Journal of Geomatics Vol. 13, No. 1, April 2019

Techniques developed for large area Mars image mosaic using ISRO's Mars Color Camera (MCC) data

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(Received: Jan 02, 2019; in final form: May 13, 2019)

Abstract: Multispectral remote sensing planetary datasets covering same and adjacent locations at different acquisition times allow for image mosaicking to study local, regional and large-scale processes of planetary bodies. ISRO's Mars Orbiter Mission launched on November 5th 2013 increases our curiosity to examine planet Mars using scientific instruments on-board MOM. Mars Color Camera (MCC) is among the five science payloads which operates in visible range (0.4 µm to 0.7 µm) to image the surface feature of mars with varying resolutions and scales from highly elliptical orbit. The systematic processing procedure for mosaicking MCC images primarily requires radiometrically corrected MCC data with areographic co-ordinates tagged in planetary data system (PDS) standard as input and involves techniques of image processing domain that includes geometric and photometric corrections, image registration, blending and normalization. These techniques are described in this paper to generate mosaic product of Mars terrain using different MCC datasets at variety of scales to illustrate compositional diversity, morphological changes to view the features of Mars and geological issues using different perspectives. In addition, the techniques are also used to generate planet level seamless mosaic, North Pole mosaic using available MCC datasets to monitor dynamic behavior of dust devils/storms and cloud conditions over larger area of Mars.

Key words: Image Mosaic, Mars Color Camera, Photometric Correction, Image Registration, PDS

1. Introduction

Mars Color Camera (MCC) images obtained from Mars Orbiter Mission (MOM) are gaining scientific popularity since Mars Orbiter Mission (MOM) insertion into an elliptical orbit around Mars on 24th Sep, 2014 (Moorthi et al., 2015; Arya et al., 2015). MOM is still active beyond four years in orbit, the coverages from MCC are sufficient to begin constructing mosaic products on a regional and global scale. MCC is a RGB Bayer camera which operates in visible range (0.4 to 0.7 µm). The detector array of MCC has 2048x2048 elements on a pixel pitch of 5.5µ. MCC imaging is influenced by the special characteristics of MOM's orbit, which is highly elliptical with a periapsis of 261 km and an apoapsis of 78000 km. As a consequence, the ground resolution of MCC images varies from 15m to 4 km that can map a specific crater with more feature details to the full disc images covering large area of Mars in coarser resolution (MCC Team. 2013).

Multiple MCC frames taken at different time can stitch together at areoreferenced space (equivalent to georeferencing of Earth observation data) to generate any mosaic product. The construction and use of MCC mosaic datasets can increase the present understanding of Mars in many aspects that include geo-morphological studies, change detection, dust devil/clouds at different locations, crater counting, active processes, climate and geological history. The systematic data processing procedure to create large scale mosaics is illustrated in the subsequent sections of this paper and present some unique MCC mosaics that can cover the longest canyon system, a large shield volcano and multiple craters together.

2. Data processing steps

MCC data processing system is an automation intensive software system that processes instrument data for edited and calibrated products, derives meta data about mission events, spacecraft operations, instrument operations, processing parameters, orbit and housekeeping details from ancillary data to generate data products following PDS standards (Moorthi et al., 2015). The MOM data Processing system is ingested with decompressed, formatted, time tagged MCC raw data along with orbit and attitude information.

2.1 Radiometric processing

The first step involves radiometric correction that includes photo response non-uniformity correction (PRNU) using pre-launch calibration data sets and then demosaic all colors at every pixel locations from Bayer filter mosaic. The aim of a demosaicing algorithm is to reconstruct a full color image from the spatially under sampled color channels output from the color filter array (CFA) (Roy et al., 2014).

