Intelligent Methods and Tools for Sensor Data Combination in the Analysis of Food and Agricultural Products

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Abstract—The work in this paper defines the problem with the application of intelligent methods for combining data from sensors in the analysis of agricultural and food products. Results and comparative analyzes from the researches of the indicated products with optical, ultrasonic, capacitive sensors and sensor devices, as well as combinations of them are presented. The features according to which the classification of the studied objects according to the indicated characteristics are performed, as well as a certain set of relations between them are defined. Methods and tools for classification and prediction of main indicators for product quality have been developed. The obtained results demonstrate that the algorithms used in determining the optical, ultrasonic and dielectric characteristics in the analysis of some food and agricultural products allow the development of adequate classification models for rapid and non-destructive determination of the main quality indicators of these products. Through the obtained results, it is proved that the classification methods and the predictive models manage to keep the values of the classification error low. It was found that the informativeness of the features, the choice of methods for reducing the volume of data and ways of classification and regression, depend largely on the product under study and its characteristics. This necessitates further research on the application of different types of sensors and combinations of them in the analysis of food and agricultural products. This obtained results has the prospect of direct application of data from visual images, spectral, ultrasonic and dielectric characteristics, in combination with the selected classifiers and prediction models in the systems for quality assessment of food and agricultural products.

Keywords—sensor data fusion, eggs, cucumbers, regression, comparative analysis

1. Introduction

Traditional methods of measuring and evaluating the quality of food and agriculture products include labor-intensive laboratory analyzes related to the destruction of the measured sample and the need for qualified personnel. This necessitates the search for new methods for objective assessment of the quality of food products, automation of processes and means of control in their production.

The joint use of data from optical, ultrasonic, capacitive and other sensors for analysis is used in the field of production and processing of food and agriculture products [1], because they are based on automatic measurement of various surface characteristics that can correlate with the quality of food products. When using methods for analysis of food and agricultural products based on sensor data, it is necessary to take into account the influence of the conditions and duration of their storage [2, 3]. Under inappropriate storage conditions, physical, biological and microbiological changes can occur in the products, which affect not only the organoleptic properties, but also their quality and safety.

The improvement of traditional and the creation of new technologies for food production must meet the needs of consumers for a rational and healthy diet. For this purpose, it is necessary for food producers to improve and refine the technologies so that they have a certain technological and economic effect. In laboratory analyzes to determine the effect of various additives in food products [4], there is a discrepancy between the results obtained and those of actual production. This necessitates the improvement of laboratory methods for food analysis.

An important condition for the storage of food and agriculture products is the maximum preservation of their organoleptic and physico-chemical properties, which can be achieved by adding biologically active substances during their production. Scientists are still looking for methods for contactless and express determination of the state of food products in the agricultural sector (Fig. 1). The aim is to fully automate the processes of receiving, processing and analyzing these products, using modern applications in mobile devices such as tablets, phones and laptops. This would lead to improved production processes, reduced energy costs and, last but not least, a reduction in the harmful impact on the environment.

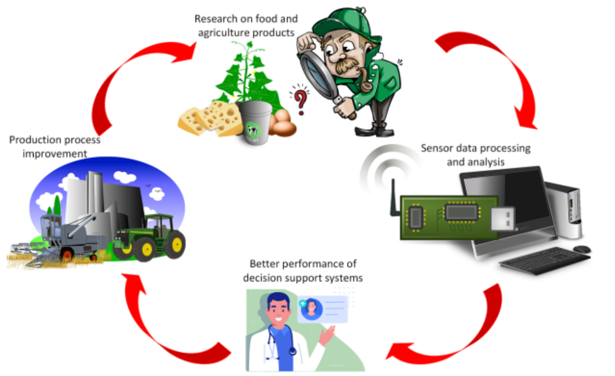

Fig. 1. Application of non-contact measurement methods

According to European legislation [5, 6], food producers are responsible for ensuring the safety of products placed on the market. Foods are safe when quality raw materials and technologies are used in their production and by applying systematic control and management.

The aim of the present work is to establish the influence of the used data obtained from combinations of different types of sensors, as well as the methods for their processing.

2. Material and Methods

Data from different types of sensors are presented in determining the main characteristics describing the condition and quality of eggs, cucumbers, tomatoes and yogurt, grown and stored in conditions specified by their producers.

Fig. 2 shows the stages of obtaining and sharing data from different types of sensors in modern intelligent systems. The initial stage includes obtaining data about the tested products through ultrasonic, optical, capacitive sensors. They are also defined – the technological characteristics of these food and agricultural products.

