Original scientific paper
UDC 613.2-026.613:614.31

COLOR MEASUREMENT OF FOOD PRODUCTS USING CIE L*a*b* AND RGB COLOR SPACE

Ivana Markovic[1*], Jelena Ilic[1], Dragan Markovic[1], Vojislav Simonovic[1], Nenad Kosanic[1]

[1]Faculty of Mechanical Engineering, University of Belgrade, Kraljice Marije 16, 11000 Belgrade, Serbia

[*]e-mail: imarkovic@mas.bg.ac.rs

Abstract

Color of the food is the first parameter of quality evaluated by consumers. What is important is the acceptance of the product even before being consumed. Inspection of food products is done using machine vision, particularly analyzing and processing the images, where the parameters of each pixel on the surface of the recorded product must be known. Using different color spaces quantitative color value is obtained. Although there are many different color spaces, when it comes to food, the most frequently used is the CIE L*a*b* color space, due to its uniform color distribution and because its perception of color is closest to the one human eye. RGB color space, where a sensor in each pixel records the intensity of light in the red, green and blue spectrum, is also similar to human perception of colors and it is also frequently used. The problem with the L * a * b * scale is that commercial color-meters measure only a dozen of square centimetres of the product itself and the measurements are not representative for the most of heterogeneous materials.

The aim of this paper is to present the analysis of images of chosen food products using the two color spaces. In each of the two color spaces, after determining the range of parameters appropriate to good quality products, the criteria for the discrimination of damaged products is defined and tested. The comparison of the applications of those criteria shows that, in the case of food, the transformation of RGB coordinates into the CIE L*a*b* color space makes it possible to achieve greater accuracy and improved calculation of appropriate color parameters.

***Key words**: Color, Scale, Machine vision, Food inspection, RGB, CIE Lab.*

1. Introduction

The first property of food that is evaluated by a consumer is its colour. During the processing of agricultural products, inspection and sorting are some of main technological operations. Observation of the colour of the product enables detection of certain imperfections and defects [1, 2 and 3]. The progress in food industry and the growth of the amount of processed food lead to the necessity of development and application of mechanized sorting systems for bio-products. "Machine vision", as a crucial part of sorting systems, enables automatic and non-destructive selecting of the products that satisfy certain requirements. The processing and analysis of an image is the core of machine vision computer system [4]. The method is based on taking the image of the products, its analysis and comparison with the standard products, and finally deciding on accepting or rejecting of the products.

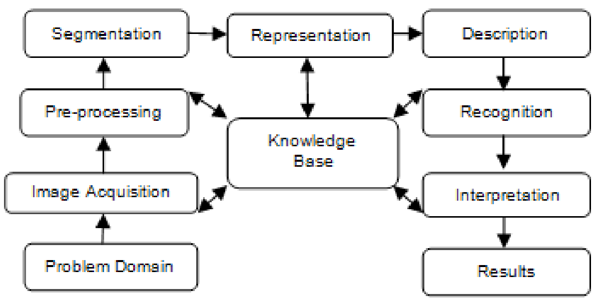

Figure 1. Basic steps for image processing/analysis

Some important steps in product image analysis are presented in Figure 1 [5, 6]. While the morphological analysis of an image and pattern recognition are abundantly present in literature, the analysis of colour, and recognition of adequate or inadequate colour fully started in this century and algorithms are still to be optimized. Unlike the industrial products, whose properties are usually precisely defined, fruits and vegetables are biological products. It means that even the samples of the same species, cultivated in the same manner, have a variety of shapes and colours. Therefore, each variety of a species requires its own standardization of shape and colour recognition procedure. The aim of this paper is to define parameters for good quality raspberries, peas and corn, and to propose an algorithm of recognizing the damaged samples.

2. Materials and Methods

Chosen products - raspberries, peas, and corn, are placed in one layer on the plates and photographed. The images of raspberries are taken immediately after the harvest. Peas and corn are photographed after their defrosting. Thus, parameters of colours are that of fresh raspberries and defrosted peas and corn. Raspberries and corn are photographed by Nikon Coolpix L120 and S3100, respectively, whereas peas are photographed by Olympus mue300. All of the original images were formatted in JPEG. In all the cases, applied lighting was diffuse daily light D65 (the light of "cloudy day").

