Automatic Quality Classifiers of Food Products – Rate of the Speed Problems

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Abstract – **The automatic quality classifiers (AQC) are a basic element of the modern systems for quality control of food products. Of the day direction of the development of these systems is providing traceability of quality in the chain "from the producer to the consumer". This determines as a fundamental the "on-line" function of AQC, meaning high requirements to the rate of speed**

Keywords – **Quality of food, Automatic quality classifier, "On-line" quality assessment.**

I. INTRODUCTION

The purpose of the investigation is to find out the possibilities for improving the rate of the speed of AQC sorting of food, especially of agricultural products (fruits and vegetables). As a base, some of the modifications of Bulgarian automatic sorting systems of the family AQS: ASM5.01, AQS 4PAP and AQS602, developed in the University of Food Technologies (UFT), Plovdiv, have been used. The general functional model of these systems is presented on Fig.1, where: FOMP is the module realizing the function "feeding the objects to the measuring position (MP)"; OET –"optic-electronically transformation", formation of the"initial image" as an electrical signal, this is the sensor module (IS) of the system; PPII – "preliminary proceeding of the initial information", operations as discretization, quantization, filtration, etc. The next functions are the functions that the automatic classifier of the system AQS performs: TIOSS means "transformation of the images of the objects into symptoms' space; SDC "standard description of the classes" of the products; RACP - "realization of the algorithm for classification of products" and EFDC "elaboration the final decision for the class of the products", concerning applying to the proper class. It is evident, that the main element of the system is AQS and the basic directions for improving the rate of the speed of the system have to be searched for in its whole functioning. The last function of AQS, according in Fig. 1, is SP – "sorting products" by quality. Recourses suggested from modules FOMP and SP of the system are object of other investigations [1].

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In this paper the possibilities for inpruving the rate of speed of AQS by more effective "transformation of the initial image" in the symptoms' space. As an example, in Fig.2, the processed in FOMP image of a product (apple) from the abstract being classified is shown. This image is a result of transformation of the optical signal $\mathbf{E}(x, y)$ into electrical $\mathbf{s}(\xi,\eta)$ in the module OET. The optical signal presents "the light intensity" of the beam, radiated from the product to the module OET, as a result of its transmitting (T) and reflecting (R) ability after lightening with white light. This is the reason of using the indices T and R with **s,** or $\mathbf{s}_{(TUR)}(\xi, \eta)$. This signal has been formed as an ratio of the transmitting and reflecting abilities at two different, informative for the products, wavelengths of electromagnetic radiance (EMR) – λ_1 and λ_2. As a norm these wavelengths are in the visible and near infra red (NIR) range of the spectra. The signal $\mathbf{s}_{(T\cup R)}(\xi,\eta)$ formed in FOMP is a result of consecutive two-dimensional discretization.

$$\left|\mathbf{s}_{(T\cup R)}(i\Delta\xi, j\Delta\eta)\right| = \mathbf{\Phi}_D[\mathbf{s}(\xi,\eta)] = \mathbf{s}(\xi,\eta).\mathrm{comb}(i\Delta\xi, j\Delta\eta), \tag{1}$$

where $\mathbf{\Phi}_D$ is an operator of discretization $\mathrm{comb}(i\Delta\xi, j\Delta\eta)$, i.e. fenestration function of the type

$$\mathrm{comb}(\alpha,\Delta\alpha) = \sum_{i=0}^{\infty}\delta(\alpha - i\Delta\alpha) = \begin{cases}\infty & \text{at } \alpha = i\Delta\alpha\\ 0 & \text{at } \alpha \neq i\Delta\alpha\end{cases} \tag{2}$$

and "quantization" (discretization by "level" with the operator $\mathbf{\Phi}_k$)

$$\begin{aligned}\left|\mathbf{s}_k(i\Delta\xi, j\Delta\eta, k\Delta z)\right| &= \mathbf{\Phi}_k[\mathbf{s}_{(T\cup R)}(i\Delta\xi, j\Delta\eta)] = \\ &= 2^{-\nu}\,\mathrm{ent}\,\frac{\mathbf{s}(i\Delta\xi, j\Delta\eta, k\Delta z) + 2^{-\nu-1}}{2^{-\nu}}\end{aligned}, \tag{3}$$

where "ent" means operation "rounding", "k" is a running index of the values by "level"(ordinate z), and for simplicity of writing the index $(T \cup R)$ has been skipped.

