IMPLEMENTATION OF FUZZY EXPERT COOLING SYSTEM FOR CORE2DUO MICROPROCESSORS AND MAINBOARDS

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Abstract

The aim of this study is to construct an effective fuzzy logic based control system for multi core (core2duo) microprocessors and mainboards. Fuzzy Expert Systems were constructed for controlling the power delivered to CPU and mainboard cooling fans. The CPU cooling FES consists of three inputs named as CPU temperature, CPU frequency and CPU core voltage. The output of this FES calculates the optimum speed of microprocessor fan and sends the speed value to the electronic fan driver circuit via serial port. The mainboard cooling FES consists of two inputs named as CPU temperature and the mainboard temperature. This FES calculates the optimum fan speed and controls the power delivered to the chassis fans via electronic fan driver circuit connected to the serial port of the computer. Safe, effective and silent cooling systems were realized by using the FES.

Keywords: Microprocessor cooling, mainboard cooling, fuzzy expert system, microprocessor and mainboard fan speed control

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1. Introduction

The new technology devices that use fuzzy logic based control systems increased the quality of control in many fields such as control technologies, intelligent systems etc [1]. The frequencies and the core voltages of advanced CPU and mainboard systems can be changed by the computer users by using overclocking software. Using the computers above their nominal frequency values can easily give harm to the microprocessors by means of overheating and overclocking and can be very dangerous for some microprocessor types [2]. CPU frequency, CPU core voltage and CPU temperature are input variables used to construct the first fuzzy expert system (FES) because higher CPU core voltage and frequency values increase the temperature of the processor and can give harm to the processor immediately. Intel Core2Duo 2.8 GHz. CPU was used during the test operation. The fuzzy logic membership functions were constructed according to the critical catalogue temperature values of the microprocessors. Because of all the reasons that are mentioned above, CPU temperatures must be controlled before overheating affects the central processing unit. When the microprocessor reaches the critical temperature degrees, the system enters in an unstable working stage and the processor can be out of order in a short period of time in the classical CPU temperature control systems. Fuzzy Expert System (FES) software was developed in C#.net programming language for controlling the cooling mechanisms of the microprocessor and the mainboard cooling systems. Two FES were constructed for cooling mechanisms of microprocessor and mainboard. The first FES controls the fan speed of the microprocessor and has three inputs named as “CPU temperature”, “CPU frequency” and “CPU core voltage”. CPU frequency and CPU core voltage can be changed by advanced overclocking programs made for compatible microprocessors and mainboards. So the classical control systems sometimes become inadequate for controlling temperature of an oveclocked CPU. The second FES controls the speed of fans of the mainboard and computer case cooling system. The second FES has two input variables named as CPU temperature and the Mainboard temperature. The developed systems propose new fuzzy logic based CPU and mainboard cooling systems that differ from the classical CPU and mainboard cooling systems that are developed before in many ways. In the classical CPU cooling systems only “the temperature” is accepted as the input variable for the cooling mechanism and classical logic is used for cooling purposes, but in the developed systems, three input variables named as CPU temperature, CPU Frequency and CPU Core voltage are used for the first FES for CPU cooling mechanism and two input variables named as CPU temperature and mainboard temperature are accepted by the second developed FES used for mainboard cooling. The developed system consists of two Fuzzy Expert Systems with multiple input variables and provides an expert system based control for cooling the CPU and mainboard. The constructed expert systems use the expert system based rule bases and fuzzy logic approach and have a changeable rule base support system.

2. Materials and Method

Fuzzy logic is a form of multi valued logic that uses fuzzy set theory. In contrast with "crisp logic" fuzzy logic variables may have a value that ranges between 0 and 1. [2-6]. The General Structure of a Fuzzy Expert System consists of four main parts: fuzzifier, fuzzy rule base, Mamdani inference mechanism and defuzzifier. The parts of the constructed fuzzy expert system are expressed below. Mamdani Inference system and center of sums defuzzification method is used in the constructed FESs.

