ALGORITHMS FOR RELATIVE RADIOMETRIC CORRECTION IN EARTH OBSERVING SYSTEMS "RESOURCE-P" AND "CANOPUS-V"

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ABSTRACT:

The present paper has considered two algorithms of the relative radiometric correction of information obtained from a multimatrix imagery instrument of the spacecraft "Resource-P" and frame imagery systems of the spacecraft "Canopus-V". The first algorithm is intended for elimination of vertical stripes on the image that are caused by difference in transfer characteristics of CCD matrices and CCD detectors. Correction coefficients are determined on the basis of analysis of images that are homogeneous by brightness.
The second algorithm ensures an acquisition of microframes homogeneous by brightness from which seamless images of the Earth surface are synthesized.
Examples of practical usage of the developed algorithms are mentioned.

1. INTRODUCTION

Radiometric correction is connected with elimination of brightness distortions on images of the Earth surface due to peculiarities of the imagery camera operation. These distortions are caused by difference in transfer characteristics of some CCD detectors and CCD matrices operating under time delay and charge integration mode and they become apparent in the form of vertical stripes on images of high spatial resolution obtained from the spacecraft "Resource-P" (Fig. 1). Exposure of the camera by standard optical sources and calculation of correction coefficients according to these data are traditionally carried out on the satellite board for correction of such distortions (Ming. 2011). More accurate method is based on calculation of correction coefficients according to results of processing of the video data obtained under "sliding" mode (Henderson, 2004, Anderson, 2011, Lachérade, 2012). There are no sources of onboard calibration on the spacecraft "Resource-P" and coefficients obtained at the stage of preflight camera certification do not meet requirements to processing accuracy. Since imagery under "sliding" mode is not provided, so imagery of the Earth surface images that are homogeneous by brightness is carried out to determine correction coefficients (Henry, 1993). Algorithm for calculation of correction coefficients and peculiarities of their practical applications have been considered.
Imagery cameras of the spacecraft "Canopus-V" consist in several CCD matrices forming a group of overlapping microframes within the imagery. Radiometric distortions become apparent within changes of brightness from the beginning to the end of microframes and various brightness of microframes obtained from adjacent CCD matrices. Besides, images of foreign objects are observed on microframes (Fig. 2). Nature of these distortions and algorithm of their correction have been considered.

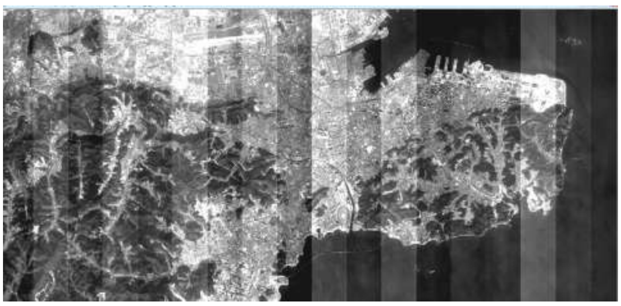

Figure 1. Example of radiometric distortions of the panchromatic image obtained from the spacecraft "Resource-P"

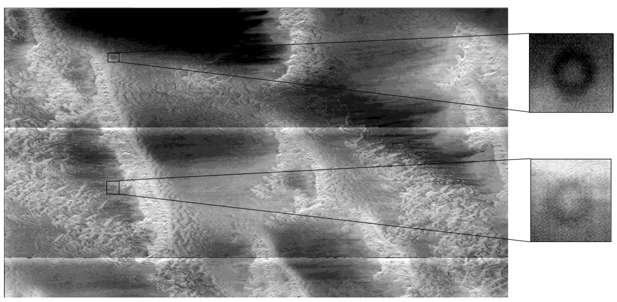

Figure 2. Example of radiometric distortions of the panchromatic imagery from the spacecraft "Canopus-V"

2. ALGORITHM OF RADIOMETRIC CORRECTION OF VIDEO DATA OBTAINED FROM THE SPACECRAFT "RESOURCE-P"

Researches have determined that the level of radiometric distortions of the image depends on a number of accumulation steps in the CCD matrix. So, all steps of the radiometric correction algorithm are carried out for each value of accumulation lines.
Step 1. Imagery of the starry sky is carried out and values of the dark signal $u_i(m)$ are calculated, where i - a number of the

CCD matrix, and m - a number of a CCD detector in the matrix.

