Leather Features Selection for Defects' Recognition using Fuzzy Logic

Kaloyan Krastev, Lidia Georgieva, Nikola Angelov

Abstract: *In the present work are investigated 12 histogram and statistical features for analysis of leather surface images. A research of the features suitability for surface defects detection is done. For the image analysis was used the quadtree decomposition method – a technique that partitions an image into homogeneous blocks. This method gave the possibility of investigation the changes of the features values depending on the area size. It is proposed a scheme for defective regions identification using fuzzy set theory.*

Key words: *Leather, Surface Defects Detection, Histogram Features, Statistical Features, Quadtree Decomposition, Fuzzy Set Theory.*

INTRODUCTION

A trend in the modern production process is the replacement of the human-expert assessments with automatic inspection systems. In the estimation process of leather quality is used an expert opinion of the defect's presence on the sample's surface. This opinion depends on a number of subjective factors like the expert's experience, his vital condition (tiredness, indisposition and illness), etc. Therefore, the development of automatic visual inspection system is needed to unify the quality estimation process.

The leather surface has complex structure (texture). For defects detection on textures usually are used image analyses. The presence of defects change some textures features and for that reason a good decision are the statistical methods for analysis – statistical analysis of the histogram end levels [5], local texture features analysis [8], internal and external color level methods [11], oriented vector field computation [2], etc.

In [6] are investigated three features for analysis of leather surface images. A conclusion has made that it is necessary an expansion of the investigated features set and finding the best subset for leather analysis. A conclusion could be made in addition that the size of the feature's differences in non-defective and defective regions depends on the area of the defects. When more pixels belong to defects, there is more feature difference. For this reason in the present work are investigated different size areas – in that way it is achieved a bigger proportion of defective/non-defective pixels.

Widely used method for analysis of different size areas is the quadtree decomposition – an image analysis technique that partitions an image into homogeneous blocks. A block is homogeneous if some feature does not exceed a threshold value. The quadtree decomposition is used in variety of image analysis [10], motion segmentation [9] and compression [1] applications.

The main method problem is the determination of the threshold value. In general, it is determined by a training set and even a small error can cause a jump over the threshold. Therefore it is suitable the use of the fuzzy rules. The fuzzy set theory is used in many image segmentation [4], image enhancement [3] and morphological image processing [7] applications.

The purposes of the present work are investigation of features set for analysis of leather images and threshold values determination by using fuzzy rules.

FEATURES SET AND FUZZY RULES

The histogram is a graph used in image analysis that shows the distribution of intensities in an image. The information in a histogram can be used for texture features extraction. In the present work are used some features calculated from the gray level image histogram. The histogram characteristics are (Fig.1): left border – the smallest pixel value; right border – the greatest pixel value; range – the difference between the right and the left borders; maximum – the biggest amount of pixels with same value; position of the histogram's maximum – the pixel value where is situated the histogram's maximum; median value – the pixel value which divide the histogram on two equal parts.

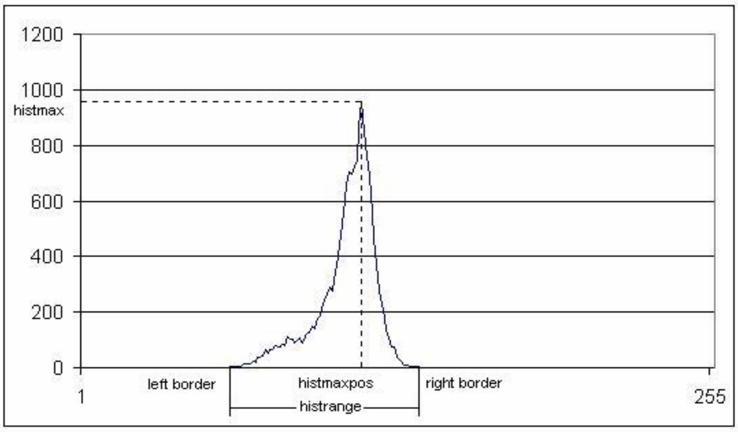


Fig.1. Histogram features.

The first-order statistical features of the histogram are possible to be calculated. They are defined as follows:

- Mean value:

$$\mu = \frac{1}{N}\sum_i \sum_j p(i,j)\,; \tag{1}$$

- Variance:

$$\sigma^2 = \frac{1}{N}\sum_i \sum_j [p(i,j) - \mu]^2\,. \tag{2}$$

Where p(i, j) is the gray-level of the (i,j)th image pixel and N is the total number of the image pixels.

