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VPLYV ŠUMU TYPU SOĽ A KORENIE NA KÓDOVANIE OBRAZU ZALOŽENOM NA ŠTIEPENÍ OBRAZU

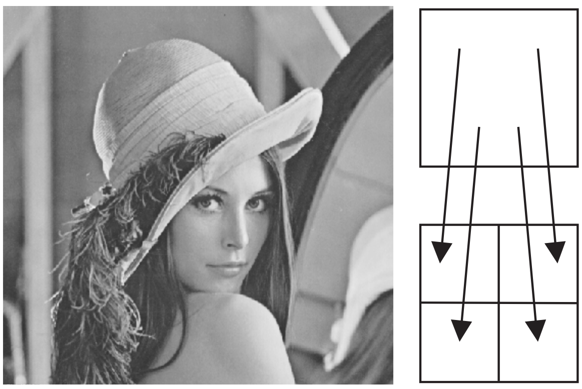
SALT & PEPPER NOISE IMPACT ON IMAGE CODING BASED ON IMAGE SPLITTING

Tento článok sa zaoberá vplyvom šumu a riadiacich parametrov (segmentačné kritériá) na zvolenú metódu segmentácie. Boli použité dva riadiace parametre. Dynamické kritérium a kritérium vyhodnocujúce varianciu oblasti. Ako segmentačná metóda bolo použité štiepenie obrazu. Vplyv šumu a riadiacich parametrov na segmentačnú metódu a kódovánie bol vyhodnotený pomocou objektívneho kritéria kvality obrazu (vrcholový odstup signál šum) a počtu oblastí segmentovaného obrazu.

The paper deals with the influence of noise and two control parameters on a segmentation method for image coding. Dynamic min_max criterion and variance criterion were used as segmentation control parameters. For the segmentation of images we have used the method of image splitting. The influence of the value of variance and dynamic criterion on the quality of the segmentation coded image is demonstrated. We have evaluated the objective criterion of the quality of the image (peak signal-to-noise ratio) and number of regions in the image for different values of segmentation control parameters and noise density.

Introduction

During the segmentation for the segmentation-based coding [3] we analyse a given image and we try to find areas homogenous in a certain sense (for example colour or grey level). The internal parts of certain areas (textures) and borders are coded separately. These segmentation methods involve the region growing, combinations of growing and splitting and a whole number of other methods adopted from the scientific discipline of computer vision and medical data processing.



(a) (b)

Figure 1 (a) Image Lena-original. (b) One splitting step of quadtree decomposition algorithm.

Quadtree decomposition

For the segmentation of image we have used the method of quadtree decomposition which is one of image splitting methods. The advantages of quadtree decomposition compared to other segmentation methods are speed and simple coding of area borders [2]. Quadtree decomposition divides a square image into four equal-sized square blocks (see Figure 1 (b)) and then tests whether each block fulfils the criterion of homogenity. If not, it is divided again into four equal-sized square blocks. This procedure is repeated again for every block in the image until the criterion for the tested block is met or until the size of the block equals one pixel or a set minimum value (our minimum set value is one pixel).

The first criterion of homogenity that we used (1) splits a block when the difference between the maximum value of the block pixels and the minimum value of the block pixels is greater than the set value (threshold) (2). The threshold is specified as a value between 0 and 1, where 1 corresponds to the maximal possible value (255) for the eight bits representation of a grey level image. Therefore, the threshold controls the segmentation method. The splitting procedure is defined as follows:

Let X_i be an area (block) of the image and $x(m,n)$ are points in this area $x(m,n) \in X$. Then, the criterion of homogenity is

$$min\_max(X_i) = \max_{X_i}(x(m,n)) - \min_{X_i}(x(m,n) \qquad (1)$$

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and the splitting condition is

$$min\_max(X_i) > threshold_i \begin{cases} TRUE & split\ area\ X_i \\ FALSE & do\ not\ split\ area\ X_i \end{cases} \quad (2)$$

This criterion is simple and fast and recommended in [1], [4]. We code the value of particular pixels by the mean value across the area to which pixels were assigned by the segmentation algorithm. The influence of the value of threshold for *min_max* criterion (dynamic criterion [1]) on the quality of the segmentation coding is depicted in Figure 2 (a).

The second criterion of homogenity that we used is the variance of area. Variance is defined as follows.