2.1. The General Structure of the Fuzzy Expert Cooling System for Multi Core Microprocessors & Mainboard

The general structure of this FES consists of two combined FESs. The first FES calculates the speed value of the microprocessor fan according to the input variables CPU temperature, CPU frequency and CPU core voltage. The second FES controls the speed of cooler fans of the mainboard by evaluating the input variables named as CPU temperature and Mainboard temperature. The calculated rpm values are converted to 9 degrees speed values and the converted values are sent to microcontroller based electronic fan speed control system via the serial ports.

The temperature input variable of the FESs acts like a feedback control signal in the PID circuits. If the temperature rises, the FES rises the power delivered to the CPU cooling systems and mainboard cooling fans by sending higher speed values to the microcontroller based electronic speed control unit via serial ports of the computer. The speeds of the microprocessor and mainboard fans are controlled by changing the duty cycle value of the PWM signal. The software of FES was developed in C#.net software language and the rule base can be changed by the user because the rules were defined in the tables of Microsoft Excel and the software reaches the rules by reading values from the excel tables.

Mamdani inference mechanism is used as the inference method. This inference system uses implication method as minimum, and aggregation method as the maximum [7-9]. Center of Sums defuzzification method is used for calculating the crisp values of the outputs of the systems [10]. 64 rules were defined for the rule base of microprocessor cooling system and 16 rules were constructed for the mainboard cooling system. In the developed software, PIC Basic programming language was used for programming 16F877 microcontroller that receives the speed values of the microprocessor and mainboard fans and produce PWM signals to drive the fan circuits. In the Figures 1-2, the general structures of the FESs are shown. Also the developed software shows the firing strength of the input and output variables in the list boxes in addition to the calculated crisp output values of fan speeds.

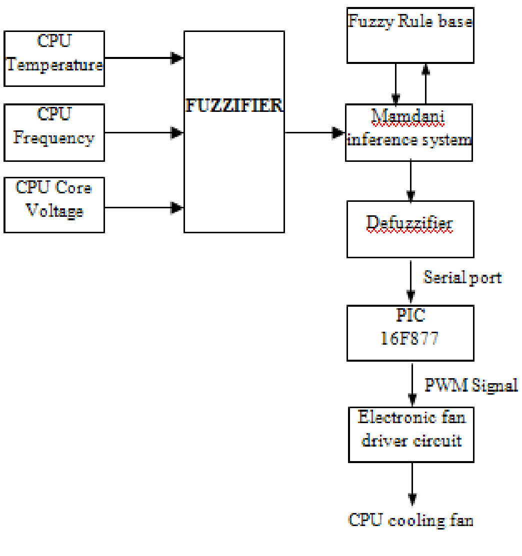


Figure 1. The general structure of CPU cooling FES

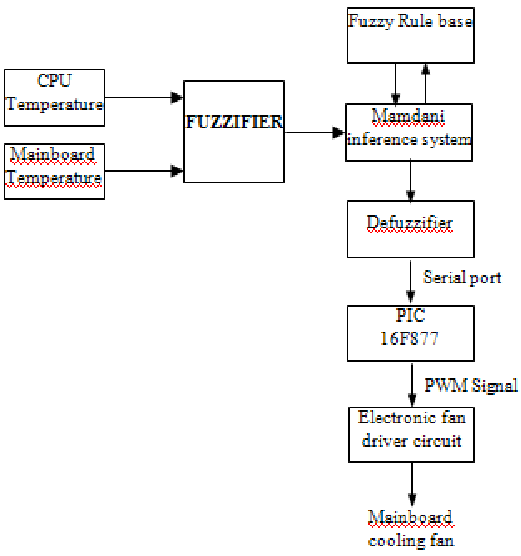
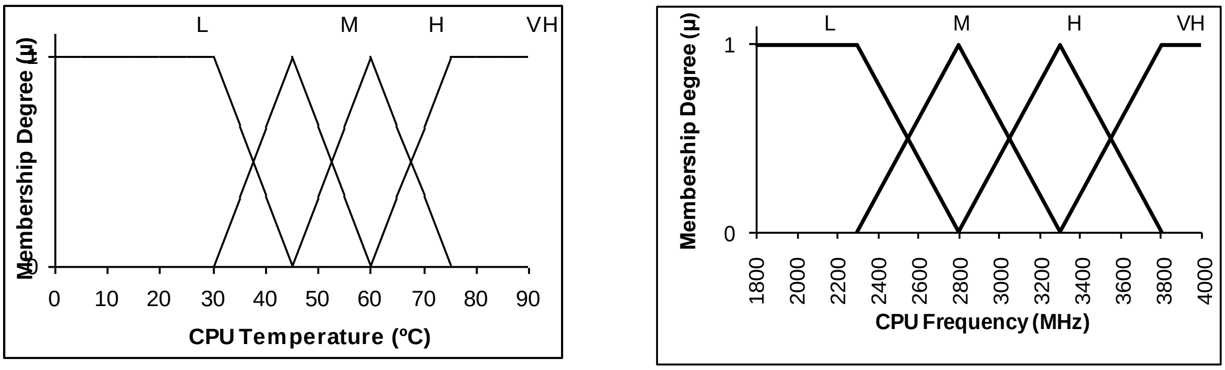


