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A New Method of Mosaicking Context Camera (CTX) Images for the Geomorphological Study of Martian Landscape

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Abstract

Various spacecraft and satellites from the world's best space agencies are exploring Mars since 1970, constantly with great ability to capture the maximum amount of dataset for a better understanding of the red planet. In this paper, we propose a new method for making a mosaic of Mars Reconnaissance Orbiter (MRO) spacecraft payload Context Camera (CTX) images. In this procedure, we used ERDAS Imagine for image rectification and mosaicking as a tool for image processing, which is a new and unique method of generating a mosaic of thousands of CTX images to visualize the large-scale areas. The output product will be applicable for mapping of Martian geomorphological features, 2D mapping of the linear feature with high resolution, crater counting, and morphometric analysis to a certain extent.

Keywords

Mosaicking, ERDAS Imagine, Context Camera (CTX) Images, Mapping

1. Introduction

Planet Mars has an opulence of different satellite datasets, which have been acquired since the beginning of the Mariner Program by NASA's Jet Propulsion Laboratory to explore the Red planet to the present day. Images have been acquired by different imaging cameras and spectrometers such as the Viking Orbiter Visual Imaging Subsystems (VIS) [1], the Mars Orbiter Camera (MOC) of Mars Global Surveyor [2], the Thermal Emission Imaging Systems (THEMIS) [3] [4] using multispectral thermal-infrared and visible/near-infrared images, the High-Resolution Stereo Camera (HRSC) [5] onboard ESA's Mars Express

Mission bridging the gap between medium to low resolution coverage and the very high-resolution images of the MOC, the Mars Reconnaissance Orbiters High Resolution Imaging Science Experiment (HiRISE) [6], Context Imager (CTX) [7] on the Mars Reconnaissance Orbiter (MRO), the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) [8] having hyperspectral imager on the Mars Reconnaissance Orbiter (MRO), and Mars Color Camera (MCC) onboard Mars Orbiter Mission [9]. A number of rover/lander missions set out on Mars since the 1970s have revolutionized the way we understand the Planet. Furthermore, the new era of the rover and rover helicopter combination onboard Perseverance Rover and Ingenuity will, for the first time, fly on Mars and help in providing new and unique views of the Planet, increasing our knowledge to many folds.

The Mars Reconnaissance Orbiter (MRO) Context Camera (CTX) is designed to obtain grayscale (black and white) images, captures broadband of visible light from 500 to 800 nanometers in wavelength of Mars at 6 meters per pixel scale from an altitude of 300 km (186 miles) over a swath of 30 km (18.6 miles). The Context Camera, called CTX, provides a view of the terrain around smaller rock and mineral targets studied by other cameras on the Mars Reconnaissance Orbiter [7]. CTX (Context Camera) makes observations simultaneously with high-resolution images collected by HiRISE and data collected by the mineral-finding CRISM spectrometer. CTX provides a broader context for the data collected by the other two instruments. Scientists examine details of rocks and mineral fields with the other instruments, while CTX provides a bigger-picture view of the terrain. Together HiRISE, CRISM, and CTX are an extremely powerful toolset for terrain mapping, rock identification, and mineral fields on the Martian surface. For example, many of the layered terrains observed by the Mars Orbital Camera [2] on the Mars Global Surveyor spacecraft could be water-deposited sediments. They could also be layers of volcanic lavas, ash, or wind deposited sediments.

To discern the different facets of Martian studies like the currently active processes, climatic changes, geomorphic and geologic history, magnetic anomalies, regolith, thermophysical properties, and life and water, the widespread satellite data sets have increased our present understanding enormously. However, the images provided by different cameras on different satellites do not present broad-scale coverage in a single image. They only provide meter to kilometer scale snapshots of the terrain. However, an amalgamation of hundreds to thousands of these images makes a powerful tool for scientific investigation. There are very few options for the mosaicking of CTX images for geomorphological study viz. Integrated Software for Imagers and Spectrometers (ISIS) [10] [11] and Mars System of Information (MarSI) [12] in both the method, output product has a reduced resolution than the captured image by the instrument. Here we document the processes that are used to create a single large-scale regional and global mosaic from thousands of individual Context Camera Images (CTX) to understand better large-scale coverage and terrain response to natural processes in the area of concern. Further, the output product can be used for the morphometric analysis of the Martian landscape and large-scale visualization of the geomorphic features.

