COMPARISON OF EFFICIENCY OF LOCAL THRESHOLDING ALGORITHM AND THE PROPOSED ALGORITHM FOR SEGMENTATION OF SPACE OBJECTS' (SO) IMAGES AGAINST THE STARRY SKY BACKGROUND

N.Z.Strygin, P.P.Sukhov, G.F.Karpenko

Astronomical Observatory of I.I.Mechnikov Odessa National University, Odessa, Ukraine

ABSTRACT. In the article are presented comparative results of the space objects separation algorithms test on the television images of the sidereal sky regions – both the local thresholding method with the scanning apertures of various sizes and the new algorithm developed at the OAO. Advantages of the OAO algorithm are shown.

The problem of space objects (natural and artificial SO) image segmentation on the sidereal sky (SS) background is considered in respect of functional algorithmic support for astronomical television measuring system (ATVMS) to observe artificial satellites. The peculiarities of such observation conditions are edduced in the article (Strygin N.Z., 2010), and the place of SO separation operations in the technologic chain of digital image processing (DIP) operations when artificial satellites observating is given in [Strygin N.Z. et al., 2007]. The tests were carried out for several real television frames of the SS images obtained when geostationary satellites observating.

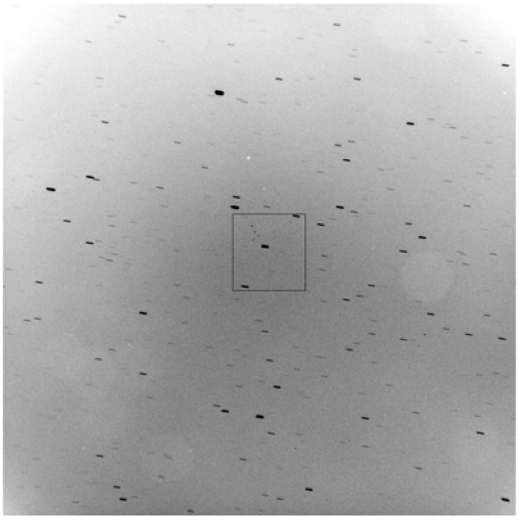

Figure 1. The SS region including geostationary satellites HotBird selected for the test. 28.11.2006. "Tair-19" lens. Field - 3° × 3°, CCD FLI 1024×1024 pixels. Processor INTEL Pentium–4, 1.6Ghz.

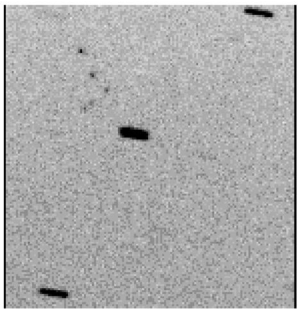

Figure 2. Fragment of the frame including 5 GSS Hot Bird and 3 reference stars. 150×150 pixels

The only feasible in our conditions (Бакут П.А. и др., 1987) the local thresholding algorithm for separation of compact low-sized objects on the complex dynamic background, was tested, as well as the the OAO algorithm. The local threshold (LT) in the scanning aperture (SA) was determined by the valley point of its pixel signals bimodal histogram formed with the algorithm given in (Стрыгин Н. З., 1987).

The peculiarities of separation of SO in the SS image using local threshold processing method – (Бакут П.А. и др., 1987); (Strygin N.Z., 2009/2010) are the following:

1) A local threshold can not be defined if there is only either SO or background in the SA.

2) Even distribution of SO and background brightnesses in the corresponding image regions, as well as a rather sharp contrast of SO against the background are the perfect conditions to select a local threshold. If the brightness of SO and the background vary within the corresponding image regions, or the contrast of SO against the background is not enough, some errors similar to false positive ('false alarm') and false negative ('target missing') occur. Such errors imply that the background image regions with brightness value equal or greater than the local threshold are labeled as the SO regions; and the SO regions with the brightness value less than the local threshold are labeled as the background regions.

3) A local threshold can be defined if there is only one SO against background in the SA.

4) To distinguish clearly two modes on the SA pixel signals histogram, it is necessary to match the SA sizes with

the segmented SO dimensions: the area of the mentioned SO image region must occupy 30-40% of the SA area.

5) The bigger SA size is, and the larger SO density per area unit of a frame is, the more probable is that more than one SO are to occur in the SA.

To illustrate the above, the processed television frame is shown in Fig. 1, and its fragment is shown in Fig. 2. The observed and computed data for GSS and reference stars are presented in Table 1, 2: optical brightness centroids - $(x, y)_i$, SO images areas - S_i, the total brightness of that area - $B(S_i)$, i = 1, …k, with k – the number of SO segmented in the image frame.

The local threshold processing was carried out for the following sizes of the SA (in pixels):19×19, 11×11, 9×9, 7×7 and 5×5.

