Using radial basis elements for classification of food products by spectrophotometric data

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A Training Model of a Microprogramming Unit for Operation Control: *The paper describes an approach for classification of food products into quality groups using radial basis elements and spectrophotometric data. A software instrument is developed in order to perform the classification and to assess the classification accuracy. An example of using the software for classification of spectral characteristics of white cheese in two classes, which represent the change in quality of the samples during the storage in irregular conditions, is presented. All the procedures are developed in MATLAB environment.*

Key words: *spectral characteristics, classification, food quality, radial basis elements.*

INTRODUCTION

The traditional methods for assessing the Quality and Safety (QS) for food products are: sensory evaluation, chemical and microbiological analysis. These are laboratory methods that require specific conditions, equipment, materials and personnel with relevant training. They are not suitable for "on-line" monitoring, suggesting the existence of substandard or unsafe foods in the production and storage. Furthermore, they do not allow correction of the process in order to correct the resulting imbalance in "real time". They are not suitable for express evaluation of food QS "on the ground" - in stores, warehouses, catering, home, etc., where they are not always stored at regulated by the manufacturer conditions.

As an alternative to traditional methods, methods for express non-destructive evaluation of food QS are more and more widely applied in recent years. Among them the most perspective are noncontact optical methods based on analysis of color images, spectrophotometric and hyperspectral analysis.

In the dairy products industry Computer Vision Systems (CVS) are mainly utilized for evaluation of: color characteristics and texture features of cheese and cheese melting [1], degreasing control [4], to determine the distribution and the amount of spices, vegetables and other components [3], for predicting the moisture content and evaluation of fat content of the cheese [4], for detecting microorganisms [5] and other features of cheeses and dairy products [9].

The near infrared spectroscopy (NIRS) is a non-destructive technology, which is mainly used for determining the composition of a variety of dairy products such as milk [8] and cheese [2] as well as evaluation of major QS indicators of these products. Some typical examples of the application of NIRS analysis for assessment of various features associated with QS of dairy products may be indicated: determining the sensory features and age of cheese [2]; determining the composition of cheese [7]; the composition of cow's milk [8]; of moisture, fat, and inorganic salts in the processed cheese, analysis and prediction of maturity and sensory features of the cheddar cheese [2], etc.

Hyperspectral analysis systems (HSA) found relatively few applications in solving various tasks related to the assessment of the QS of dairy products. Published analyses are related to the possibilities of defining the content and distribution of fat and protein, casein, lactose, to identify the type of dairy product, the presence of foreign fat and other [6].

The aim of this study is to describe an approach for classification of food products into quality groups using radial basis elements and spectrophotometric data as well as to present the main parts of the software, developed for that purpose.

MATERIALS AND METHODS

Fig. 1 shows the general appearance of the graphical interface of the software developed. It consists of several basic blocks. The controls in block 1 serve to load the

spectral characteristics of multiple objects from two or three classes that are displayed in the graphic field 2. In block 3 the data is presented by properties derived using data dimensionality reduction by Principal Component Analysis (PCA). The button in block 4 starts a classification procedure, which will be used for assessment of data separability. The classification results are exported in Microsoft EXCEL worksheet for further analysis.

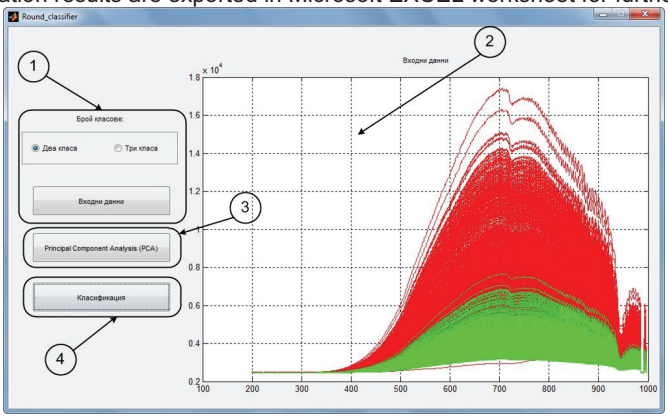

Fig. 1 Graphical user interface of the software.

MATLAB is used for software development, because of the rich mathematical abilities of that environment and the ability to use a variety of built-in procedures for assessment of classification accuracy.

Data dimensionality reduction. To extract the properties of spectral characteristics and to reduce the dimensionality of the spectral data principal components analysis (PCA) is used.

PCA is mathematically defined as an orthogonal linear transformation that transforms the data to a new coordinate system such that the greatest variance by some projection of the data comes to lie on the first coordinate (called the first principal component), the second greatest variance on the second coordinate, and so on. Consider a data matrix, *X*, with column-wise zero empirical mean (the sample mean of each column has been shifted to zero), where each of the *n* rows represents a different repetition of the experiment, and each of the *p* columns gives a particular kind of datum (say, the results from a particular sensor). Mathematically, the transformation is defined by a set of p-dimensional vectors of weights or loadings $w_{(k)} = (\varpi_1, \ldots \varpi_p)_{(k)}$ that map each row $x_{(i)}$ of X to a new vector of principal component scores $t_{(i)} = (t_1, \ldots, t_p)_{(i)}$, given by

$$t_{k(i)} = x_{(i)} \cdot w_{(k)} \qquad (1)$$

in such a way that the individual variables of *t* considered over the data set successively inherit the maximum possible variance from *x*, with each loading vector w constrained to be a unit vector.