Figure 2. The general structure of mainboard cooling FES

2.2 The Membership Functions of the CPU Cooling System

The membership functions of the Fuzzy Expert CPU cooling systems (The First FES) are shown in the Figure 3. Figure 3a, 3b, 3c shows the membership functions of the input variables of the first fuzzy system named as CPU tempearature, CPU frequency and CPU core voltage. Figure 3d shows the membership functions output of the first FES (CPU fan speed).



a.The First Input Variable of CPU Cooling FES

b. The Second Input Variable of CPU Cooling FES

c. The Third Input Variable Of CPU Cooling FES

d. The Output Variable of CPU Cooling FES

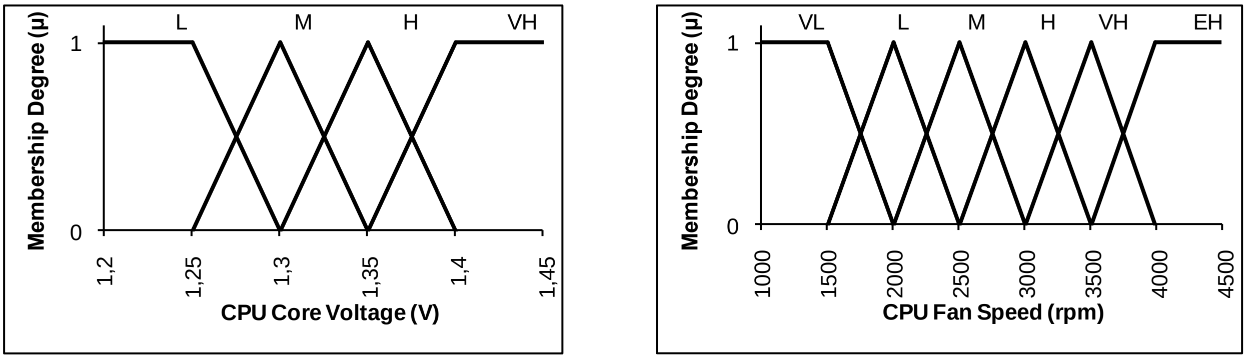
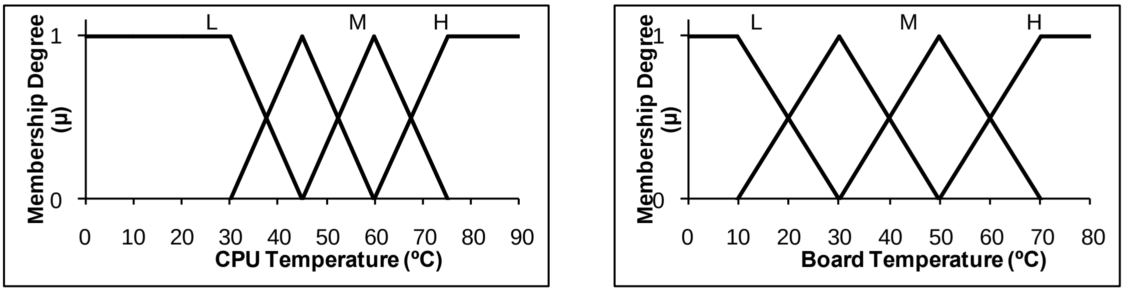


Figure 3. Membership functions of CPU cooling FES

2.3 The Membership Functions of the Mainboard and Computer Case Cooling Systems

Figure 4 shows the membership functions of the input variables of the second fuzzy system constructed for cooling mainboard and the computer cases. In the Figure 5, the output (rpm value) of the second fuzzy system is shown. The general appearance of the FES software was shown in the Figure 6.



