A New Global Image of the Moon by Chinese Chang'E Probe.C.L.Li, J.J.Liu, L. L. Mu, X. Ren, Y. L. Zou, H. B. Zhang, C. LU, J. Z. Liu, W. Zuo, Y. Su, W. B. Wen, W. Bian, X. D. Zou, Z. Y. Ouyang., National Astronomical Observatories, Chinese Academy of Sciences, Beijing 100012, PR China. Correspondence: licl@bao.ac.cn.

Introduction: China launched its first lunar probe satellite, Chang'E-1 (abbreviate, CE-1), at10:05 GMT, October 24, 2007. One of the Scientific Objectives of CE-1 is to obtain 3D images of the lunar surface. CE-1 uses a three-line array CCD stereo camera to map the whole surface of the Moon in VIS (0.5μm ～ 0.75μm), could provide a uniformal in resolution and global data for lunar topographical analysis, selenological research and origin study of Moon. These images would be also an important data of selection of landing sites of lander and rover in our next lunar exploration phase.

The scientific data acquired by 8 instruments were collected by a 50m and a 40m dish simultaneously, then the signal were demodulated, decoded, processed. Up to now, global image data of the whole Moon have landed. The first image from CE-1 was released on December 26, 2007. After about one year, the first vision of Global Map of the Moon was released on December 12, 2008.

Data description: All the CCD image data are acquired by a three-line-array CCD stereo camera((Figure 1)). It means that we could get 3 planar images for the same object from three different view angles (forward, nadir and backward), which makes it possible to get DEM data and orthophoto image data of the whole Lunar Surface. The CE-1's nominal working orbit is a circular polar orbit of 200Km altitude.The orbital period is about 28 Earth days.[1].

Figure 1. Artistic figure of CE-1's CCD Stereo Camera Mapping the Moon.

The spatial resolution of the CCD image is about 120m and swath width is about 60 km. A scan track of image has about 40 000 line data, and each line data including 512 pixels. In the scan direction, the image overlap ratio is about 41% on the equator. From November 20, 2007, to July 1, 2008, the CCD camera successfully mapped the whole surface of the Moon, including the polar areas, where the solar illumination is quietly weak 589 tracks of image data, most of which is vertical view angle, have been used to make a global map of the Moon. . For ortho-rectification, the LAM (Laser Altitude Meter) data were adapted to calculate DEM, by interpolating evenly about 3 million points.

Data preprocessing: Generally, orbital image data are distinctly affected by attitude, solar elevation angle, incidence angle, view angle, exposure time and so on. Data preprocessing is to eliminate the above factor in order to get uniform data in the same situation. The data preprocessing for lunar image includes radio-, geo-, and photo- metric correction.

(1)Radiometric calibration: It includes offset and subtraction of dark current, exposure time normalization, gain calibration, and flat field correction. Because of solar illustration, we had to use different exposure times for the polar region and low latitude region, which leads to a strong DN (Digital Number) difference. To remove the difference, an exposure time of 3.2 microseconds is assigned as the uniform exposure time. A calibration process could provide the correction function for camera gain and offset operating modes.

(2) Geometric correction: Geometric correction is very important for lunar image processing. Geometric parameters are all derived from the telemetric data, mainly including orbit elements and satellite attitude.

Geometric control frame creation: It is not necessary to calibrate the geometric position pixel by pixel. In order to reduce computation and facilitate projecting, we selected limited points to control the geometric distortion. After several tests, we found an ideal control frame which can keep the location with enough accuracy. The control frame for each image is made up of grids. Each grid has 4 control points, meaning that a control frame has no more than 2000 control points.

Projection selection: In our projecting model, the Moon is assigned as a "spherical body" with a radius of 1737.4km. Because the projection distinctly affects the geometry accuracy, after testing several different warping methods, the Sinusoidal Area-equal Projection was found appropriate and be selected. In our projection, the centre longitude of the image was assigned as the centre longitude of the projection. So, different image has different centre project longitude.

