New Techniques of Products Analysis

Marius Buzera, Marius-Constantin Popescu, Nikos E. Mastorakis, Jean-Octavian Popescu

***Abstract*—** researches throughout the past few years, having as a goal the automatic classification of products, via calculus systems implementation, as well as machine vision techniques, and artificial intelligence field methods, have lead to very promising results. Together with the colour, shape is one of the most important parameters of vegetal products. Thus, it helps one learn further information on the integrity of products, information which can be used in their classification, while taking the shape into consideration.

Using them allowed for the assessment of some parameters such as shape, colour and the integrity degree of the products analyzed, having much more superior results than the classical classification installations. Still, due to these techniques particularities, the classification process implies going through some more phases. Both the experimental methodology for classifying vegetal products and some original algorithms are presented in this paper. To classify the shape it has been developed back-propagation feed-forward artificial neural network, and for colour a fuzzy algorithm. In order to test these techniques, an experimental device was created to allow a video inspection of products, some of the conclusions being presented in this material.

***Keywords*—** machine vision, shape, colour, classification, image processing, neural network, fuzzy logic**.**

I. Introduction

Over the last 20 years, there has been a higher and higher interest focused on the problems of recognition and identification of surfaces and image processing, via machine vision techniques and artificial intelligence. Using these new technologies in developing classification systems of industrial products brought about various benefits such as: doing away with inconsistency and the dependence on human labour, raising accuracy and labour speed. Focusing on these premises, over the last years, several studies and researches have been carried out that hint to the adjustment of both these techniques and the image processing algorithms to the particularities of vegetal products classification. Thus, Buzera [3] presented in a paper the advantages and disadvantages of using human operators in the inspection and classification process of vegetal products, while Deck [5] pointed out to the disadvantages of using a semi – automatic sorting.

The importance of using non-destructive techniques in the process of classifying vegetal products, based on video inspection has been also stated by Baoping [1].

Still in 2002, Laykin [6] develops automatic classification devices for vegetal products on the basis of color describer, all of that while valuing the mean and standard deviation of all pixels in the product area.

On a classification device for apples [15] be presents and validates a series of identification algorithms of color and shape, by mixing up image pre-processing techniques with the algorithms belonging to the artificial intelligence neural networks. An algorithm of apples shape setting and identification of their stalk is developed by Popescu [16], while Popescu [14], develops a sorting algorithm of fruit according to shape via neural networks.

A quick method of orange classification was developed by Cruvinel [4], based on image processing with correlation analysis in frequency domain, while [13] validates a series of classification algorithms of potatoes according to the shape, color, and analysis of faults via classification system. Buzera [3] developed a series of identification algorithms of the shape, color and size of the products by using processing techniques of images, fuzzy algorithms and neural networks.

The colour, shape, size and surface defect of fruit are important features in classification. The method to describe and identify the shape of fruit to be studied was the radius signature analysis with artificial neural networks and as concerning colour, the method used was fuzzy algorithm [7].

The biological products are unique into the nature and the features of the background can determine various irregularities of their shape and colour. Also, considering the particularities of vegetal products, an attempt of both the developing of some original automatic classification algorithms and the setting of a methodology of vegetal products classification, was made.

A brief description of these original algorithms projected as well as of the stages in the making while using machine vision techniques is further presented.

II. The Experimental Device

In order to validate these algorithms, an automatic classification installation of products has been projected and carried out, having being focused on a Pentium IV/3200MHz

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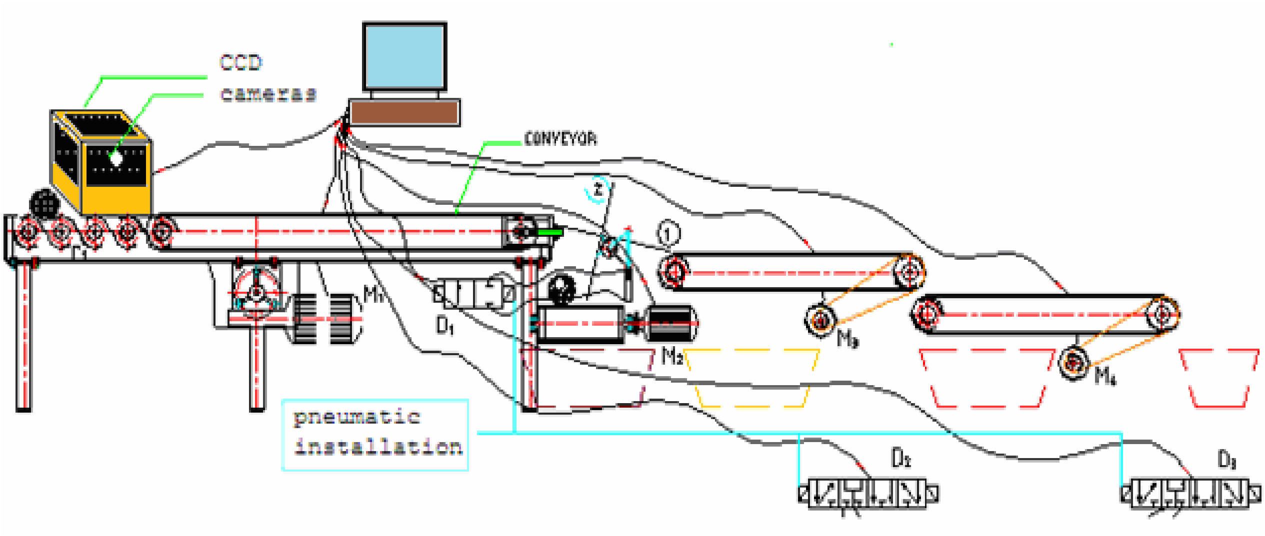