The last group of features that has been used includes second-order statistical measures based on the grey level co-occurrence matrix. These statistical measures capture well the spatial dependence of gray level values. The co-occurrence matrix can be specified as a two-dimensional matrix consisted of the frequency with which two pixels separated by distance *d* at orientation *Θ* occur in the image, one with gray level *i* and the other with gray level *j.* The elements of the matrix were normalized by dividing each of them to the total number of pixel pairs. In this way, the sum of all elements is equal to 1.

Four features based on the co-occurrence matrix are investigated:

- $Energy = \sum_i \sum_j C(i,j)^2\,;$ (3)
- $Entropy = -\sum_i \sum_j C(i,j)\log C(i,j)\,;$ (4)
- $Contrast = \sum_i \sum_j (i-j)^2 C(i,j)\,;$ (5)
- $Homogeneit\ y = \sum_i \sum_j \frac{C(i,j)}{1+(i-j)^2}\,.$ (6)

Where C(i,j) is the (i,j)th element of the normalized co-occurrence matrix.

The defined features above have been calculated for 12 non-defective images of leather surfaces each one of them with different structure and color. The size of the images is 128x128-pixels and over all of them is applied quadtree decomposition - an efficient and simple method for image representation. The quadtree is constructed by recursively decomposing the image into four equal-sized quadrants. The process continues until covering some conditions or reaching a pre-specified smallest block size

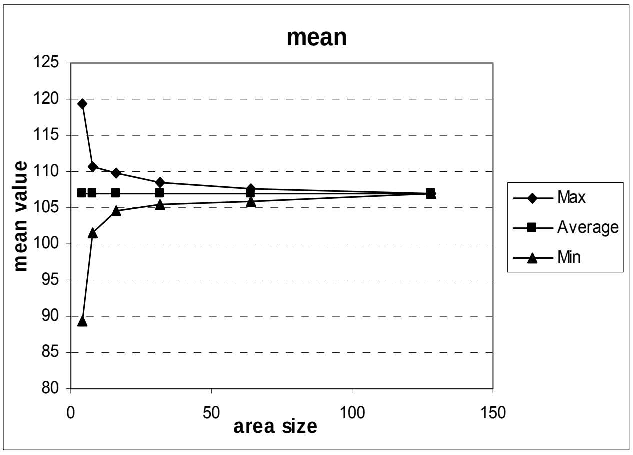
(4x4 pixels in this case). In that way, there are six levels of decomposition. The above defined features were calculated for all these areas. The maximal, minimal and average features values were estimated from these data and were investigated their variation depending on the area size. The range of the feature variation has been estimated in this training phase and thus will determine the threshold values.

The maximal, minimal and average features values for one of the investigated images are shown in Table 1.

Table1. Maximal, minimal and average features values of non-defective areas.

		Left Border	Right Border	Hist Range	HistMax	HistMax Position	Median	Mean	Variance	Energy	Entropy	Contrast	Homogeneity
128x128	**Value**	50	138	88	958	114	110	106.93	132.74	0.0186	23.73	818.37	0.475
64x64	**Max**	66	138	83	265	114	110	107.69	150.27	0.0213	23.89	930.75	0.493
	Average	59.3	136	76.8	239.5	114	109.5	106.93	132.25	0.0197	23.28	817.87	0.474
	Min	50	133	72	214	114	109	105.88	114.01	0.0167	22.87	695.53	0.453
32x32	**Max**	70	138	81	78	117	111	108.4	166.17	0.0281	23.08	1047	0.518
	Average	63.1	132.3	69.2	63.3	114.1	109.6	106.93	132.19	0.0235	22.04	818.42	0.473
	Min	50	128	60	49	112	109	105.49	108.12	0.0166	21.42	643.91	0.414
16x16	**Max**	77	138	75	29	118	112	109.75	192.17	0.0558	20.14	1191.6	0.62
	Average	67.3	129.3	62.1	18.3	112.8	109.6	106.93	132.08	0.0396	19.3	817.36	0.474
	Min	50	124	50	13	106	107	104.52	94.86	0.0296	18.42	554.45	0.36
8x8	**Max**	89	138	73	13	123	113.5	110.55	317.59	0.193	15.54	1886.6	0.9
	Average	72.5	125.9	53.5	6.1	111.8	109.5	106.93	131.89	0.112	14.74	817.73	0.477
	Min	50	117	33	4	96	105	101.48	66.27	0.085	13.2	364.66	0.263
4x4	**Max**	109	138	66	5	125	120.5	119.25	597.93	1.324	9.36	3046.6	1.592
	Average	82.6	121.4	38.8	2.5	107.9	109.2	106.93	124.13	0.481	8.76	824.59	0.478
	Min	50	110	11	1	62	97	89.25	8.83	0.389	5.46	44	0.077

