMRAS and fuzzy control rules above, as shown in Figure 5.

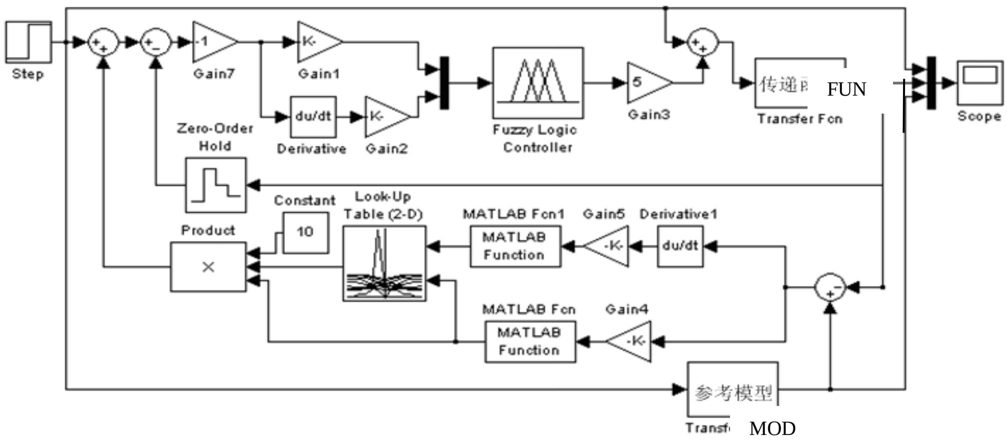


Figure 5. Adaptive FMRAS Simulation Model

2.3.2. Simulation Result and Analysis: Considering variety of light source problem, it simulates 1st order and 2nd order controlled models [15], the results are shown as Figure 6.

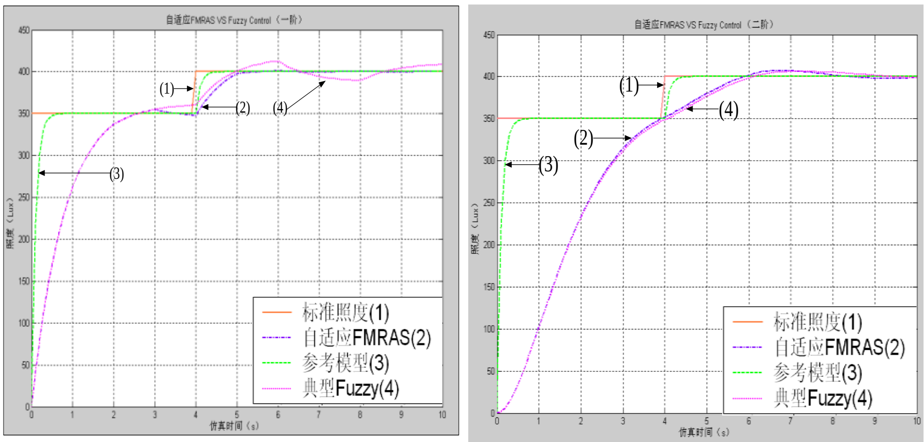


Figure 6. Simulation Results

Simulation results show that adaptive FMRAS has better tracking-performance, higher steady accuracy, less overshoot and faster response speed than traditional fuzzy controller.

2.4. Realization in the CC2430

The algorithm of fuzzy controller is realized by C language with two parts [16]: the procedure of computing LUT (look-up table) off-line information, the one of computing *e*, *ec* and *u* with on-line information[17]. The flow chart of algorithm is shown as Figure 7.

