ESTIMATION OF FAT IN MILK: AN APPLICATION OF DAQ

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ABSTRACT

Data Acquisition System (DAQ) plays a vital role where the analog environment needs to be sensed and controlled by digital system. Ultrasonic Fat detection in milk is implemented using ELVIS – II+ as DAQ. The system senses current sample temperature of milk and it is heated upto desired setpoint that is controlled through MATLAB based Neuro-Fuzzy System. Here analog and digital systems are in command of interfacing between both of them. Also different membership functions are tested and results shows triangular-shaped membership function is suitable for this application.

I INTRODUCTION

Ultrasounds are pressure waves which can be propagated in materials, with frequencies ranging from 20 kHz to few hundreds of megahertz[3]. Material sensors based on ultrasonic transducers often measure some wave parameters, since these parameters are strongly dependent on the characteristics of the media the wave is travelling through. Ultrasounds are widely used in sensing system due to its non-invasive measurements, rapid response time, low power consumption etc., however substances under investigation must be acoustically conductive and also signal may corrupt due to bubbles and attenuates at high frequency. The amplitude of an ultrasound beam decreases exponentially as a function of distance that it travels through a medium[1].

$$A(z) = A_0 e^{-\propto Z}$$

where *A* is the attenuated amplitude of the ultrasonic beam, *A0* is the initial amplitude of the beam at distance 0, *z* is the distance (thickness of the sample) and *α* is the amplitude attenuation coefficient.or by alternating solution

$$p(t,x) = p_0 e^{-\propto x + j\omega(t - \frac{x}{c})}$$

where *p*0 is the wave amplitude in *x* = 0, for *t* = 0, α the spatial attenuation and *c* the velocity of the ultrasound wave which propagates with the wavelength

$$\lambda = \frac{c}{f}$$

The speed of propagation *c* and the spatial attenuation α are specific of the material which the wave propagates in. In detail, for simple liquids:

$$c_{liquids} = \sqrt{\frac{K}{\rho}}$$

With ρ the density of the liquid and *K* its bulk modulus (inverse of the compressibility β). The spatial attenuation on the contrary depends on several contributions: the absorption, the viscous, thermal and scattering losses and the losses due to the relaxation processes; the latter, in turn, depend on other material-specific parameters[9,11].

II DAQ SYSTEM

DAQ systems capture, measure, and analyze physical phenomena from the real world. Light, temperature, pressure, and torque are examples of the different types of signals that a DAQ system can measure. Data acquisition is the process of collecting and measuring electrical signals from transducers and test probes or fixtures, and sending them to a computer for processing. Data acquisition can also include the output of analog or digital control signals. The DAQ system includes[13,14]:

• Transducer—A device that converts a physical phenomenon such as light, temperature, pressure, or sound into a measurable electrical signal such as voltage or current.

• Signal conditioning—Hardware that you can connect to the DAQ device to make the signal suitable for measurement or to improve accuracy or reduce noise. The most common types of signal conditioning include amplification, excitation, linearization, isolation, and filtering.

• DAQ hardware—Hardware used to acquire, measure, and analyze data. Also it works as bridge between analog and digital system.

• Software—Application software that supports hardware and able to design and program measurement or control applications.

2.1 Analog Input

The ELVIS system provides Analog Input (AI) channels 0 through 7 ± positive and negative input channels lines to differential AI channels. These analog channels can be configured as Referenced Single Ended (RSE) or Non-referenced single Ended (NRSE) modes. In RSE mode, each signal is referenced to AIGND. In NRSE mode, each signal is referenced to the floating AISENSE line. The analog input channels are differential; hence ground point needs to be established somewere in the signal path. As long as the signal you are measuring is referenced to one of AI GND pins, the measurement is correctly referenced. Also a floating source can be measured such as battery of which one end of signal is connected to ground. The programmable gain instrumentation amplifier is a measurement and instrument class amplifier that minimizes settling times for all input ranges. The ELVIS II series can perform both single and multiple Analog to Digital conversions of a fixed or infinite number of samples into 16-bit digital number. A large first-in-first-out (FIFO) buffer holds data during AI acquisitions to ensure that no data is lost.

