Non-contact ultrasound method for identification of yogurt according to its butter content

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Abstract:

In the current paper is proposed an approach for identification of yogurt according to its butter content, based on the methods for recognition of images with receiving of initial information by ultrasound. There are results presented from the made research regarding the ability for synthesis of symptoms for classification by means of discrete wavelet transformation. Classifiers are synthesized with the method "K-nearest-neighbors" (KNN) and are tested with independent control sample. It is realized a classification of yogurt with butter content 1, 2, 3, 3.6 and 5% with accuracy above 94%.

Key words: *yogurt; symptoms; automatic classification; wavelets*

INTRODUCTION

The fermentation is one of the oldest methods used by the human for conserve of food products. One of these products is the Bulgarian yogurt, which have high nutritive value and quality.

The quality of the yogurt can be examined from different aspects. It can be obtained by using of different methods, reading its chemical, physical, microbiological and nutritive characteristics [9]. The quality is evaluated by tests with different objectivity, as far as they are dealing with its different aspects [9]: human safety, concerning the different chemical or microbiological components; accordance with the standards and norms established by the health organizations and other authorized organizations; ability for reaching of the declared expiration date without change of the quality; high organoleptic value, which can be reached into the limits set by the production or the marketing.

The analysis of the end result is essential characteristic from the quality control in the milk industry. The control of this stage [9] – protecting the user from consuming of a product with lowered quality or product which is hazardous for the health; protecting of producer from disadvantages and expenses for confiscation of the product from the trade network; contribute for detecting of the quality changes and influence in the production process.

In the last years there is active work over the application of the ultrasound for quality control into milk industry [3, 6].

In this direction should be examined and the conducted by the team researches concerning the applicability of non-contact ultrasound method for automatic classification of yogurt from different Bulgarian firms according to its declared on label butter content. The proposed way of approach is build on the base of ultrasound echolocation principle as the reflected signal from the object is carrying information for its structure.

MATERIALS AND METHODS

The experiments are realized in off-line mode with ultrasound sensors of type UST40T/UST40R from Nippon Ceramic Company. The experimental setup scheme, shown on fig. 1 consists from the next modules and program part:

Hardware modules:

- PC station with Microsoft Windows XP;
- Programmable microcontroller PIC16F84A;
- Oscilloscope Tektronix TDS1002;

Program modules:

- Program for generating of pulse modulated signal (40 kHz) – stored in PIC16F84A for excitation of the transmitter UST40T;

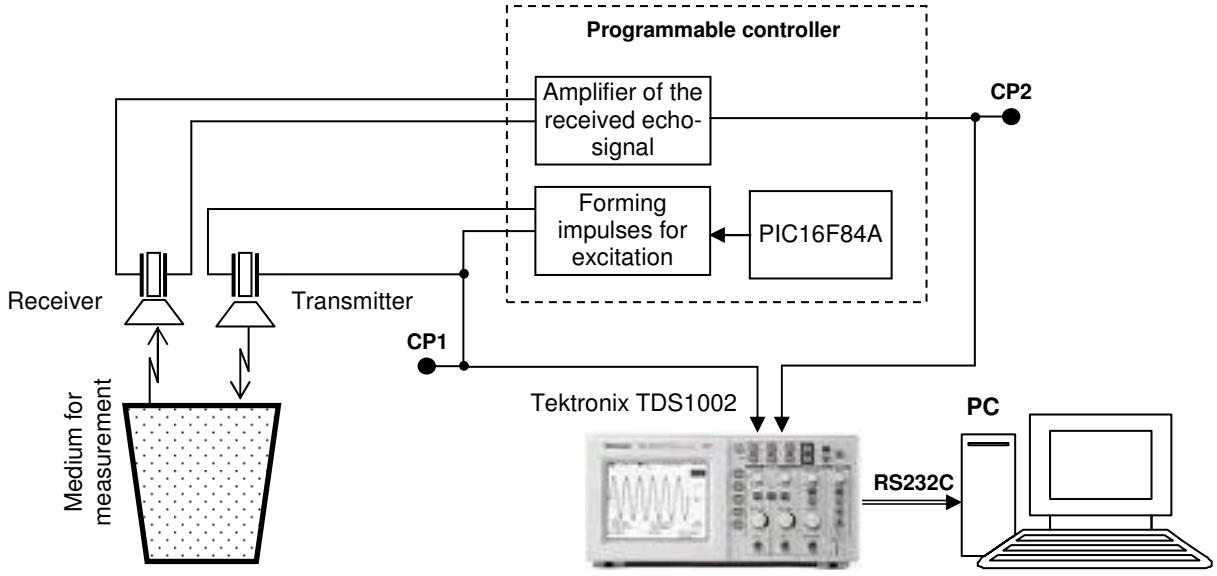


Fig.1. Experimental setup scheme

- TekVISA software – for transferring of the measured data from the oscilloscope to the personal computer. The read data are stored in PC as Comma Separated Values (CSV) file.