2. Methodology

Earth Resources Data Analysis System (ERDAS) Working Environment

The mosaicking of images with the ERDAS platform is often common for the earth dataset with preferential geographic data and a pre-assigned geographic co-ordinate system. For the processing of Mars images selecting the datum for further processing is an important step. In the working procedure, ERDAS Imagine has been used to process Context Camera Image (CTX) (length of 160 km and swath of 30 km) to generate large scale global mosaics from individual strip images (Figure 1 and Table 1). To setup the working environment for ERDAS Imagine, firstly, the images have to be converted to a format compatible with ERDAS Imagine Platform (viz., *.img) for the mosaicking. The visual examination of every image is included as an additional step. For CTX images, an ellipsoidal coordinates system Mars 2000, builtin ERDAS Imagine, is used. ERDAS software package provides the ability to load CTX image data (among various other file

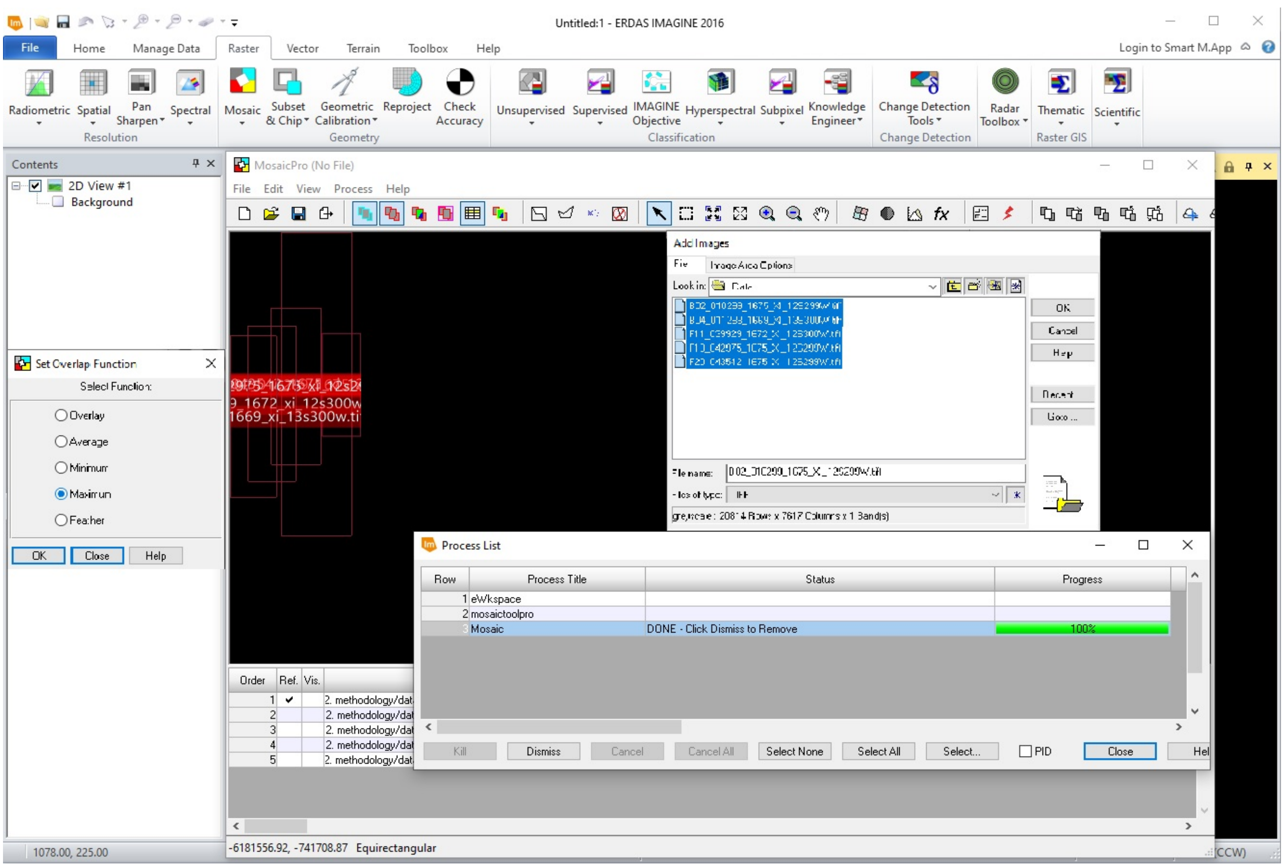

Figure 1. Image mosaic computer algorithm in ERDAS Imagine platform mosaic making tool.