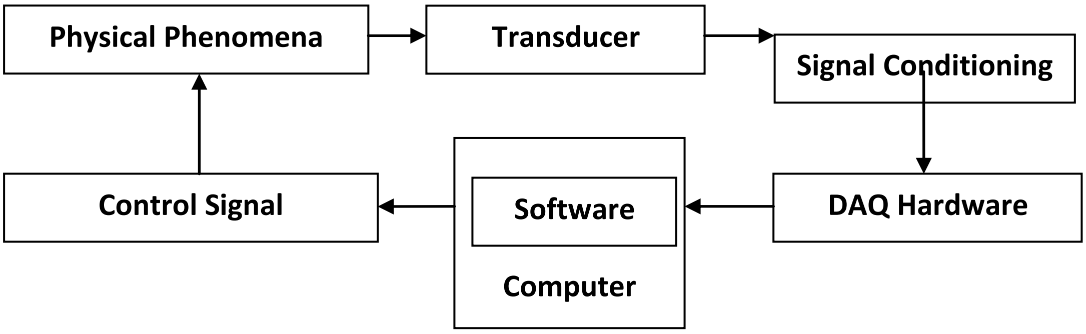

Figure 1: Block diagram of Data Acquisition

2.2 Analog Output

The hardware provides access to the two analog outputs (AO) at the AO 0 and AO 1 terminals controlled by a single clock. These channels are used for arbitrary waveform generation. Digital-to-Analog converters (DACs) convert digital codes to analog voltages. The AO FIFO enables analog output waveform generation. The FIFO memory buffer between the computer and the DACs allows you to download the points of waveform to the DACs without host computer interaction. Analog outputs are referenced to AIGND.

2.3 DAQ in MATLAB

Data Acquisition Toolbox provides functions for connecting MATLAB to data acquisition hardware. The toolbox supports a variety of DAQ hardware, including USB, PCI, PCI Express, PXI, and PXI-Express devices, from National Instruments, Measurement Computing, Advantech, Data Translation, and other vendors. The DAQ can be performed using two different interfaces, based on the hardware and the platform: The session-based interface, which works on both Windows 32-bit and 64-bit systems, and only works with National Instruments devices, including Compact DAQ chassis and Counter/Timer modules. The other devices cannot be used with this interface. Here an instant for a session is created and then the instructions add Analog Input Channel, add Analog Output Channel, etc. reads and writes data to hardware.

The legacy interface, which works only on Windows 32-bit systems, and works with all other supported data acquisition hardware. Hence cannot use Compact DAQ or Counter/timer devices with this interface. Proper installation of DAQ mx driver can be check using daqhw info and Installed Adapters. These instructions provides list of drivers that are installed in the system. Further analog input, analog output, add channel and put sample instructions may be help full for reading and writing data to and from the DAQ hardware.

III EXPERIMENTAL SETUP

The measurement system consists of circular piston like transducers with diameter of 5mm and normal frequency of 5MHz. The distance between transducers is maintained large enough i.e. 110mm to avoid Fraunhofer diffraction zone.