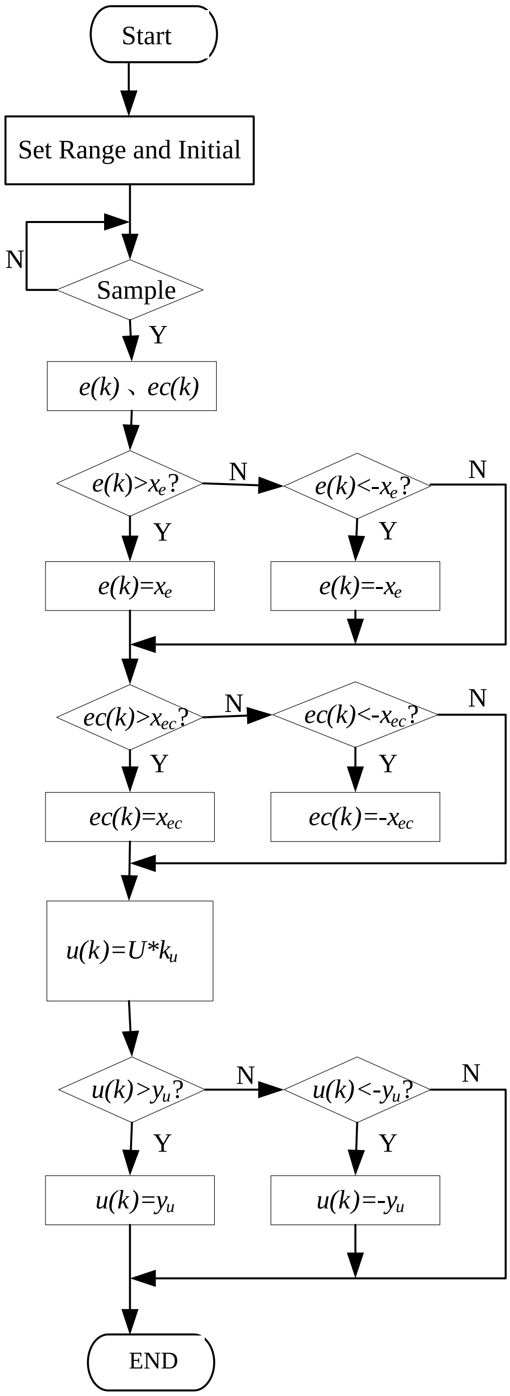
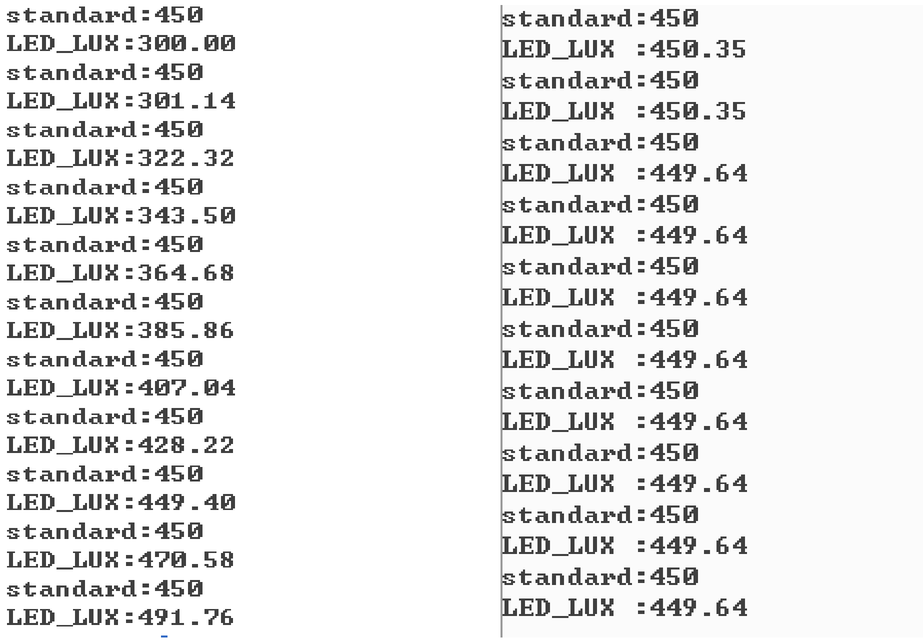


Figure 7. Flow Chart of Algorithm

Where k expresses sample time, xe, -xe, xec, - xec, yuand -yu are the range of deviation, rate of deviation and control value respectively, ku is ratio factor. The fuzzy controller is as a two-dimensional table, and it is as a two-dimensional array In C. The procedure is downloaded in the Flash of CC2430 by simulation. The control effective curves are shown as Figure 8.

In Figure 8, standard is standard illumination value, and LED_LUX is practical illumination value through fuzzy control. Simulation results show FMRAS controller has a better stability and faster implementation velocity.



(a) Traditional fuzzy controller **(b) Adaptive FMRAS controller**

Figure 8. Actual Mearment Result

5. Conclusion

The system expressed from this paper integrates sensor, wireless and adaptive fuzzy control technology, and improves traditional fuzzy control program. Experiments show that the system not only adjusts illumination output automatically and steadily based on environment changes, but also has smart structure for achieving. It adopts schoolroom environment of college, and guarantees illumination constant with energy conservation.

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