Fig. 1. Conveyor and device of video-inspection.

computer [2]. Its activity is to be coordinated by a soft application called Image Analyzer allowing for a real time assessment of products. Such a type of automatic classification is focused on the machine vision system. The device has been realized around a transporter with a belt (Fig.1) activated by an electric engine, which ensures the moving of the product in face of the video-inspection system, made of two video CCD cameras [8], [9], [10]. These allow the acquisition of 4 colored RGB pictures of 512*512 pixels that they transmit in a real time, to the analyzing mechanism. The activity is coordinating by a special program named Image Analyzer.

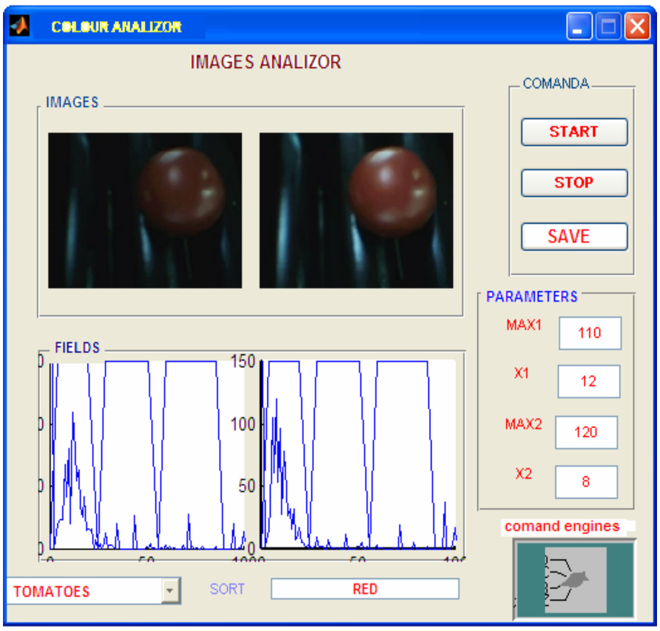


Fig. 2. The interface of the application Image Analyzer.

Considering the very high variation field of shape, size and colour describers under analysis, as well as the particularities of products the artificial sight system was especially projected, its structure being presented in Fig. 3.

The acquisition system is focused on the image sensor carried out from two digital cameras, with manual focusing, and it carries out itself the entire amount of operations starting with the electronic acquisition of images, being followed by digitization and to its being brought to a number format, held in the RAM memory of the calculus system.

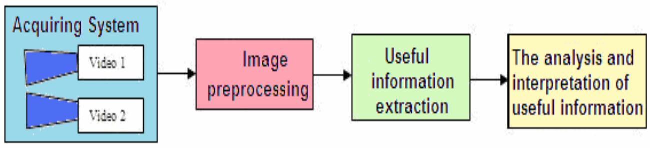


Fig. 3. The block scheme of the artificial sight system.

The preprocessing block carries out a series of graphical transformations on the acquired images hinting to do away with any possible disturbers to the images or useless information. These transformations are necessary in order to improve both the execution time and the results.

When projecting the preprocessing block, the following terms have been considered:

- the application takes time in real timing;
- the high amount of features hinted and their high dynamics;
- getting a previous acquaintance of the types of noises introduced;
- the presence of an illuminating and visualizing system which limits the number of the noise typologies that alter the image;

The illumination system represents an essential component part of a „machine vision" classification system.

One usually tends to ignore the importance of illumination in such applications, although the illumination system is known to be one of the most crucial component parts of the application. Thus, an inadequate illumination can frequently make the difference between a good and a bad functioning of the application. Tests regarding this study have proved the fact that a poor illumination system leads to serious errors in classifying the produces. Implementing software filters may fix the errors, but they can also result in longer periods of execution for the application [3], [11], [12].