A. Input Variable of Second FES

B. Input Variable of Second FES

Figure 4. Membership functions of the input variables of second FES (CPU temperature, board temperature)

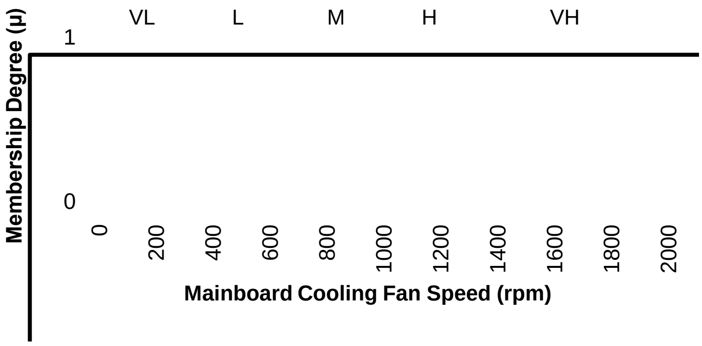


Figure 5. Membership functions of output variable of second FES (mainboard cooling fan speed).

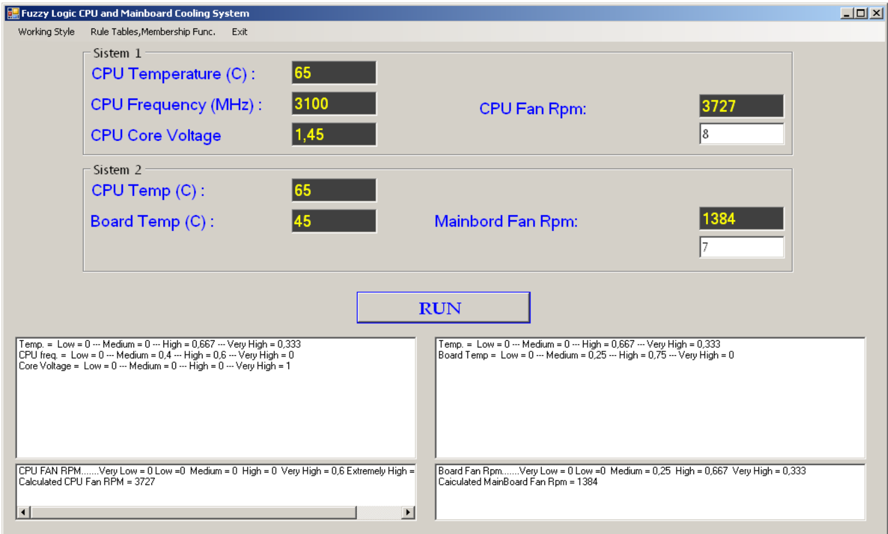


Figure 6. The General Appearance Of The Fuzzy Control Software

2.4. The Rule Bases of the Constructed Fuzzy Expert Systems

The rule base of the first FES that controls the speed of CPU fan consists of 64 rules. The rule base of the second FES consists of 16 rules. Some of these rules of the first FES are shown below:

Some of the rules of the first FES are :

Rule 1 If the CPU temperature is Low, CPU frequency is Low and CPU core voltage is Low than CPU fan speed is Very Low.

....

Rule 4 If the CPU temperature is Low, CPU frequency is Low and CPU core voltage is Very High than CPU fan speed is Low.

....

Rule 10 If the CPU temperature is Low, CPU frequency is High and CPU core voltage is Medium than CPU fan speed is Medium.

....

Rule 22 If the CPU temperature is Medium, CPU frequency is Medium and CPU core voltage is Medium than CPU fan speed is Medium.

Rule 23 If the CPU temperature is Medium, CPU frequency is Medium and CPU core voltage is High than CPU fan speed is High

....

Rule 32 If the CPU temperature is Medium, CPU frequency is Very High and CPU core voltage is Very High than CPU fan speed is Very High

....