The process of analog to digital conversion of the initial images is the first stage of transformation of the output information. This conversion is necessary but not sufficient condition for the purposes of automatic classification. This is why there must be and next, different conversion, related with change of the space of description of the image. The form of the new space thoroughly is defined by the chosen for the next processing methods for recognition. The transforming of these images into other space has to be subordinate to few requirements: the new description C[m], m = 1, 2, …, M have to be with less coordinates, i.e. N < M (N is the number of symptoms); to be saved the significant information for classification; into the new space to be maximized the separability of the classes by increasing of the distances between the classes and decreasing of the distances into the classes [8].

There are not universal objective methods for forming and evaluation of the complex symptoms for classification of foodstuffs. In the practice more popular application has the heuristic ways of approach, based on the experience, the knowledge and the intuition of the developers of systems for qualification. The classic way of approach is the symptoms to be synthesized in mathematic-heuristic way – for one part from them are chosen strictly mathematical defined, objective symptoms, and other part usually are synthesized heuristically. This is the reason our attention to be directed to other, less used methods for recognition, for example, the spectral ones, whose adapting to similar tasks is in its initial stage.

The spectral methods for recognition of images suppose transforming of the initial description **X**[n] into new space with symptoms, coefficients **C**[m] from the decomposition of **X**[n] in some basis, most often orthogonal. Not every known systems from orthogonal functions are suitable as basis for the transformation. Main reason for this is the impossibility for factorizing of their matrixes, and from there and the lack of fast algorithms for conversion.

With the application of a discrete wavelet transformation (DWT) for synthesis of symptoms space of the classifier, are searched for two main effects:

- Elimination of the heuristic way of approaches by strict mathematical basis of the procedures for forming of symptoms spaces.
- Reduction of the symptoms space.

For forming of the symptoms space appropriate is a way of approach based on the algorithm of Mallat [2, 4] and popular in the literature as fast discrete wavelet transform

(DWT). It is developed for orthogonal wavelets and is realized on the base on lowpass filter G_0 and highpass filter H_0 with transfer functions accordingly [2, 4]:

$$H_0(\omega) = \sum_{\kappa \in Z} h_n e^{-i\kappa\omega} \quad (1)$$

$$G_0(\omega) = \sum_{\kappa \in Z} g_n e^{-i\kappa\omega} . \quad (2)$$

The coefficients of the filters h_κ and g_κ are calculated in dependence on the applied wavelet and k is integer. After decreasing in half of the count of the composite frequencies (operation binary decimation ($\downarrow 2$)) are obtained the coefficients of approximation of level m=1 a_1 from the filter G_0 and the detailed coefficients d_1 from the filter H_0. At the higher level decomposition the coefficients of approximation from level m=1 (a_1) are subject to analogical operations according to the scheme on Fig. 2.

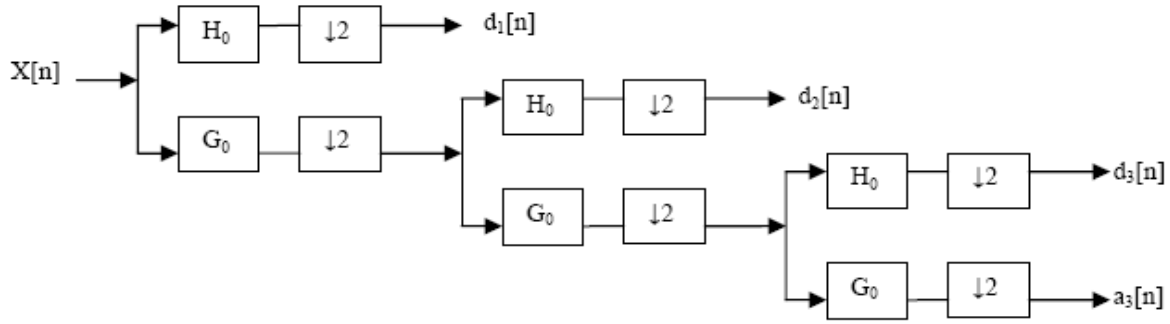


Fig. 2. Three-level (m = 3) wavelet decomposition tree

In general the output signal on level m can be presented by the equation:

