WEB-based Controller for Monitoring of Yoghourt Process Making

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Abstract – **This paper presents a WEB-based controller that enables remote monitoring of yoghoutrt process making via HTTP browser, WAP browser or Java 2 Micro Edition application (MIDlet). The moment of ending the process of souring of the milk is estimated indirectly, by analysis of the reflected from yoghourt ultrasound signal in frequency domain.**

Keywords – **Remote Process Monitoring, fuzzy classification**

I. Introduction

Milk acid products are known from the ancient times. Milk acid products are those, who have endured milk acid fermentation as a result of their sours with milk acid bacteria. It is characteristic for them, that they are obtained from fresh milk, put under fermentation. The fermentation technology is the main domain, where the biotechnology finds application [1-3].

One of these milk acid products is the Bulgarian sourly milk. It is known also under the name yoghurt. It is prepared mainly in the areas of the Balkan Peninsula and the Caucasus. It is very important the process of souring of the milk to run properly for the sake of receiving the product with necessary chemical composition and properties. That's only way the received yoghourt to represent perfect, easy digestible and refreshable dietetic food. The process of the souring is watched, as the acidity and the consistence of the soured milk are determined regularly. The moment of the souring is determined when the acidity of the souring milk reaches 75–80°T, but the consistence and the density are determined by shaking of the jar or plastic pail. When during the shaking of the jar only the middle part of the surface layer is shaking, but the edge remains still, this means that the souring milk had received enough density. If the so prepared soured milk is pull out of the thermostat too early it will remain with a rare consistence [2]. That's from the technological point of view and with the aim of receiving souring milk with the necessary composition and properties is very important to determine properly the moment of the souring.

For avoiding the subjectivity during the control of this process and its fully automation we suggest a developed controller, which determines more precisely the process of the souring of the milk. Its description follows.

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II. Hardware Realization

The controller is realized with minimal number of components because of the use of he System-On-Chip (Soc) IPC@CHIP SC12 firm Beck GmbH [4]. The use SC12 modules are as follows:

- Micro controller AMD186;
- Ethernet controller for IEEE 802.3 with integrated 10Base-T transceiver;
- 512 KB FLASH disk;
- 512 KB DRAM;
- Programmable Interrupt Controller;
- Two programmable 16-bits timers (Timer 0, Timer 1);
- Programmable digital inputs and outputs;
- I2C interface;
- Watchdog timer.

The integrated in AMD186 microprocessor 8086 works at frequency 20 MHz (50 ns). The network controller and 10base-T transceiver enables the connections of SC12 to LAN to be realized only with one external component - 10Base-T filter (FB2022). Via RJ-45 connector the controller has a connection to HUB, Switch or Wireless Ethernet Bridge. The network configuration can be static or dynamic when DHCP server is used.

The external components, necessary for the realization of the controller are as follows:

A. Ultrasound transmitter and receiver

We use UST40T as an ultrasound transmitter and UST40R as a receiver. The recommended frequency for the driving of the transmitter is 40 kHz. The distance between the transceiver and the analyzed object is 30 cm. The control of the module for the driving of UST40T (CMOS invertors 4069) is realized with digital outputs P9 and P10 of the SC12 SoC.

B. Analog-to-Digital-Converter (ADC)

An integrated circuit AD976A from Analog Devices, Inc. [5] is used. AD976A is a 16-bit ADC, working at a maximum sampling frequency of 200 kHz. The circuit requires single supply voltage of +5V. When the internal reference voltage of +2.5V is used, the range of input signal is ±10V.

The connection between SC12 and AD976A is realized trough the following signals:

- Data bus - the result after the conversion (16-bit) is read in two cycles, because the SC12 data bus is 8-bit (AD0-AD7). When signal BYTE is 0 the lower 8 bits of the result (D0-D7) are read, and when BYTE is 1 the last 8 bits (D8-D15) are read.

- R/C# - falling edge on R/C# starts conversion, a rising edge enabled the output data bus. R/C# signal is controlled by the output of the Timer 1 (TMROUT1 pin of SC12);
- BUSY# - this signal goes low when a conversion is started. Output data will be valid when BUSY# goes high. It is connected directly to the input INT0 of SC12 - after conversion an interrupt request is generated. The Interrupt Service Routine (ISR) reads data from ADC and writes this information into the DRAM.

