GEOMETRICAL TRANSFORMATION OF PANORAMAS OF MARS SURFACE RECEIVED FROM PHOBOS-2 SPACE STATION; I.M.Bockstein, M.A.Kronrod, Institute of Problems of Information Transmission, Russian Academy of Sciences, Moscow, Russia
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Methodology of geometrical transformations of planetary images is described that leads to transferring these images to the format of a photographic map available. The results of practical use of the corresponding software for geometrical transformation of Mars surface panoramas obtained from Phobos-2 space station are also presented.

In 1989 Soviet space station Phobos-2 has made four sessions of Mars surface surveying. Two-channel opto-mechanical scanner THERMOSCAN was used for this purpose. It gave possibility to register four surface panoramas in visual and thermal spectral channels. The procedure and the results of pre-processing these images are described in [1].

Now it became necessary to transfer these Mars panoramas to the format of the existing photographic map of Mars surface for interpretation purposes. Since the parameters of Phobos-2 station's orbit for the periods of registration of panoramas are known inexactly, it is impossible to realize the transformation by means of direct calculations according to some exact formulae. That is why we have chosen the following well-known way of transformation:

- a lot of near-located points of correspondence were found on the panorama to be transformed, and on the photographic map;
- triangulation network was constructed across these points;
- affine geometrical transformation was realized inside each triangle of the network. Its parameters were chosen to achieve the coincidence of the vertices of this triangle (i.e., the points of correspondence) on both the map and the transformed panorama. Due to some properties of affine (linear) transformation the deformations of the panorama on either side of borders of the neighbouring triangles were the same, and no ruptures arose in the subject of the panorama.

Practical application of the above-described methodology to geometrical transformation of Mars surface panoramas led us to the necessity to solve a lot of difficult problems. The main problem was to find the points of correspondence on real panorama (Fig. 1a) and real photographic map (Fig. 1b). Since Mars surface consists mostly of craters of approximately the same shape and size, and since these craters look differently in visual and thermal spectral channels, all the attempts to find the points of correspondence automatically were doomed to failure. That is why we decided to find such points (usually, the centers of craters) interactively. IMS-VGA image processing system [2] was used for this purpose. The base of this system was IBM-compatible PC with SuperVGA card; it gave possibility to display gray-scale images and to support the dialogue directly on the screen of computer console. The size of the screen was 512*512 pixels. A program for piece-affine geometrical transformation of images was created as a part of IMS-VGA system. Special subroutine of this program was used to find the points of correspondence. This subroutine enabled user of the system to see both panorama and the photographic map as wholes, to set roughly the positions of each pair of points of correspondence, and then to display and to compare on the console screen the enlarged fragments of the panorama and of the map (with the size of 128*128 pixels, or about 200*200 km). These fragments were centered in chosen positions; the user could shift them up, down, left, or right, rotate panorama fragment to an arbitrary angle, or change its scale. User's task was to achieve the correspondence not only of the central crater (with the point of correspondence inside) but, as far as possible, of all the parts of map and panorama subjects. This decreased strongly the possibility of gross mistakes, when a crater on the panorama was supposed to correspond with quite a different crater of similar shape on the map. In order to reduce the demands of user's skill, approximate position of each new point of correspondence on the panorama was predicted after establishing the rough position of this point on the map. The information about scale and rotation of the panorama in the nearest points of correspondence was used to realize this prediction.

Automatic construction of triangulation network at the second stage of transformation process also caused many problems in practice. After some experiments we have proposed and realized in software the following procedure of triangulation:

- each of the points of correspondence found at the first stage was connected with the nearest of its neighbouring points that answered the following conditions: it was still not connected to the current point, and the line that connected them did not cross the lines drawn earlier;
- after each reaching the end of the list of points of correspondence, the first step of the procedure was repeated while it was possible to draw a new line.

This procedure ensured the construction of the triangulation networks that consisted mainly of the small triangles of almost regular shape. An example of such network is drawn on the photographic map Fig. 1b.

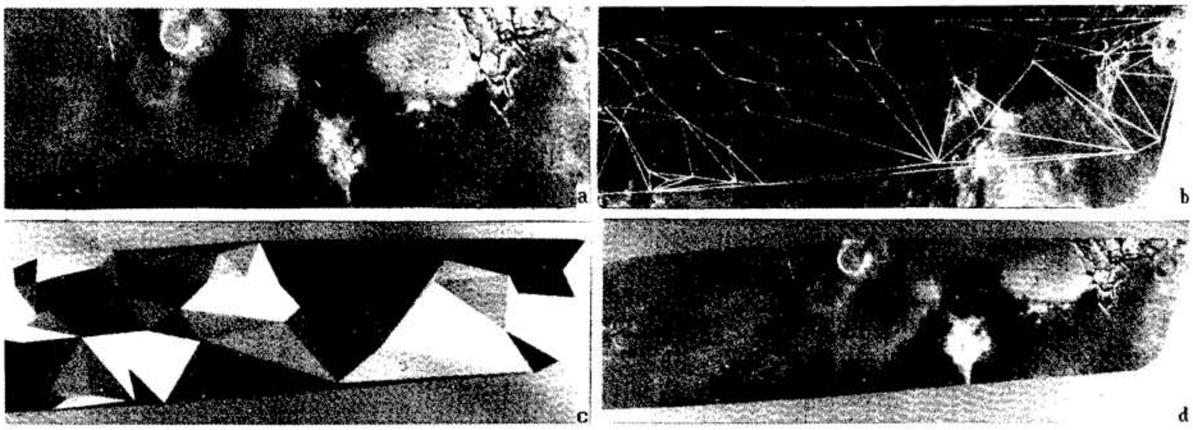

Figure 1. (a) fragment of the panorama of Mars surface (thermal spectral channel); (b) fragment of the photographic map with the triangulation network; (c) mask image; (d) result of the piece-affine geometrical transformation of the shown fragment of panorama

At the stage of piece-affine transformation all the problems were caused by the necessity to determine for each pixel of a panorama the triangle of the network that surrounded this pixel. In order to simplify and to speed up the transformation, we drew in advance a special mask image (Fig. 1c), the size of this image being the same as the size of the photographic map. Mask image consisted of the same triangles as the triangulation network for this map, and the brightness values inside each triangle were equal to its number. For each pixel of the photographic map we found from the mask image the number of triangle that surrounded this pixel, the coordinates of its vertices on the map and on the panorama, and the parameters of affine transformation that leaded to coincidence of these vertices. The coordinates of a pixel of the panorama that corresponded to the pixel of the map were then found as a result of transformation itself. This mode of calculations ensured the absence of ruptures of the transformed panorama irrespective of its local scaling. Transformation procedure was optimized to achieve maximum speed.

The application of our methodology has leaded us to success in solving the problem of transferring the panoramas of Mars surface to the format of an arbitrary photographic map. The result of geometrical transformation of the panorama Fig. 1a in order to correspond it with the map Fig. 1b is shown on Fig. 1d. More than 50 points of correspondence were found and used to transform this panorama.

We have to note that the above-described methodology and the created software means can be used very widely. In particular, we intend to use them when working with Mars panoramas that will be obtained in 1995 as a result of surveying this planet by Russian space stations.

[1] Bockstein I.M. et al. Processing of Mars surface images received from Phobos-2 space station. *LPSC XXI, 1991.*

[2] Bockstein I.M. and Kronrod M.A. IMS-VGA interactive image processing system. *Pattern Recognition and Image Analysis, v. 3, No. 4, 1993.*