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FUZZY CONTROLLER FOR RICE COOKER

YU-CHENG LI, ZHI LUO

College of Electromechanical Engineering, North China University of Technology, Beijing, 100041,PRC
E-MAIL: lyc@ncut.edu.cn

Abstract:

The fuzzy controller with Hitachi HD404328 micro-controller is presented to meet the special requirements and some limitations of the Rice Cooker. A new inference scheme is given to estimate the total amount of rice and water to be used, and the authors have developed two new types of Rice Cookers. The working states of the Rice Cooker are divided in order to make the software structure more effective and more modularized. Finally, the results obtained from the experiment are given in the paper.

Keywords:

Fuzzy control; Rice Cooker controller; micro-controller application

1 Introduction

With the development of people's living standards, they expect more and more for the quality and efficiency of life. Rice is the staple food in many Asian countries including China. Just as offered in Figure 1, the perfect process of cooking rice is divided into six stages: preheating and sucking water, heating, boiling, stewing, swelling and heat preservation.

One kind of the present Rice Cooker in market is mechanical. It controls the switch of the heat silk through the peculiarity of alnico. The magnetism of alnico will be weakened when being heated. The cooker will be heating continuously as the power is put through. And when reaching the maximal temperature, the switch will be cut off automatically and so the cooking is over. This kind of cooker can't perform the preheating, sucking water and heat preservation. So it can't finish the cooking process offering in Figure 1. Due to that, the cooked rice doesn't taste good and the quality is also relatively poor. And this kind of cooker can't be used to cook gruel and perform timing cooking, etc.

The intelligent Rice Cooker in market (including the fuzzy logic cooker from aboard) can finish the process shown in Figure 1.But there are still problems existing in its quality. For example, when the voltage of the power is lower and the cooking rice is a little more, the top layer of rice will get half-cooked. When the voltage is higher, the bottom of the cooker will get burned. The rice gruel overflows occasionally when choosing Fast-cooking. Worried about overflowing, people may take little power to cook gruel. In this case, if the water is a little much, the gruel will not get boiled all along, or get boiled too quickly only cooked into branch water gruel. All the bad cases add to the users' trouble.

So, we develop this new kind of Rice Cooker based on fuzzy logic.

2 The design of hardware

The hardware of our cooker is almost the same with common intelligent Rice Cooker. In the field of the design

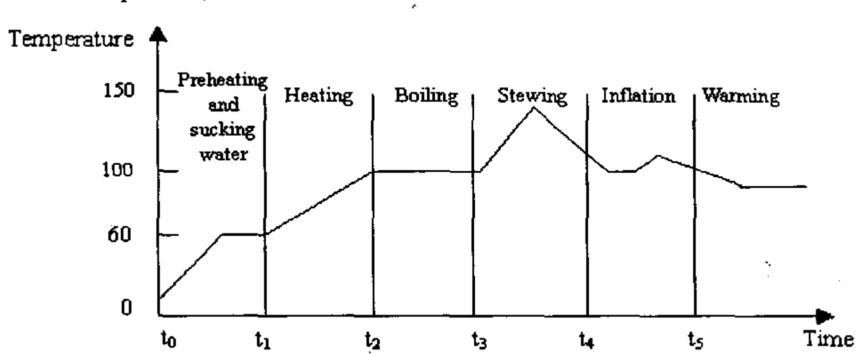

Figure 1 Desired curve of cooking

and low cost is the chief problem needing to be considered. So the selection of the CPU is very important. We have chosen a micro-controller HD404328 from Company Hitach. This 4-bit controller has stronger functions and lower price. This controller is mainly used in many kinds of household appliance which needs LCD. LCD, A/D converter and other control port are integrated in this controller. That simplifies the peripheral circuit in application. So we use this type of controller as our selection. The functions and characters of architecture are list below.

a) 64-pin, the patterns of package include DIP and QFP.

b) Built-in LCD driving circuit, support 24SEG×4COM, display data can be automatically transmitted to the segment signal pins without program intervention.

c) A/D converter (4 channels×8 bits)

d) 3 channels×8 bits timer/counters

e) Double crystal oscillators: fosc=4MHZ, 32.768kHZ crystal sub-clock. Four low-power dissipation modes.

f) 35 I/O pins including 8 high-current pins (15mA,max.)

g) 280-digit × 4-bit (or 536-digit × 4-bit) RAM, 4k-word×10-bit(or more) ROM

The designed architecture of our Rice Cooker is shown in Figure 2.

A/D converters do real-time detection on the temperature of the lid and the bottom of the cooker. And in this way, the cooker can form a fuzzy feedback control. Then the LCD continue displaying the time and the choosing menu. When the cooking is almost over, the LCD will display the last 10-14 minutes in counting down mode. The heat of the cooker is from the heating set, which is controlled by relays. The heating wires on lid and the cooker body is used to aid heating and keep heat preservation. They are controlled with bi-directional controllable silicon rectifier because the heating power is relatively low.