The raspberry image size is 300x300 pixels. The first step in image analysis is differentiation between background and products of interest. This process, called segmentation, has to be performed in order to find parameters of exclusively product colour, needed in further deciding process. That process can be performed in either Matlab® or Adobe Photoshop®. In this case, the later showed to be easier and more efficient.

a) b)

Figure 2. a) Digital photo of raspberries; b) Segmented photo of raspberries

In Figure 2, the examples of original raspberry image (a), and segmented image (b) are shown. After the segmentation two parallel analyses of images are performed: a) the analysis of an image in red-green-blue -RGB colour space, and 2) the analysis of an image in *CIE L*a*b** colour space (Commission internationale de l'Eclairage). In both colour spaces each image consists of three colour matrices. In RGB colour space, those three matrices are the matrix of pixel values of red *r*, the matrix of pixel values of green *g* and the matrix of pixel values of blue *b*. In *CIE L*a*b** colour space, those three matrices are the matrix of pixel values of lightness *L*, the matrix of pixel values of parameter *a* (greenness to redness) and the matrix of pixel values of parameter *b* (blueness to yellowness). This dissolving of images into matrices was performed in Matlab®, as well as the further calculation of mean values and standard deviations of each colour component.

In attempts to find a criteria by which imperfect products can be recognized three approaches are chosen. The first approach is based on rejection of all products whose colour is not within the standard deviation interval around the mean value of each colour component (*r*, *g*, *b*, and *a*, *b* in *L*a*b** colour space). That way, too many good quality products were rejected as inappropriate.

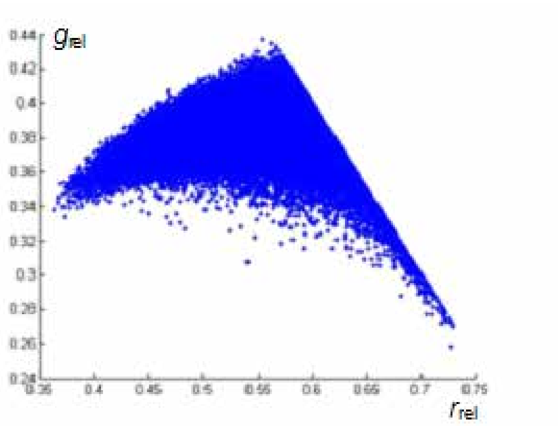

Figure 3. The relation between relative values of green and red component in the image of standard quality corn

In second approach, an image in RGB colour space was analyzed. For each pixel, relative values of each component were found: relative value of red component is $r_{rel} = {}^{r}/_{(r+g+b)}$, and relative values of green and blue are found in the same way. The relation between relative values of green and red component of all pixels in the image of standard (acceptable) quality corn is presented in Figure 3.

The idea is to define the region covered with dots in diagram in Figure 3, and to assume that any pixel that falls out of this region is unacceptable. That region might be defined in many ways. Here chosen definition uses the approximation of the region by a triangle. Among the set of triangles, applied as the criterion of rejection, the best result was obtained with triangle whose boundaries are directions: $g_r = 0{,}4167r_r + 0.2067$, $g_r = - r_r + 1$, $g_r = - 0.1143r_r + 0.4066$. Thus, unacceptable pixels were those who satisfy any of three following inequalities: $g_r > 0.4167r_r$, $g_r > -r_r + 1$, $g_r < -0.1143r_r + 0.4066$.

In the third approach, an image in *L*a*b** colour space was analyzed. For each pixel of the image, in which bad products should be recognized, the Euclidean distances from mean values of *a* and *b* in the standard image are calculated. Then, in the matrix of Euclidean distances, the elements with values over the certain threshold are found.

In the cases of all three approaches, after applying checking each pixel for the selected criteria, matrix places of pixels that satisfy the criteria are assigned as logical 1 and all the other places are assigned as logical zeroes. That way, it is obtained the mask with "holes" in the places where unacceptable pixels are found. Isolated elements of the value 1, or small clusters of them in the mask, i.e. small groups of unacceptable pixels in the original image, usually are the result of stochastic changes in lighting or inclination of produce surface. They rarely present a product defects. In order to eliminate isolated unacceptable pixels, or small clusters of them, noise removal is performed. It can be repeated several times. Higher number of iterations of noise removal might leave some real defects unobserved. Therefore some compromising number of noise removals should be found after which new mask is obtained. That new mask can be put over the original image (using element wise product), making only bad colour products visible.