$$X[n] = \sum_{\mathbf{k}=-\infty}^{\infty} \mathbf{a}_{\mathbf{m,k}} \varphi_{\mathbf{m,k}}[n] + \sum_{\mathbf{j}=1}^{m} \sum_{\mathbf{k}=-\infty}^{\infty} \mathbf{d}_{\mathbf{j,k}} \psi_{\mathbf{k}}[n], \quad (3)$$

where $\psi[n]$ - wavelet function reflecting the details of the signal and forming the detailed coefficients;

- $\varphi[n]$ - scaling function, determining the approximation of the signal and forming the approximation coefficients. The φ–functions are inherent only on the orthogonal wavelets – Haar, Daubechies, Coiflet and etc. [2, 5].

Important meanings for classification have the selection of the informative symptoms. The full searching requires time and calculation resources. The most often applied are the methods of the consecutive selection and the consecutive rejection. It is chosen the selection of the symptoms for classification to be by the method of consecutive rejection in which initially are chosen all M symptoms and after that they are rejected one by one, and with the rest of the multitude are made the classification. On the each step is canceled the symptom, whose elimination from the symptoms multitude leads to lower general error from classification E_0. The condition for the end of the procedure is reaching of minimum of the general error at classification.

The errors at classification are calculated according the methods, described in [1]:

– highway (main) error e_i shows the relative part of the objects from some class i, related wrongly from the classifier into other classes;

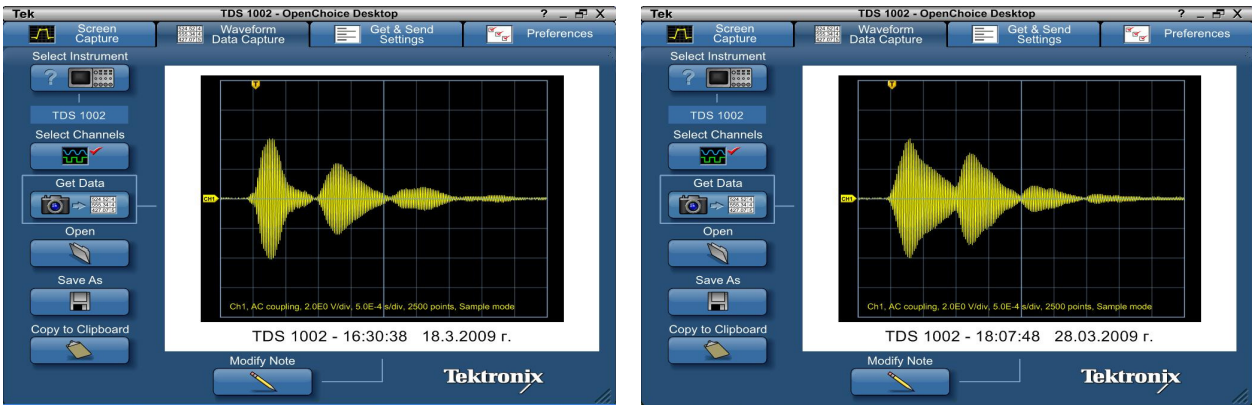
– marginal (real) error g_i shows the relative part of the objects from other classes wrongly related from the classifier into given class i;

– general error E_0 – shows the wrongly classified objects according all objects from the excerpt.

RESULTS AND DISCUSSION

- **Obtaining of the initial data**

A piezoelectric transmitter generates a packet from ultrasound pulses into the working medium (air in the case). At their reaching to the medium for recognition they are reflected from it under the form of an echo-signal. The last is returning back toward the



a) yogurt "Elena" with butter content 2% b) yogurt "Elena" with butter content 3,6%

Fig. 3. Received at the research reflected ultrasound signals (echo-signals) for yogurt from one producer

receiver and is detected by it. The reflected from the object signal is amplified, detected and is applied on the input of the oscilloscope.

The discretization of the reflected signal is realized by analog-to-digital converter built into the used for the purpose oscilloscope Tektronix TDS1002. The discretization frequency (F_D) is 500 kHz. Every realization (measurement) X[n] consists of 2500 discrete values. The TekVISA software is used for transferring of the measured data from the oscilloscope to the personal computer (PC). The read data are stored in PC as Comma Separated Values (CSV) file. For this purpose the oscilloscope is connected to the PC by the interface RS232. In the Fig. 3 are shown the received echo-signals for yogurt "Elena" with butter content 2% and 3.6%.