2.2 Geometric processing

The next step is to compute areographic coordinates of Mars for every pixel using the orbit and attitude information provided along with the data. Areographic coordinates should be precise enough to locate DEM height, demands an extra procedure enough to adjust the geometric accuracy of the mapping using a Mars image mosaic of known accuracy. Mars Digital Image Model (MDIM) 2.1 is a widely used Mars reference image mosaic for asserting location accuracies by Mars science communities (Som et al., 2008). The MDIM 2.1 is a 231 meters/pixel global Viking/Mariner mosaic of Mars having improved geodetic accuracy from its earlier version. Geometrically, MDIM 2.1 is an orthoimage dataset, draped on the Mars Orbiter Laser Altimeter (MOLA)-derived radius model (Archinal et al., 2004). MCC images are co-registered with respect to MDIM 2.1 making it geometrically confirming to MDIM and MOLA data sets. The image registration automatically detect and match features, estimate transformation between MCC and MDIM 2.1 to correct the input MCC images. Registered MCC images ensure geometric features continuity between adjacent scenes which is pre-requisite for large area mosaic (Misra et al., 2012).

2.3 SPICE computations

The MCC data processing also uses SPICE kernels to compute photometric angles, solar angles and sensor view angles at every MCC pixel location. The SPICE kernels are structured parameter files that describe, among other things, the ephemeris and attitude of the spacecraft, the spatial orientation of the instrument, the ephemeris and physical parameters of the Earth, Mars and other natural bodies in the Solar System, the relationship between spacecraft time and time as measured on Earth, and the locations and orientations of ground stations. SPICE kernel files are intended for use with the SPICE software library, which contains functions that perform computations for space mission-related and astronomical applications (Action et al., 1998).

2.4 Topographic correction

MCC images are also corrected for topographic effects to normalize the radiance measures before considering the data for science analysis (Smith et al., 1999). It is proposed here to use non Lambertian Minnaert semi empirical approach for correcting MCC image photometry further used for deriving results for Mars surface science. The methodology outlined here uses terrain parameters such as slope and aspect values derived from MOLA DEM to compute local illumination angle. Topographically corrected images were evaluated for the improvement in its radiometry quantitatively and it is found to reduce topographic shading and improve the overall image quality (Misra et al., 2015).

3. Mosaic data selection and processing

Image mosaicking is initiated with the selection of high quality and well calibrated data. During the MOM mission, images were both systematically and priority targeted, potentially covering the same area on the planet many times over. Prior to mosaicking, visual examination of every image is often included as an additional step. Data that are often excluded include images containing elevated line-to line or white noise and excessive repeated dropouts, which makes blending of several images difficult, and images collected during periods of high atmospheric dust condition where the overall contrast of the image is reduced. Datasets are selected based on highest visual quality and other lower quality data is removed, reducing the probability of blending poorly registered data. The sequence of steps performed for mosaic processing is described in the below sub-sections.

3.1 Contrast stretching

Mosaic processing is ingested with MCC reduced data records (RDR) available in PDS standard, which is radiometrically, geometrically and topographically corrected data derived from MCC experimental data record (EDR). In order to display the data for viewing, linear contrast stretch must be applied to scale the intensity of the data and maximize the dynamic range. Linear contrast stretching for normalization attempts to improve an image by stretching the range of intensity values it contains to make full use of possible values. Contrast stretching is restricted to a linear mapping of input to output values. Linear contrast stretch is used in this work for stretching that maximizes the spectral variation while retaining most of the morphological context. The Figure-1 shows original MCC image with no stretch and MCC image with linear contrast stretch for better understanding. In the blending process, MCC datasets are intelligently interwoven by incorporating information from overlapping pixels using two dimensional linear ramp.

In the first step, overlap region is extracted between adjacent MCC images using polygon intersection in areographic space. According to the overlap region statistics between the images, normalized weighting factors are computed which is applied to the subsequent image to generate seamless MCC mosaic. The blending algorithm does not blend all MCC images at a time rather a pair is blended into an output and the final mosaic generated by taking the average intensities of overlapping images (Edwards et al., 2011).

