COMPUTER METHODS AND ALGORITHMS FOR PROCESSING IMAGES OF VOLCANOES

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Video surveillance systems is one of the efficient means of monitoring volcanoes. They include stationary video cameras, software and hardware systems that provide collection, storage, and certain data processing depending on the purpose of the system. Researchers of the Computing Center FEB RAS and the Institute of Volcanology and Seismology created a video surveillance system for volcanoes in Kamchatka, designed to quickly monitor the status of these dangerous natural objects (Sorokin et al., 2016).

A large archive of images and a high intensity of its filling requires the development of tools for filtering out uninformative and corrupted images, as well as identifying images with signs of activity of volcanoes. Within the first stage of the work, the authors developed several algorithms aimed at solving some of the problems under consideration.

The first of them, based on the analysis of the visibility of the volcano in the image (Kamaev et al., 2018), provides for the initial evaluation of a photograph, excluding non-informative images from the archive. The algorithm is implemented based on analysis of contours (Urmanov et al., 2017) of the observed objects and frequency characteristics of the images. The analysis of the contours is represented by the procedures for constructing and comparing the parametric contours of the volcano. In this case, the visibility of the volcano is determined by comparing the most stable contours on the reference images with the contours in the analyzed image. The result of the comparison is the estimate $\sigma \in [0..1]$. Examples of the obtained estimates for three images of Klyuchevskoy volcano are presented on fig. 1.

Fig. 1 Examples of the evaluation of contours in images with different visibility of Klyuchevskoy volcano: a - the volcano is covered by clouds ($\sigma = 0.062919$), b - the volcano is partly covered by clouds ($\sigma = 0.308513$), c - the volcano is clearly visible ($\sigma = 0.886154$).

In the case where the estimate of σ is in Δ near the decision threshold τ of the unsuitable image for research, the result of the σ boundary analysis algorithm is corrected by estimating the frequency response of the image $\rho \in [0..1]$, which is represented by the octave contribution vector of the frequencies in the formation of the luminance components of the image. In this algorithm, to evaluate the visibility of the volcano, a comparison is made between the reference frequency response and the characteristic of the analyzed image. Fig. 2 shows examples of the calculated frequency characteristics for Klyuchevskoy volcano images taken under different weather conditions and the results of comparing these characteristics with the reference one.