Let $\bar{x}_i = \frac{1}{S_i} \sum_{\forall x \in X_i} x(m,n)$, where

$$i = 1, 2, \ldots\ number\ of\ areas\ in\ an\ image \quad (3)$$

and S_i = the number of pixels in area X_i. Then, the variance of area is

$$\sigma_i^2 = \sigma^2(X_i) = \frac{1}{S_i} \sum_{\forall x \in X_i} (x(m,n) - \bar{x})^2 \quad (4)$$

and the splitting condition is

$$\sigma_i^2(X_i) > variance\ threshold$$

$$unnormalized_i \begin{cases} TRUE & split\ area\ X_i \\ FALSE & do\ not\ split\ area\ X_i \end{cases} \quad (5)$$

The variance threshold is specified as a normalized value $\in (0, \infty)$, where 1 corresponds to the maximal possible value (255) for the eight bits representation of a grey level image. In other words:

$$variance\ threshold = \frac{variance\ threshold\ unnormalized}{255}. \quad (6)$$

The influence of the value of *variance threshold* on the quality of the segmentation coding is depicted in Figure 2 (b).

When we code areas of image using the mean values of areas, we calculate the value of *PSNR*. Given that *MxN* is the size of the image and $y(m,n)$ is the value of pixel of that processed image.

$$e(m,n) = y(m,n) - x(m,n)$$
$$\text{where } m = 1, 2, \ldots, M \text{ and } n = 1, 2, \ldots N. \quad (7)$$

$$Mean - squared - error$$

$$e_{MSE} = \frac{1}{MN} \sum_{i=1}^{M} \sum_{j=1}^{N} e(m,n)^2 \text{ and} \quad (8)$$

$$the\ peak\ signal - to - noise\ ratio$$

$$PSNR = 10\log_{10} \frac{255^2}{e_{MSE}}. \text{ [dB]} \quad (9)$$

The influence of the value of *threshold* and *variance threshold* on the distribution of areas in segmented image Lena is depicted in Table 1. We selected very closed values of *PSNR* to compare the dynamic criterion and the variance criterion each other. We have calculated *normalized # of areas*.

(a) threshold = 0.3, PSNR = 26.96 dB

(b) variance threshold = 1.2745, PSNR = 27.01 dB

Fig. 2 Images segmented by (a) min_max criterion and (b) variance criterion. In this figure, each region is filled with the corresponding grey level.

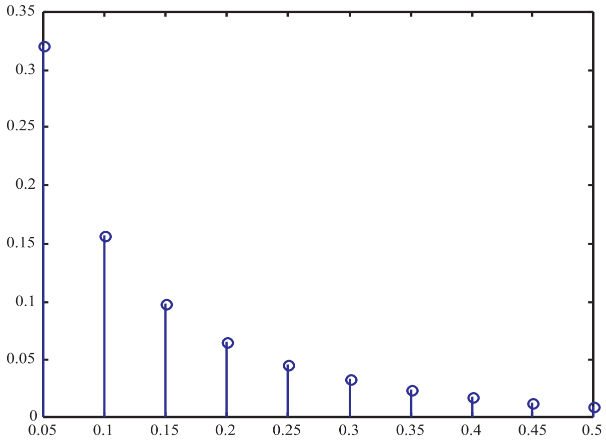
$$normalized\ \#\ of\ areas = \frac{\#\ of\ areas}{maximal\ \#\ of\ areas}, \quad (10)$$

$$\text{where } maximal\ \#\ of\ areas = M*N. \quad (11)$$

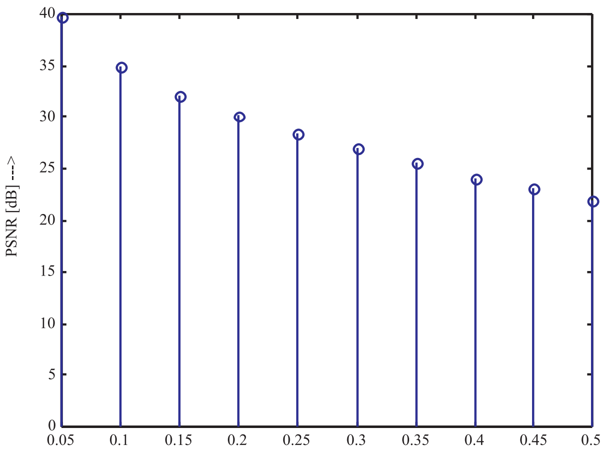
In our case: *maximal # of areas* = 512*512 = 262144.