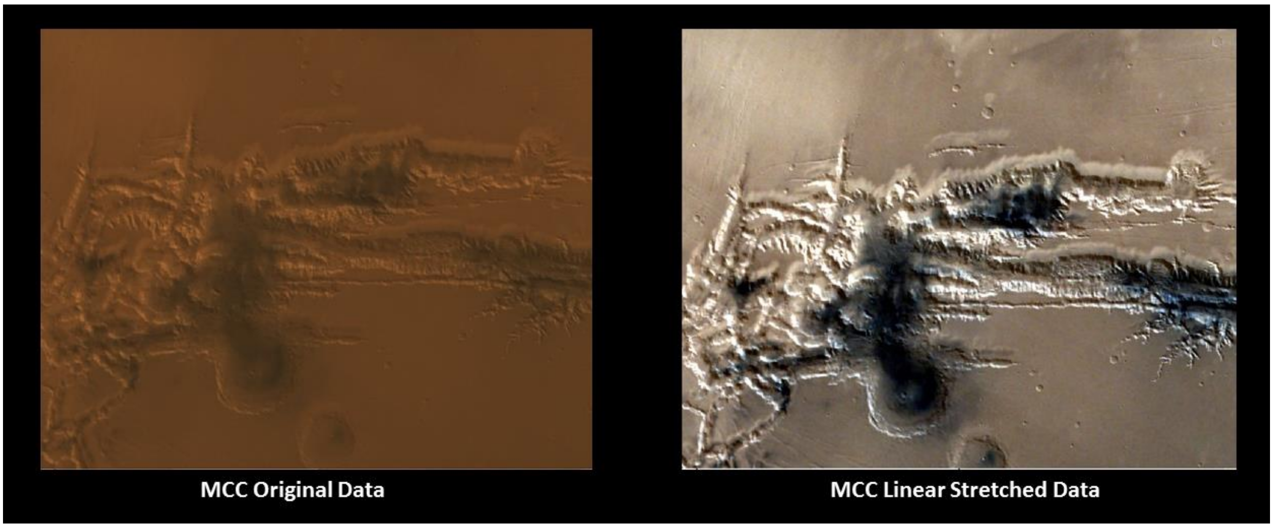

Figure 1: MCC contrast stretch for data viewing (Region: part of Valles Marineris)

3.2 Image to image blending

To summarize, topographic correction is applied before linear stretch and then multi-dimensional blend is applied to be inserted into the final mosaic area.

4. MCC mosaic processing workflow

The processing workflow is divided into three major processing stages. In the first stage of processing MCC datasets are radiometrically corrected. In geometric processing stage, MCC data is tagged with areographic coordinates and photometric angles are derived from SPICE kernels. Automatic image registration with MDIM 2.1 standard reference is executed to improve the absolute location accuracy of the MCC product which is a pre-requisite for image mosaicking. Topographically corrected MCC data sets can better resolved different features than its uncorrected counterpart. The Figure-2 (Mangala Valles) clearly show a flow pattern with channel bar in the MCC image indicating release of vast quantities of water in this area by catastrophic floods. Topographic correction better demarked the features for scientific analysis. The images shown in figure 1 and figure 2 are linearly stretched for better visual analysis.

In the final stage of mosaic procedure images are picked automatically for mosaic construction, contrast stretched and blended as depicted in figure 3.

