Application of Auto_Threshold plugin for cut surface evaluation of white cheese in brine

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Abstract. This paper presents a research over application of global thresholding methods for evaluation of cut surface of white cheese in brine. Six trademarks Bulgarian white cheese in brine produced of cow, sheep and goat milk are used for cut surface evaluation. Examined cheese samples are evaluated by experts and the results are used as referent assessment for results of image processing trough thresholding algorithms. A Java program is developed for image segmentation with specific thresholding algorithm using two or three colors in different modes to produce segmented image. The images of cheese samples (their cut surfaces) are processed with developed program using all of the seventeen thresholding algorithms which are implemented in Auto_Threshold plugin for open source software ImageJ in different modes. A correlation analysis shows that some of thresholding algorithms which are implemented in Auto_Threshold plugin could be used for cut surface evaluation of white cheese in brine.

1. Introduction

Milk and milk products are essential foods for human and thus they are very popular food in everyday meal. A lot of milk products there are known such as cheese, yoghurt, curd and etc. Cheese has a high energy, nutritional and biological value for human body. Various human-useful vitamins are included in the composition of the cheese, such as: group A and D vitamins which are fat-soluble; water-soluble vitamins of group B (B2 and B6) and others [1]. The consumption of mature cheese, such as the Bulgarian white cheese in brine, give to the human necessary quantities of essential amino acids. From ancient to now the technologies for dairy processing are constantly evolving. As the analysis shows European countries, and particularly Bulgaria, have well-functioning dairy industry [2]. The cow, sheep and goat milk is most popular raw materials for dairy industry in Bulgaria [3]. According to information in statistical report of Bulgarian Ministry of Agriculture, Food and Forestry, white cheese in brine, yoghurt and packed milk are the most produced milk products in Bulgaria. The quality of milk and milk products are strictly controlled by standards. In Bulgaria there are a lot of standards for quality control of milk products. For white cheese in brine quality control standards are about fourteen (BDS 15:2010).
Some parameters of food quality could be evaluated visually. In the field of food quality evaluation, computer vision systems are popular and effective technique for quality investigation [4, 5, 6, 7, 8]. A lot of researches are done about application of computer vision for cheese quality evaluation. Area occupied of gas holes on Emental, Ragusano and Cheddar cheese are successfully measured using image processing [9]. Some functional features which are related to thermal processing (cooking) of cheese of type Mozzarella are also evaluated through image processing [10, 11]. Computer vision is applied also in inspection of distribution and amount of ingredients in pasteurized cheese [12]. Cut surface of Bulgarian white cheese in brine is inspected through processing of microscopic images (SEM) which are specifically colored [13, 14], through image processing with NI VisionBuilder [15] and through image processing in HSV color space [16].

The aim of current research is to propose fast and effective approach for cut surface evaluation of white cheese in brine using image segmentation based on methods which are implemented in Auto_Threshold plugin.

2. Materials and methods

2.1. Image segmentation

The main purpose of image processing is to extract information about foreground (objects) and background of images [17]. In the beginning every pixel has to be associated with a specific group i.e. the pixel has to be grouped with other pixels according to its color and relation with neighbours. This process is popular as image segmentation. The segmented image gives significant information about objects on the image. Thus the image segmentation is a very important step in process of automatic object recognition because the result of image segmentation is an image with pixels which are grouped in regions by their similarity. Algorithms for image segmentation are based on different techniques such as region growing, edge detection, thresholding and etc. The algorithms for image segmentation are widely used for biomedical images processing [18, 19, 20, 21], food quality evaluation [4, 22, 23], microbiological analysis [24, 25, 26] and etc.