Another means of visualization of rejected products is the application of edge detection on new mask. It produces white lines around the holes of the previous mask, and black background. Logical negation of this matrix gives the opposite image: black lines around the holes of the previous mask on the white background. Element-wise product of the last mask and the original image results in black lines around the regions of unacceptable pixels.

3. Results and Discussion

Colour parameters of the images of good quality products (raspberries, peas and corn without damaged or inadequate items) are presented in Table 1 and Table 2.

Table 1. Average RGB values and its average standard deviation in images of standard quality products

Summary of mean values	Mean value of red colour	Mean value of green colour	Mean value of blue colour	Standard deviation of red colour	Standard deviation of green colour	Standard deviation of blue colour
Raspberries	206.3885	88.9485	98.7142	50.9591	37.8580	39.4015
Pea	71.2053	115.3763	54.1591	40.4565	49.2706	39.9645
Corn	191.0180	142.3136	38.251	17.5525	28.3926	32.7461

Table 2. Average CIE L*a*b* values and its average standard deviation in images of standard quality products

Summary of mean values	Mean value of *L**	Mean value of *a**	Mean value of *b**	Standard deviation of *L**	Standard deviation of *a**	Standard deviation of *b**
Raspberries	131.7739	173.3189	147.3202	46.5464	15.2528	9.5449
Pea	96.3877	107.4478	150.746	53.3264	10.7994	15.9537
Corn	160.0650	141.0278	184.9622	22.9546	7.9143	7.7405

For each of 24 images, mean values of a colour components, and their standard deviations over the image are calculated. Then, their mean values for all the images of the same species are found. In Table 1, the means of the values of three components in RGB colour space, and the means of their standard deviations, are presented. Likewise in Table 2, the means of values of *L*, *a* and *b*, as well as means of their standard deviations, in images of standard products, are presented. It can be noticed that, mean standard deviation of parameters *a* and *b* are smaller than that of parameters *r, g* and *b* (10% or less of mean value).

In order to use colour measurement in detecting inadequate items, all the imperfect items in image are noticed and labelled. The example is shown in Figure 4, where imperfections were of tree kinds: white, hard i.e. inedible "roots" of the corn grains (5, 7-9, 14, 16, and 17), darker grains or grains with black spots (1-4, 6, 10 -12, 15) and one greenish grain (13).

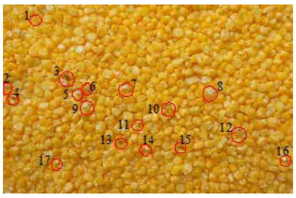

Figure 4. Image with imperfect corn grains

Figure 5. Image (RGB): non-black pixels are out (av±st.dev)

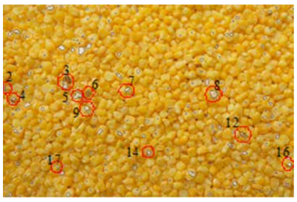

Figure 6. Imperfect grains detected by the 2. approach

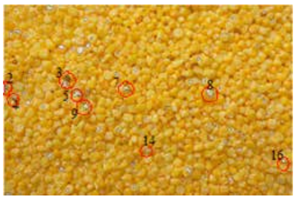

Figure 7. Imperfect grains detected by the 3. approach

The example of the application of the first approach, explained in previous section is presented in Figure 5. It is the result of analysis of image in RGB colour space. Visible, i.e. non-black pixels are all the pixels from the original image (Figure 4), whose values of red *r*, green *g* or blue *b* are out of interval (mean/average value ± standard deviation) that are presented in Table 1. It is obvious that this criterion is too week, and rejects too many good items. Next intention might be to use interval (mean/average value $\pm$ n standard deviation), where n should be varied, and even be different for different colour components, in order to find an optimum value for differentiating bad grains. Mean values and standard deviations can be used in evaluation of fruit or vegetable ripeness [7], food overall quality [8], but detection of bad parts requires more sophisticated analysis of an image.