C. Sensor for relative humidity and temperature

An integral sensor SHT11 from the Sensirion AG [6] is used. This sensor requires single power supply of +5V. The communication between SC12 and SHT11 is realized trough a specialized two-wire serial synchronous interface. The accuracy of the sensor is:

- ±0,9°C in the range 0°C to 40°C when the temperature is measured;
- ±3,5% when the relative humidity in the range 20 % to 80 % is measured;

The communication with SHT11 is realized trough the programmable inputs-outputs P7 and P8. Because of the high relative humidity during the process of the souring of the milk, integrated in SHT11 heating element is switched on. It will increase the temperature of the sensor by approximately 5°C.

D. Real-Time Clock (RTC)

The date and time are needed when software generates a report for process status. As RTC an integrated circuit PCF 8583 from Philips [7] is used. The communication between SC12 and RTC is realized trough the interface I2C.

E. Power Supply

The controller is powered with +12V/800mA. LM340 and 7809 integral voltage regulators are used to obtain +5V and +9V.

III. ALGORITHM REALIZATION

The main goal of the controller is to detect the exact moment of terminating the process of souring of the milk. The goal is indeed to measurement of the density of the milk. For that purpose the reflected ultrasound signal is analyzed. The analysis is performed in the frequency domain. It is established experimentally, that the interest is for the spectral components in the narrow band, included the frequency of the transmitter (40 kHz). If sampling frequency is F_s=100kHz and number of discrete is N=2048 the spectral components with indexes from N_a=775 (37842 Hz) to N_b=865 (42236 Hz) are analyzed. 91 spectral components are included in that frequency band. To reduce the number of spectral coefficients and to increase the noise immunity of the system a filtration in the frequency domain is realized. We use 22 filters with coefficients **h**={0,25; 0,5; 0,75; 1,0; 0,75; 0,5; 0,25}. If *PS*(*i*) is the *i*-th spectral component, the reaction of the *k*-th filter *PSF*(*k*) is calculated according to the equation:

$$PSF(k) = \sum_{j=-3}^{3} PS\left[\left(N_a - 1\right) + 4k + j\right] h(j+3)\ ,\ 1 \le k \le 22\ . \qquad (1)$$

During the training of the system the coordinates of the centers of the every one of the following 3 classes are calculated:

- Class 1 – the training vectors are obtained just after the heal treatment of the milk (start of the souring);
- Class 2 – the training vectors are obtained at the end of the process of the souring (usually from 2,5 to 3 hours after the start of the process, if temperature is in the range 44-46 °C);
- Class 3 – the training vectors are obtained in the interval 15 to 30 minutes after the terminating of the souring.

As a result of the training three 22-dimension features vectors $\mathbf{c}_k$ (*k*=1, 2, 3) are obtained and used during the classification. The classification is realized in on-line mode. Its aim is to give a qualitative estimation of the probability every new test vector to belong to every one of the defined classes. The evaluation is received according to the following equation:

$$\mu_i = \frac{\left[1/\left(\left\|\mathbf{x},\mathbf{c}_i\right\|_G\right)\right]^{\frac{1}{m-1}}}{\sum_{j=1}^{Nc}\left[1/\left(\left\|\mathbf{x},\mathbf{c}_j\right\|_G\right)\right]^{\frac{1}{m-1}}}\ ,\ \text{if}\ \mathbf{x} \ne \mathbf{c}_i\ ,\ 1 \le i \le N_c\ \text{ and,} \qquad (2a)$$

$$\mu_i = \begin{cases} 1,\ j = i \\ 0,\ j \ne i \end{cases}\ ,\ \text{if}\ \mathbf{x} = \mathbf{c}_i\ \text{where:} \qquad (2b)$$

N_c is the number of the cluster centers;

$\left\|\mathbf{x} - \mathbf{c}_i\right\|_G$ is G-estimation of the distance between the test vector ***x*** and center of class ***i*** - $\boldsymbol{c}_i$, ;

$d\left(\mathbf{x},\mathbf{c}_i\right) = \left\|\mathbf{x} - \mathbf{c}_i\right\|_G = \left(\mathbf{x} - \mathbf{c}_i\right)^T G\left(\mathbf{x} - \mathbf{c}_i\right)$. If G=I Euclidean distance is calculated;

m is a parameter that influences the degree of fuzziness between classes. Usually 1.25≤m≤ is chosen [8].