2.2. Software

It is developed a Java application (ImgSegJ) for image segmentation using seventeen thresholding algorithms which are implemented in Auto_Threshold plugin for open source software ImageJ. These algorithms are: Default (private implementation of IsoData method), Huang, Huang2 (alternative implementation of Huang's method by J. Schindelin), Intermodes, IsoData, Li, MaxEntropy, Mean, MinError, Minimum, Moments, Otsu, Percentile, RenyiEntropy, Shanbhag, Triangle, Yen. On figure 1 it is presented a model of application ImgSegJ. Developed application works with BMP images and uses global thresholding algorithms in two basic modes: binarization and segmentation.

![Figure 1. Application model of ImgSegJ.](image-url)
has two options: “Separate in Black area” and “Separate in white area”. When the option “Separate in black area” is selected then image processing consists of next steps:

1) Major threshold (Th\textsubscript{1}) value has to be found with selected algorithm;
2) A histogram of image has to be modified so that all pixels which have color which is bigger than threshold (i.e. the pixels in the result image have to be black color) are removed from histogram;
3) Second threshold (Th\textsubscript{2}) value has to be found using selected thresholding algorithm and based on modified histogram;
4) The result image contains three colors (white, gray and black) and it is generated using major and second thresholds by formulae:

\[
p_{\text{out}} = \begin{cases} 
\text{white}, & p_{\text{in}} \leq Th_{1} \\
\text{gray}, & Th_{1} < p_{\text{in}} \leq Th_{2} \\
\text{black}, & p_{\text{in}} > Th_{2}
\end{cases}
\]

where \(p_{\text{in}}\) is color of pixel in input image, \(p_{\text{out}}\) is color of pixel in resulting image (after segmentation), \(Th_{1}\) is major threshold and \(Th_{2}\) is second threshold (based on modified histogram).

When the option “Separate in white area” is selected then image processing consists of next steps:

1) Major threshold (Th\textsubscript{1}) value has to be found with selected algorithm;
2) A histogram of image has to be modified so that all pixels which have color which is smaller than threshold (i.e. the pixels in the result image have to be white color) are removed from histogram;
3) Second threshold (Th\textsubscript{2}) value has to be found using selected thresholding algorithm and based on modified histogram;
4) The result image contains three colors (white, gray and black) and it is generated using major and second thresholds by formulae:

\[
p_{\text{out}} = \begin{cases} 
\text{white}, & p_{\text{in}} \leq Th_{2} \\
\text{gray}, & Th_{2} < p_{\text{in}} \leq Th_{1} \\
\text{black}, & p_{\text{in}} > Th_{1}
\end{cases}
\]

where \(p_{\text{in}}\) is color of pixel in input image, \(p_{\text{out}}\) is color of pixel in resulting image (after segmentation), \(Th_{1}\) is major threshold and \(Th_{2}\) is second threshold (based on modified histogram). On figure 2 is presented GUI (Graphical User Interface) of application ImgSegJ.

![Figure 2. ImgSegJ – GUI (Performance with two images in segmentation mode with option “Separate in black area” and thresholding algorithm Intermodes).](image-url)
2.3. White cheese in brine
Six trademarks of Bulgarian white cheese in brine are bought from marketplace. They are produced from cow, sheep and goat milk. On figure 3 are presented three samples of examined trademarks.

![Cheese samples](image)

**Figure 3.** (a) Cheese of cow milk; (b) Cheese of sheep milk; (c) Cheese of goat milk.

Two samples of every trademark are used for experiments. All examined samples of white cheese in brine are cut and their cut surface are captured with camera Sony DSC-HX300. On table 1 are presented cut surfaces of examined trademarks of cheese.

| Trademark 1 | Trademark 3 | Trademark 5 |
|-------------|-------------|-------------|
| Cow milk    | Sheep milk  | Goat milk   |
| Trademark 2 | Trademark 4 | Trademark 6 |
| Trademark 1 | Trademark 3 | Trademark 5 |
| Trademark 2 | Trademark 4 | Trademark 6 |

**Table 1.** Cut surface of six trademarks Bulgarian white cheese in brine.

3. Results and discussion
The samples of white cheese in brine are evaluated by experts and results for quality of cut surface are presented on figure 4.

