ON THE ISSUE OF SEGMENTATION OF SPACE OBJECTS IMAGES AGAINST THE STARRY SKY BACKGROUND IN ASTRONOMICAL TELEVISION MEASURING SYSTEM FOR ARTIFICIAL SATELLITES OBSERVATION

N.Z.Strygin

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

Segmentation refers to the process of automatic partitioning of an image into meaningful regions, so the important part of it in applied respect is the extracting (detection) of objects that differ in their brightness and geometric characteristics, as well as in physical interpretation (Денисов Д.А., Низовкин В.А., 1985).

Segmentation of nontrivial images is one of the most difficult tasks in image processing (Гонсалес Р., Вудс Р., 2005).

The problem of segmentation is one of the most important tasks of image analysis (Tetsuo Asano and Naokazy Yokoya, 1981).

As far as the results of segmentation are the only to be further processed, segmentation is the major image processing operation in information extraction systems, which the examined astronomical television measuring system (ATVMS) belongs to (Стрыгин Н.З. и др., 2007); the place of segmentation in the production string of IPC operations in ATVMS is given in (Стрыгин Н.З. и др., 2007).

Ideally, the devising of segmentation methods for some image model (class) should rely on specific knowledge of the subject, of the equipment and of technical processes of the image-forming system (Розенфельд А., Дейвис Л.С., 1979). In television astronomy, the last includes natural factors, such as atmosphere and lighting. Atmosphere is a compound optical constantly moving medium, which is not homogeneous as the refractive index varies.

On traveling through the atmosphere, the light beams are randomly deflected, causing image tremor and spreading (Селиванов А.С., 1990); the above indicates that the image-forming system parameters vary haphazardly (Хант Б.Р., 1980); therefore, in the present case, the knowledge of influence of the atmosphere, of the conditions of observation and natural illumination is indispensable (Стрыгин Н.З. и др., 2007).

As a rule, segmentation algorithms for monochrome halftone images of scenes with compact objects are based on one of the two basic characteristics of the brightness signal B(x, y) – image function: discontinuity and homogeneity.

In the first case, the approach consists in image partitioning on the base of sharp changes of the signal – image brightness jumps B(x,y); that approach is called ‘edge detection’.

In the second case, the approach called ‘interest points detection’ is used; that means image decomposing into domains with features of the same preliminary given types (Гонсалес Р., Вудс Р., 2005; Денисов Д.А., Низовкин В.А., 1985).

A lot of segmentation procedures are worked out; however, there is neither any sufficiently strict and general solution of the problem nor even its definition that causes the heuristic and, sometimes, interactive nature of the devised procedures (Борисенко В.И. и др., 1987).

By analyzing of compound images, designing of efficient algorithms for segmentation “becomes a separate important task of principle. As a rule, the segmentation procedures are aimed at solution of specific applied problems, and the quality of the solution is estimated by an expert at that” (Борисенко В.И. и др., 1987).

Image segmentation methods are effective only for those image classes that they were devised for (Путятин Е.П., Аверин С.И., 1990). Hence, it is important to define a class of the processed image, as well as applicability of certain methods (algorithms) for segmentation of images of that class.

There is no complete classification of images from a position of their processing. With development of science, engineering and production, that is caused not only by ever-increasing diversity of objects, effects, events, as well as variety of subjects, their compositions, scenes, observation conditions and processing purposes, but also by the lack of formalized criteria of image quality and estimation of quality of image processing.

The peculiarities of observation conditions and segmentation of space objects images against the starry sky background are the following:

1. The conditions of observations are short-term and nonreproducible.

2. As space objects are moveable, it is necessary to analyze a sequence of images that is the subject of a specific field of image analysis.

3. Natural space objects can be either an interfering background for segmentation of artificial satellites images or attendant objects, recognition and definition of image numerical characteristics of which is necessary to specify the latter for the observed artificial satellites.

4. The background "breathes" (its brightness distribution and location on the image field change with time).

5. The foreground reduces the contrast of space object image.

6. The areas of the regions of space objects images can be from several pixels up to several tens and even hundreds of pixels depending on the conditions of observation and the photoelectric converter used; the areas of artificial satellites images can be from several units to several tens of pixels.

7. The space object image function B(x,y) is an upper convex (concave downwards), falling down from the maxima along x- and y- axes. Sometimes, on the down trend, there are hills and valleys up to 7% of the current value B(x,y) in 1,2,3,4 pixels either compactly connected or horizontally or vertically deployed. It is rare that B(x,y) is a convex (concave upwards) due to appearance of hills along the edges of a space object image.

8. There is an evolution of spatial variations of the background and space objects brightness.

In television astronomy, by analogy with the most advanced application of digital image processing – computer vision, segmentation can be reduced to π and π_1 imaging by methods of interest points detection and edge detection, respectively (Путятин Е.П., Аверин С.И., 1990).

