Implementation of Fuzzy System for Fat detection in milk

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ABSTRACT: Fuzzy based temperature controller is implemented for detection of fat content in cow / buffalo milk. The system uses MALAB for Fuzzy Inference System (FIS) to take control action and ELVIS – II+ as DAQ which acts as bridge between FIS and test sample temperature control unit. The temperature of milk sample is controlled at 35oC and the fat content in sample is measured with the help of Ultrasonic detection method. The milk sample temperature is maintained to have identical distribution of fat globules. Different cow and buffalo milk samples are tested and the results are compared with Gerber's Method. The results seem to be better for input milk samples.

Keywords: Fuzzy Inference System, Fuzzy Logic Toolbox, Ultrasound, Milk Fat.

I.   INTRODUCTION

Fuzzy logic has been widely used in control systems in the last decade [25]. The survey [8, 9, 23] revealed that fuzzy logic has been recognized to be very appropriate in implementing the operators experience in the design of control systems. The fuzzy controllers are successful in the process control applications because of their capability to handle imprecise noisy data and to handle the nonlinear conditions. Thus the Fuzzy Inference System can be applied to control temperature of milk sample precisely.

The quality of milk is directly related to the health of consumers. To ensure the quality of milk and dairy products, dairy industry in several key areas such as cows scientific farming, the acquisition of raw milk, milk and dairy processing quality control, milk products qualified inspection, etc. need to repeatedly test the quality of milk. There are many indicators that value the quality of milk, but the most commonly used is the main nutrients in milk – fat, protein and lactose content. Lactose content relatively changes smaller, while fat and protein changes dramatically[4]. So the standards require that the fat and protein content in milk quality testing mandatory monitoring indicators. As for these two components in the detection, the traditional method is chemical based, (which are complicated and requires chemical reagents to test a long time) such as the fat in milk is usually measured by Babcock method, Geber method, Rose-Gottlieb method and the protein content measure used Kjeldahl method[2, 6].

II.   ULTRASONIC FAT DETECTION

Ultrasound is widely used medically and in industrial process control nevertheless the application of ultrasound in the quality control of foods, and biological media is yet to be sought after. Ultrasonic techniques can avoid the important hazard of product contamination. Another important feature of ultrasonic measuring techniques is that, in most cases, neither reactive nor replaceable elements need to be added to the medium under test [24]. Ultrasonic characteristic parameters, velocity and attenuation coefficient changes with the quality of milk[1,7]. The temperature of test sample has a great effect on accuracy measure of ultrasonic parameters [1]. Also the ultrasonic parameters find good stability within 35^oC to 45^oC temperature range and it is relatively appalling when the temperature is lower than 35^oC or higher than 45^oC. Thus milk ultrasonic parameters measure with dynamic temperature diminished the impact of temperature and makes detecting relatively accurate for measurement of fat and protein content in milk. Using Surface Acoustic Wave devices different liquid samples can be analyzed keeping the sample temperature under controlled conditions of 23^oC [4].

The determination of fat content according to Gerber involves running off the fat into a special measuring vessel, the butyrometer, and determining its volume as a percentage by mass. The fat is present in milk in the form of small globules of various diameters, from 0.1 to 10 micrometers [2]. Milk fat is lighter than water and creams if it is left standing. A fat-rich layer accumulates on the surface. Stirring and careful shaking restore the original distribution. If the layer of cream cannot be evenly distributed in this way, the milk should be slowly heated to 30^oC – 40^oC and gently swirled around until a homogenous fat distribution is achieved. The milk is cooled to 20^oC for further process of test. The volumeters for Gerber test are calibrated at 20^oC. Any variation in temperature will influence the volume. Thus for determination of fat content in milk, the desired milk sample temperature has to be maintained. It can also be said that for different technique of fat detection different temperature levels are used, which should be precisely controlled.
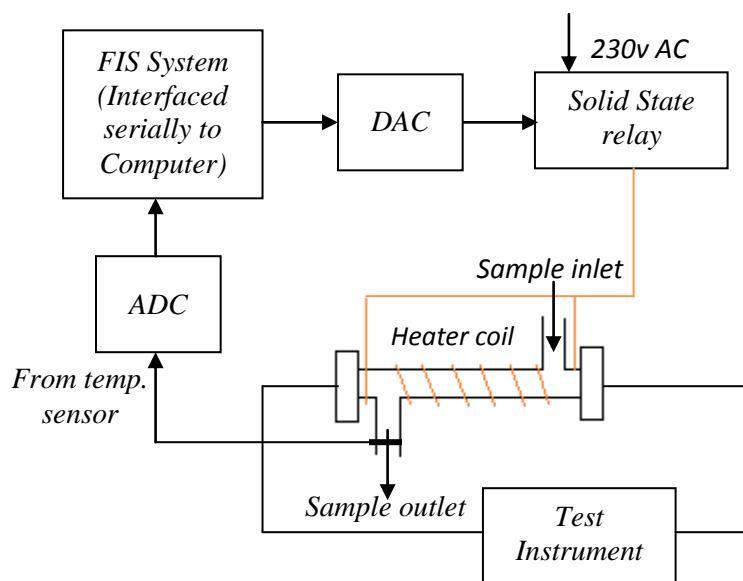
III.   SYSTEM OVERVIEW