The following features have been considered when choosing the devices for the illumination system (halogen, electric bulb, fluorescent lamp):
- the illumination force;
- the relation price/performance;
- answer speed;
- liberty in shape projection;
- warming level due to radiations.

As a consequence to the experiments carried out, the best result was achieved by using electric bulbs. As it is shown in Fig. 4. they supply the best results and, moreover, they use DC power [3].

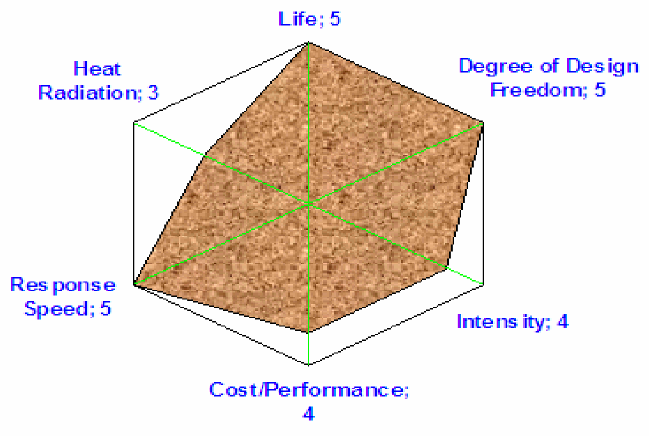


Fig. 4. The diagram of the features of the bulbs.

For a better illumination of the product, the interior walls of the illuminating room were painted white, such that they can ensure a diffuse illumination of the object under inspection. Also, the illuminating room was implemented on a mobile metallic framework that allows to change the distance between electric bulbs and the object, and to reposition the electric bulbs on the prop, as shown in Fig. 5.

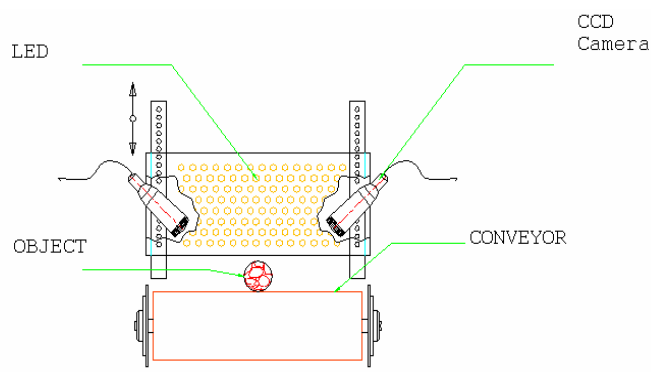


Fig. 5. Illumination system.

III. Description of the Process

On the basis of the variation of describers and experiments carried out, a complex algorithm was proposed and carried out for the Image Analyzer, having the following functions:
- it turns the acquired images pattern belonging to the RGB (Red, Green, Blue), into HIS (Hue, Intensity, Saturation);
- resize the images to 256x256 sizes;
- filters the pass-down images followed by the pass-up image in the frequency field;
- detection the shape describers;
- detection de color detection;
- analysis and interpretation of the useful information;
- commands to the execution mechanism;

Thus, the block scheme of the algorithm proposed for the preprocessing block is presented in Fig. 6.

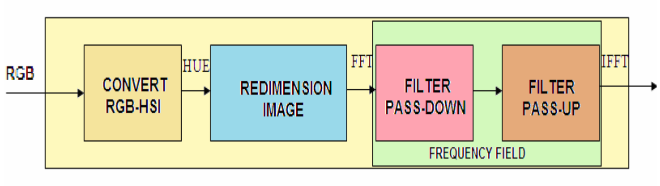


Fig. 6. The block scheme of the preprocessing block.

By converting the RGB model into the HIS one, a significant decrease of the work volume, together with the quality of the analysis through the hue invariance to the illumination intensity variations, is obtained.

Image resized is carried out by doing away with the outlines of the image matrix in order to also do away with those image areas containing portions belonging to the ceiling, conveyor or any other parts of the installation.

Resize also hints to bringing the image to multipliable sizes to two, that can be used during the pass down or pass up filtering from the frequency field.

In order to pass into the frequency field, or in order to restore from the frequency field the Fast Fourier Transform (FFT) or the Inverse Fast Fourier Transform (IFFT) are used.

The extracting block of useful information and the block of analysis and interpretation information ensure extracting the shape and colour describers on the basis of which the classification process is carried out.

A. The shape. The Analysis of the shape

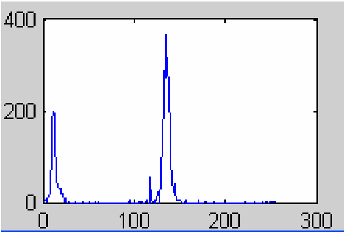
The examination of the shape of an object allows us to get enough information to classify it. Thus, this information can be used to obtain some information concerning the integrity of the object [9], [10].

