Multiscale Centroid Filtration of Noisy Graphics Image

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Abstract. Multiscale centroid filtration allows to allocate mass centers of graphics image structure elements. This work highlights insufficient reliability of multiscale centroid filtration while analysing noisy graphics image. The paper proposes a new scheme of multiscale centroid filtration graphics image by accumulating current values of structure element mass within the analysis window. The solution in question enables to considerably decrease relation between analysis result and image noise.

Keywords: structural elements, spatially chromatic parameters, multiscale centroid filtration, graphics image, image analysis

INTRODUCTION

Graphics images (GI) are distinguished by spatial and graphical distinctness. GI is created by plotting structural elements (SE) on image surface in accordance with a priori assigned imaging plan [1]. One can define maps, schemes, drafts, traffic sings and others among GI. The centroid filtration method [2] allows to efficiently solve the problems of detecting and recognising SE on GI. Multiscale centroid filtration may be carried out by calculating spatially chromatic parameters (SCP) [3–5]. SCP are based on calculating moment functions W_i of SE cross section $f(n)$ and makes it possible to evaluate coordinates, dimension and brightness of the object. The first two spatially chromatic parameters are valuable for the centroid filtration – mass and centroid. Mass $M = W_0$ defines SE mass, and the centroid $C = W_1/M$ points at its «mass center». SCP are calculated in inverse gray scale (0 is a code for white background). Multiscale centroid is performed as follows:

$$Z[n + C(n)] = Z[n + C(n)] + 1, \quad (1)$$

meanwhile, accumulation of centroid information occurs.

Multiscale centroid filtration is performed iteratively. The first stage sees analysis window width $N = 2$. With each of the following iteration the window extends by 1 pixel up to some predefined maximum value N_{max}. Meanwhile, at each stage centroid image accumulates data about location of mass centers of image objects. The further threshold processing with threshold:

$$p = N_{max} - 1, \quad (2)$$

allows to detect SE and GI. Figure 1a shows cross-section with two SE and its centroid image before threshold processing ($N_{max} = 10$). The centroid image function values are enlarged tenfold for the ease of display. The threshold post-processing of the centroid image with threshold:

$$p = N_{\max} - 1 = 9,$$

reserves two discreet centroid impulses with coordinates corresponding to mass centers of structure elements.

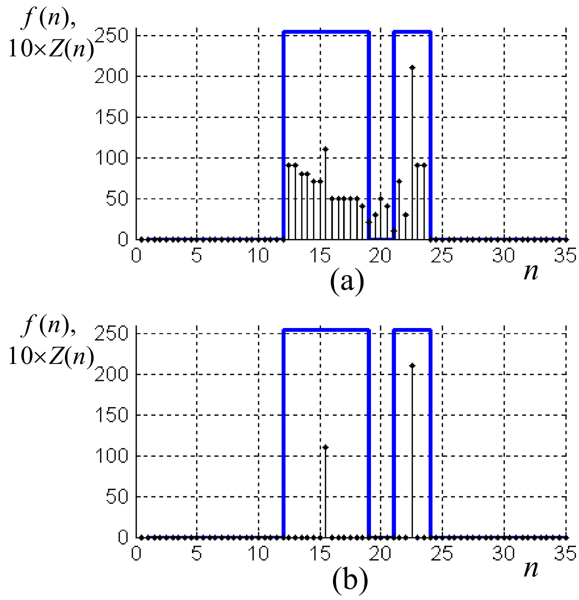

Figure 1. SE cross-section and its centroid image: without threshold processing (a); after threshold processing (b)

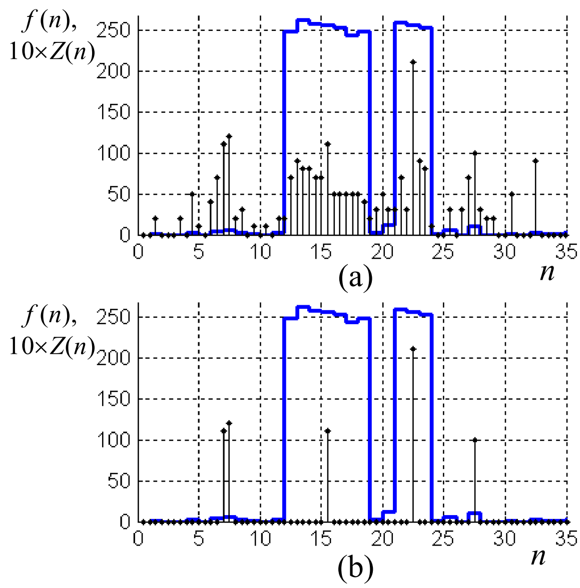

Figure 2. Noisy SE cross-section and its centroid image: without threshold processing (a); after threshold processing (b)

According to the work [6], noise occurrence on the GI corrupts substantially SCP. Figure 2 shows the result of multiscale centroid filtration of GI cross-section corrupted by additive gaussian noise with $\sigma = 5$. False centroid impulses conditioned by noise are shown in Figure 2b. However, basic centroid impulses correspond to mass centres of structure elements.

The data analysis in Figure 2b enables to draw conclusions as follows:

1. Coordinates of basic centroid impulses are robust to GI noise distortion.
2. Noise on GI results in multiple false centroid impulses on background GI spots and hinders gating out basic centroid impulses.

Suppressing False Centroid Impulses

One of the disadvantages of the execution algorithm of multiscale centroid filtration described above is accumulating information with equal weighing about SE mass centers and information about GI element mass centers conditioned by noise. In other words, the expression (1) considers only image element location regardless of the element nature occurred in cross-section.