The large volume of data of feature vectors can be reduced by appropriate methods – principal component analysis, factors and weights. The obtained data are convenient to use in the classification of products and for forecasting their technological characteristics, using appropriate regression models. As a result of these studies, non-contact measuring devices for express and non-destructive analysis of food and agricultural products can be created.

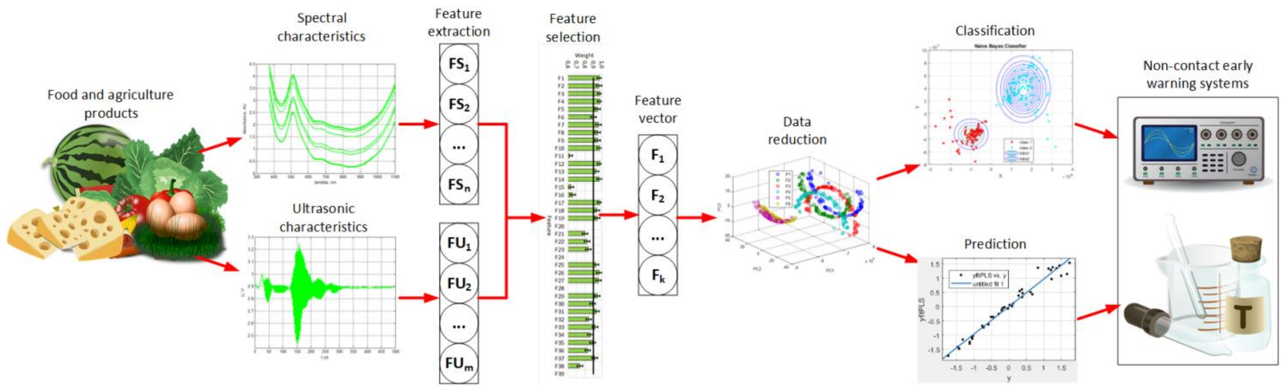

Fig. 2. Scheme for obtaining, processing and analysis of main characteristics of food and agricultural products by sensors data combination

The characteristics used are color, spectral, ultrasonic and dielectric, as well as combinations of them.

The methods for selection of informative features are factor analysis and Correspondence analysis.

The data in the obtained feature vectors are reduced by the methods of analysis of the main components and latent variables. Also, appropriate classification procedures are used, according to [7].

3. Results and Discussion

3.1 Sharing data from spectral characteristics and color components

The features by which eggs will be classified according to their digital images and spectral characteristics during ovoscopy are defined. As shown in Fig. 3, spectral indices were calculated from the spectral characteristics.

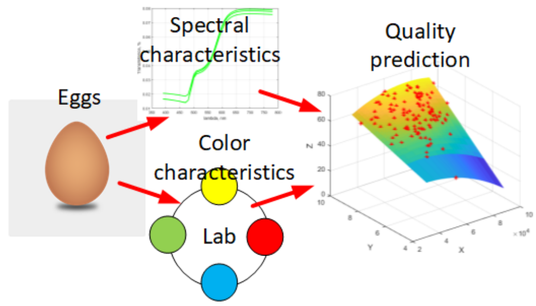

Fig. 3. Prediction of main indicators for egg quality

In the same way, color indices are determined from the color components of the Lab color model. The data from the obtained measurements were used for selection of features from color and spectral characteristics of quail eggs (healthy and with microcracks). Out of a total of 19 features, 32% are color and 42% are spectral, and the remaining 26% are uninformative or correlate with the selected features.

The vectors with features are formed during the analyzes and correspond to the types of external defects of the examined eggs.

The use of an informative set of classification features reduces the required computational resource.

The evaluation of the possibilities for classification by means of linear, nonlinear separating functions and three types of classifiers shows that the linear classifiers are not suitable for separating the elements in the images of quail eggs by color characteristics.

In the two examined types of microcracks in eggs, the nonlinear separating functions of the discriminant analysis and the method of support vector machines show a total error e=2-6%. When using the Decision Tree method, the error in separating healthy eggs from those with microcracks is e=12-19% for all three classes.

A comparative analysis was performed to determine the influence of vectors of selected features obtained by combining the color and spectral characteristics of cucumbers infested with aphids on the accuracy of classification, depending on the stage of the pest.

As shown in Fig. 4, spectral indices were calculated from the spectral characteristics. In the same way from RGB, XYZ, Lab, HSV, YIQ color model their color components are used. Measurement data were used to select features for color and spectral characteristics of cucumber leaves infested with aphids. Out of a total of 26 features, 42% are color and 39% are spectral, the remaining 19% are uninformative or correlate with selective features.