If in the case of industrial processes the objects that are usually classified have well-defined structures, in the case of vegetal products, this thing is very difficult [2].

That is why we have to know very well the shape and its variations before we classify the products.

Every RGB picture captured by the two cameras is converted into the HIS [Hue, Saturation, Intensity] space.

From the H matrix, based on the analysis of the histogram (Fig. 7a) it has been carried-out an algorithm of linearization and the outline of the fruit from the picture has been carried-out when applying a "Laplace" (Fig. 7b) filtration.



a)

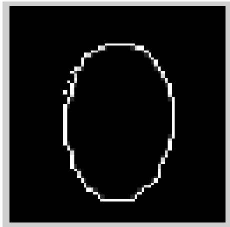

b)

Fig. 7. The steps in the determination of the shape: a) The histogram of the initial picture; b) The outline of the product from the picture.

This outline was used to detect the shape of the fruit from the picture. [3]

A part of algorithm write in Matlab language is presented.

```
% Chose the filter mask
% Laplace Filter
w=handles.masca;
img=handles.foto;
img1=imresize(img,[256,256]);
imgh=rgb2hsv(img1);
imgh1=imgh(:,:,1);
fimgh1=fft2(imgh1);
fw=fft2(w,256,256);
rez=fimgh1.*fw;
rezd=ifft2(rez);
handles.foto=rezd;
guidata(hObject,handles);
etime(clock,t0);
set(handles.activex1,'value',x);
axes(handles.axes4);
```

B. *The analysis of the signature of rays using the Fourier techniques*

By converting the RGB model into the HIS one, a significant decrease of the work volume, together with the quality of the analysis through the hue invariance to the illumination intensity variations, is obtained.

Image resized is carried out by doing away with the outlines of the image matrix in order to also do away with those image areas containing portions belonging to the ceiling, conveyor or any other parts of the installation. Resize also hints to bringing the image to multipliable sizes to two, that can be used during the pass down or pass up filtering from the frequency field.

In order to pass into the frequency field, or in order to restore from the frequency field the Fast Fourier Transform (FFT) or the Inverse Fast Fourier Transform (IFFT) are used.

The algorithm proposed has a few particularities regarding the variety of shapes of vegetal products. The phases of the algorithm developed in order to generate the features of the shape are the following:

Phase 1. The image obtained from the preprocessing block going out is divided so as to identify the surface of the product;

Phase 2. The outline of the product is identified out of the image by using a contrasting filtering:

Phase 3. Determining the *Cg* coordinates, on the basis of inertia moments;

The signature of the shape of the object supposes that the weight-centre of the outline should be determined. These can be determined due to the moments of stillness.

$$x_c = \frac{\left[\iint_{x,y\in O} xdxdy\right]}{\iint\limits_{x,y\in O} dxdy}, \quad y_c = \frac{\left[\iint_{x,y\in O} ydxdy\right]}{\iint\limits_{x,y\in O} dxdy} \qquad (1)$$

We will continue by presenting some notions necessary to the introduction of these theorems using the basic formula called Green-Riemann.

If MCR^2 is an elementary compact with the FrM border and P and Q are two functions of class C^1, on a simple convex domain which contain M, then

$$\iint_M \left(\frac{\partial Q}{\partial x} - \frac{\partial P}{\partial y}\right) dxdy = \oint_{FrM} Pdx + Qdy \qquad (2)$$

By using the fundamental Green-Riemann's formula with P and Q chosen, from formula (1) we get:

$$x_c = \frac{\left[\frac{1}{2}\oint\limits_{x,y\in C}\left(yxdx - \frac{1}{2}x^2dy\right)\right]}{\left[\frac{1}{2}\oint\limits_{x,y\in C}(ydx - xdy)\right]} \qquad (3)$$

$$y_c = \frac{\left[\frac{1}{2}\oint\limits_{x,y\in C}\left(\frac{1}{2}y^2dx - xydy\right)\right]}{\left[\frac{1}{2}\oint\limits_{x,y\in C}(ydx - xdy)\right]} \qquad (4)$$

By using the definition with Riemann's sums in (3) we get:

$$x_c = \frac{\sum\limits_{k=0}^{n}\left(y_k\left(x_k^2 - x_{k-1}^2\right) - x_k^2\left(y_k - y_{k-1}\right)\right)}{2\sum\limits_{k=0}^{n}\left(y_k\left(x_k - x_{k-1}\right) - x_k\left(y_k - y_{k-1}\right)\right)} \qquad (5)$$

$$y_c = \frac{\sum\limits_{k=0}^{n}\left(y_k^2\left(x_k - x_{k-1}\right) - x_k\left(y_k^2 - y_{k-1}^2\right)\right)}{2\sum\limits_{k=0}^{n}\left(y_k\left(x_k - x_{k-1}\right) - x_k\left(y_k - y_{k-1}\right)\right)} \qquad (6)$$