Table 1. CTX image details used for the mosaicking (https://pds.nasa.gov/).

Image ID	F11_039929_1672_XI_12S300W	B04_011288_1669_XI_13S300W	F18_042975_1675_XI_12S299W	F20_043542_1675_XI_12S299W	B02_010299_1675_XI_12S299W
Center Lat	−12.92˚	−13.15˚	−12.61˚	−12.57˚	−12.58˚
Center Lon	59.82˚	59.51˚	60.25˚	60.62˚	61.02˚
Scaled Pixel Width	5.84 m	5.19 m	5.93 m	6.01 m	5.22 m
Incidence Angle	38.86˚	59.2˚	54.24˚	58.51˚	61.76˚
Emission Angle	19.41˚	2.71˚	20.92˚	22.11˚	1.68˚
Orbit	39,929	11,288	42,975	43,542	10,299
Spacecraft Altitude	260.84 km	259.02 km	260.02 km	259.26 km	260.92 km
Target Name	MARS	MARS	MARS	MARS	MARS
Data Quality	OK	OK	OK	OK	OK
Scaled Image Height	161.44 km	168.02 km	161.76 km	317.43 km	105.69 km
Mission Phase	ESP	ESP	ESP	ESP	PSP

formats). The software can manage the files into the required format and extract the information for mosaicking, stacking images, set overlap to maximum, including mapping parameters such as the coordinate system, the line, and sample projection offset, resolution/map scale, image width, and height, etc. as well as quantitative spectral data

All image IDs are uploaded in a pop-up window (Figure 1) with a footprint in the red line border, which needs to be selected for mosaicking. If a single band mosaic is desired, then a single band can be extracted from the images after loading preferred images selected for a specific area. Further, we need to run the command: maximum overlap to get the same resolution output before running the mosaic tool command.

The CTX image swath onboard Mars Reconnaissance Orbiter (MRO) is undersized to visualize the major morphological features, identification, and classification. A prerequisite is large scale coverage of an area. This requirement is fulfilled by the design algorithm (Figure 1) within the ERDAS platform, allowing the image conversion into large-scale Mosaic. To set an example in this study we have used five Context Camera Images (CTX) (Table 1, Figure 2(a)) of Liris Valles, east of Huygens crater, showing prominent drainages and surficial erosional valley assemblages with very less/younger impact craters on the surface (Figure 2(b)). The output resolution of the mosaicked images remains the same 5 - 6 m/pixel that can be used in any GIS platform with an inbuilt Mars 2000 coordinate system for 2D raster as well as vector mapping. This process can generate mosaics from thousands of CTX images to get global coverage of the planet.

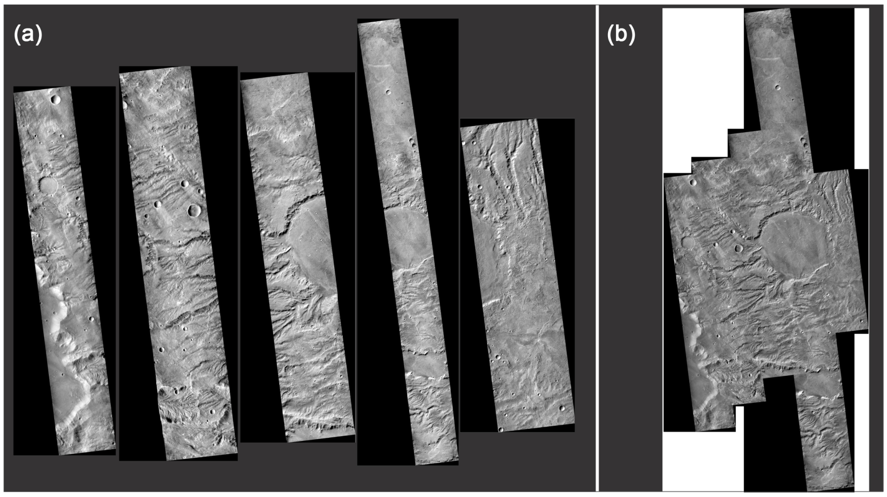

Figure 2. (a) Individual images captured by context camera in strip. (b) Final image mosaic output product of mosaicking procedure.