5. Results

The MCC mosaic product at regional scale and global scale aid better understanding of Mars. At regional scale, Valles Marineris Grand Canyon system mosaic is generated. The Valles Marineris is a large tectonic crack present on the Martian crust running up-to a length of around 4000km, 200 km wide and 7 km deep. Figure 4 shows MCC multi-scene images (from Nov, 2014 acquisitions) mosaic portraying complete Valles Marineris feature produced by applying geometric and radiometric corrections. As proposed, different canyons in the Valles Marineris are seen in MCC image such as Ophir Chasma, Hydrae Chasma and Melas Chasma

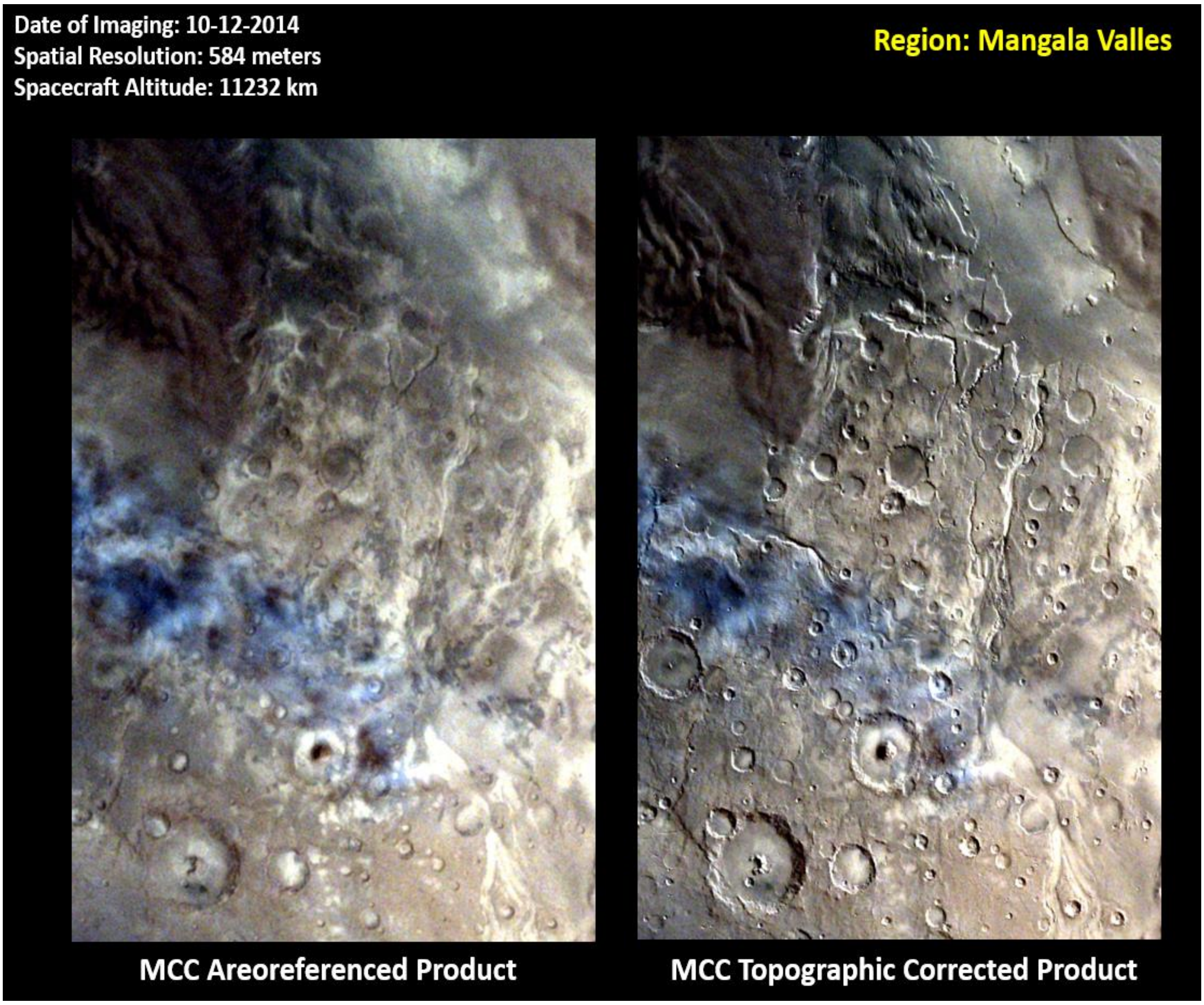

Figure 2: Comparison of MCC original Areoreferenced image (Left) and MCC topographic corrected image (Right) (Mars Region: Mangala Valles)