Phase 4. For each point on the outline, radius is determined with the help of the relation:

$$R_k = \sqrt{(x_k - x_k)^2 + (y_k - y_c)^2} \qquad (7)$$

Talking into account the fact that fruits have usually unique shapes and thus, they can have sizes and shapes that are very different, the rays have been normalized with the medium ray, thus:

$$r_p = \frac{1}{n}\sum_{k=0}^{n-1} r(k), r_g(k) = {r(k)}/{r_p} \qquad (8)$$

where: r_p = the medium ray and $r_g(k)$ is the ray obtained after the operation of normalization.

Phase 5. By applying TFR on the signature of the shape, one gets the relation:

$$F(u) = {1}/{N}\sum_{k=1}^{N} r(k)\exp[-j2\pi uk / N], u = 0,1,2....N \qquad (9)$$

The histogram on which FFT is applied shows how many times each of the values of the radius of the product analyzed appears in the picture.

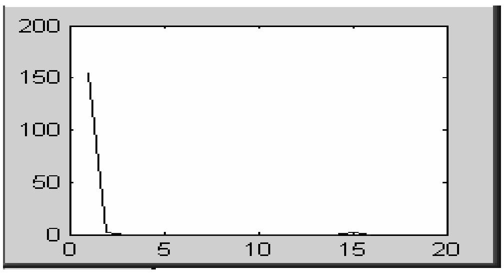


Fig. 8. The Fourier transform of the radius.

From these two features there have been extracted the highest value that indicates the ray that has the highest frequency and the highest abscise value for a frequency different from zero (Fig. 8). If the abscise value is higher, the fruit is less round.

C. *Shape recognition based on artificial neural network*

Fourier describers, obtained as a result of that, contain useful information regarding the shape under analysis. Generally the images having homogeneous values of accordions, or contain a low amount of them, represent regularly shaped object, and via Inverse Fast Fourier Transform (IFFT), the reconstruction is quite simple.

Shape is one of the main features in assessing the quality of fruit and vegetables, while one can easily assess both the integrity of the products analyzed and their size on the basis of the shape parameters transmitted to the analysis and interpretation block of information.

The integrity classification algorithm obtained was developed on the basis of neural networks. In order to analyze the structural integrity of products one is to take into account the fact that, once entering the analysis and interpretation block of results, 16 parameters (shape describers) will be applied, while products will be classified into two classes: good and understandart, at their going out.

That is why the neural network developed has 16 neurons on the first and second strata, and 2 neurons on the third one, as one can also notice in the structure of the network projected and presented in Fig. 9.

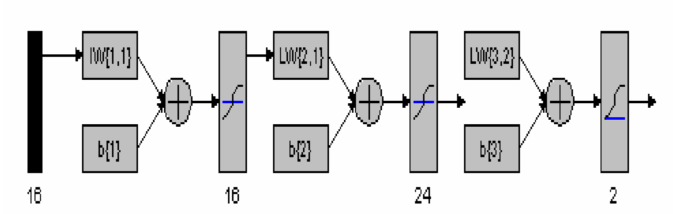


Fig. 9. The structure of the three strata network chosen so as to set the integrity of fruit and vegetables under analysis.

Considering the classification role of the algorithm, as well as on the basis of tests and essay carried out, the activation function was chosen to be of hyperbolic tangent type, for the first two strata, and of sigmoid type for the third stratum.

For a better neurons amount setting, in the hidden stratum, several tests and assay have been carried out, hinting to: the classification proficiency, the amount of products used for the training, as well as the necessary time for training the classification algorithm network. The training algorithm chosen is backpropagation.

D. *The Colour. The Analysis of the colour*

Colour analysis techniques are algorithms which help detecting the colour of the objects of the acquired images. In this paper a new method is implemented and tested for colour detection by using the hue histogram [12].

Thus, in the hue histogram the highest average value of the pixel corresponds to the colour of a surface, i.e., the value of the average density of the hue can be taken to represent the systematic distribution of colour on the surface of products.

The method relies on correct identification of the area of that part of the histogram belonging to the object whose colour is to be analysed. Once the histogram is obtained, it is easily to set the domain of the pixels values belonging to the object under analysis, as a result of using the following algorithm: [4]

Phase 1. Calculating Cg - the histogram's centre of gravity:

$$Cg = \frac{\sum n \cdot k}{\sum k}, \text{ where } k = 0, 1, ..., L-1 \qquad (10)$$

where
- L is the degree of maximum intensity; L=256;
- *k* is the degree of grey;
- *n* is the frequency of grey degree occurrences.