The paper in question proposes a new algorithm of centroid filtration in case of accumulating information with the usage of mass accumulation instead of expression (1):

$$Z[n + C(n)] = Z[n + C(n)] + M(n). \tag{3}$$

Expression (3) considers SE masses center as well as their mass. In this case it makes sense to point to mass-centroid image of SE cross-section.

Figure 3 shows noisy SE cross-section and its mass-centroid image before threshold processing and after threshold processing.

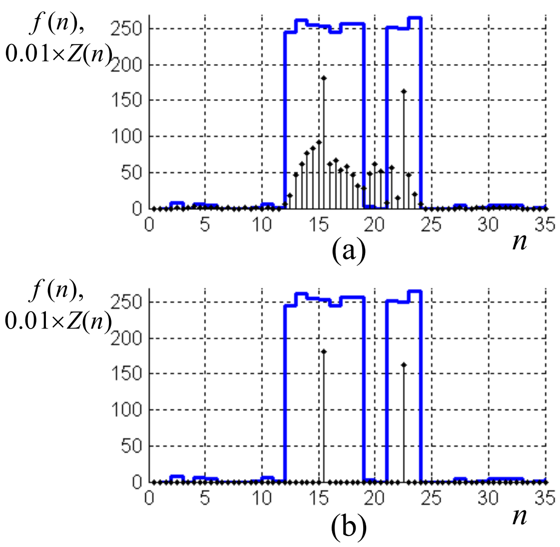

Figure 3. Noisy SE cross-section and its mass-centroid image: without threshold processing (a); after threshold processing (b)

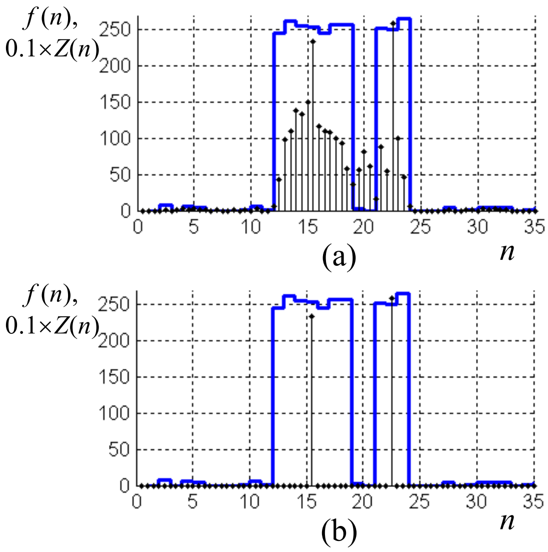

Figure 4. Noisy SE cross-section and its weighed mass-centroid image: without threshold processing (a); after threshold processing (b)

The mass-centroid image values are diminished hundredfold for the ease of display. It is evident that accumulating centroid information by mass value increases noise resistance of centroid filtration and it allowed to accurately define SE mass centers in Figure 3b.

The major disadvantage of mass centroid filtration is relation of mass centroid image values to maximum analysis window dimension N_{max} , which makes it difficult to choose objective threshold value in case of mass-centroid image post-processing.

Accumulating centroid information with the usage of weighed mass values enables to diminish the given relation:

$$Z[n+C(n)]=Z[n+C(n)]+\frac{M(n)}{N}, \tag{4}$$

where N is dimension of analysis window on the current iteration.

Figure 4 shows icross-section of noisy SE and its weighed mass-centroid image before and after threshold processing.

Figure 4b shows, that weighed mass-cenroid image also increases noise resistance of centroid filtration. In addition, it simplifies a choice of post-processing threshold of weighed mass-cenroid image.

RESULTS

To analyse reliabity of various techniques of centroid filtration in dependence on noise degree of GI processed an experiment was carried out. Additive Gaussian noise with standard deviation range from 0.01 to 150 was added to a 1000 pixel long cross section. Centroid images were calculated for every noise level added in accordance with expressions (1), (3) and (4). After threshold post processing of centroid images false centroid impulses was calculated. Every experiment was repeated two hundred times. The experiment findings are summarized in Table 1.

Table 1. Reliability of various techniques of noise centroid filtering

Root-mean-square error of additive noise, σ	The amount of false centroid impulses per 1000 pixels of cross section		
	Multiscale centroid filtration	Multiscale mass-centroid filtration	Multiscale weighed mass-centroid filtration
0.00	0	0.000	0.00
0.01	248	0.000	0.00
5.00	249	0.000	0.00
10.00	248	0.000	0.00
15.00	245	0.005	0.00
20.00	250	0.010	0.01
30.00	250	0.100	0.06
40.00	248	0.290	0.19
50.00	248	0.470	0.35
60.00	248	0.590	0.44
80.00	249	1.500	1.20
100.00	249	3.100	2.80
120.00	250	7.100	6.50
150.00	250	16.900	16.60

Table 1 shows, that the initial technique of accumulating centroid information sees any amount of small value of noise, which results in abrupt amount decrease of false impulses up to the maximam value. For its turn, mass-centroid and weighed mass-centroid filtration techniques are irresponsive to noises with standard deviations right up to the value $\sigma = 10$.

If we admit potential occurrence of false centroid impulses with frequency not exceeding one time per 1000 pixels of GI cross-section, permissible noise level may be increased up to the value $\sigma = 60$.

Conclusion

Based on the experiments carried out we can make conclusions as follows:

1. Multiscale centroid filtration in initial performance has low reliability in processing GI even with slight noise.
2. Multiscale mass-centroid and multiscale weighed mass-centroid filtration techniques are irresponsive to noises with standard deviations right up to the value σ=10 and weakly responsive to noises up to the value $\sigma = 60$.
3. Multiscale mass-centroid and multiscale weighed mass-centroid filtration techniques have equal antinoise proofness.
4. Multiscale weighed mass-centroid filtration sets less requirements to the choice of threshold value at post-processing stage of cross-section centroid image.

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