Topographical correction: The Moon has a topographic range of 16~18km, which could lead to position offset of the images. The CE-1 carried a Laser Altitude Meter to measure the distance between the orbiter and the surface of the Moon, in a frequency of 1 Hz. The LAM data was used to reduce position offset.

After these steps, we can obtain the angle parameters for photometric correction and location of control points for projecting.

(3)Photometric correction: In order to get a comparable radiance of lunar surface, a improved Lommel-Seeliger Photometric model is used, which can eliminate or remove those effects caused by solar incidence angle , view angle and solar irradiation condition.

Procedure of Image Map-making: After above preprocessing, we got only the single track of radiance image data, which can't been mosaicked together because they have not uniform geo-reference. This processing is just to warp all track of images and create a single global map.

Projecting: Projecting of the images is based on the above geometric control frame and Thin Spline Correction model. To get smooth images, we used cubic convolution resampling method.

As shown as above, each track of images has different projecting center longitude, which means that all the individual images should be projected in the same map coordinate system. So we had to transform the images with the same projection and parameters to put them together. The surface of Moon was divided into three regions: north polar region (60°~90°), low latitude region (-70°~70°) and south polar region (-60°~-90°). The polar images are all transformed into a polar stereographic projection. The Mercator Projection was used for the low latitude region with offset 0, center longitude 0, standard parallel 35, in order to keep their geometric characters of lunar surface as fully as possible.

Geometric positioning and Mosaicking: After projecting and projection transmission, the geometric matching of the same point in the neighbor images was checked detailedly. The offset of the match points of 94% is no more than 4 pixels. In order to correct the position offset, we assume half images data as base images, others were warped with Tie Points between neighbor images. Then, all the images can be warped and put together without relative position offset.

Cartographic editing: After The last step of mapping is to add and edit essential supplementary constituents for the image map. The constituents of the globe image map of the Moon include title of the map, main scale, grid of latitude and longitude, essential geographic names, and some instruction.

Results and Summary: The global image map of the Moon is shown in Figure 2. On the left is the low latitude region (-70°~70°). The upper right is north polar region (60°~90°), and the lower right is south image (-60°~-90°). This image map covers the whole Moon surface at uniform spatial resolution of 120m.

The Chinese global image map of the Moon provides a new, highly precise and global data for lunar topographic demonstration and research. Because the CCD data is based on the three-line CCD stereo camera, this makes it possible to map the whole Moon in 3D at a very high resolution The next step is to extract the DEM data using the three line data by the photogrammetry method. In the geologic and geographic analysis, and selection of landing sites for the lunar lander and rover, the new image and 3D map will play an important role.

References: [1]Yongchun Zheng, Ziyuan Ouyang, Chunlai Li, Jianzhong Liu, Yongliao Zou(2008) Planetary and Space Science 56 881－886.

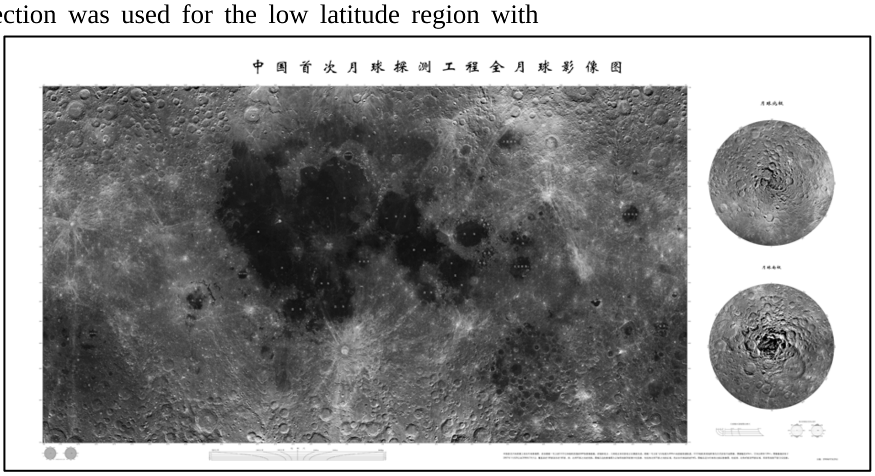

Figure 2. Global Lunar Image Map