Phase 2. The histogram is divided into two areas to this limit (*Cg*) and the maximum values belonging to these areas are estimated MAX 1 and MAX 2. MAX 1 is in the 0-Cg area and MAX 2 is in the Cg+1 – 255 area.

Phase 3. The minimum value MIN from the two maximums is determined. If the minimum value MIN doesn't differ enough from the value Cg, the segmentation limit receives the value *Cg*. If the minimum value MIN differs a lot from Cg the segmentation limit receives the value MIN and the third stage will be repeated.

Analyzing these describers have proved the fact that, unlike the classical algorithms based on the average of the values of the pixels from the main area, in the case of any illumination intensity alternation or some shadows or brightness appeared on the surface of the products analyzed, these techniques do not lead to any faulty results.

The colour detection algorithm, presented in Fig. 10 is simple and easily to implement. The tests have pointed out to the fact that, in the case of an image correctly acquired, the centre of gravity is one and the same with then minimum value identified.

After having correctly identified that part of the histogram belonging to the object under analysis, the maximum value of the object histogram respectively, the value of the vector abscissa X is estimated. Also, the range of colour variation of the prevalent pixels is estimated.

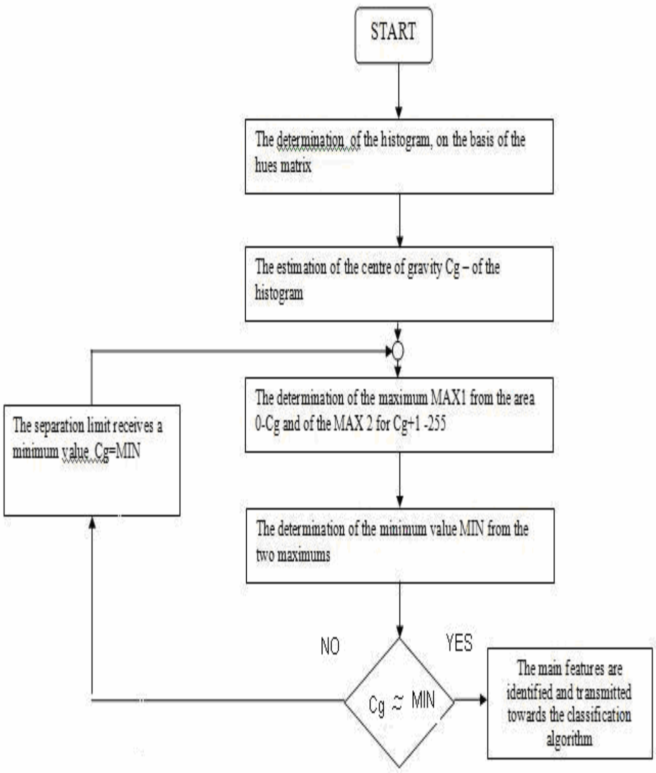


Fig. 10. The algorithm of colour detection on the basis of colour.

The colour detection algorithm, presented in Fig. 10 is simple and easily to implement.

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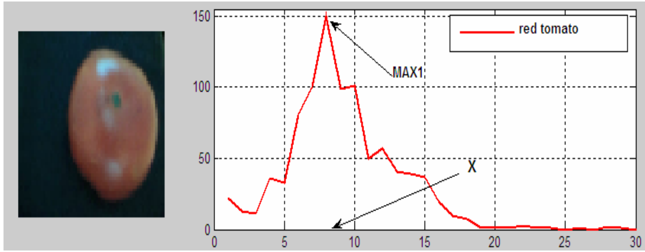

Fig. 11. The histogram of the tomato hue.

Thus, the X value points to the main color of fruit, while MAX1 points to the frequency of its appearance. Both X value and MAX1 value are determined by tests, thus setting the variation values for each class of products.

E. The recognition of colour by using a fuzzy algorithm

The classification algorithm according to color is based on the calculus of the average of the histogram. For this purpose, we directed the parameters MAX1 and X, obtained from each image acquired, to the analysis and interpretation block of information.

Taking into consideration the high variation degree of the parameters hinted, both for color and shape, the analysis and interpretation algorithm of useful information provide good result just in the case in which artificial intelligence techniques are used instead of the classical decision algorithms.

The classification implies the process of establishing the affiliation of a product to one of the classes above, for which the concept of fuzzy mass was used.

That is, between the affiliation of an object to a class, and non-affiliation, there is a series of transitory situations, of continuous nature, and which are characterized by the so-called degrees of affiliation.

Thus, the 0 and 1 values represent the lowest, respectively the highest degree of affiliation of an object to a class.