![Cut surface evaluation](image)

**Figure 4.** Cut surface – expert’s evaluation

It is obviously that the best result for quality of cut surface have cheese “Trademark2” (produced of cow milk) and cheese “Trademark 4” (produced of sheep milk). Cut surface of these two trademarks is smooth, without big technical pores thus they receive high score from experts (near to maximal value which is 15 according to Bulgarian national standard for sensory evaluation of milk and milk
products). The cheese which have low score for cut surface of expert evaluation are “Trademark 1” (produced of cow milk) and “Trademark 3” (produced of sheep milk) because their surface is grainy with technical pores. Cheese of goat milk (trademarks “Tra” (produced of cow milk) and “Trademark 3” (produced of sheep milk) because their surface is grainy products). The cheese which have low score for cut surface near to the middle of the scale (about 8) because they have small number of big pores and structure with visually highlighted layers. Images of evaluated trademarks are processed with ImgSegJ and ratio of number of white pixels to all pixels in segmented images is presented in table 2 as mean value of the samples.

**Table 2.** Ratio of white pixels to all pixels in segmented images of Bulgarian white cheese in brine. (ImgSegJ, mode “Binarize”).

| Trademark | Cow milk | Sheep milk | Goat milk |
|-----------|----------|------------|-----------|
|           | Tm 1     | Tm 2       | Tm 3      | Tm 4     | Tm 5     | Tm 6     |
| Default   | 45.27    | 36.03      | 29.71     | 44.33    | 32.49    | 29.88    |
| Huang     | 53.72    | 50.73      | 49.45     | 47.62    | 46.27    | 53.37    |
| Huang2    | 56.03    | 50.94      | 49.05     | 48.53    | 46.73    | 56.42    |
| Intermodes| 27.99    | 0.084      | 1.66      | 27.36    | 2.57     | 0.769    |
| IsoData   | 47.68    | 34.06      | 30.54     | 45.15    | 33.85    | 34.55    |
| Li        | 51.32    | 50.73      | 39.74     | 45.93    | 44.44    | 48.21    |
| MaxEntropy| 3.42     | 0.05       | 0.31      | 0.154    | 1.13     | 0.912    |
| Mean      | 48.93    | 48.37      | 44.89     | 47.57    | 46.27    | 46.66    |
| MinError  | 55.96    | 23.99      | 44.89     | 47.57    | 46.27    | 23.93    |
| Minimum   | 28.93    | 0.012      | 0.189     | 14.89    | 0.485    | 0.066    |
| Moments   | 45.27    | 45.24      | 26.57     | 45.91    | 31.23    | 30.40    |
| Otsu      | 48.93    | 45.24      | 35.53     | 45.15    | 39.63    | 40.37    |
| Percentile| 50.09    | 48.37      | 50.38     | 50.10    | 49.61    | 50.16    |
| RenyiEntropy| 3.57   | 0.057      | 0.408     | 0.232    | 1.09     | 1.02     |
| Shanbhag  | 51.32    | 0.02       | 17.89     | 45.15    | 42.71    | 48.21    |
| Triangle  | 2.66     | 1.61       | 4.05      | 0.39     | 2.27     | 4.22     |
| Yen       | 3.29     | 0.046      | 0.261     | 0.054    | 1.05     | 0.78     |

**Table 3.** Ratio of white pixels to all pixels, gray pixels to all and black pixels to all in segmented images of Bulgarian white cheese in brine. (ImgSegJ, mode “Separate in black area”).

