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New processing of Luna archive panoramas and geologic assessment of the Lunokhod landing sites

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Abstract

From the successful Soviet lunar missions Luna-9, Luna-13, Luna-17 (Lunokhod-1), Luna-20 and Luna-21 (Lunokhod-2) about 350 panoramas of the lunar surface were returned [2, 5, 11]. Unfortunately, only a small part of the data from the missions has been converted to digital form and made available for the scientific community. The main purpose of the FP7-project "PRoViDE" is to give scientists and the public access to data products from planetary surfaces of uniform quality (http://www.provide-space.eu/). The MIIGAiK Extraterrestrial Laboratory (MExLab) task is to re-process lunar panoramas based on modern techniques [9], and then to subject them to more detailed geologic analyses [1, 3, 4].

1. Introduction

In January 1973, more than 40 years ago, the Soviet spacecraft Luna-21 was launched and deployed Lunokhod-2 which moved along a 37 km traverse on the lunar surface. Its camera took several tens of panoramic images. A main challenge of all panorama processing is that interior and exterior orientation parameters (focal length, distortion, coordinates of principal points, pixel size, locations of panorama stations) are lost. Also, the panoramas have low resolution and suffer from noise (e.g. vertical linear artifacts) which aggravate automatic processing of the data. Stereo overlap – crucial for object reconstruction – is limited, ~ 50%. Using modern GIS tools and supported by LRO image data products obtained from orbit, we carried out mapping and geoanalyses of the Luna-17 landing site area**,** beginning with the Lunokhod-1 route [10]. Approximate coordinates of surveying points from which some of the panoramic images during Luna-17 mission were taken, were identified. We have also proposed new names for craters along Lunokhod-1 route that facilitate identification and retrieval of objects in geological discussions.

2. Method

We make an attempt to recover lost Lunokhod camera calibration parameters and to obtain precise panorama reconstructions.

2.1 Determination of internal camera orientation

To calculate the internal camera orientation parameters, we apply iterative methods using the known sizes of objects in the images, such as the landing module of Luna-17, for which data were provided by members of the Soviet lunar program. Images showing the landing module of Luna-17 from different points of view were selected. Using manually identified tie-points measurements and bundle-block adjustments, a photogrammetric model is established based on the dimensions of the structures of the Luna-17 lander (such as width and length of the ladder). The apparent spacing of Lunokhod wheel tracks plays an important role. This "self-calibration" helps recover lost geometric parameters of the camera.

2.2 Exterior camera orientation and orthorectification of panoramas

Next, we recover exterior orientation parameters with purposes of panoramas orthorectification. First, all separate fragments of panoramas will be manually combined into a full panoramic image. Panoramas were obtained in a spherical projection and have vertical dimension of 30° and a maximum angular width of the horizontal panoramas of ~180°. The rover camera was tilted from the horizontal surface to -15° down. Using the known height of the camera

(~0.8 m) the horizontal position Lunokhod's closest visible point is 1.4 m. Typically, we compute metric scale grids for the horizontal position of the Lunokhod on an ideal flat surface.

Knowing the geometric properties of an ideal symmetric panorama in a perfectly flat terrain, we can measure any tilt of the Lunokhod and its camera. Correcting for such tilt, we can transform individual panoramas to a local horizontal coordinate system, Several iterations of the adjustment of the images are required to obtain exact orientation (azimuth and zenith of the camera). At the last stage, attempts are made to determine the camera position by comparing features in the resulting panorama (e.g., craters or boulders) with the LRO orthoimages.

2.3 Geology and morphology assessment of lunar surface

The general task of geological and morphological study of lunar panoramas is to identify the structure and processes of the evolution of elements of surface topography [6, 7]. The geologic description of panoramas could include: 1) the description of terrain around - mare, highland; 2) characteristics of relief, such as flat smooth plains, or rugged terrain; 3) the prominent geologic objects – big craters, mountains, large rock fragments; 4) the description of neighboring craters: their size, class, type; 5) the description of rock fragments: their size, class, type; 6) the description of soil, including its structure and character of rover tracks.

3. Summary and Conclusions

Based on methods described above we derived new digital data products based on archived Lunar panoramas: 1) parameters of interior and exterior orientation for Lunokhod's camera; 2) 3D surface reconstruction based on stereo-images [9]; 3) panoramic images based on spherical projection for visual geologic analyses and measurements; 4) orthopanoramas which will be implemented for small-scale mapping (cm level) and detailed geology description including comparison of neighboring orthoimages; 6) results of geological and morphological study which will be included into metadata. The first results of the photogrammetry image processing of lunar panoramas and their GIS-analyses will be available through MExlab Geoportal, which provides a spatial context of the data and metadata access [8].

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