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AUTOMATIC SYSTEM FOR COPYING AND RESTORATION OF TELEMETRIC IMAGES

By A. N. Balakirev, N. E. Moskalenko, Kh .G. Tadjidinov

Abstract: Since 1959, more than 20 launches of Russian, automatic interplanetary stations producing photo-TV surveys of the Moon, Venus, Mars and Phobos surfaces have been made in Russia. Images received were transmitted by radio link to the Earth and were written on magnetic tapes. The main feature of the phototelemetric data (PTD) is in their uniqueness.
In connection with that, a task has been set up before in RSDSRC to provide the PTD safety by means of rewriting documents on new magnetic tapes in the digital standard format, and the task of partial restoration of visualised photo-TV images. The automatic system of processing of PTD (ASPPTD) was made for that purpose as the soft-hardware for the digital processing of the PTD.
The digital restoration allows to remove various defects, including :
- gradation defects (distortions in visualisation of optical density,
- frequency-contrast ones (disturbances of image sharpness),
- colour defects,
- local (in the form of dust, scratches, strips and dots) defects.

A restoration of unique photo-TV images of the surface of the Moon, Venus, Mars and Phobos were made by means of the ASPPTD.
The information of the image files is contained in the database MAGTYPE.

At the end of the 1980ies, the Russian Space Documentation Scientific Research Centre (RSDSRC) developed and put into industrial operation the Automatic System for Processing of Photo-telemetric Documents (ASPPD), aimed at visualisation, restoration and copying for security purposes (in digital form) of the data fixed in these documents (1).

Phototelemetric documents (PTD) are the images of the surface of natural space bodies (Moon, Venus, Mars, Phobos) transmitted from space vehicles to the Earth by radio link in the form of coded radio signals and written on magnetic tapes. Such information also can be called « phototelevision image » ; this term is used in various sources for this type of telemetric documents. Since 1959, more than 20 launchings of space vehicles producing the phototelevision shootings of the

surface of these space bodies has been made in our country. The information which had been received is unique and have a great importance for the development of modern space techniques, space explorations and planetary physics.

The PTD adopted to the state storage in the RSDRC had been received from 22 space vehicles from 1959 up to 1987. In spite of special measures taken during the transmission of radio signals from space vehicles to the Earth (pulse-code and frequency modulation), there are various defects in the PTD caused by radio-technical interferences, such as errors, noises, attenuation of the level of legitimate signal.

Moreover, many photos of the Moon and Mars are of insufficient contrast, lowered definition and irregularity of background. There are pulse noises in the most part of signals ; these noises cause image defects, which are analogous to the presence of dust and scratches.

Because of the line-by-line transmission of telemetric data, the sound background of signal becomes non-isotropic (the noise level is different in two neighbouring lines when the correlation in two neighbouring points of the same line is high). The records were made at non-standard equipment in different formats. The long-term storage in unsuitable conditions led to damages of many magnetic tapes, such as breaks, warnings, crumbling of magnetic layer.

This is why for the conservation and further use of PTD, it was necessary to rewrite them on new magnetic tapes in the single standard format, to visualise them (to form lines and stills of images) and to restore ; all this allowed to get more full and qualitative data about transmitted stills of images. The RSDRC adopted to storage PTD with various types (analogous and digital) and parameters (characteristic of frequency modulation, format of digital coding) of records. Hardware and software of the ASPPD allow to bring all the PTD into the single digital form in the Unified System of Computer Standards, which widens the circle of the consumers of phototelemetric information as much as possible.

Analogous frequency-modulated records are preliminary processed at the demodulator. Then, the videosignal is subjected to the numbering at the special electronic computer by analogous-to-digital converter (digitaliser) and recorded in standard form to the magnetic tape; the recording can be made in the form of a video file. The PTD initially presented in digital form are brought to the standard format with the help of specially developed re-coding programs.

The hardware of the ASPPD is divided into the following subsystems:

- reproduction of the initial data,
- demodulation, numbering, conversion and recording of data,
- visualisation and restoration,
- copying for security purposes in the single digital form.

The software of the system which is processed at the RSDSPC contains:

- system of programs for numbering, re-coding and rewriting of phototelevision images ;
- system of programs for visualisation and restoration of images.

For the visualisation of images with the help of colour half-tone display of high resolution, the scientific workers of the RSDRC developed the programs for data transformation into video files (each element of image is presented as a number in diapason from 0 up to 255) and for the forming of geometrically correct image stills, from the continuous line-by-line record of the signal on the magnetic tape.

This system allows to realise the restoration processing of images on the electronic computer both in automatic and in interact regimes (2).

The analysis which had been carried out during the development of this system allowed to divide the defects of telemetric images into the following groups :

- geometrical ones which determine the distortion of image form,
- gradation ones which determine the distortions of optical density,
- frequency-contrast ones which distort the image sharpness,
- colour distortions,
- local ones, in the form of little spots, strips and scratches.