The values obtained during the training process were used to implement a trapezoidal affiliation function [8].

$$m(x) = \min\left[1, h_t(1 - 2\frac{|x-c|}{b-a}\right], \qquad (13)$$

with h_t>1.

where: h_t –the height of the trapezium;

a, b, c – the discontinuity points of the function.

Consequently, the analysis and classification can be represented like in Fig. 12.

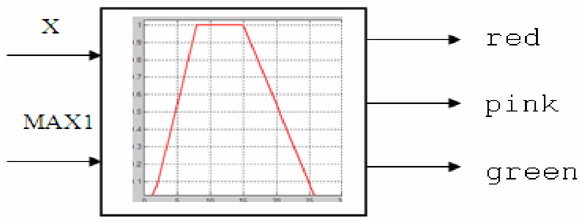

Fig. 12. The block of colour analysis.

In Fig. 13, the diagram of the algorithm proposed for the classification process on the basis of colour using a fuzzy algorithm is presented.

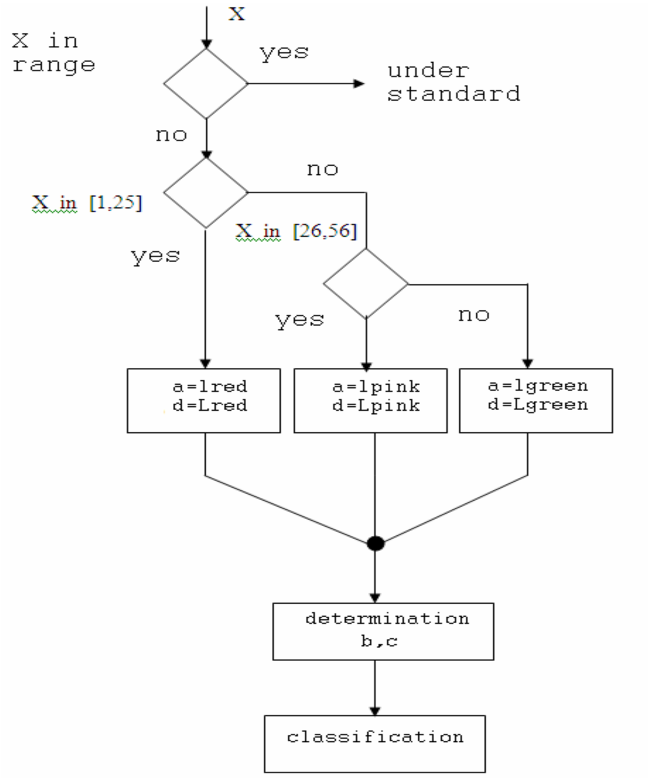

Fig. 13. The algorithm of colour establishment.

The algorithm presented in Fig. 14 can be developed for a larger amount of classes. The function of fuzzy algorithm was chosen to be of a trapezoidal type, due to the fact that, as about fruit and vegetables, it is not likely to get one single value of red.

Concerning the industrial products, it is useful to use a triangular function, due to the very narrow domain of colour variation. The X values from the abscise vector and the MAX1 value were determined as a result of hard training for each class this getting the variation fields for each class.

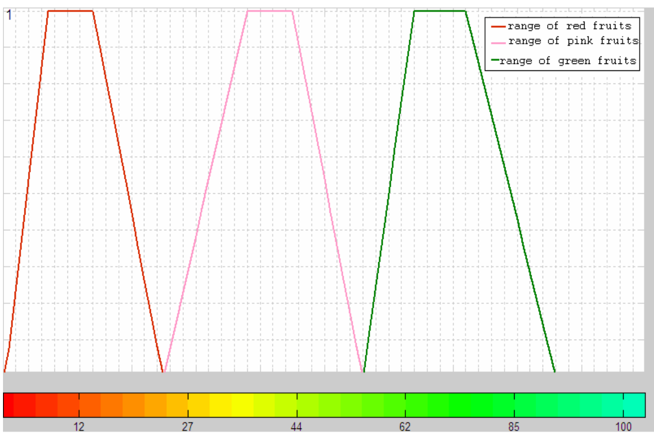

Fig. 14. The colour variation field for each class of products to be tested.

IV. EXPERIMENTS

In order to test the algorithms proposed 30 tomatoes and 30 bills belonging, to the same type as those used during the training period have been chosen. The main parameters hinted during the testing of the two algorithms were the precision of the classification as compared to the speed of the conveyor, as well as the classification speed. The algorithm based on the calculation of the average of the histogram provides very good result allowing for a quick a correct identification of variation field for each class as one can also see in Fig. 15.