| Trademark | Cow milk | Sheep milk | Goat milk |
|-----------|----------|------------|-----------|
|           | w/all    | g/all      | b/all     |
|           | w/all    | g/all      | b/all     |
|           | w/all    | g/all      | b/all     |
|           | w/all    | g/all      | b/all     |
|           | w/all    | g/all      | b/all     |
|           | w/all    | g/all      | b/all     |
|           | w/all    | g/all      | b/all     |
|           | w/all    | g/all      | b/all     |
|           | w/all    | g/all      | b/all     |
| Default   | 45.27    | 33.52      | 21.20     |
| Huang     | 53.72    | 24.99      | 21.29     |
| Huang2    | 56.03    | 23.59      | 20.38     |
| Intermodes| 27.99    | 0.010      | 0.085     |
| IsoData   | 47.68    | 33.35      | 18.04     |
| Li        | 51.32    | 31.24      | 17.77     |
| MaxEntropy| 3.42     | 65.95      | 30.63     |
| Mean      | 48.93    | 27.98      | 33.72     |
| MinError  | 55.96    | 21.92      | 22.12     |
| Minimum   | 28.93    | 0.011      | 0.085     |
| Moments   | 45.27    | 31.05      | 18.02     |
| Otsu      | 48.93    | 33.05      | 18.02     |
| Percentile| 50.09    | 25.06      | 24.85     |
| RenyiEntropy| 3.57   | 65.80      | 30.63     |
| Shanbhag  | 51.32    | 32.84      | 13.84     |
| Triangle  | 2.66     | 96.49      | 20.85     |
| Yen       | 3.29     | 69.79      | 26.91     |

* w/all – ratio of count of white pixels to all pixels in segmented image in percent; g/all – ratio of count of gray pixels to all pixels in segmented image in percent; b/all – ratio of count of black pixels to all pixels in segmented image in percent;
On this table (table 2) Trademark 1 to Trademark 6 are named “Tm 1” to “Tm 6”. Table 3 and table 4 present ratio of white to all pixels, gray to all pixels and black to all pixels for segmented images in modes “Separate in black area” and “Separate in white area”. The results are calculated as a mean value for samples of every trademark of white cheese in brine.

**Table 4.** Ratio of white pixels to all pixels, gray pixels to all and black pixels to all in segmented images of Bulgarian white cheese in brine. (ImgSegJ, mode “Separate in white area”).