The design of the control scheme

The difference between the fuzzy Rice Cooker and common intelligent cooker is the application of the fuzzy logic technique. As everyone knows, in the traditional control method, the effect of control lies in master of the exact mathematic model of object. But in the control of the cooker, the mathematical model changes greatly with the change of the total amount of the water and the rice. The initial temperature of water, the temperature of the environment and the airtight degree of the lid will affect the result of the control. On the other hand, in each stage of the cooking process, the purpose of controlling is different from each other. That brings the difficulties for traditional control method to cook rice and cook gruel.

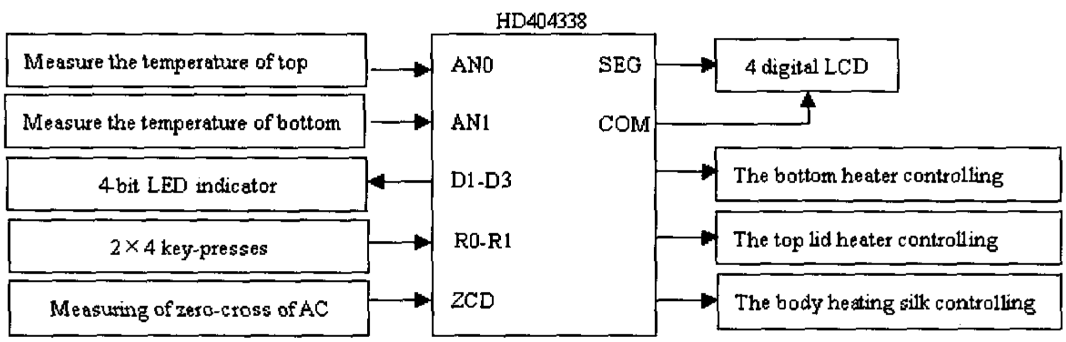

Figure 2 Hardware structure of Rice Cooker

At normal state, LCD display the time: hour, minute and second. The precision is the same with common quartz clock. The 8 keys is set to receive user's request, for example, choose the cooking menu, adjust the clock time, set the cooking time, start cooking, start heat preservation and cancel functions, etc. The four state LEDs show the current working mode. When starting cooking, two channel

Especially when cooking gruel, the total amount of rice and water is varying each time, and thermal resistor also has errors. When the water is boiling in the cooker, the difference of bottom temperature can reach about 10℃. If the power is a bit stronger, the water will overflow. If the power is a bit weaker, the water will not get boiling. In the 70 minutes of cooking gruel, it is rather difficult to keep the water boiling without overflowing for 40 minutes. Furthermore, if the voltage of power is too high (245V) or too low (170V), the power of the heating will change. In this case, it is also rather difficult to keep the cooking process immune from the change. Therefore, even we apply the technique of fuzzy logic control to the cooker, if the strategy and the rule of fuzzy control were not designed critically, it would be also very difficult to get a satisfying result of control.

Considering all the cases, we take several steps to solve the above questions.

1) Reason the total amount of water and rice in the initial stage of heating. Reference [2] suggests that inferring of the total amount should be performed in the stage of preheating. Test of the cookers on market (including cooker from aboard) show that inferring of the total amount of the water and rice is mainly performed in the stage of the preheating. But in this case, the result of inferring is greatly influenced by the initial temperature of water and the temperature of environment. So we can't get accurate estimation. Experiments show that after preheating the temperature of the water is about 60℃. Based on this condition we can avoid the influence of the initial temperature, inferring and judging of the amount can be more accurate. So we decide to infer the total amount of water and rice in the initial stage of heating. The following is our detail steps: use the main heating parts in a certain power, based on the temperature of the lid and the increment of the temperature in certain time, we can infer the changing of the total amount of the rice and the water, as shown in Figure 3. In this way, the error of the inferred amount is less than half cup. In the late stage of the heating and the stage of boiling, power can be regulated optimally according to the reasoned the total amount of rice and water

2) In countryside, condition of low voltage of power happened frequently. Considering this case, the power will be reduced and the time of heating will be prolonged. From the view of equivalence, that equals the addition of the total amount of rice and water. So the key of the problem is to reason the equivalent amount of the water and rice accurately. Then boost up the power to compensate the reduction created by the low-voltage power. Similarly, in the condition of high voltage, that equals the reduction of the total amount of water and rice. In this case we should weaken the power.