As it seen from Table 1 there are significant differences in some of the features values when the area size decreases, because these features are functions of the number of pixels in the investigated regions. Some of the features are constant like the average values of the mean, median, contrast and homogeneity, the minimal values of the left border and the maximum values of the right border. Others slightly decrease - the maximal values of the histogram maximum and the average values of the histogram maximum position and the variance. The rest features have big changes into their values when the block area becomes smaller.



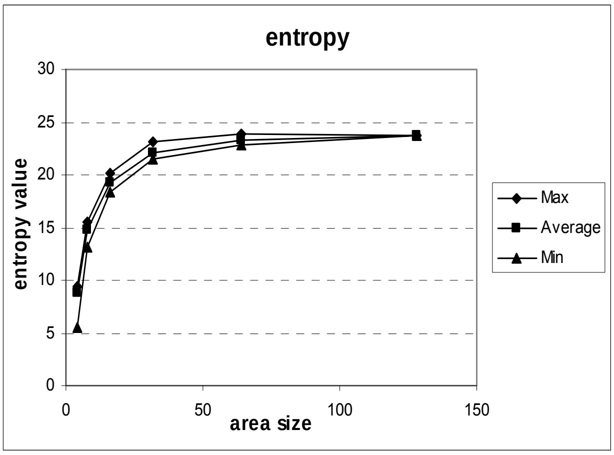


Fig.2. Mean and Entropy maximal, minimal and average values.

As well a question of interest is the direction of changes of the maximal and minimal features values. There are two possibilities – the directions are opposite or they coincide. The examples given in Fig. 2 are the Mean and Entropy. If the directions are opposite the range between the maximal and the minimal value grow when the area size decrease. If the directions are coinciding – the range varies in narrow borders and stays almost constant. In both cases, there is a pronounced non-linearity of the characteristics for small area sizes. This is because there is not sufficient texture information included in the smaller blocks and features values vary significantly. An interesting problem will be the determination of the optimal block size that have enought texture information and have as small area as possible. This is one of the directions for future work.

Correspondingly to every type non-defective leather surface included in the test set are investigated few images of defective leather. For the sample, which features values are shown in Table 1, were analyzed eight images contained defects with different shape, size and type. The quadtree decomposition been applied to these images too and features values were calculated. As threshold values are accepted the maximal and the minimal features values for the respective non-defective block size. All analyzed areas from the defect-containing images outside the thresholds, are marked.

As an example one of the analyzed defective images is shown on Fig.3 and on Fig.4 - the areas that are found defective for that image.

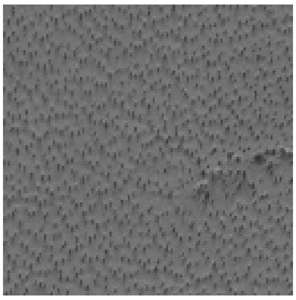


Fig.3. Sample of the defect-containing image.