Rule 46 If the CPU temperature is High, CPU frequency is Very High and CPU core voltage is Medium than CPU fan speed is Very High

....

Rule 57 If the CPU temperature is Very High, CPU frequency is High and CPU core voltage is Low than CPU fan speed is Very High

....

Rule 63 If the CPU temperature is Very High, CPU frequency is Very High and CPU core voltage is High than CPU fan speed is Extremely High

Rule 64 If the CPU temperature is Very High, CPU frequency is Very High and CPU core voltage is Very High than CPU fan speed is Extremely High

The rule base of the second FES consists of 16 rules. These rules are shown in the Table 1.

Table 1. The rule base of the mainboard cooling fan.

Rule	Board Temperature	CPU Temperature	Mainboard Cooling Fan Speed
1	Low	Low	Very Low
2	Low	Medium	Very Low

3	Low	High	Low
4	Low	Very High	Low
5	Medium	Low	Medium
6	Medium	Medium	Medium
7	Medium	High	High
8	Medium	Very High	High
9	High	Low	Medium
10	High	Medium	High
11	High	High	High
12	High	Very High	Very High
13	Very High	Low	High
14	Very High	Medium	Very High
15	Very High	High	Very High
16	Very High	Very High	Very High

2.5. The Defuzzification Method

The center of sums defuzzification method was used in the software. This process involves the algebraic sum of individual output fuzzy sets like c_1 and c_2 instead of their union. Defuzzified value z* is calculated by the formula below (Eq. 1). $\overline{z}$ is the distance to the centroid of the respective membership functions [9-10].

$$z^{*}=\frac{\int_{z}\overline{z}.\sum_{k=1}^{n}\mu c_{k}(z).dz}{\int_{z}\sum_{k=1}^{n}\mu c_{k}(z).dz} \qquad (1)$$

3. Results and Discussions

During the test operation frequency is raised by computer software and the increment of CPU fan speed is observed in the developed FES. When the frequency is constant and the CPU core voltage is increased, increment of CPU fan speed is observed too. Constructing a more effective cooling system was aimed because this system increases the fan speed of CPU before CPU enters the dangerous and critical temperature ranges which can easily give harm to the CPU. Overclocking the high end computer systems become safer by the constructed fuzzy logic algorithm. The first graphic in Figure 7 shows the change between the CPU fan speeds (rpm) versus the input variables CPU temperature and frequency when the CPU core voltage is constant and adjusted to 1.325 V. The Figure 8 shows the change between the CPU Fan speed (rpm) versus the input variables CPU Temperature and CPU Core voltage when the CPU frequency is constant and adjusted to 2.8 GHz. Figure 9 shows the speed of mainboard cooling fan versus the input variables mainboard temperature and microprocessor temperature. In the future work, developing the FES control models for other microprocessor families is aimed.

During the test operation the frequency of the CPU is raised from 1.8GHz to 4 GHz by using overclocking software when the CPU core voltage is 1.3 V. The FES of CPU cooling system gives better results than the standard cooling system. The standard cooling system became insufficient when the frequency and core voltage are raised to the critical values. Figure 10.a shows the temperature test results obtained with classical fan and FES of CPU cooling system. Figure 10.b shows the test results when the CPU core temperature was raised from 1.2 V to 1.45 V when the CPU frequency is 3.4 GHz. During the test operations the fuzzy cooling system gave better temperature results and protected the CPU against defective overheating.