The second approach, explained in previous section and applied in Figure 4, resulted in Figure 6. The program, created in Matlab®, tested each pixel in the image according to second criterion, and generated the image with the regions of inadequate colour encircled by black lines. Red circles were put manually in order to highlight the defects, noticed in Figure 4, that are also recognized by the second criterion. Applied criterion did not detect the 5 out of 17 defects. But it also detected about 60 another regions of pixels that satisfy the second criterion, but represent normal grains. Those misfits are mostly too bright surfaces of grains, and several dark shadows between the grains. The number of both groups of misfits could be decreased by improving the lighting at taking the photographs. The criterion could also be refined by approximation of region of acceptable colours in Figure 3, not with triangle but with the region surrounded by three curved lines that describes it better.

The regions of inadequate colour, by the third criterion are presented In Figure 7. This particular image is obtained using the threshold of the Euclidean distances 17, and 5 iterations of noise removal. This way, 8 out of 17 defects were left unnoticed by the third criterion, whereas about 40 regions were erroneously detected as inadequate. Like in Figure 6, the errors are mostly glittering surfaces of grains, and shadows (here orange) between the grains, and its number could be diminished by better lighting.

In both, the second and the third approach, small dark spots were left unnoticed (1, 10, 11, 15), and one greenish grain (13), too. Small dark spots might be noticed with increased image resolution, which requires greater processor memory. In order to be noticed, green in grain should be defined better in any of two colour spaces. Finally, in Figure 6, there are less unnoticed defects (5), but, more misfits (about 60), whereas in Figure 7 the opposite is true: there are more unnoticed defects (8), but, fewer misfits (about 40).

4. Conclusions

- Considerable research suggests the need and potential for the computerized inspection and grading of fruits, vegetables and grain quality, as well as specific inspection and assessment of the quality of food products.
- Colour has proven to be good indicator for successful and objective evaluation of many types of food products. This paper shows us, that the chosen parameters of the colour could be used to define criteria for differentiation of good and inappropriate product. It shows that suggested approaches gave useful results, but not good enough to satisfy needs of contemporary inspection systems, because too many good quality products were rejected as inappropriate and some inadequate product was not recognized as such.
- Clustering algorithms performance can be improved if we use more quantity of information. Further research will be conducted based on submitted suggestions in the paper, to improve presented approach and to define additional criteria for inspection.

Acknowledgement

This paper is the result of research project 'Research and development of equipment and systems for industrial production, storage and processing of fruits and vegetables' partially funded by the Ministry of Science and Technological Development, Republic of Serbia. Project No TR35043, for the period 2011-2014.

5. References

[1] Du C., and Sun D. (2004). *Recent developments in the applications of image processing techniques for food quality evaluation*. Trends in Food Science and Technology, 15, pp. 230 - 249.

[2] Hatcher D. W., Symons S. J., and Manivannan U. (2004). Developments in the use of image analysis for the assessment of oriental noodle appearance and color. Journal of Food Engineering, 61, pp. 109 - 117.

[3] Pedreschi F., Aguilera J. M., & Brown C. A. (2000). Characterization of food surfaces using scale-sensitive fractal analysis. Journal of Food Process Engineering, 23, pp. 127–143.

[4] Krutz G. W., Gibson H. G., Cassens D. L., and Zhang M. (2000). Colour vision in forest and wood engineering. Landwards, 55, 2 - 9.

[5] Gunasekaran S., and Ding K. (1994). Using computer vision for food quality evaluation. Food Technology, 6, pp. 151 - 154.

[6] Sun D. W. (2000). Inspecting pizza topping percentage and distribution by a computer vision method. Journal of Food Engineering, 44, pp. 245–249.

[7] Jaffar A., Jaafar R., Jamil N., Low C. Y. and Abdullah B. (2012). Photogrammetric grading of oil palm fresh fruit bunches. Int. J. of Mechanical and Mechatronics Engineering, 9 (10), pp. 18 - 24.

[8] Lu J., Tan J., Shatadal P. and Gerrard D. E. (2000). Evaluation of pork color by using computer vision. Meat Science 56, pp. 57 - 60.