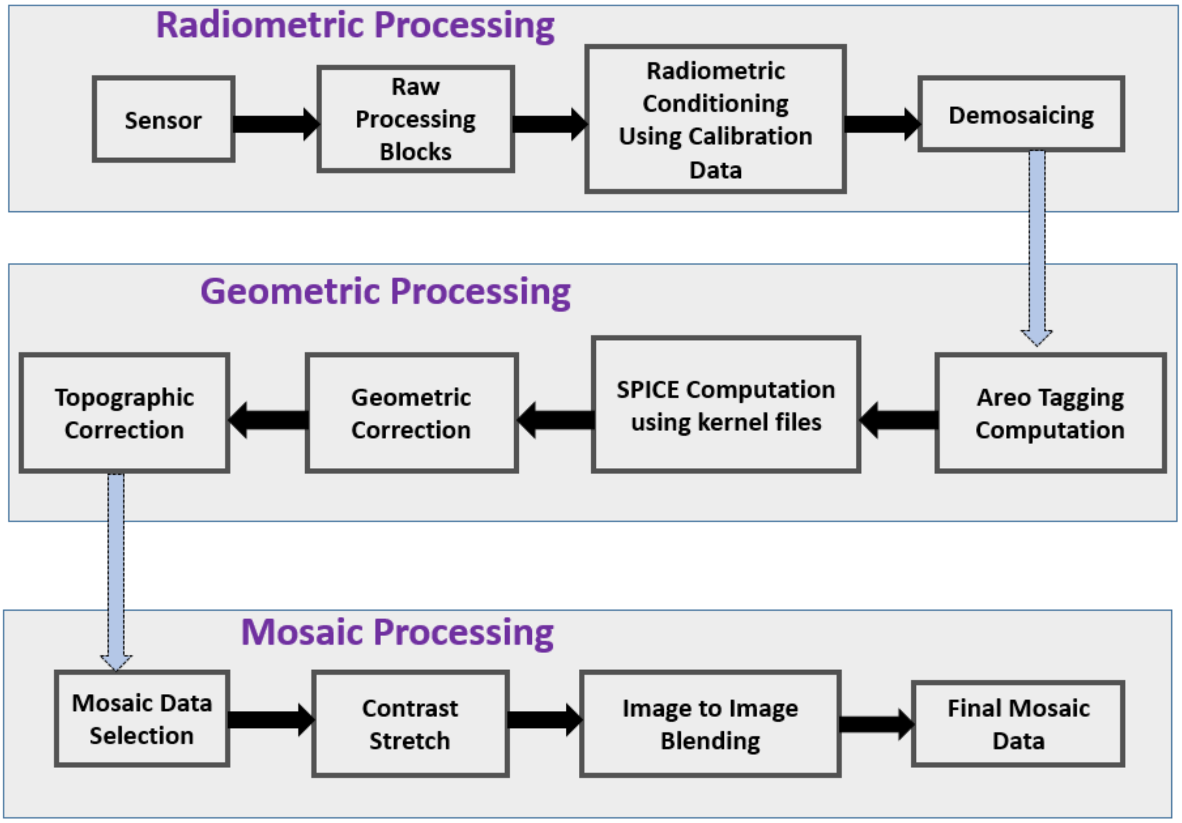

Figure 3: MCC mosaic processing workflow

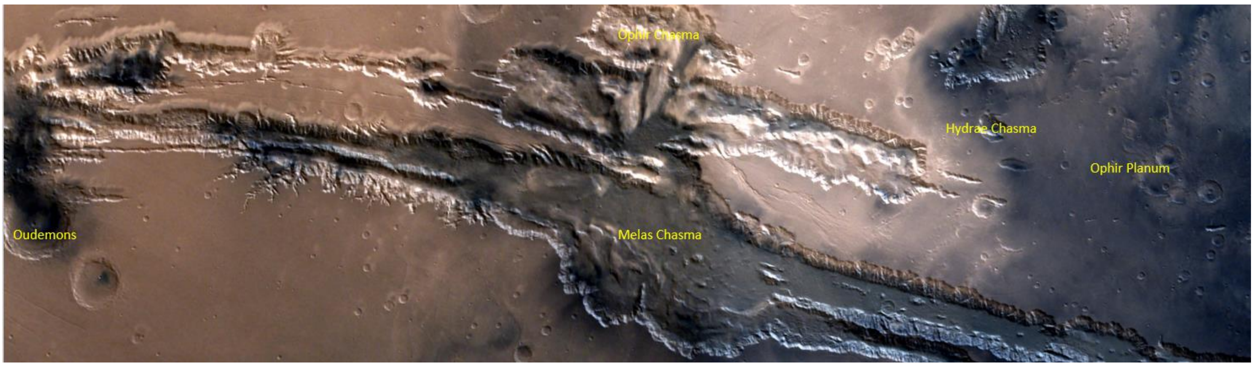

Figure 4: Valles Marineris mosaic using MCC datasets

At global scale, MCC full disc images are used which are actually obtained in perspective view. These images have been rectified using geometric correction steps including a map projection step. Each one of the full disc images covers partial portion of the Mars disc but not complete. While mosaicking the images, relative geometric differences were removed by additional image registration procedure. A seamless Mars full disc canvas was prepared shown in figure 5, adjusting the colour differences between images. Eight full disc images obtained during Dec2015 and Jan 2016 MCC were used. The Pixel Resolution was uniformly scaled to 4 km pixels.

Figure 5 also shows MCC 3D view by warping global mosaic over Mars globe. The global mosaic in figure 5 still left with unbalanced colors. Further improvements can be bought by fine-tuning the present procedure.

Conclusion