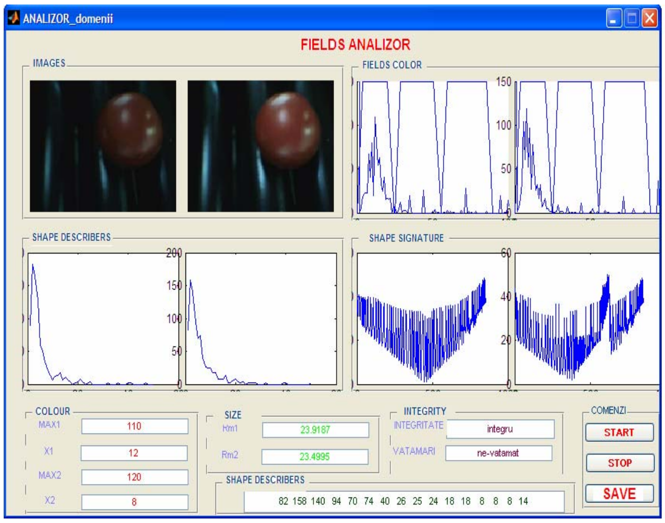

Fig. 15. The variation field for red tomatoes.

As one can notice, the max1 value was found and re found in the colour field identified during the training period. Thus, the tests carried out at various speeds of the conveyor, have allowed for setting an accuracy in the classification of tomatoes of 97%. As one can also see in table 1 the percent of 90% in the classification of pink tomatoes is mainly due to the choice of a too little training set of products. For balls, where the colour is much more homogeneous, the classification accuracy is 100%.

Tab. 1. The variation of the classification accuracy while using the calculus algorithm of the histogram average.

The speed of the conveyor [m/s]	The class	The no. of products to be tested	The no. of products suitably tested	The accuracy
0,05 – 0,1	Red tomatoes	10	10	100%
	Pink tomatoes	10	9	90%
	Green tomatoes	10	10	100%
	Red balls	10	10	100%
	Pink balls	10	10	100%
	Green balls	10	10	100%

Also for the mean and standard deviation algorithm, the results are good, the accuracy is 90% for tomatoes and 100% for the balls, as one can notice from Tab. 2. The neural network developed for the shape parameters analysis and interpretation was trained until the average error reached a lower value than 0.0001, and in this way the structure of the network was also chosen, as one may easily observe in Tab. 3.

Tab. 2. The variation of the classification accuracy while using the mean and standard deviation algorithm.

The speed of the conveyor [m/s]	The class	The no. of balls to be tested	The no. of balls suitably tested	The accuracy
0,05 – 0,1	Red tomatoes	10	9	90%
	Pink tomatoes	10	8	80%
	Green tomatoes	10	10	100%
	Red balls	10	10	100%
	Pink balls	10	10	100%
	Green balls	10	10	100%

Tab. 3. The accuracy and precision of the training and classification process of tomatoes according to the structure of the network.

The structure of the network	Number of steps	The precision of the training set	The precision of the classif.
16-8-2	1400	100%	100%
16-12-2	1110	100%	100%
16-14-2	1250	100%	100%
16-20-2	1010	100%	100%
16-22-2	940	100%	100%
16-24-2	820	100%	100%
16-26-2	970	100%	100%
16-28-2	1150	100%	100%

V. CONCLUSIONS

The tests and experiences carried out have pointed out to the following conclusions:

- the technique of the signature of rays is quite easy to apply, is quick and can be used both in the classification of the products according the shape and in the analysis of the products quality.
- It can be easily correlated with the classification of neuronal type.
- taking into account the numberless amount of forms that the vegetal products can have, the utilization of the classificatory of neuronal type can be considered an important alternative (in comparison with the rest of the techniques of classification).
- the HIS pattern (used for image analysis) also proved efficient, saving a large amount of time and resources.
- the illumination system based of electric bulbs turned out to be very reliable and flexible, and can be used both for bright and opaque produces.
- any of the algorithms are not influenced by the speed of the conveyor, thus providing results irregardless of its speed;
- the mean and the standard deviation algorithm imply a low amount of calculus, it is faster, but it doesn't provide enough information for the analysis of the hue homogeneity of vegetal product. Also, a high amount of hues of such a product depending on the environment may cause real problems to the product. On the contrary it is but very efficient in the analysis of the colours of the industrial products, because the homogeneity is a much higher one in this case.
- the calculation algorithm of the histogram average is rather easy to implement and it also provides good results, irregardless of the variation degree of the colours of the vegetal products from a set, but it depends a lot of the representativity of the set of products chosen for the training, in order to identify the variation fields of the colour for each class of products. Plus, this algorithm introduces an invariance to the sudden alteration of the values of the hue duet o the light modifications.
- the fuzzy technique provides much better results than the classical decision algorithms, especially if their amount and variation degree is a very high one.
- the structure of the training set directly influences the classifier's performance. The larger the training set is, the more accurate the decision limits are placed, and the less the error of classification is.

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