The volume of the initial data is presented in the Table 1. The data are obtained at researching of yogurt from five different producers with different butter content.

In the case the task for synthesis of the system for automatic classification is reduced to an analysis and a classification of random curves – realizations of random process.

Table 1

Volume of the initial data

Class	Butter content	Volume
№	%	number
1	1	60
2	2	300
3	3	130
4	3,6	130
5	5	60

- **Synthesis of a classifier**

The synthesis of a classifier is realized with developed software in the programming medium Matlab.

From the initial data are formed learning and control excerpts. The learning excerpt is formed by method of self-random excerpts with repeated choice and by random selection of the numbers of the realizations. The excerpt have volume N = 300 numbers. The control excerpt with volume N = 433 numbers is composed by selection of the realizations which are not included into the learning excerpt and without repeated choice.

With the help of the learning excerpt are formed symptoms with fast discrete wavelet transform (DWT), realized according the algorithm of Mallat with wavelets of Haar, Daubechies 2, 3, Simlet 1, 3, and Coiflet 1, 3. The obtained wavelet coefficients a[n] and d[n], after the realized in this way transformation, are researched in the quality of symptoms for classification in common with classifier working by method of "K-nearest-neighbor" at K = 3 [7, 8].

In the same time with the forming of the symptoms space is performing and reduction determinate by the character of the performed wavelet transformation. The selection of informative symptoms for classification is realized by the method of consecutive rejection.

With the synthesized in this way classifier is performed classification of independent control excerpt.

The best results are obtained with applying of wavelets of Haar and Simlet 1 with using of the approximation $a_8[n]$ and detailing $d_8[n]$ coefficients of decomposition level m = 8 in the quality of symptoms for classification. It is worked with the absolute values of the symptoms.

At classification of control excerpt (433 samples) with wavelet "Haar" level m=8 with symptoms $a_8[n]$, n= 2, 4 and $d_8[n]$ n=2, 3, 4 is obtained general error E_0=7,85%.

The results at classification of the control excerpt (433 samples) with wavelet "Coiflet1" are presented in Table 2.

Table 2

Results at classification of control excerpt (433 samples) with wavelet "Coiflet1", level m=8 with symptoms $a_8[n]$, n= 7,8,9 and $d_8[n]$ n=3,4, 6,7,8

Butter content		Classified by the classifier, number						Errors	
		1%	2%	3%	3.6%	5%	Total	Real	Main
	m_{ik}	m_{i1}	m_{i2}	m_{i3}	m_{i4}	m_{i5}	numb.	g_i,%	e_i,%
1%	m_{1k}	41	0	0	0	0	41	6,82	0
2%	m_{2k}	2	188	0	0	0	190	3,09	1,05
3%	m_{3k}	0	3	71	3	0	77	15,47	7,79
3.6%	m_{4k}	1	3	13	67	0	84	4,28	20,23
5%	m_{5k}	0	0	0	0	41	41	0	0
Total	numb.	44	194	84	70	41	433	General error E_0=5,77%	

The analysis of the obtained errors shows high accuracy of classification – above 94% and correct classifying of the yogurt with butter content 1%, 2% and 5%. The high value of the main error at 3.6% butter content is due to incorrect classified 13 numbers (from overall 84 numbers) to the yogurts with 3% butter content and 4 numbers to yogurts with 1% and 2%. This is the reason for 15.47% real error at 3%, i.e. from 84 numbers definite by the classifier as yogurt with 3% butter content – 13 numbers are with 3.6% butter content.

CONCLUSIONS AND FUTURE WORK

The good initial results shows that it is possible the development of portable ultrasound analyzer of the butter content of yogurt, based on the methods for recognition of images and realized with one-chip computer. The researches of the team are directed in the next directions – increasing of the database, recognition of producer and identification of the butter content with elimination of the influence of the aluminum foil of the package. In these directions are made experiments, which show hopeful results.

Conclusions:

1. Experimentally is proven the possibility for automatic classification of the Bulgarian yogurt by butter content with non-contact ultrasound method for receiving of information.
2. The questions for synthesizing of symptoms space at automatic classification of yogurt by using of orthogonal wavelet basis functions for synthesis of symptoms are analyzed.
3. With the used methods for non-contact and fast receiving of information, the used fast wavelet transformation and KNN-classifier, it is possible the recognition of the examined materials to be realized in real time ("on-line").

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