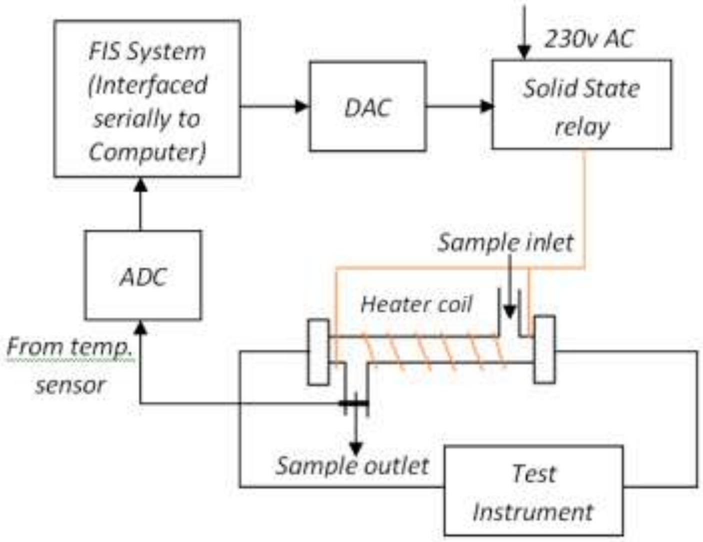

Figure 2: Block diagram of Experimental

The Fraunhofer diffraction zone is the region of the acoustic field produced by a transducer in which the beam behaves as a simple exponentially decaying curve. Far field starts at the distance where near field or Frèsnel zone finishes. Frèsnel diffraction zone is more complex than the far field and measurements carried out within this zone require correction for diffraction losses. All measurement procedures have been made at a distance corresponding to far field so that compensations are unnecessary. The distance where Fraunhofer zone starts depends on the frequency and radius of the transducer as can be seen in

$$Z_0 = \frac{r^2}{\lambda}$$

where Z_0 is that distance, λ is the wavelength associated to the frequency and r is the radius of the transducer. This condition may result in major challenge when trying to determine attenuation for frequencies over 5 MHz. 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 (RM 1E23AA25 Industrial, 1-Phase Analog Switching Type) works in accordance with the phase angle control principle. 4mA corresponds to no switching and 20mA corresponds to full sine wave. The heater coil is controlled as per the sample temperature detected initially. The milk sample is tested by ultrasonic measuring instrument that provides the result in fat.

IV NEURO-FUZZY INFERENCE SYSTEM

Fuzzy if-then rules or *fuzzy conditional statements* are expressions of the form *IF A THEN B*, where *A* and B are labels of *fuzzy sets* characterized by appropriate membership functions[4,5,6]. Due to their concise form, fuzzy if-then rules are often employed to capture the imprecise modes of reasoning that play an essential role in the human ability to make decisions in an environment of uncertainty and imprecision[2,7]. For example:

If pressure is high, then volume is small

The Fuzzy inference systems which are also known as fuzzy-rule-based systems, fuzzy models, fuzzy associative memories (FAM), or fuzzy controllers when used as controllers [8,10,12].

The function of the neural fuzzy compensator is to compensate for any unsatisfactory performance of the basic fuzzy controller.

Here a Neuro-Fuzzy Inference System is designed and implemented to control the temperature of milk sample under test using ANFIS tool in MATLAB. Two Fuzzy Inference System are required, one is used for error input and other is for change-in-error. The first FIS is called for first iteration in programming and for rest of iterations the change-in-error FIS is used. The initial temperature of milk sample is detected and feed as input to ANFIS through DAQ hardware. The error may be calculated using difference between setpoint and current value of sample. This real time value is then converted to crisp value, which can be inputted to ERROR FIS.

According to initial input, heater is made ON with the output value (amount of heater to be made ON) provided by FIS. From the second iteration the second error is available, so that change in error can be calculated. Know the two values, ERROR and CHANGE-IN-ERROR works as input to FIS and intensity of heater is changed accordingly.

V EXPERIMENTAL RESULTS & CONCLUSION

The whole system consists of two sub-systems: 1. Temperature controller for heating milk sample and 2. Ultrasonic system that detects fat content in the milk. It is very important that sample under test should be heated upto desired setpoint say 40^{o}C. Here the fat globules get evenly distributed all over the milk sample. Know the Ultrasound Wave is fired and respective attenuation of signal is measured. For error and change-in-error the mean and variance is calculated for three different shapes of membership function. The Triangular-Shaped membership function is best suited for this application.

Membership Fun. Type	40^{o}C	
	Mean	Variance
Bell Shaped	0.119	0.085
Triangular Shaped	0.085	0.068
Trapezoidal Shaped	0.102	0.225

Table 1: Mean and Variance for given setpoint (40^{o}C) and membership function for ANFIS controller

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