| Trademark | Cow milk | Sheep milk | Goat milk |
|-----------|----------|------------|-----------|
|           | w/all | g/all | b/all | w/all | g/all | b/all | w/all | g/all | b/all | w/all | g/all | b/all |
| Default   | 9.08  | 36.19 | 54.73 | 4.57 | 31.45 | 63.97 | 4.60 | 25.11 | 70.29 | 17.87 | 26.46 | 55.67 | 2.08 | 30.41 | 67.51 | 3.97 | 25.90 | 70.12 |
| Huang     | 22.84 | 30.87 | 46.28 | 16.46 | 34.27 | 49.27 | 18.08 | 31.37 | 50.55 | 23.92 | 23.70 | 52.38 | 18.90 | 27.37 | 53.73 | 19.54 | 33.84 | 46.62 |
| Huang2    | 21.00 | 35.03 | 43.97 | 21.13 | 29.82 | 49.06 | 17.06 | 31.99 | 50.95 | 23.92 | 24.61 | 51.47 | 19.75 | 26.98 | 53.27 | 20.58 | 35.84 | 43.58 |
| Intermodes| 22.04 | 5.95  | 72.01 | 0.02 | 0.07 | 99.91 | 0.33 | 1.32 | 98.34 | 0.11 | 27.25 | 72.64 | 0.72 | 1.85 | 97.43 | 0.14 | 0.63 | 99.23 |
| IsoData   | 9.48  | 38.21 | 52.31 | 4.75 | 29.31 | 65.94 | 4.69 | 25.84 | 49.66 | 18.46 | 26.69 | 54.85 | 2.17 | 31.68 | 66.15 | 4.51 | 30.04 | 85.45 |
| Li        | 13.87 | 37.45 | 48.68 | 14.10 | 36.63 | 49.27 | 7.59 | 32.15 | 60.26 | 20.61 | 25.33 | 54.06 | 11.27 | 33.17 | 55.86 | 7.33 | 40.87 | 51.79 |
| MaxEntropy| 0.15  | 3.27  | 96.58 | 0.01 | 0.04 | 99.95 | 0.08 | 0.23 | 99.09 | 0.03 | 0.12 | 99.85 | 0.11 | 1.02 | 98.87 | 0.13 | 0.78 | 99.09 |
| Mean      | 18.39 | 30.53 | 51.07 | 16.46 | 31.90 | 51.63 | 15.55 | 29.35 | 55.10 | 21.87 | 25.70 | 52.43 | 16.87 | 29.40 | 53.73 | 15.24 | 31.42 | 53.34 |
| MinError  | 32.56 | 23.40 | 44.04 | 8.15 | 15.85 | 76.00 | 23.15 | 21.75 | 55.10 | 26.06 | 21.51 | 52.43 | 16.87 | 29.40 | 53.73 | 7.76 | 16.17 | 76.07 |
| Minimum   | 20.89 | 8.05  | 71.06 | 0.01 | 0.01 | 99.99 | 0.08 | 0.11 | 99.81 | 0.00 | 14.89 | 85.10 | 0.02 | 0.47 | 99.52 | 0.00 | 0.07 | 99.93 |
| Moments   | 9.08  | 36.19 | 54.73 | 4.57 | 40.66 | 54.76 | 2.60 | 23.97 | 73.43 | 17.52 | 28.38 | 54.09 | 2.84 | 28.39 | 68.77 | 3.59 | 26.81 | 69.60 |
| Osu       | 10.93 | 37.99 | 51.07 | 8.11 | 37.13 | 54.76 | 5.65 | 29.88 | 64.47 | 19.24 | 25.90 | 54.85 | 5.02 | 34.61 | 60.37 | 5.37 | 34.99 | 59.63 |
| Percentile| 23.77 | 26.32 | 49.91 | 22.39 | 25.98 | 51.63 | 23.42 | 26.96 | 49.62 | 23.86 | 26.25 | 49.89 | 23.94 | 25.67 | 50.39 | 23.73 | 26.43 | 49.84 |
| RenyiEntropy| 0.22 | 3.35  | 96.43 | 0.02 | 0.04 | 99.94 | 0.09 | 0.32 | 99.59 | 0.04 | 0.19 | 99.77 | 0.12 | 0.98 | 99.90 | 0.15 | 0.88 | 99.98 |
| Shanbhag  | 11.08 | 40.23 | 48.68 | 0.01 | 0.01 | 99.98 | 0.78 | 17.11 | 82.11 | 17.87 | 27.28 | 54.85 | 1.25 | 41.46 | 57.29 | 1.87 | 46.34 | 51.79 |
| Triangle  | 0.34  | 2.32  | 97.34 | 0.12 | 1.49 | 98.39 | 0.35 | 3.70 | 95.95 | 0.06 | 0.33 | 99.61 | 0.72 | 1.54 | 97.73 | 0.73 | 3.49 | 95.78 |
| Yen       | 0.17  | 3.12  | 96.71 | 0.01 | 0.04 | 99.95 | 0.08 | 0.18 | 99.74 | 0.04 | 0.05 | 99.95 | 0.13 | 0.91 | 98.95 | 0.12 | 0.67 | 99.21 |

* w/all – ratio of count of white pixels to all pixels in segmented image in percent; g/all – ratio of count of gray pixels to all pixels in segmented image in percent; b/all – ratio of count of black pixels to all pixels in segmented image in percent;

On figures 5, 6 and 7 are presented correlation coefficients for expert evaluation and calculated ratios of segmented images in modes “Binarization”, “Separate in black area” and “Separate in white area”.