The distribution of areas in the segmented image Lena for dynamic and variance criterions. Table 1

	Dynamic criterion - threshold			**Variance - variance_threshold**		
Size of Area [pixels x pixels]	0.1	0.3	0.5	0.2157 (55)	1.2745 (325)	3.4314 (875)
512 x 512	0	0	0	0	0	0
256 x 256	0	0	0	0	0	0
128 x 128	0	0	0	0	0	2
64 x 64	0	4	14	3	11	16
32 x 32	14	65	98	30	69	79
16 x 16	166	283	234	207	215	161
8 x 8	1041	886	486	815	631	378
4 x 4	3909	2140	655	2540	1688	736
2 x 2	13329	3542	712	9630	4382	1157
1 x 1	22828	1640	112	34824	6472	1132
Normalized # of Areas	0.1575 (41287)	0.0327 (8560)	0.0088 (2311)	0.1833 (48049)	0.0514 (13468)	0.0140 (3799)
PSNR [dB]	34.9021	26.9573	21.9891	34.5415	27.0141	22.0196

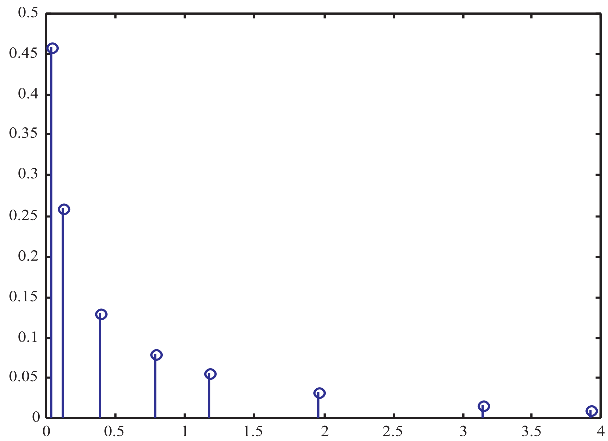


(a)

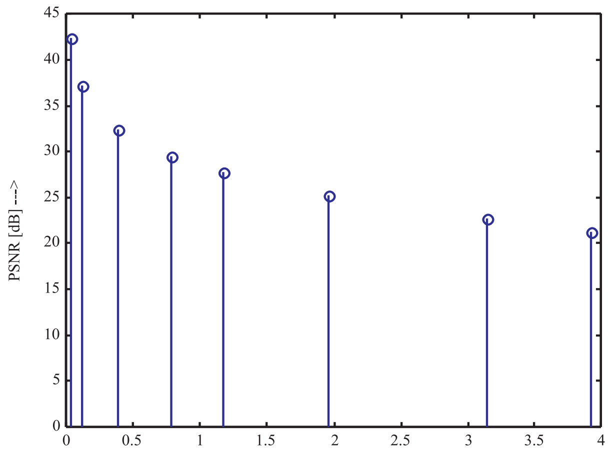


(b)

Fig. 3 (a) normalized # of areas versus threshold,
(b) PSNR versus threshold.



(a)



(b)

Fig. 4 (a) normalized # of areas versus variance threshold.
(b) PSNR versus variance threshold.

PSNR and *normalized # of areas* versus *threshold* and *variance threshold* are shown in Figure 3 and Figure 4, respectively.

We have calculated the correlation coefficients (9), (10), which are normalized measures of the strength of the linear relationship [7] between variable *PSNR* and variable *normalized # of areas*.

$$corrcoef\,(PSNR,\ normalized\ \#\ of\ areas) = \tag{12}$$
$$= \begin{bmatrix} 1 & 0.9352 \\ 0.9352 & 1 \end{bmatrix}$$

It is seen that the *PSNR* and the *normalized # of areas* are highly correlated data (nearly equivalent data) for *min_max* criterion (12) and *variance criterion* (13). Therefore, it is enough to evaluate only the influence of noise on *normalized # of areas* and not to calculate *PSNR*. We have to be aware of the fact that the *PSNR* criterion depends also on the methods which are used for the coding of areas. If we evaluate only *normalized # of areas* and do not evaluate *PSNR* we will probably eliminate the problem of area coding.

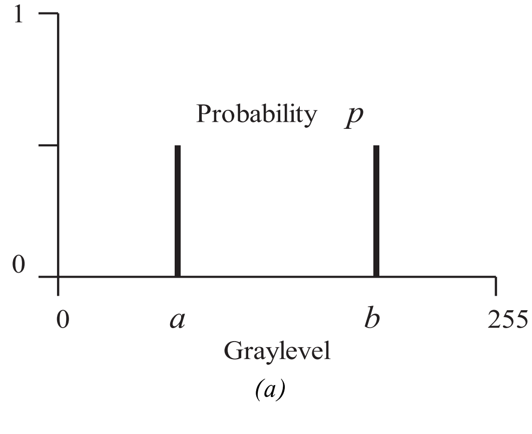
$$corrcoef\,(PSNR,\ normalized\ \#\ of\ areas) = \tag{13}$$
$$= \begin{bmatrix} 1 & 0.9544 \\ 0.9544 & 1 \end{bmatrix}$$

Noise

Image capture mechanisms are not ideal. Therefore, noise is found in the image. This noise hinders the ability to effectively process and compress the image. The noise affects also the image segmentation and the image coding.