Each point of the image (3) from Fig.2 presents a vector $\mathbf{s}_k(\xi, \eta) \equiv \mathbf{s}_{(T\cup R)}(\xi,\eta) \equiv \mathbf{E}(x, y)$ in three-dimensional space, and the multitude of images of the products from one classified extract form linear vector space. In it each image is described by combination of matrices.

$$\{\mathbf{s}(i, j, k)\} = \{[\mathbf{s}_{ij}]^{(0)}, [\mathbf{s}_{ij}]^{(1)}, [\mathbf{s}_{ij}]^{(2)}, \ldots, [\mathbf{s}_{ij}]^{(k)}, \ldots, [\mathbf{s}_{ij}]^{(M-1)}\} \tag{4}$$

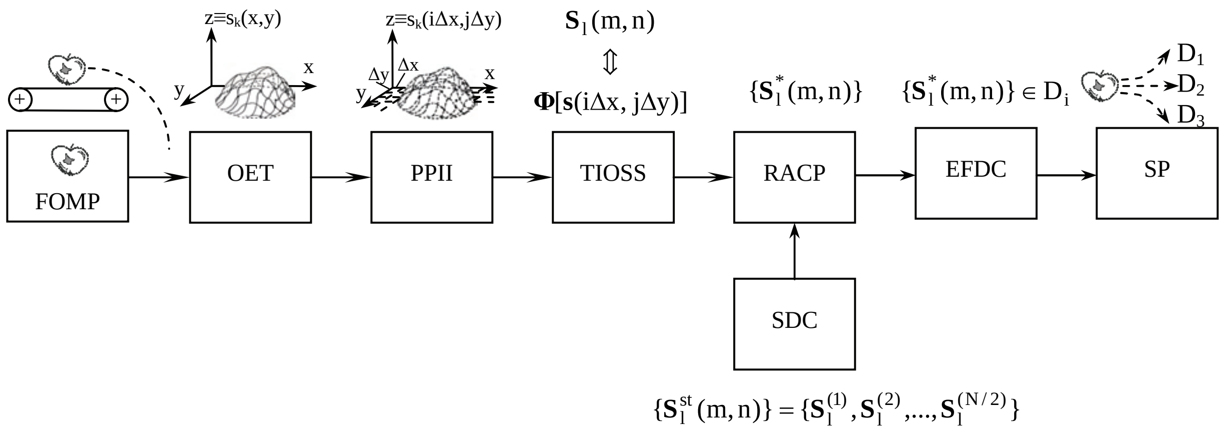

Fig. 1 General Functional Model of Automatic Sorting Systems AQS

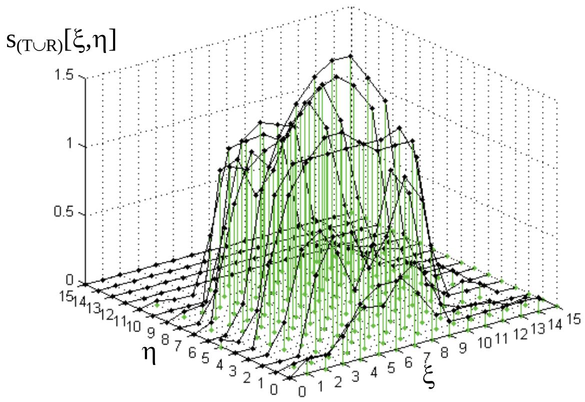

Fig. 2 Processed in FOPM Image of a Product (Apple)

When AQS works in “on-line” conditions (as it is in systems for quality “tracing”), the time for processing the information from the moment of the product entering in AQS, up to completing their sorting in the module SP, is of the rate parts of 1ms. This is determined from the requirements for “productivity” of the system. This is the reason for impossibility of using “initial images” of product (Fig.2), and the necessity of their transformation into new (symptoms’) space with the aim of sizable compression of data saving the value of the information of quality in them. Approaches for solving such tasks suggest “the general theory of signals”, in its part “approaches for harmonic and sequential analysis” of analog and discreet signals. In this way the images (4) from Fig.2 could be presented as equivalent in space with “basic”-functions of the type Ψ[ξ, η; m, n], classical example for it could be “discreet exponential functions” (DEF), a base of the harmonic Fourier analysis:

$$\Psi[\xi,\eta;m,n] = \exp\{-j\frac{2\pi}{N}(m\xi+n\eta)\}\,. \qquad (5)$$

Then $\mathbf{s}_k(\xi, \eta)$ will be transformed to space {ξ, η, l}, where the signal will be described by no monotonously decreasing series of coefficients of Fourier decomposition

$$\mathbf{S}_l(m,n) = \sum_{\xi=0}^{N-1}\sum_{\eta=0}^{N-1} s_k(\xi,\eta)\exp\{-j\frac{2\pi}{N}(m\xi+n\eta)\}\,, \qquad (6)$$

where $\frac{2\pi}{N}\xi$ and $\frac{2\pi}{N}\eta$ are space frequencies.

Criteria for choosing a basis for transformation is the assessment of its abilities for using fast algorithms, especially when taking into account, that part of the functions Ψ allow “factorization” and as a result “fast transforms”.

II. Results and Conclusion

A lot of orthonormal transforms have been applied for transformation of the “initial image” in the symptoms’ space of space spectral components of the respective decomposition. The achieved acceleration of the algorithm of transformation will be illustrated with the example of ordinary “discreet” (DFT) and “fast Fourier transform” (FFT).