On figure 5 are presented absolute values of correlation coefficients which are calculated using MS Excel. The results show that algorithms Triangle and Moments have significant correlation with expert evaluation for cut surface of white cheese in brine (their correlation coefficients are near to 1). Because of this, these two algorithms could be used for automatic evaluation of cut surface of cheese using ImgSegJ in mode “Binarization”.

![Figure 5](image-url). Correlation coefficients for expert evaluation and ratio of white pixels to all (ImgSegJ, mode “Binarization”).
On figure 6 are presented absolute values of correlation coefficients which are calculated using MS Excel. The results show that algorithms Triangle, Percentile and Moments have significant correlation with expert evaluation for cut surface of white cheese in brine (their correlation coefficients are near to 1). Algorithms Triangle and Moments have correlation coefficients above 0.7 for ratio of white pixels to all. Only algorithm Percentile has correlation coefficients above 0.7 for ratio of black pixels to all.

On figure 7 are presented absolute values of correlation coefficients which are calculated using MS Excel. The results show that algorithms Huang2, Li, MaxEntropy, Moments, RenyiEntropy and Triangle have significant correlation with expert evaluation for cut surface of white cheese in brine (their correlation coefficients are near to 1). Algorithms Huang2, Li, MaxEntropy and RenyiEntropy have correlation coefficients above 0.7 for ratio of white pixels to all. Only algorithms Moments and Triangle have correlation coefficients above 0.7 for ratio of black pixels to all (algorithm Triangle has also high correlation coefficient for ratio of gray pixels to all). The highest correlation coefficient is achieved for ratio of black pixels to all using algorithm Triangle in mode segmentation- “Separate in white area”. The same algorithm (Triangle) gives significant correlation with expert evaluation using “Binarization” mode too. On figure 8 are presented images of white cheese in brine before and after processing with Triangle algorithm in different modes.

Processing with Triangle algorithm emphasize on technical pores and some borders of areas in cheese structure. The next equations could be used to calculate the score for cut surface of white cheese in brine based on ratio of white or black pixels to all for segmented image (ImgSegJ, mode “Separate in black area”). With c in formulae 3 and 4 it is noted a constant.

\[
score = \begin{cases} 
5, & \text{ratio}_{\text{white/all}} + c > 15 \\
\text{ratio}_{\text{white/all}} + c & \end{cases} \quad (3)
\]

\[
score = \begin{cases} 
15, & \text{ratio}_{\text{black/all}} + c > 8 \\
\text{ratio}_{\text{black/all}} + c & \end{cases} \quad (4)
\]

On figure 9 are presented expert evaluation and calculated scores by formulae 3 and 4 for cut surface of tested trademarks of white cheese in brine (for score calculation are used data of table 2 and table 4 for algorithm Triangle and constant value 13.8 for formula 3 and -90 for formula 4).

The score for cut surface of white cheese in brine is near to their expert evaluation (fig. 9) and average relevant error by evaluation is about 16% using formula 3 and about 10% using formula 4.
This is the reason that developed software (ImgSegJ) could be applied for objective evaluation of cut surface of white cheese in brine. Developed software could support experts in their work.

Figure 8. Cut surface of sample white cheese in brine (trademark “Trademark 3” produced of sheep milk) before and after processing with ImgSegJ.

Figure 9. Expert evaluation and score for cut surface of white cheese in brine (ImgSegJ, thresholding algorithm Triangle).
4. Conclusion

Six trademarks white cheese in brine produced of cow, sheep and goat milk are used for evaluation of cut surface. Evaluation of cut surface is performed using two methods: expert evaluation according to standard BDS 15612-83 (Dairy products. Sensory analysis,) and computer analysis using image segmentation through proposed software ImgSegJ. There are proposed equations to calculate the score for cut surface based on ratio of white or black pixels to all in segmented images and statistical analysis (correlation). The results show that developed software (ImgSegJ) could be applied for objective evaluation of cut surface of white cheese in brine.

Future work will continue with research over larger set of trademarks and with developing automatic classifier for white cheese in brine based on quality of cut surface.

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