IV. SOFTWARE DESCRIPTION

The software is developed on Borland C++ v. 5.2 and is compiled to an EXE file, which is started automatically after the switching on of the power supply. The program code works under the control of the multi-task Real Time Operation System (RTOS) of the SC12. The tasks switching interval is 1 ms. RTOS

The description of the software is as follows:

A. Main Task

This program module realizes the initialization of the hardware and software modules.

The initialization is realized in the following sequence:

- load information for centers of classes;
- initialize digital inputs and outputs;
- Activate internal security system: install a User Error Handler for processing the fatal errors (invalid operation code,

system stack overflow, TCP/IP fatal error and etc.) and activate a Watchdog timer. If fatal error has been occurred the controller is rebooted;

- Enable interrupt request for input INT0 and set the edge-triggered interrupt request mode (low-to-high).
- Install Interrupt Service Routine (ISR) for handling the INT0 requests;
- Init Timer 1: continuous mode, internal clock use, enable TMROUT1 pin. We use TMROUT1 to start of the ADC - 100 KHz clock (10μs), 50% duty cycle;
- Create task that communicate with the ADC (ADCC). After the creation the task is suspended;
- Create task that controls the ultrasound transmitter (USTT). After the creation the task is suspended;
- Install CGI CallBack functions for HTTP, WAP and J2ME clients. Information for the status of the technological process can be received by three ways: from HTTP browser started on a personal computer, from WAP browser started on GSM terminal or from MIDlet, started on a mobile terminal with integrated Java Virtual Machine.

After the initialization Main task performs in loop following algorithm:

1. Activate task USTT.
2. Waiting until the task USTT is ended - flag USTTready=true.
3. Activate task ADCC (2048 ADC conversions).
4. Waiting until the task ADCC ended - flag ADCCready=true.
5. Calculate Power Spectrum and Filtered Power Spectrum (functions getSpectrum and frequencyFiltering).
6. Classification - function fuzzyClassifier.
7. Measure temperature and relative humidity - function getTHinfo.
8. Update values of global variables, necessary a report is generated.
9. Sleep the task for 1 minute.

B. Task ADCC

The task is activated with the function RTX_wakeup from RTOS API. The Timer 1 is started with function StartTimer. After 2048 analog-to-digital conversions flag ADCCready is set, and the task is suspended (RTX_Sleep_Request). Conversion timing diagram using BYTE signal is shown in Fig. 1.

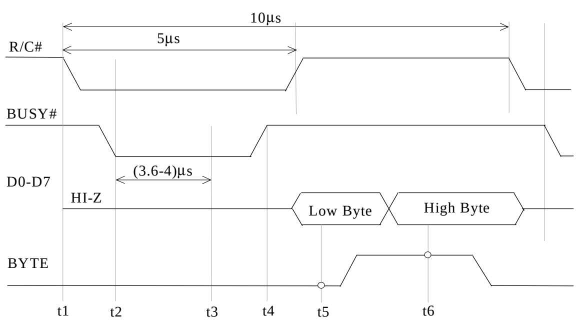

Fig. 1. Conversion Timing diagram using BYTE signal

C. Task USTT

After task wake-up a packet of 6 impulses (40kHz) for driving of the ultrasound transmitter UST40T is generated. For that purpose the digital outputs P9 and P10 are used.

The time diagrams of the signals, which control the ultrasound transmitter, are shown in the Fig. 2.

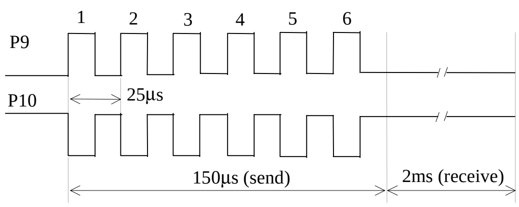

Fig. 2. UST40T driving diagram

When the working temperature is in the range (44–46)°C and distance between the receiver and the controlled medium is 30 cm, the time needed for waiting the reflected signal is about 1.7 ms. USTT task waits 2 ms, after which sets the flag USTTready and enters in suspend state.