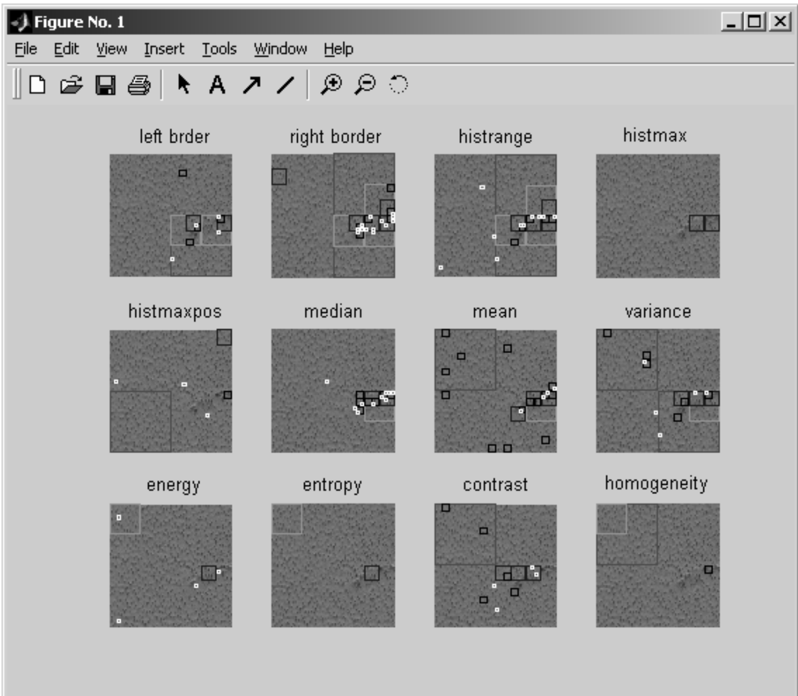


Fig.4. Defective blocks of different sizes found for the feature set.

Seen from Fig.4 and from the rest of the samples that more appropriate features for defect detection are the histogram's ends (left and right border), median and mean values. The variance and the histogram's range shown also good results. The worst results obtained for the second-order statistical features and the histogram's maximum value and position.

Another conclusion which can be made is that as faults are found these blocks that contain big amount of pixels belong to the defect. This confirms the above-mentioned assertion that the proportion defective/non-defective pixels is very important for clear differentiation of the faults. The appropriate area sizes for defects detection are 16x16 and 32x32 pixels. The bigger area size contains unnecessary information and the smaller areas – insufficient information. As well there were many fault-free areas, which are marked as defective. This impose profound analysis of all marked areas. Suitable analysis is the fuzzy set theory.

A scheme of defect identification by using fuzzy logic is shown on Fig. 5. The first step is to define the main histogram features. The linguistic variables (LVs) and terms (LTs) are linguistic characterization of fuzzy sets. The set of linguistic variables consists following six members:

- Histogram's left, right border and range;
- Histogram's median;
- Histogram's mean values;
- Histogram's variance.

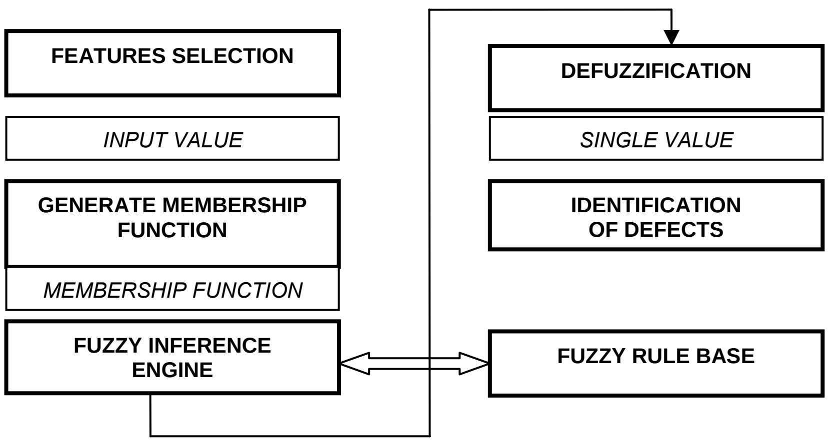


Fig.5. A scheme of fuzzy defects identification.

Each of the linguistic variables is defined with three LTs – Small difference (SD), Medium difference – MD and Big difference – BD. Every pixel in the image will have a membership value.

The output LV is Defective areas – DA. It has five LTs – Not belongs to the defect NBD, Small possible belongs to the defect –SPBD, Possible belongs to the defect –PBD, Most possible belongs to the defect –MPBD and Belongs to the defect –BD.

The recommended shapes of membership functions of LTs are – "trapezoidal" for extreme LTs and "triangular" for the rest, which is in correlation with the defuzzification method. The generation of membership function's features is aim of another article.

CONCLUSIONS AND FUTURE WORK

The investigations and analyses that are made have led to the following conclusions:

- From the investigated feature set most appropriate for leather surface defect detection are histogram ends (left and right border), median and mean values. Good results showed the variance and the histogram's range. The least

appropriate are the second-order statistics (energy, entropy, contrast and homogeneity) and histogram's maximum value and position.
- The quadtree decomposition is a suitable method for fast localizing of defective regions, but additional local analysis is needed for the exact defect contour determination.
- Bigger features values difference is obtained with bigger proportion defective/non-defective pixels in the examined area.

It is necessary to research the optimal area size. Generation of fuzzy membership functions and rules for defects detection is also a direction for the future work.

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