Figure 1: System block diagram

The system implemented mainly consist two parts: a Fuzzy Inference System (FIS) based temperature controller that controls the temperature of sample and the Ultrasonic testing equipment that measures fat of sample. The figure 1 depicts block diagram structure of implemented system. The temperature sensor is inserted at outlet of milk sample. The ELVIS – II+ makes an analog interface between sensor, solid state relay and computer system. The sample test chamber is formed with 5mm diameter and distance between Ultrasonic transducers is 110mm. A heater coil is wound along the chamber. Milk sample at room temperature enters into chamber and controlled milk sample at constant temperature is available at outlet. To analyze and control, the FIS based system is developed. The control signal is available in the range of 0v to 5v. For solid state relay this signal is converted in the range of 4mA – 20mA. Solid state relay operates linearly providing output power from 00% to 99%. The heater coil is controlled as per the sample temperature detected initially. The milk sample is tested by ultrasonic measuring instrument to get the result in fat.

IV.   FUZZY INFERENCE SYSTEM

Fuzzy logic, which is the logic on which fuzzy control is based, is much closer in spirit to human thinking and natural language than the traditional logical systems. It provides an effective means of capturing the approximate, inexact nature of the real world. The essential part of the fuzzy logic controller (FLC) is a set of linguistic control rules related by the dual

concepts of fuzzy implication and the compositional rule of inference. In essence, then, the FLC provides an algorithm which can convert the linguistic control strategy based on expert knowledge into an automatic control strategy. The methodology of the FLC appears very useful when the processes are too complex for analysis by conventional quantitative techniques or when the available sources of information are interpreted qualitatively, inexactly, or uncertainly. Thus fuzzy logic control may be viewed as a step toward a rapprochement between conventional precise mathematical control and human-like decision making [8].

Fuzzy controllers are used were control action is computed by means of fuzzy logic operations. It receives crisp data from the data acquisition system and sending control or references to manipulated variables. In this case, the input and output variable, the decision / control levels, and the controller flow diagram relating are defined as the involved variables. The controller knowledge includes linguistic variable (LV), set of the rules, the reasoning period, the way of the handling the physical data, the fuzzy logic operation, and the deffuzification method.

The number of LV is determined the ability to qualitatively distinguish different variables conditions, that is, the ability to express different operating rules for each LV. They will lead to set of rules.

The reasoning period selection is made in the similar way to the sampling period in the sampled data system. Physical variable range can be tuned according to the experience. Also, membership function (MF) parameters like shape, support, or gain will allow establishing smoother or sharper control actions.

Since past several years, fuzzy control has emerged as one of the most active and fruitful areas for research in the application of fuzzy set theory. Various authors have described their pioneering research based on fuzzy logic system. The application such as water bath temperature control [5, 10, 19], temperature control of polymerization reaction [14], solar air-conditioning system [17], estimate heat tolerance of plants by chlorophyll fluorescence measurement [11], implementation of fuzzy logic system based on FPGA using VHDL [12, 13], educational light tracking system [15], petroleum separation process [16], fluid level control system using SCADA [18], refrigeration plant [20] and many more are found to be giving valuable results for Fuzzy Logic Controllers (FLC) as compared to conventional controllers that tested. Fuzzy logic is the logic on which fuzzy control is based, is much closer in spirit to human thinking and natural language than the traditional logical systems. The FLC provides an algorithm which can convert the linguistic control strategy based on expert knowledge into an automatic control strategy.