In our experiment we have added salt and pepper noise to the image. The salt and pepper noise occurs e.g. in images which are obtained by camera containing malfunctioning pixels or can occur due to a random bit error in a communication channel [6]. Its histogram is defined as

$$h_i = \begin{cases} \text{pepper noise with probability } p & \text{for } G_i = a \\ \text{salt noise with probability } p & \text{for } G_i = b \\ 0 & \text{elsewhere} \end{cases}, \tag{14}$$



(a)

Fig. 5 (a) A histogram of salt and pepper noise. (b) The salt and pepper noise degraded image with a combined probability (density) of 5 %. (MATLAB's default value) PSNR = 18.5 dB.

where G_i is the grey level value of the image. The salt and pepper noise each occur at grey level values *a* and *b* with probability *p* (see Figure 5 (a)). The influence of noise on the image is shown in Figure 5 (b).

The graphs of *normalized # of areas* versus *threshold* (dynamic criterion) and *variance threshold* (variance criterion) for different values of noise density are shown in Figure 6.

Conclusion

We conclude that the number of areas in the image and PSNR for coding of areas by mean values of appropriate areas are highly correlated data. Therefore, we think that it is enough to evaluate only number of areas in the image and not to evaluate PSNR for different values of noise density and splitting control parameters.

The number of areas, which is produced by the dynamic splitting criterion, is smaller than the one produced by the variance criterion for equal quality (i.e. PSNR). Thus, the coding of borders of image areas which are obtained by dynamic splitting criterion spends less bits than the coding of areas borders obtained by variance splitting criterion (see Table 1).

The noise affects significantly the image segmentation method. When the noise density is increasing the number of areas in image is also increasing (see Figure 6). Nevertheless, we have to be aware that the quality of image does not improve when the number of areas in the image increases, because we do not have the original noiseless image for coding of image.

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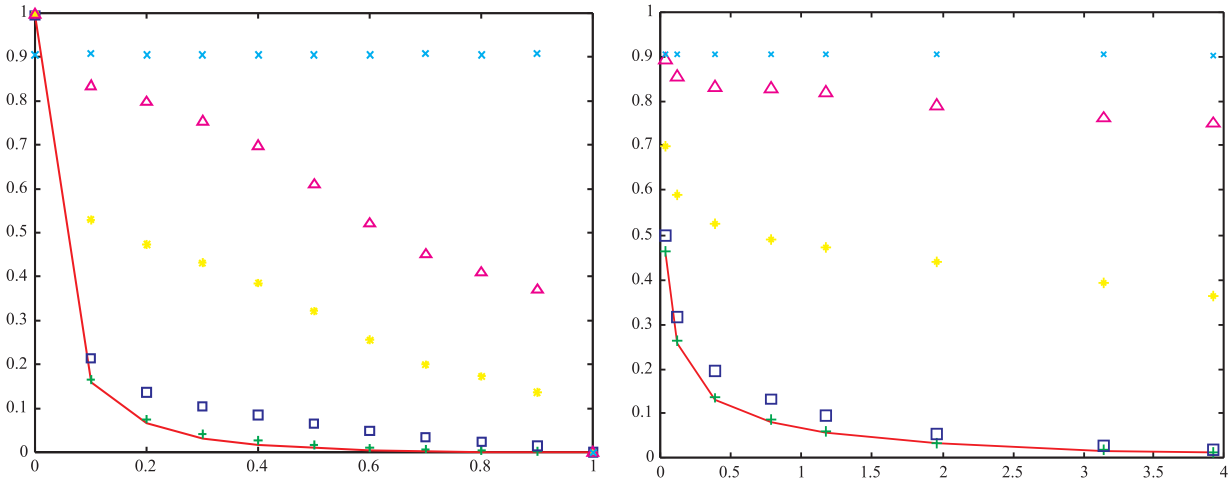

(a) *(b)*

Figure 6 normalized # of areas versus (a) threshold and (b) variance threshold for quadtree decomposition and different noise densities. Density = 0 (full line), 0.001(+++), 0.01 (square), 0.1 (***), 0.3 (triangle), 1 (xxx). Noise density ∈ ⟨0,1⟩.

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