3) Things get more complicated when cooking gruel. In order to keep the water boiling without overflowing, various factors should be considered when controlling the power. In the rule for the stage of boiling in cooking gruel, the antecedents include the temperature of the bottom and its changing rate, the temperature of the lid and its changing rate, the initial temperature of the environment and the total amount of water and rice. The consequents include the

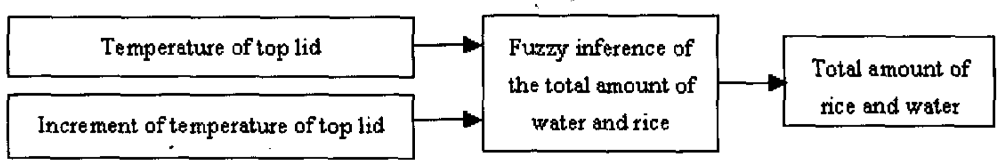

Figure 3 Inference of the total amount of water and rice

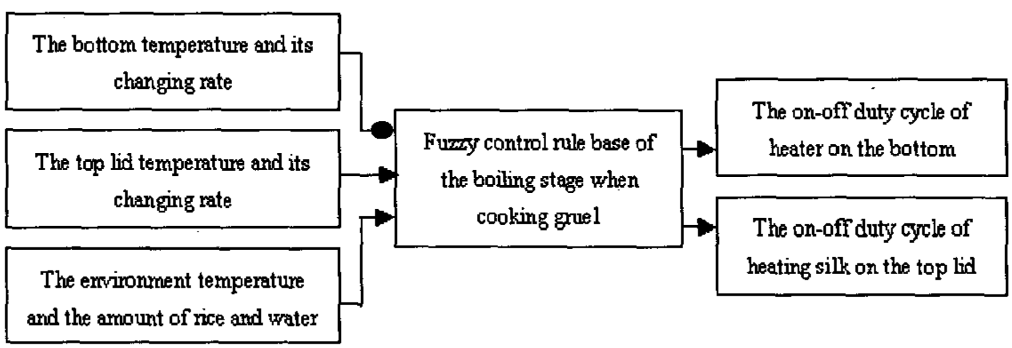

Figure 4.Fuzzy control rule base of the boiling stage when cooking gruel

on-off duty cycle of the bottom heating block and the on-off duty cycle of heating wire on the lid. But in another way, if one rule includes 6 antecedents and consequents, the operation and the inferring of the rule base will be very complicated. So in fact, the rule we use only includes 2-4 antecedents and 1 consequent, just like:

IF (t_bot = high AND dt_bot = medium
AND t_cov = high)
Then bot_power = low

We have used dozens of rules to form the rule base of cooking gruel, as shown in Figure 4. Though the normal control method need to construct a multi-variable controlling system of multi-input and multi-output. The regulation of control will become pretty complex and unrealizable.

4-bit microcomputer. This series of microcomputer has more than 100 instructions, and most of them has runtime of a machine cycle. The instructions are divided into arithmetic instructions, input/output instructions, controlling instructions, register instructions and data transferring instructions of internal RAM. In other words, the instruction system of HD404328 provided all the instructions that the other system instructions can provide.

This cooker we have designed four menus: (1) Rice Normal-cooking. (2) Rice Fast-cooking. (3) Cooking gruel. (4) Rice Soft-cooking. In addition, boiling water and cooking soup can be finished by (1) or (2). Each menu has sub-menus including starting cooking and timing cooking automatically. Except that the heat preservation is forbidden in cooking gruel, the other menu options will make the cooker automatically switch into heat preservation after