Here, analog value of temperature sensor is acquired through ELVIS – II+ data acquisition system. This provides the resultant 16 bit quantity in equivalent hexadecimal. The value so obtained is converted to temperature The MATLAB environment consists Fuzzy Logic Toolbox.
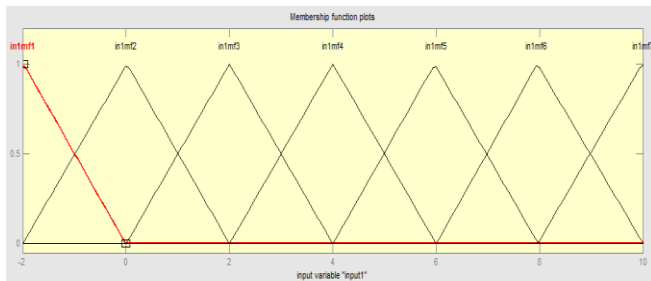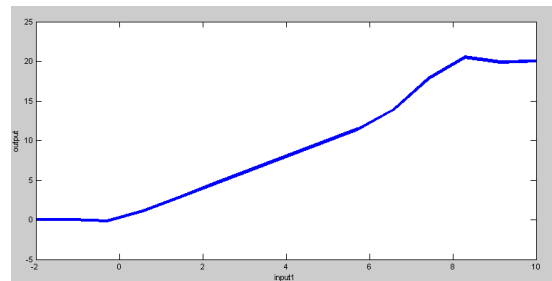

Figure 2: (a)

Figure 2: (b)
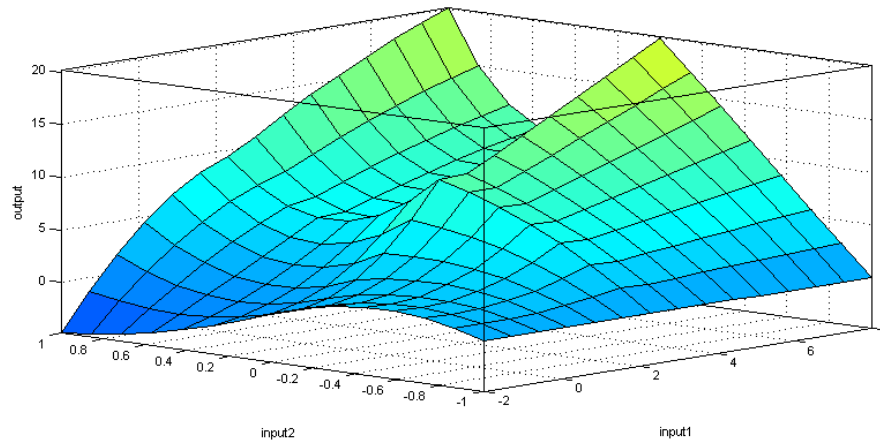
Figure 2: (c)

Figure 2: (a) Triangular Membership Function plot.
(b) Surface view for error FIS.
(c) Surface view for change-in-error FIS

V.   EXPERIMENTAL RESULTS & DISCUSSION:

The four milk samples are selected having different fat concentration directly from farm. From each sample 20ml of milk is taken for testing which will be heated upto $35^{o}C$ exactly. The milk in the specimen bottle is thoroughly mixed through gentle shaking. This is done to bring about an even distribution of fat and to prevent frothing and formation of butter. Milk is lighter than water and creams if it is left standing. A fat-rich layer accumulates on the surface. Stirring and careful shaking restore the original distribution. The prepared sample is sucked to testing chamber that is temperature controlled. Fuzzy Inference System detects the initial temperature of milk sample and compares with setpoint ($35^{o}C$). According to the error generated the first iteration output is fired using error FIS file. Figure 2(a) indicates the Triangular Membership Function distribution for error FIS and its respective surface view is shown in figure 2(b). For next successive iterations the change-in-error is considered, the surface view for change-in-error is shown in figure 2(c). Hence, once the exact temperature is achieved the fat content in sample is measured. The ultrasound is fired immediately and the velocity of milk attenuation coefficient is measured.

Table 1 shows the resultant values indicated by Ultrasonic equipment where attenuation of signal is measured. The sample is tested repeatedly to get exact value of fat contents in given milk sample.

Sample Number	Fat contents (No. of repetitions)			
	1	2	3	4
1	5.25	5.20	5.19	5.30
2	1.19	1.15	1.09	1.18
3	3.51	3.45	3.48	3.54
4	2.79	2.71	2.74	2.79

Table 1: The values of Fat contents in different milk sample.

VI.   CONCLUSION

Fat globules content in milk largely depend on sample temperature. The fat globules can be evenly distributed with increase in temperature of sample. The Fuzzy Logic controller is applied to precisely control the temperature of milk sample. System is effective to indicate correct value of fat contents in milk sample, keeping constant the temperature of sample each time it is tested. Hence to detect fat content in milk, the sample temperature can be controlled by Fuzzy Logic type temperature controller technique. The stumbling block in system is time consumed for heating sample temperature, as it take many seconds to reach the desired set point. This hurdle may be rectified in future study to reduce the time consumption.

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