The space spectra of the product from Fig.2 is presented in Fig.3. If in the description of the “initial image” (3), Fig.2, each row is considered as one-dimensional discreet

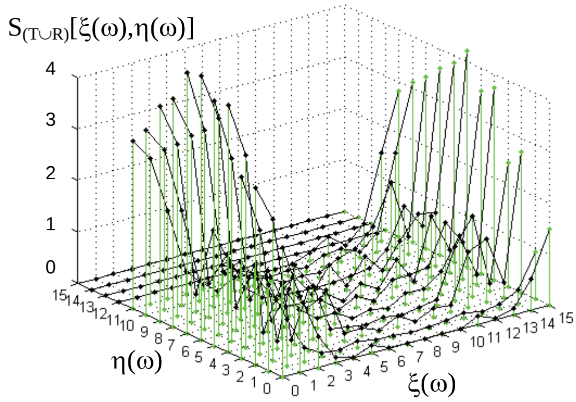

Fig. 3 Space Spectra of the Product from Fig.2

TABEL I

NUMBER OF NECESSARY OPERATIONS IN DFT AND SUGGESTED NEW ALGORITHM AT N=4, 8, 16 И 32

N / Algorithm	4	8	16	32
FDFT	4.1+2.1+8=1	4.3+2.3+24=4	4.17+2.17+64=164	4.49+2.49+160=45
(r.prod.+add.prod.+add.)*	4	2		4
New algorithm (addition)	8	24	100	356
Improved effectiveness, %	42,9	42,9	39	21,6

* real product +addition from products+additions

description of part of the object $\mathbf{s}_k(\xi, \eta) = \mathbf{s}_k(\xi, \eta = \text{const})$ then for it could be applied one-dimensional DFT

$$\mathbf{S}_1(m) = \sum_{\xi=0}^{N-1} \mathbf{s}_k(\xi) \exp\{-j\frac{2\pi}{N} m\xi\}, \quad \eta = \text{const} \tag{7}$$

and if DEF is indicated briefly as $W_N^{m\xi} = e^{-j\frac{2\pi}{N}m\xi}$

$$\mathbf{S}_1(m) = \sum_{\xi=0}^{N-1} \mathbf{s}_k(\xi) W_N^{m\xi}, \quad m = 0,\ 1,\ 2,\ ...,\ N-1$$
$$\xi = 0,\ 1,\ 2,\ ...,\ N-1 \tag{8}$$

and for all m, the system of equations is

$$\vec{\mathbf{S}}_1(m) = \left|W_N^{m\xi}\right| \vec{\mathbf{s}}_k(\xi) \tag{9}$$

where $\vec{\mathbf{S}}_1(m)$ and $\vec{s}_k(\xi)$ are N-dimensional vectors, respectively of the transformed and the initial description of the products, and $\left|W_N^{m\xi}\right|$ is a matrices of the operator DFT.

At N=16 for realizing of (9) are necessary N^2=256 and N(N-1)=240 complex additions.

If some conditions, determined from the functions of AQS, are used: (1) because of the presence of great amount of equal values of addends in the system and preliminarily known values of DEF $W_N^{m\xi}$ and their loading in the memory of processor for previously processing of information (DSP); (2) taking into account the periodical character of $\left|W_N^{m\xi}\right|$ when increasing the exponent, the values of DEF repeat these from the first period N, i.e. $\left|W_N^{m\xi+pN}\right| = \left|W_N^{m\xi}\right|$ for p – positive integer, it is possible apriority in AQS to be organized a matrices of production

$$\begin{array}{ccccccc}
k \rightarrow & 0 & 1 & 2 & \cdots & M-1 & m\xi
\end{array}$$
$$Q = \left|\begin{array}{ccccc}
W^0 s(0) & W^0 s(1) & W^0 s(2) & \cdots & W^0 s(M-1) \\
W^1 s(0) & W^1 s(1) & W^1 s(2) & \cdots & W^1 s(M-1) \\
W^2 s(0) & W^2 s(1) & W^2 s(2) & \cdots & W^2 s(M-1) \\
\vdots & \vdots & \vdots & \cdots & \vdots \\
W^{N-1} s(0) & W^{N-1} s(1) & W^{N-1} s(2) & \cdots & W^{N-1} s(M-1)
\end{array}\right| \begin{array}{c} 0 \\ 1 \\ 2 \\ \vdots \\ N-1 \end{array} \tag{10}$$

and at N-even number, the exponents decrease to N/2, i.e. the dimension of the matrices will be N/2xM.

Determined this way productions form the system for definition the symptoms:

$$\begin{array}{c}
S_1(0) = Q(0, m_{\xi 0}) + Q(0, m_{\xi 1}) + ... + Q(0, m_{\xi N-1}) \\
S_1(1) = Q(0, m_{\xi 0}) + Q(1, m_{\xi 1}) + ... + Q(N-1, m_{\xi N-1}) \\
\cdots \quad \cdots \quad \cdots \quad \cdots \\
S_1(N-1) = Q(0, m_{\xi 0}) + Q(1, m_{\xi 1}) + ... + Q(1, m_{\xi N-1})
\end{array} \tag{11}$$

in such a way in the algorithm (9) all operations "production" are eliminated and only N(N-1) $\approx N^2$ complex additions are necessary.

In Table 1 are given data for the number of necessary calculations when using DFT, FFT and suggested new algorithm.

It is evident from the data the sizable increasing of the rate of the speed with the new fast algorithm, which has been tested with other orthonormal transformations - "cosine", "sine", Hartley, Wavelet etc.

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