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Statistical properties of image pixel brightness from the onboard optical system

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Abstract
The research of statistical properties of image pixel brightness has been carried out, allowing us to improve the quality of the choice of the required mathematical model. The results of the analysis of ground-based background-target videos obtained by an unmanned aerial vehicle's onboard optical-location system are presented. The requirements to the mathematical model of brightness in the ground-based noise-target environment is formulated.

Introduction

Many domestic and foreign publications are devoted to the effective use of information obtained from the onboard optical locating system (OLS) for the purpose of tracking ground objects [1-9]. Such objects include civil and military ground transport, people, infrastructure objects and others. At the same time, the problems of tracking in OLS are exacerbated by observation of objects on a complex and heterogeneous background (pavement, landscape, vegetation, other ground objects). Also, for ground-based background-target situation, the presence of a large number of objects in the radar frame at the same time is characteristic, which complicates the task of tracking in manual mode by the operator. In case of a multi-target situation, an effective solution is to automate the process of ground object tracking based on onboard radar data. Most often, the automation process is realized by means of several well-known approaches, based on image contour analysis, selection of reference (reference) points, extremal-correlation analysis, as well as application of neural network algorithms [1, 2, 6, 7]. However, the issue of their effective application in ground-based background-targeting conditions remain relevant, due to the great diversity of the obtained images. In turn, the diversity has led to a number of generally accepted mathematical models of images [2, 6]. The work presents the research of statistical properties of image pixel brightness, allowing us to choose a mathematical model with the highest degree of adequacy. The results of the analysis of video recordings of ground background-target conditions obtained by the airborne optical-location system are presented, allowing us to put requirements to the selected mathematical model.

Material and Method

We have developed a methodology for investigating statistical properties of brightness, which consists of the following stages: formation of a data bank containing similar video recordings for given observation conditions; extraction of images belonging to the objects of interest from the data bank. Formation of pixel brightness slices; estimation of the law and numerical parameters of image brightness distribution by histogram method; analysis of individual pixel brightness distributions, construction and analysis of autocorrelation functions (ACF); estimation of dynamic stability of image pixel brightness (estimation of stationarity). To conduct research in accordance with the stated methodology, developed a software package of experimental studies, the block diagram of which is shown in Figure 1.

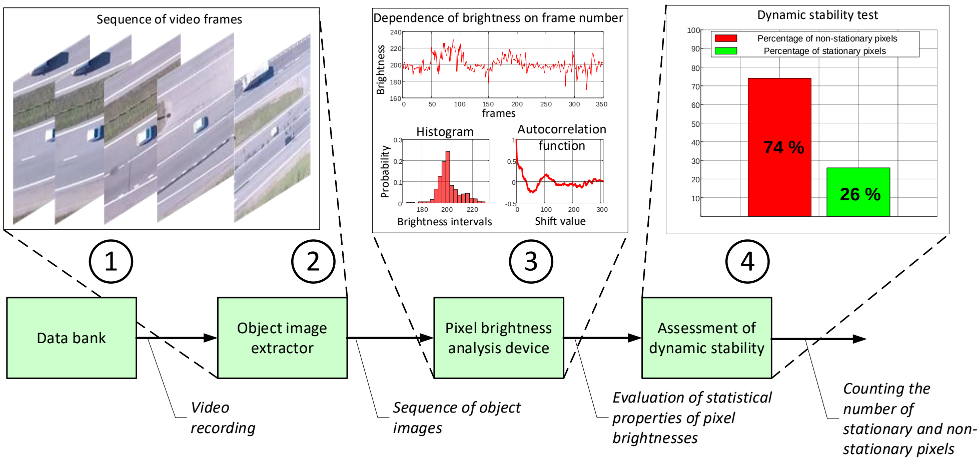

Figure 1. The structural scheme of the program complex of experimental research

Results and discussion

The input data for the experimental studies are video recordings obtained by the onboard OLS. The recordings show moving ground vehicles, both military and civilian (Figure 2). The footage was recorded during daylight hours with good visibility and no interfering factors (rain, snow, fog, etc.). Recording was performed with a resolution of 1920×1080 pixels and 29 frames per second.

a *b* *c*

Figure 2. Conditions of ground objects observation according to onboard radar data: a, b - civilian vehicles on the highway; c - military vehicles on the march

The data bank of the images of the objects, consisting of 18 records, was formed. The total size of the analyzed sample was more than 100000 brightness counts. The sizes of images of objects are fixed and were 32x32 pixels. In this case it is considered, that in the process of observation the sizes of images of objects remain invariable. Objects are observed from different angles due to their own movement, UAV movement and rotation of the OLS. The background has a complex structure, as it includes various elements, such as the road with markings, areas of vegetation, as well as other passing cars. It is considered that a part of background pixels belongs to images of objects and constitutes no more than 10% of the total number of pixels.