Classification procedure. Separability of data for the same sample on different days of storage of the product is a major criterion for the correct classification both with regard to composition of the product and of its freshness. The separability between the data of the investigated areas was quantitatively assessed by the overlap error ε_{pr}% (the ratio of incorrectly classified examples to the total number of examples). The separability determination was made by association of the assessed sample to the nearest prototype using network architectures with radial basis elements (RBE) [6].

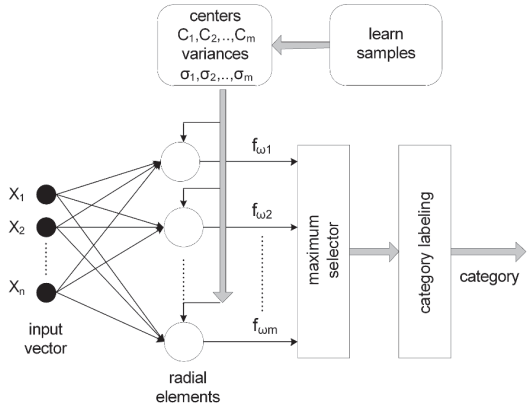

Fig. 2 Round shaped class regions approximation using standard RBEs.

Only one RBE is used for approximation of each class region. The RBEs centers correspond to class average values obtained from class learning samples (Fig. 2).

With $f_{\omega i}$ the output of i-th RBE, which corresponds to class ω_i is denoted. In the case when one standard RBE is used for each class region approximation, the class boundary is round shaped. This corresponds to the case, when the distributions of the input vector components are equal in all directions of the feature space. If this precondition is not carried out, then the class region shapes are different from sphere.

The bias value of the i-th RBE is determined by the equation:

$$b_i = 0.833 \Big/ \left(k\sigma_{\omega_i}\right) \qquad (2)$$

where σ_{ω_i} is the standard deviation of the vectors of class ω_i; k is a parameter, which determines the dimension of class boundary surface.

EXPERIMENTAL RESULTS

Multiple spectral characteristics of different food products in the visible and near infrared region are preliminary recorded, in order to trace their change during storage of food samples in irregular operating conditions (at a temperature of 20ºC and lack of light). The products used are meat, bacon, white cheese and yellow cheese. For samples of meat and bacon spectral characteristics of their individual components are also collected - in meat: meat tissue, fat tissue and bone tissue; in bacon - meat tissue and fat tissue. Data is structured in such a way that allows solving the following several tasks: separability assessment of individual areas (e.g. areas with meat, fat and bone tissue in pieces of meat) on a certain day of the storage of the product and separability assessment of data for the same sample on different days of storage.

As an example of the operation of the program the classification of the samples of white cheese on different days of storage is performed. The samples spectral characteristics are taken in near infrared region (900 ÷ 1700nm), and represented by its first three PC's (Fig. 3).

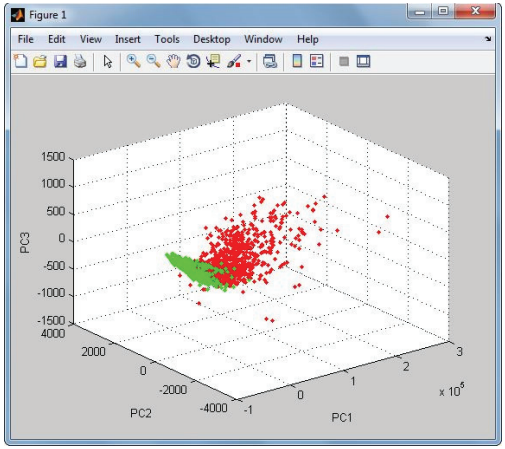

Fig. 3 Representation of spectral characteristics by Principal Components

Classification is performed in two classes, where each class is represented by spectral characteristics of cheese samples on a certain day of storage. The classification accuracy is assessed by the ratio of incorrectly classified examples to the total number of examples ε_{pr}%. The results are presented in Table 1.

Table 1 Classification results.

Day	Error value, ε_{pr}%
	NIR
	Cheese
1 vs 2	11.9
2 vs 3	0.6
3 vs 4	0.3
4 vs 5	35.2
5 vs 6	35.8
6 vs 7	20.5
1 vs 3	11
3 vs 5	0.9
5 vs 7	41.9

The results show that there is a good separability between the classes in the first few days of storage of the product. Particularly well this is evident in results of the classification for the period between day 2 and day 5. Considering the conditions under which the products are stored, this suggests that in this period of time changes occurred in the products that affect their spectral characteristics in the near infrared range. After this period of time separability of the classes deteriorates sharply.

CONCLUSIONS

The performed research and presented results allow drawing the following main conclusions:

1. The developed software package for the classification of food products by spectrophotometric data allows different investigations, concerning assessment of changes in product quality during storage, the change in the quality of individual areas and recognition of these areas within the same sample to be performed.

2. The presented results from the classification of samples of cheese on different days of storage at irregular conditions show that this approach allows tracing in time the

change of the characteristics and quality of the product. This, combined with the capabilities of the classifier that uses radial basis elements to form models of the classes allow both the creation of predictive models of the change of basic characteristics of the products examined and searching the relation between visual characteristics of the product and the main indicators of quality and safety.

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Докладът е рецензиран.