D. ISR for serving the requests from ADC

The procedure reads the result after ADC conversion. When signal BYTE is 0 the lower 8 bits of the result are read, and when BYTE is 1 - the last 8 bits (D8-D15) are read. The received data are written in the buffer (receivedData).

E. Function getSpectrum

This function calculates Power Spectrum of the discrete signal, written in the buffer receivedData. Radix 4, Decimation in Frequency Fast Fourier Transform (R4 DIF FFT) is used.

F. Function frequency Filtering

A filtration of the spectral components, obtained trough the function getSpectrum is realized. For that purpose the equation (1) is used. The test vector *PSF* is obtained.

G. Function fuzzyClassifier

This function classifies every new test vector *PSF* to one of the defined classes. The equation (2) is used.

H. CGI CallBack functions

Since the buildin in SC12 WEB server doesn't assure access to the value of the field "User-Agent" from the HTTP requests header, on-line identification of the client is not possible. For that reason different CGI functions for serving different clients are installed:

- Request from HTTP browser, started on the personal computer or mobile terminal, supporting XHTML;
- Request from WAP browser, started on mobile terminal;

- J2ME application, started from a mobile terminal.

In dependence from the type of request, the WEB server answer is in different format: HTML, WML or Base 64 encoded data. Independently from the type of the client, the returned information is:

- Temperature in °C or °F;
- Relative humidity in % RH;
- The process "ready status" in %;
- Date and time of the report generation.

It is accepted, that the process of the souring of the milk ends, when maximum in the "ready status" (the probability the test vector to belongs to class 2 in %) is detected. The system gives the possibility for sending a SMS via an Email-to-SMS Gateway and SMTP server at the time of the detecting the end of the process of souring and when the temperature is out of range. For that purpose the function sendSMS is used.

V. Experimental Results

The proposed controller is experimented in laboratory conditions and in the milk processing plant "ELVI" Ltd. in the village "Velkovci". On the basis of the experimentally data, received from 5 consequently circles of yoghourt making, off-line training is realized. As a result, the coordinates of the centers of the every one of the defined classes are obtained. They are recorded into a file CLASS.DAT.

The information which WEB server returns after an authorized (user name and password) HTTP request, generated from HTTP browser (HTML format) is shown in Fig. 3.

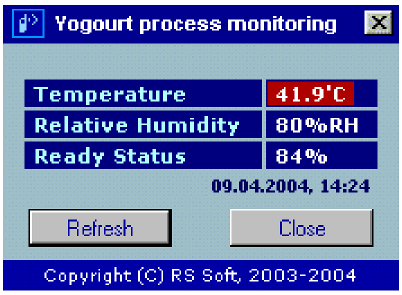

Fig. 3. HTML report

The access to this information, but trough WAP browser and Java 2 Micro Edition application (GSM terminal Samsung SGH-C100) is shown in the Fig. 4.

Fig. 4. Access to WEB server via WAP and MIDlet

The renewal of the information occurs automatically at every minute or by pressing the button "Refresh". When client is mobile terminal it is desirable to use WAP over GPRS. In this case only the really exchanged with the controller information will be paid.

Possibilities for choice of the measure for the temperature (°C, °F) and fixing the interval, after which the information is renewal automatically, are given from the menu of the MIDlet. In this case, the access to the controller is realized with POST request and base authorization (the name and password of the user are encoded with the algorithm Base64). The returned data is also encoded with the algorithm Base64. The aim is to guarantee the authenticity of the received data.

VI. Conclusion

A controller, automatically permitting precise determination of the moment of ending the process of souring of the milk, is developed. The estimate is realized indirectly, on the base of analysis of the density of the product.

The controller enables remote monitoring of the process from every point of the world, due to the buildin WEB server. Information for the status of the process of souring can be received trough HTTP browser, WAP browser or a J2ME application. As an additional possibility, automatically sending of SMS via an Email-to-SMS Gateway and SMTP server is provided.

Cooling of the components of the controller by means of fan (+12V) is needed for its correct functioning.

In our plans we anticipate realizing the connection between the proposed controller and the temperature and ventilation controller. This connection will be realized by means of interface RS485. In that way, the possibility will be given for setting different temperature profiles with the aim of finding the optimal results.

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