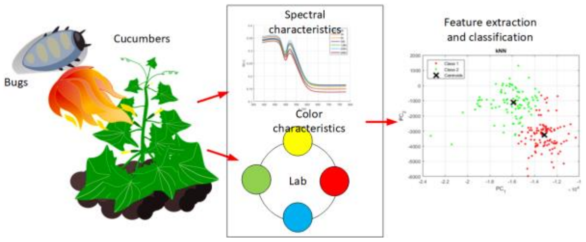

Fig. 4. Analysis and data processing for cucumbers affected by pests

A suitable method for selecting features derived from spectral characteristics and color components is the Correspondence analysis method. By this method, features suitable for classification of object areas with aphids by cucumbers, both on the adaxial and abaxial part of the leaves, have been selected. It has been found that the separation of data classes, depending on the stage of development of cucumber aphids, is possible using nonlinear separation functions. It has been shown that the separability of data classes depends more on the method of reducing the volume of data than on the type of separation function.

As a result of the conducted theoretical and empirical research, analyzes and generalizations, methods and procedures for determining the degree of ripeness of tomatoes have been created (Fig. 5). Measurement data were used to select features from color and spectral characteristics of tomatoes with different degrees of ripeness. Out of a total of 24 features, an equal number, of which 38% are color and 38% are spectral, the remaining 24% are uninformative or correlate with selective features.

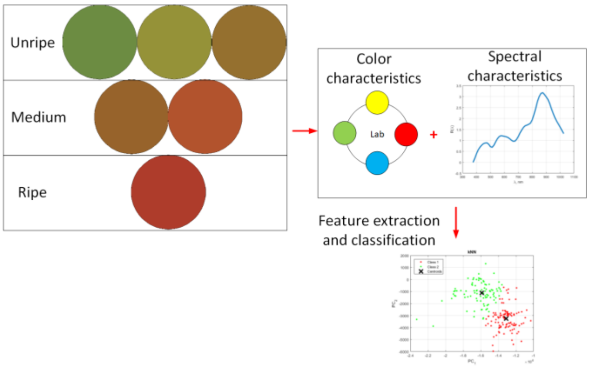

Fig. 5. Classification of tomatoes by degree of ripeness

An analysis was made to determine the degree of ripeness of tomatoes, using systematized color and spectral indices. It has been found that feature vectors containing color and spectral indices that are reduced by principal components are suitable for this purpose. The application of the developed algorithm shows that when predicting the degree of ripeness of tomatoes, the accuracy of the algorithm reaches 96-98%.

Regardless of the function used to select informative features, when reducing the data volume of feature vectors, the total error is over 20%, using latent variables. Therefore, it is appropriate to use the direct application of color and spectral indices and methods to obtain data close to the original.

3.2 Sharing data from spectral and ultrasonic characteristics

A method is proposed for the precise determination of the values of the admissible quantities of additives of bee products, without violating the properties of the final product and for it to be acceptable for the consumers.

The permissible amounts of the addition of honey and bee pollen in yoghurt have been determined. A method and tools are proposed to determine the permissible amounts of honey and bee pollen in yogurt, using data on its physicochemical and organoleptic characteristics.

These data are combined with measurements of color, spectral and ultrasonic characteristics of the product.

As shown in Fig. 6, spectral indices were calculated from the spectral characteristics. Features of ultrasound characteristics were determined in the same way.

Out of a total of 14 features, 50% are spectral and only 7% are ultrasonic, the remaining 43% are uninformative or correlate with the selected features.

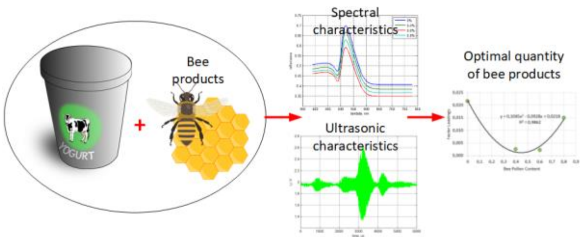

Fig. 6. Determining the optimal amount of bee products in yogurt

It was found that the permissible amount of honey in yogurt, which does not violate its physico-chemical and organoleptic properties is 7,4%, and for bee pollen is 0,42%. These results confirm and supplement the data published in the available literature [4, 8].

3.3 Sharing data from spectral, geometric and dielectric characteristics

A method and tools for predicting the mass of eggs have been developed, which is based on the basic indices of the shape of the eggs and their spectral indices, and on a certain set of relations between them.