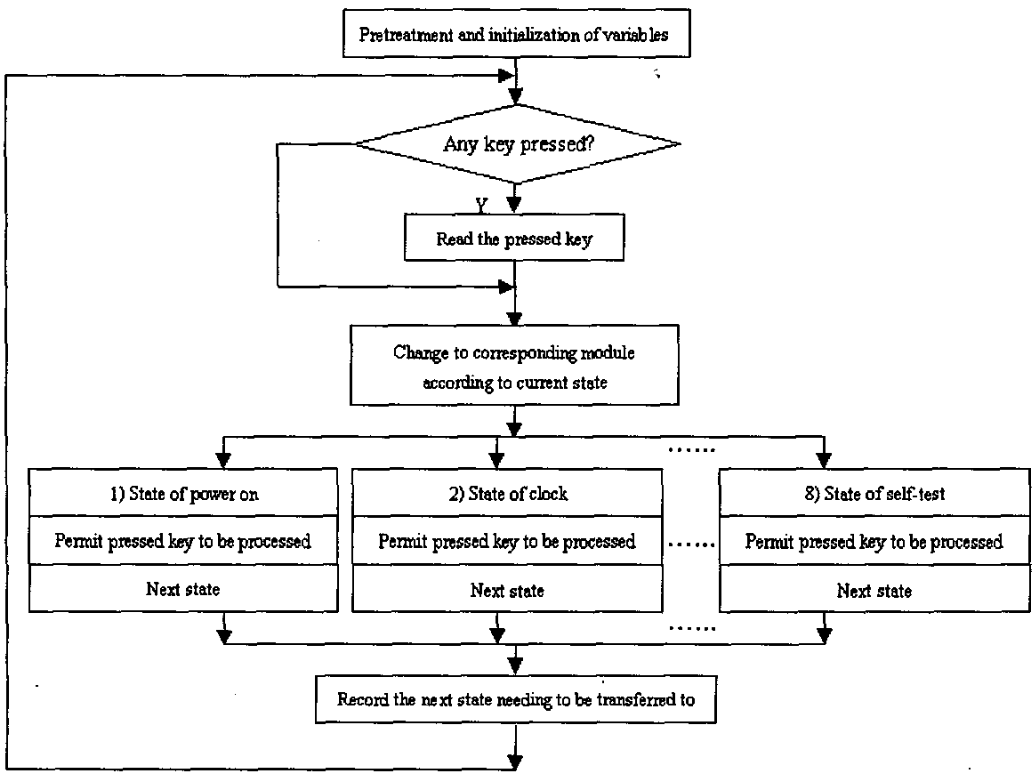

Figure 5 Software structure of the fuzzy controller

finishing cooking. And the cooker also has the functions of clock adjustment, timing cooking, the switch light of menus, the indicator light of working state, the canceling of function and the self-inspecting program running and etc. The program is pretty complex. In one way, the complexity

3 The monitoring software of the Rice Cooker

The single chip HD404328 is an HMCS400-Series comes from realizing of the fuzzy controlling and the request of the variety working state of cooking. In another, it comes from that the program should react to any key combination and operation accurately.

Quality of a program depends on three aspects:

a) Whether the functions are perfect.

b) The validity and reliability of the running.

c) Whether the program is convenient to be maintained, modified and updated.

Because in the tests of cookers, we should consider conditions listed below: different menu options, different amounts of rice, different amounts of water, different voltages of power supply, different environment temperatures, different characters of rice, and etc. So the number of tests will be large and the cycle of test will be very long. Due to these cases, we should try to avoid any hidden trouble or errors of programming in programming stage. Then we can avoid re-modifying repeatedly and delaying the whole development.

According to the request of each function, menus option and answering to the key-press, we designed the software structure with method of states-divided. First, we divide the different running situations into several states. In each state we define the task and the active key-press and the next possible state. In this way, program is running at a certain state at anytime. Each time when a key is pressed down, the monitoring program will decide to whether keep the current stage or change to another state. If no key was pressed down, the program will decide automatically whether to change the state or not. In the whole system, each state is separate from each other and the distinction is very clear. In another way, the relations between each state are also very clear. So this makes the software system easy to maintenance, amending and updating. We divide the working states of the cooker into:

1) The initial state of power on, the LCD will show the state sparklingly.

2) The state of clock timing.

3) State of adjustment of the clock time.

4) Warm state.

5) State of adjustment of the timer time.

6) Waiting state of timing cooking.

7) Cooking state (including four menus options)

8) Self-test state.

The system software structure is shown in Figure 5.

In addition, we add a 3V Lithium battery in order to keep the clock working properly and the LCD displaying the time when 220V power is cut off. Once power off, system program will soon switch CPU into low-power dissipation mode. In this mode, the current dissipation of CPU is at uA magnitude, so one Lithium battery can supply the CPU clock working for several years. Then we designed a soft "watch dog" with the timer T_c in CPU. This "watch dog" can make the system resume working properly in dozens of milliseconds in case of disorder of the running program.

4 Experiments and Conclusions

Based on the above ideas of design, we developed two types of fuzzy logic Rice Cookers, the powers are 700W and 900W respectively. The conditions of experiment:

(1). The power voltage including 170V, 220V, 245V

(2). The temperature of environment including 0℃, 30 ℃, 75℃

(3). The water used including tap water (25℃) and well water (18℃).

(4). The rice used including Chinese Northeastern rice (new rice an old) and common rice.

(5). The earth leakage current, resistance of anti-high-voltage and safe operation request are all according with corresponding national standards.

(6). Electromagnetic compatibility inspection: power on-off times are over 10,000. Interfering times of On-off of high-power transformer are over 1,000. AC power voltage varies from 130V-280V, the controlling circuit board and the Rice Cooker works properly and displays properly. Other electric performances are all in accord with the national electric standard criterion.

Under above conditions, plenty of tests show: cooking functions of each menu option can properly works, no overflowing, no half-cooked cooking, no burnt cooking. And the cooking times are all shorter than the Rice Cooker with the same power in market. Cooking gruel can keep the gruel mushy but not overflowing. The capability of cooking gruel exceeded the request of the contract of client. It has been proved that this fuzzy logic Rice Cooker made a good result.

Acknowledgements

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