MCC mosaic processing system can generate visually appealing mosaics using multiple MCC images acquired at different times covering large area of Mars. The systematic processing of MCC datasets to generate different views of Mars can be used for geological change detection studies. The construction of the mosaics using the techniques described in this paper, provide the ability to view the surface of Mars and geologic problems through many different perspectives. The current processing system only generate mosaic product for visual interpretation and geo-morphological analysis. The future work may use advance techniques for colour processing of Mars images.

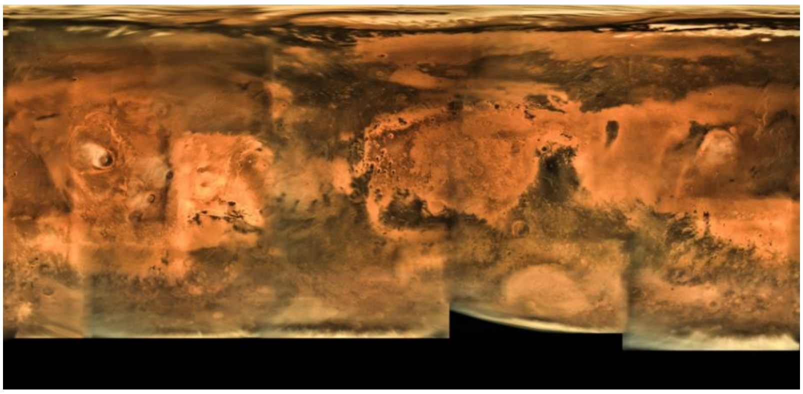


Figure 5: MCC global mosaic using full disc images and MCC 3D view generated using mosaic

Acknowledgements

The authors acknowledge Shri D K Das, Director, Space Applications Centre (SAC), ISRO for his encouragement in our research activities. The authors also thank other team members of optical data processing for their support during the course of this work.

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