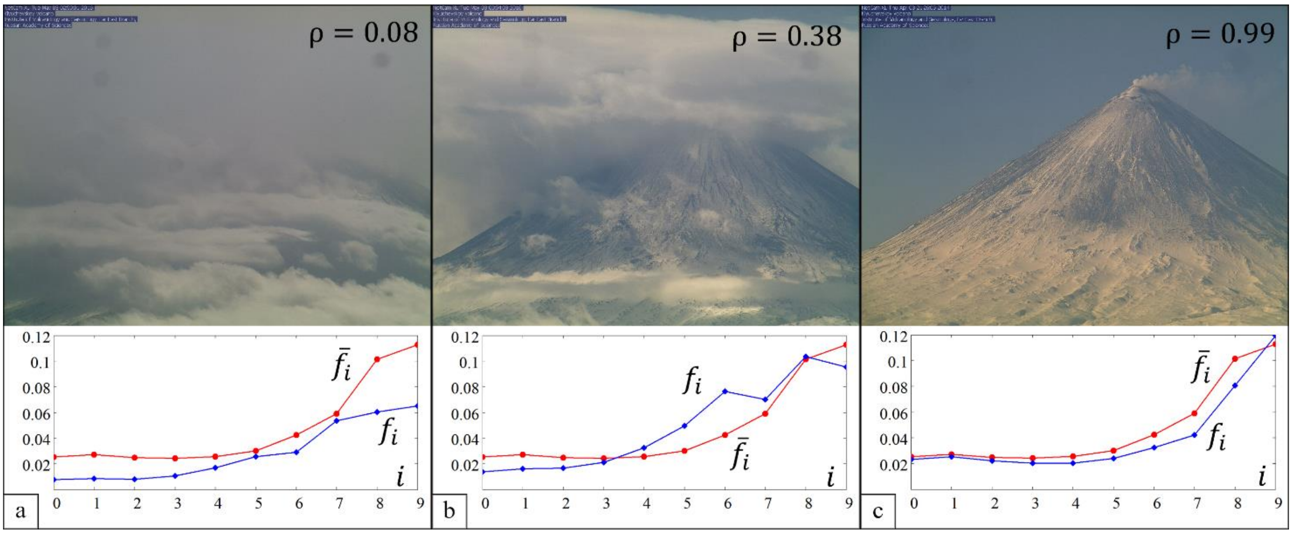

Fig. 2 Examples of comparison of frequency characteristics for images with different visibility of Klyuchevskoy volcano: a - the volcano is covered by clouds, b - the volcano is partly covered by clouds, c - the volcano is clearly visible.

The total visibility estimate is determined by the formula

$$\alpha = \sigma f(\sigma) + \rho\big(1 - f(\sigma)\big),$$

where

$$f(\sigma) = \min\left(1, \frac{1}{\Delta^2}(\sigma - \tau)^2\right).$$

This algorithm is designed to work with images taken in the daytime. For photographs taken at night using cameras that take pictures in the near infrared range, a separate algorithm was implemented.

Essentially, the “night” algorithm search for thermal anomalies in pictures that characterize the activity of the volcano. The centers of anomalies are determined using a multiscale DoG (Difference of Gaussian) detector, with only the maxima selected on the DoG layers. An attribute vector is assigned to each center of anomalies. With the help of a naive Bayesian classifier, the anomaly is related to the class of real anomalies or the class of not anomalies. The attributes are considered: the value of the DoG function at the center, the elongation of the anomaly, the ratio of the perimeter to the minimum possible perimeter (the complexity of the boundary), the asymmetry of the values at the edges, the ratio of the center-base brightness difference to the brightness value in the center, and the very value of the brightness in the center. Examples of found real thermal anomalies in the images are presented on fig. 3.

Fig. 3 Examples of infrared images with isolated real thermal anomalies

Based on the presented algorithms, software modules were developed that were integrated into the information system "Signal" (Sorokin et al., 2015), designed for management and data processing of instrumental observation networks of the Far Eastern Branch of the Russian Academy of Sciences.

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References

Gordeev E.I., Girina O.A., Loupian E.A. et al. The VolSatView information system for Monitoring the Volcanic Activity in Kamchatka and on the Kuril Islands // *Journal of Volcanology and Seismology*. 2016. Vol. 10. No. 6. Pp. 382-394. DOI: 10.1134/S074204631606004X.

Kamaev A.N., Urmanov I.P., Sorokin A.A. et al. Images analysis for automatic volcano visibility estimation // *Computer Optics*. 2018. Vol. 42(1). P. 128-140. DOI: 10.18287/2412-6179-2018-42-1-128-140.

Sorokin A.A., Korolev S.P., Romanova I.M. et al. The Kamchatka Volcano Video Monitoring System // *Proceedings of 2016 6th International Workshop on Computer Science and Engineering; WCSE 2016.* Tokyo, Japan. June 17-19, 2016b. Pp. 734-737.

Sorokin A.A., Korolev S.P., Urmanov I.P., et al. Software Platform for Observation Networks Instrumental Data Far Eastern Branch of the Russian Academy of Sciences // *Proceedings of International Conference on Computer Science and Environmental Engineering*, Beijing. May 17-18, 2015. Pp. 589-594

Urmanov I., Kamaev A., Sorokin A. Computer methods of image processing of volcanoes // *Proceedings of the IV International research conference «Information technologies in Science, Management, Social sphere and Medicine» (ITSMSSM 2017)*. 5-8 December 2017. Advances in Computer Science Research (ACSR). 2017. Vol. 72. Pp. 371–374. DOI: 10.2991/itsmssm-17.2017.77