Step 2. Imagery S of cloudless images homogeneous by brightness is carried out. Rejection of fragments containing objects different from the background is executed.
Averaged values of brightness are calculated for each CCD detector.

$$\bar{b}_i^0(m) = \frac{1}{S}\sum_{s=1}^{S} b_{si}^0(m) - u_i(m). \quad (1)$$

Then an array of multiplicative coefficients of the radiometric correction is calculated

$$a_i(m) = \sum_{i=1}^{I} \bar{b}_i^0(m) \Big/ I\,\bar{b}_i^0(m), \quad (2)$$

where I - a number of CCD matrices in the camera.
Researches have shown that there is an increased edge flare of CCD matrices in relation to central CCD detectors due to imperfection of optical filters. Besides, the level of this flare is individual for each CCD matrix. Taking this peculiarity into account, 2-stage radiometric correction is carried out at the third algorithm step. At first, initial values of brightness $b_i(m)$ are transformed according to formula $\hat{b}_i(m) = b_i(m)a_i(m)$. Then a correction function $\Delta(m)$ is prepared on the basis of analysis of shareable image areas from adjacent CCD matrices. Its form is shown in Figure 3.

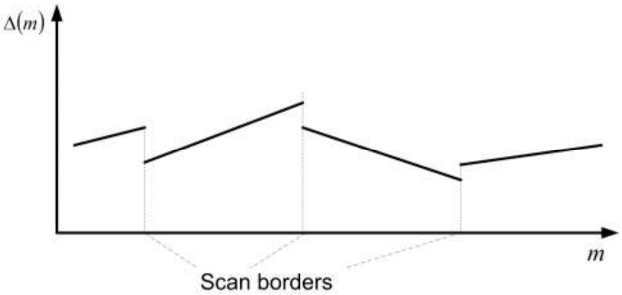

Figure 3. Graph of the correction function used for compensation of residual radiometric distortions.

3. ALGORITHM OF RADIOMETRIC CORRECTION OF VIDEO DATA OBTAINED FROM THE SPACECRAFT "CANOPUS-V"

It was determined that increase of brightness from the beginning to the end of a microframe is caused by peculiarities of the charge transfer under signal pickup from the CCD matrix operating under time delay and charge integration mode, Figure 2. Nature of these distortions depends on brightness of the Earth surface objects, so it is not fully eliminated within calibration. However, if brightness differences of the same name objects located in the shareable area of i and $i+1$ microframes are analyzed, then the correction function can be determined in the form of two-dimensional polynomial:

$$F_i(m,n) = a_{0i} + a_{1i}m + a_{2i}n + a_{3i}mn + a_{4i}m^2 + a_{5i}n^2, \quad (3)$$

where m, n = a number of the element in the CCD matrix.

Then the radiometric correction algorithm is represented in the following way.
Step 1. Imagery of some images homogeneous by brightness is carried out and radiometric distortions are eliminated on all microframes by means of functional $F(m,n)$.
Step 2. Multiplicative coefficients $k(m,n)$ eliminating images of foreign objects are calculated according to corrected microframes.
Step 3. Radiometric processing of imagery materials is carried out using functional $F(m,n)$ and a set of coefficients $k(m,n)$.

4. RESULTS OF ALGORITHM PRACTICAL APPLICATIONS

Analyzed algorithms of the relative radiometric correction provide an error of residual distortions at the level 0,2-0,3 brightness quantum. Figure 4 represents a result of correction of the image shown in Figure 1. Figure 5 represents a result of processing of the image shown in Figure 2. Mentioned accuracy is enough to obtain seamless images of separate microframes.

Figure 4. Result of the radiometric correction of an image fragment obtained from the spacecraft "Resource-P"

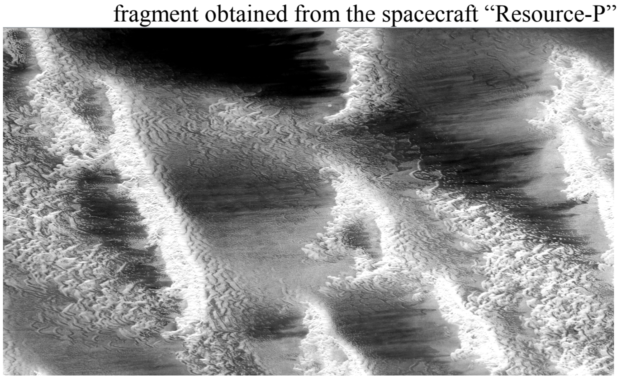

Figure 5. Result of the radiometric correction of an image fragment obtained from the spacecraft "Canopus-V"

5. CONCLUSION

Considered algorithms of the relative radiometric correction are realized in software and within several years it is successfully used by receiving offices in the Russian Federation under formation of outputs of the processing levels 1-2 from the spacecraft "Resource-P" №1, №2 and "Canopus-V".

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