Then we analyzed the distribution of pixel brightness's and their correlation properties according to the brightness slices (Figure 3a). The analysis of the distribution was carried out by the histogram method. The number of grouping intervals for histograms was 50. The histograms obtained show that the pixel and image brightness distributions have a multimode character, which means that the distribution parameters change during the observation process. Basically, the changes in the distribution parameters are due to changes in the orientation of the observed object in space, which leads to distortion of its image.

To assess the correlation relationships between the brightness values at different moments of time, we analyzed the ACF of image brightness for all pixels over the entire observation interval. Analyzing the shape of the ACF, we can conclude that it can be approximated by the exponential correlation function. However, for each individual pixel the correlation time can differ significantly. Therefore, to approximate the exponential ACF the correlation time should be chosen as an average for all pixels of the image.

Changes in the distribution parameters indicate the non-stationarity of the observed process. In order to confirm this hypothesis, the dynamic stability of the ACF was evaluated. The results are shown in Figure 3b. The graph shows that 74% of the pixels of the images composing the data bank are non-stationary, which is significantly higher than the allowable percentage determined by the research methodology. The estimation of the duration of the stationarity intervals is shown in Figure 3b. The obtained estimation of the distribution indicates a high degree of compliance with the indicative law. To assess the degree of compliance we used well-known statistical Pearson's chi-square test of agreement. As a result, it is established that the obtained distribution of stationarity intervals with confidence probability not less than 0.9 corresponds to the exponential law. Correspondence of time intervals durations to the exponential law indicates that the process of brightness change in time can be obtained by means of Markov sequence model with continuous time set by Poisson flow of events.

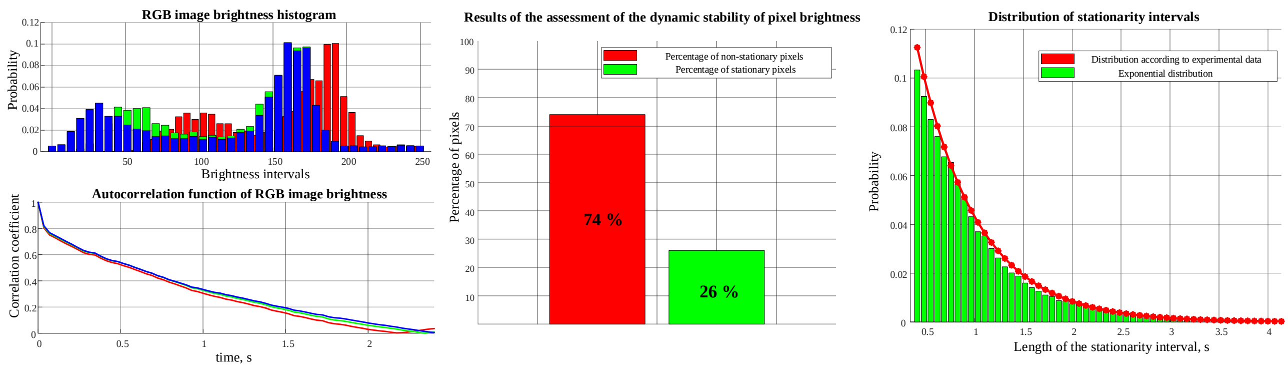

Figure 3. Brightness histograms, autocorrelation function of ground object image brightness in three RGB color channels, as well as the results of estimation of dynamic stability and distribution of pixel brightness stationarity intervals

Conclusion

Thus, in accordance with the proposed research methodology of statistical properties of pixel brightness of images formed by airborne radar, the mathematical model of pixel brightness belonging to the image of a ground object must have the following properties: the law of pixel brightness distribution is unknown and has a multi-mode structure; process of brightness change in time is predominantly non-stationary (74 %) and has properties of dynamic system, which parameters change in time; the durations of stationarity intervals are distributed according to the exponential law, and the change of states occurs at random moments of time according to the Poisson law; the autocorrelation properties of brightness in time can be described by ACF of exponential form, the correlation time of which corresponds to the average value of correlation time in each pixel of object image.

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