The difficulty of π and π_1 imaging can be caused by the fact that such concepts as 'object', 'background', 'edge of an object' are rather relative, they are not accurately formalized in terms of digital image B[i,j]. The following considerations, which should be formalized of themselves, can serve as information for such imaging:

1. objects are detected against a background;
2. object regions are coherent;
3. absolute value of the brightness gradient for the edge points of objects exceeds its magnitudes for other image points;
4. since object regions do not intersect, then the region of each object is not contained in any larger related region that consists of the objects points.

The methods and algorithms for segmentation can be considered as formalization of the concept of ability of objects detection against a background or of the concepts related to the brightness gradients (Путятин Е.П., Аверин С.И., 1990). The reliability of algorithms for segmentation depends on the level of accuracy and completeness of taking into consideration additional information, which mainly consists of the following data:

- number of objects *K* and their density per unit of area of the starry sky image;
- some characteristics of brightness distribution within object regions and the background ones; for example, extreme brightness values, number of brightness drops;
- estimation of the brightness jumps when moving between the background region and the objects region;
- information about what part of the field of view is occupied by the merged object regions (Путятин Е.П., Аверин С.И., 1990).

Starry sky is taken as a light two-dimensional pulse parametric field that is observed against natural two-dimensional random dynamic fields (or jointly with them) and in presence of natural spatially distributed noise and disturbances, the level of which is rather low under normal conditions (Стрыгин Н.З. и др., 2007).

From a position of information content and structure, a starry sky image is referred to as a locally informative type, from which interpretation objects and background part can be extracted in accordance with the task meaning (Вальтерис С.Э., Ярославский Л.П, 1983); that is why its segmentation comes to space objects extraction from a certain background. To extract space objects (either natural or anthropogenic) by that way, the local thresholding algorithm is the only among known ones that can be used due to spatial nonhomogeneity and dynamicity of a background (Бакут П.А. и др., 1987).

The ideal conditions for such segmentation are the following: there is only one object in the scanning aperture; the object brightness and the background brightness are distributed evenly within the corresponding regions and the contrast between them is rather sharp. Uneven distribution of brightness over object and background regions, as well as low contrast between their brightness cause some errors similar to false positive ('false alarm') and false negative ('lapse in attention'); such errors imply that the background regions with brightness value greater than the local threshold are labeled as the object regions; and the object regions with the brightness value less than the local threshold are labeled as the background regions. Errors of both types lead to distortion of the segmented SO parameters: the object region area S_i, the total brightness of that area $B(S_i)$ and the position of centroids of optical emission by that region area $(x_0, y_0)_i$, $i=\overline{1,k}$. In so doing, the number of space objects segmented in the frame of the starry sky image – k, and their parameters depend on the scanning aperture size; thus, the last should be adjusted to the size of the segmented SO: the object image regions should be inscribed into the scanning aperture, and their areas must equal to 30-40% of the aperture area.

The above requirement can be met by multiple scanning of an image frame with apertures of different sizes or by one-time scanning using an adaptive aperture with the size that efficiently conforms to the size of the caught space object image.

In the first case, it is necessary to promptly determine what aperture was used when the SO true parameters were detected. In the second case, it is needed to efficiently detect the size of the SO image region (i.e. to conduct a sort of preliminary rough segmentation of the SO image region), and then to form the conformable aperture. In both cases, the segmentation process is considerably complicated and prolonged, so, as for now, it can be realized only in interactive mode.

A more efficient algorithm for segmentation of SO images against the starry sky background (Strygin N.Z. et al., 2009/2010) was developed at OAO with an allowance for the considerations mentioned above. It has more fast-action and field of applicability and has better spatial resolution.

References

Денисов Д.А., Низовкин В. А.: 1985, *Зарубежная радиоэлектроника*, **10**, 5-30.
Гонсалес Р., Вудс Р. *Цифровая обработка изображений*: М., Техносфера, 2005.
Розенфельд А., Дейвис Л.С.: 1979, *ТИИЭР*, **67**, №5, 71.
Вальтерис С.Э. и др.: 1983, *Труды АН Литовской ССР*, *сер. Б*, **3(136),** Ч. I, 97-104.
Борисенко В.И., Златопольский А.А., Мучник И.Б.: 1987, *Автоматика и телемеханика*, **7**, 3-56.
Путятин Е.П., Аверин С.И. *Обработка изображений в робототехнике,* М., Машиностроение, 1990.
Бакут П.А., Колмогоров Г.С., Ворновицкий И.Э.: 1987, *Зарубежная радиоэлектроника*, **10**, 6-24.
Стрыгин Н.З., Прокофьева В.В., Сухов П.П., Карпенко Г.Ф.: 2007, *Odessa Astron. Publ.*, **20**, part 2, 118-130.
Хант Б.Р.: 1980, *Применение цифровой обработки сигналов* /ред. Э.Оппенгейм: М., Мир, 552.
Strygin N.Z., Sukhov P.P., Karpenko G.F.: 2009/2010, Odessa Astron. Publ., **22**, 52-54.
Селиванов А.С. *Космос – миру. Телевизионные системы для исследования планет*. М., Знание, 1990, 64. (сер. «Радиоэлектроника и связь», № 2).
Tetsuo Asano and Naokazy Yokoya: 1981, *Pattern Recognition*, **14**, N 1–6, 267–273.