Table 1. The comparative results of different algorithms for GSS segmentation on the fragment shown in Fig. 2

Algorithm / Object	LT 19×19	LT 11×11	LT 9×9	LT 7×7	LT 5×5	OAO algorithm
Satellite 1, pixels	0 186 0 145 216 140	0 186 0 145 216 140	0 186 0 145 216 140	0 186 0 145 216 140	0 186 0 145 216 140	133 186 0 145 216 140
$(x_c, y_c)_1$	495.99, 445.73	495.99, 445.73	495.99, 445.73	495.99, 445.73	495.99, 445.73	496.5, 445.5
S_1	4	4	4	4	4	5
$B(S_1)$	687	687	687	687	687	820
Satellite 2, pixels	161 153 137 176	161 153 137 176	161 153 137 176	161 153 137 176	161 153 137 176	161 153 0 137 176 0 0 121 121
$(x_c, y_c)_2$	501.52, 457.50	501.52, 457.50	501.52, 457.50	501.52, 457.50	501.52, 457.50	. 502.83, 458.00
S_2	4	4	4	4	4	6
$B(S_2)$	627	627	627	627	627	869
Satellite 3 pixels	0 133 134 167 0 125	0 133 134 167 0 125	0 133 134 167 0 125	0 133 134 167 0 125	0 133 134 167 0 125	123 133 134 167 0 125
$(x_c, y_c)_3$	508.76, 464.99	508.76, 464.99	508.76, 464.99	508.76, 464.99	508.76, 464.99	509.60, 464.80
S_3	4	4	4	4	4	5
$B(S_3)$	559	559	559	559	559	682
Satellite 4 pixels	–	0 133 127 120 139 0	0 133 127 120 139 0	0 133 127 120 139 0	0 133 127 120 139 0	133 127 139 0
$(x_c, y_c)_4$	–	502.00, 471.50	502.00, 471.50	502.00, 471.50	502.00, 471.50	502.33, 471.33
S_4	–	4	4	4	4	3
$B(S_4)$	–	519	519	519	519	399
Satellite 5 pixels	0 117 121 121 167 0 0 128 0 0 121 0	0 117 121 121 167 0 0 128 0 0 121 0	121 0 0 0 121 167 0 0 128	121 0 0 0 121 167 0 0 128	121 0 0 0 121 167 0 0 128	121 167 0 128 0 121
$(x_c, y_c)_5$	499.00, 474.17	499.00, 474.17	497.32, 474.01	497.32, 474.01	497.32, 474.01	498.75, 474.75
S_5	6	6	4	4	4	4
$B(S_5)$	775	775	537	537	537	537

Table 2. The comparative results of different stars segmentation algorithms

Object \ Algorithm		LT19×19	LT 11×11	LT 9×9	LT 7×7	LT 5×5	OAO Alg.
Ref. Star 1.	$x_{c,1}$	463.71	464.26	464.55	464.50	464.88	462.77
	$y_{c,1}$	409.36	409.42	409.36	409.38	409.80	408.94
	S_1	100	95	92	90	85	94
	$B(S_1)$	21102	19814	19366	19159	17994	20715
Ref. Star 2	$x_{c,2}$	523.70	524.27	524.30	524.32	524.79	522.60
	$y_{c,2}$	487.28	487.27	487.24	487.12	487.29	486.63
	S_2	87	79	78	66	59	90
	$B(S_2)$	17852	16827	16665	15068	13697	19018
Ref. Star 3	$x_{c,3}$	489.00	484.09	484.17	490.00	483.82	482.59
	$y_{c,3}$	566.00	566.29	566.36	566.00	566.53	566.15
	S_3	55	49	49	40	41	63
	$B(S_3)$	10981	10149	10149	8750	8804	12478
	$T_{el\ [sec]}$	48.5	28.7	23.8	18	14	12.81
	N_{SO}	48	48	47	47	52	63

Note: T_{el} – elapsed time of algorithms processing for the entire television frame; N_{SO} – the number of objects separated in the entire frame shown in Fig. 1.

The following interim conclusions can be made on the grounds of the tests performed:

1. As the SA size decreases from 19x19 to 5x5, the elapsed time of LT processing of the entire television frame shortens from 48.5 s to 14 s respectively.
2. As the SA size decreases from 19x19 to 5x5 (in so doing the spatial resolution of LT algorithm increases), the number of segmented SO grows from 47 to 52 (Fig. 1) respectively.
3. The LT algorithm is inefficient against furrow-like backgrounds.
4. The OAO algorithm has:

a) higher efficiency – it takes 12.81 sec for frame processing shown in Fig.1.

b) better spatial resolution – 63 SO were separated in Fig.1.

References

Strygin N.Z.: 2009/2010, *Odessa Astron. Publ.*, **22**, 49-51.

Стрыгин Н.З.: *А.С. СССР № 1487069, кл. МПК G06 F 15/66, приоритет от 2.03.1987.*

Strygin N.Z., Prokof'eva V.V., Sukhov P.P., Karpenko G.F.: 2007, *Odessa Astron. Publ.*, **20**, P. 2, 118-130.

Бакут П.А., Колмогоров Г.С., Ворновицкий И.Э.: 1987, *Зарубежная Радиоэлектроника*, **10**, 6-24.