The restoration processing of phototelemetric images consists of the following operations :

- analysis of the defect with the help of the electronic computer and the timation of mathematical models parameters,
- choice or processing of mathematical methods (algorithms) for the defect elimination,
- defect elimination with the help of programs which realise the chosen algorithms,
- visual estimation of the restored image on the display screen,
- output of the received image to the photographic film and its recording on the magnetic tape.

The defects analysis by the means of electronic computer, the estimation of the mathematical models parameters and the choice of the algorithm for defect elimination are the very important stages of the automated restoration of phototelemetric images. The defects are estimated by their quantitative characteristics ; for example, the gradation defects are ascertained by the histograms of the optical density distribution ; the sharpness defects by the wideness of the blurring zone in the image of object which had earlier sharp contours.

The ASPPD software realises various algorithms for the elimination of each type of defect. The result of restoration depends directly on the correct choice of the algorithm.

The elimination of defects by the means of special programs is carried out on the basis of the numerical value selection of the processing parameters. The estimation of parameters is carried out by the test restoration of image and by the operative representation of mathematical conversion results in the visual form on the display screen. After the choice of programs and the experimental estimation of their parameters, all the images are processed on the electronic computer and, then, the visual analysis and estimation of the received results are carried out on the display screen.

The output of restored image to the photographic film is realised by a special arrangement for photographic images output.

By the means of the ASPPD, the scientific workers of the RSDRC carried out the restoration of phototelevision images of surfaces of the Moon in different foreshortenings (including the first images of it's reverse side (3)), of Mars and Venus (these images were transmitted to the Earth by the Soviet automatic interplanetary probes in 1959-1982) and also of Phobos (1987). The restoration consisted in the filtration of pulses and strips, the elimination of local defects and noises and the scale transformation.

After the restoration we may note the defect elimination and a considerable improvement of the quality ; all this allows to unmask a number of details which had been invisible before.

Further development of the space filming equipment led to the necessity of additional software processing for the restoration of modern phototelevision images ; for example, these ones which had been transmitted from the « Phobos-2 » automatic interplanetary probe (1987). In this case, the survey was carried out by the arrangement with charge communication ; it led to a considerable

heterogeneity of background in the image stills. Earlier, this defect could be eliminated in the ASPPD with the help of the momentary or double signal processing by the one-dimensional recursive filter (4). But because of the fact that Phobos images turned out with a very important contrast and with very sharp contours, such processing proved to be unacceptable.

The researches showed that the background for such images could be presented in the following form:

$D = G(x, y) = a + a\,x + a\,y + a\,x + a\,xy + a\,y$ [1].

were x, y = Cartesian coordinates on the image ; a - a = coefficients which are constant for all the points of the given still.

These coefficients can be determined by the method of least squares by the image brightness taken in sufficiently large number of points (not less than 12) which are distributed at the still evenly. During the selection of points, it is necessary to avoid the specific places with very dark or very bright elements. The method of least squares allows, not only to find the coefficients, but also to estimate their exactness. The image at the given still can be presented as a certain function of coordinates, in the following form :

$I = F(x, y)$ [2].

Then the calculation of background heterogeneity can be described as the difference :

$I = I - D + C = F(x, y) - G(x, y) + C$ [3].

For the digital images, the calculations by the formula [3] come to the point-by-point subtraction of background brightness found by the formula [1] from the initial background brightness and to addition of the empirical constant C, for the being of received brightness I in necessary diapason (from 0 up to 255).

Such processing was carried out for 14 Phobos images and it showed the considerable improvement of images quality. The little details which earlier had been masked by the background heterogeneity now became visible.

For the preservation of information about PTD, the ASPPD laboratory created (on the basis of « dBASE IV » system for database control) the MAGTYPE database ; it contains various information about visualised stills of photo-television images which were restored in this laboratory and are kept at the RSDRC (a tape number, a file name, dimensions, date of restoration etc.). It is possible to turn to this database with the following inquiries:

- data selection at the files of visualised PTD stills (at concrete file, at a few ones, at a few files with given parameters),
- data selection at the other database attributes (at concrete ones, at a few ones and at a few ones with given parameters).

Further development of the ASPPD will be carried out in the direction of rise of the level of automation for the restoration on the basis of personal computers and broadening of the opportunities for the using of this system for the processing of phototelemetric documents which are not phototelevision images. Such documents are also taken to the state storage in the RSDRC. The uniqueness and the historicity of PTD demand to process the new software for its thorough scientific study and analysis of the development of physical processes in the Solar system by the means of comparison of the images received in different time.

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A. N. Balakirev
N. E. Moskalenko
Kh. G. Tadjidinov
Russian Space Data Scientific Research Center
Moscow
Russia