From Fig. 7, it can be seen that from the three types of sensors – capacitive, video camera, spectrophotometer, a significant amount of features is obtained, which can be used in predicting the mass of eggs. From 34 features obtained, 15% are spectral, 15% are shape indices, and only 6% are dielectric traits. The remaining 64% are uninformative or correlate with dielectric features.

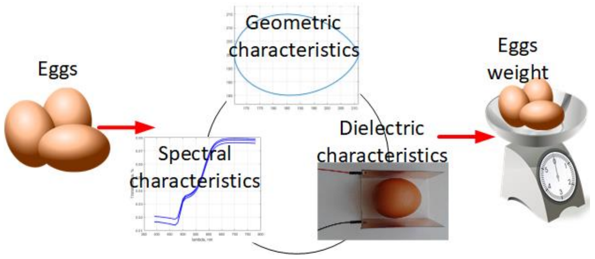

Fig. 7. Prediction of egg weight by sharing sensor characteristics

A comparative analysis was performed to survey the effect of the strategies utilized on the exactness of prediction of eggs weight. It was tracked down that the utilization of strategies for anticipating the mass of hens' eggs gives preferable outcomes over in predicting the weight of quail eggs.

The examination of the outcomes in predicting the weight of eggs shows that the volume of eggs, in combination with the ghastly files that consider the adjustment of their inner qualities, have a more prominent potential for right expectation of the weight of hen eggs than quail eggs. This technique shows the benefit that the internal properties of hens and quail eggs are additionally considered, utilizing otherworldly features, and not just the lists of shape measurements, which change irrelevantly during storage of these products.

A strategy and instruments for predicting the weight of eggs have been created, which depends on the main characteristics of the condition of the eggs and their dielectric features, just as on a specific arrangement of proportions between them. That approach improves the methods, presented in the available literature [3, 9].

Models have been created to anticipate the weight of hens and quail eggs, contingent upon the storage time. A relative examination of the models of hens and quail eggs was made. Likenesses were found in the models for hen eggs, with error rates not surpassing 5%. For these properties it is fitting to utilize arrived at the midpoint of models for the entire gathering of concentrated on items.

In quail eggs, the prediction force of the models utilized errors by over 5% somewhat recently of storage time.

In the wake of lessening the volume of information with head parts and dormant factors, quality vectors containing region, border, volume, just as electrical features and dielectric ones can be utilized to predict the weight of hen eggs.

Expectation of the weight of quail eggs is conceivable utilizing a vector of features containing region, volume, coefficient portraying the connection between the major and minor axis of the egg, just as limit and dielectric characteristics too.

Table 1 shows a summary analysis of the presented results. The comparative analysis is based on the one used in assessing the characteristics of the recognized products. It can be seen that in the formation of the vectors of the features the largest share is occupied by the data from the spectral characteristics, following the colors. Ultrasonic, dielectric and geometric characteristics participate in feature vectors with 1 to 4% of the total number of features used. It is necessary to make a result from the research on the application, the production of sensor systems other than optical.

Table 1. Summary data for the analyzed products

Product	Characteristic	Number of features	% of features used				
			Color	Spectral	Ultrasonic	Dielectric	Geometric
Eggs	Micro-cracks	19	32	42	x	x	x
Eggs	Weight	34	x	15	x	6	15
Yogurt	Bee products	14	x	50	7	x	x
Cucumbers	Aphids	26	42	39	x	x	x
Tomatoes	Ripeness	24	38	38	x	x	x
Total		117	22%	33%	1%	2%	4%

Food and agricultural products differ in composition and properties, depending on the geographical region in which they are obtained, the processing methods and a number of other factors. For this reason, the sharing of different types of sensors ensures the definition of key quality indicators and their differentiation, to a greater extent, compared to the use of data, only one type of sensors.

The results obtained, improve the methods, presented in the available literature [5, 10, 11].

The obtained results show that it is necessary to do more research on the application of different types of sensors and combinations of them in the analysis of food and agricultural products.

The informativeness of the features, the choice of methods for reducing the volume of data and ways of classification and regression, depend largely on the product under study and its characteristics.

4. Conclusion

The obtained results demonstrate that the algorithms used for analysis of food and agricultural products, their spectral and dielectric characteristics, allow the development of adequate classification models for rapid and non-destructive determination of the main indicators of quality of these products in the specified measurement conditions.

The joint use of data from several sensors leads to a comprehensive assessment and more accurate division of the characteristics of the studied products, depending on their condition.

The obtained results show that the classification methods and the predictive models manage to keep the values of the classification error low.

These facts have the prospect of direct application of different types of data from visual images, spectral, ultrasonic and dielectric characteristics, in combination with the selected classifiers and prediction models, in the systems for quality assessment of food and agricultural products.

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