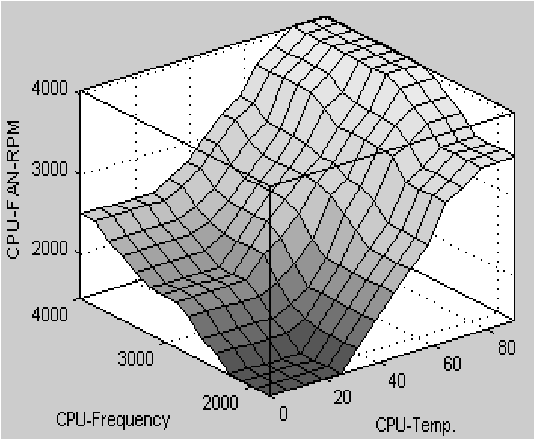


Figure 7. The CPU fan speed (rpm) vs. CPU frequency and CPU temperature

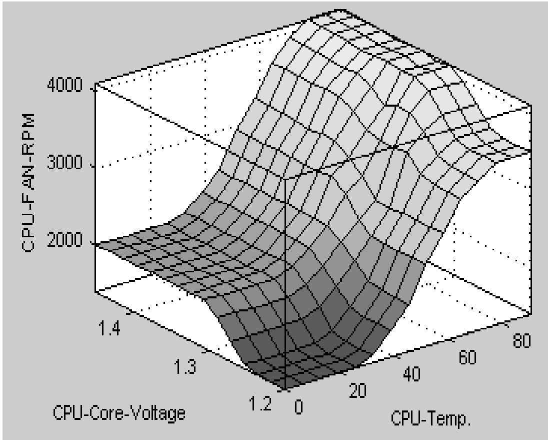


Figure 8. CPU fan speed (rpm) vs CPU core voltage and temperature

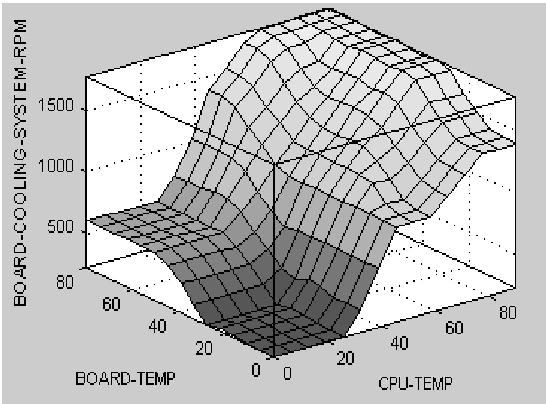
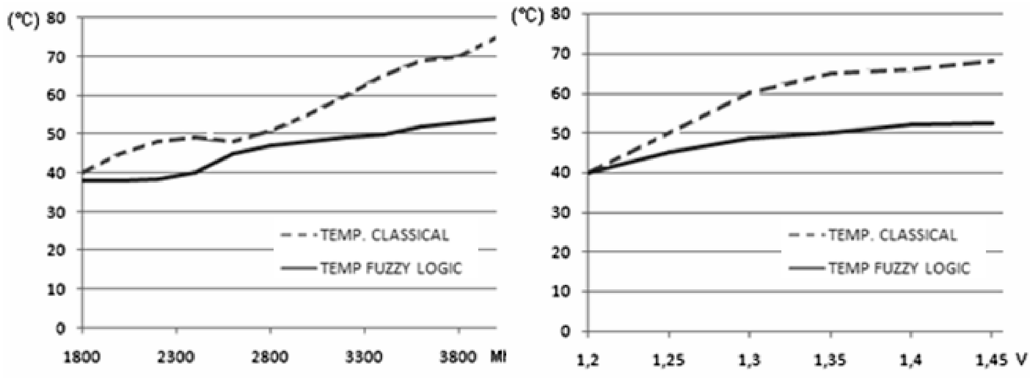


Figure 9. Fan speed of mainboard and computer case (rpm) cooling system versus mainboard and CPU, temperature (C)



a. frequency is raised from 1.8 to 4 GHz b. core voltage is raised from 1.2 V to 1.45 V

Figure 10. The Temperature test results of classical and the fuzzy expert cooling system

4. Conclusion

Advanced CPU and mainboard cooling systems were designed by constructing two fuzzy expert systems. As seen from the results listed above, when the frequency is raised and core voltage is raised, the overheating problems can occur in the classical temperature control systems. But in the developed FES, overheating problems are eliminated by the CPU cooling FES when the CPU is used in high frequencies and the CPU core voltage is adjusted to high levels. And an effective mainboard cooling mechanism is constructed by the developed mainboard cooling FES.

In the developed Fuzzy Expert systems the rule bases are constructed in the Microsoft Excel tables, and this specification supplies the flexibility of updating the rule base by the user. Successful results were obtained during the test operations shown in the Figures 7- 10 when the developed FESs are used.

Acknowledgement

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