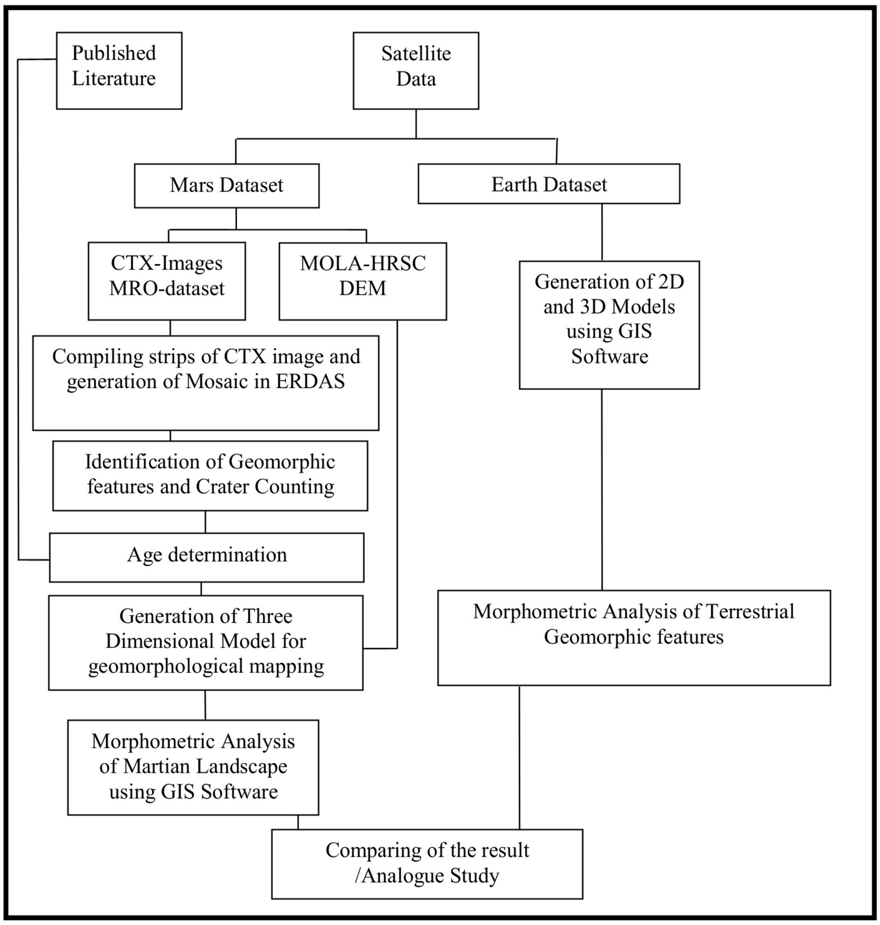

Figure 3. Summary of mosaic making process, their applications in the study of Martian geomorphological features and Earth analogue study.

3. Discussion and Applications

The construction of the mosaics using CTX images on ERDAS platform provides the ability to view the surface of Mars and geologic quandary through many different perceptions. The high-resolution geo-referenced mosaicked imagery of an area will help elucidate a complete view of geologic and geomorphic processes on Mars (**Figure 3**) and help compare the result with Earth data sets.

Furthermore, this technique consents to the mosaicking of global planetary data from Mars and other planetary bodies. This mosaicking knack provides the end-user a product that is both quantitative and qualitative. It can be used relatively easily, and scientific studies are limited to a single image; instead, they can be combinations of several images. These mosaics are the highest resolution (6 m/pixel) global-scale data sets available for Mars.

Geomorphic maps are thematic maps expressing topographical or landform features that rely on observations, comparison, and interpretation. Single images from CTX cam-era give a small exposure of the area, whereas mosaics generated from CTX images using ERDAS Imagine give a panoramic coverage that can be used for landform identification and vector quantities like lineaments, faults, crater rims, etc. [13]. Mosaiced CTX images superimposed with MOLA-HRSC DEM/DTM images can be utilized, enabling separation, model drawing, and understanding 3D aspects for making elevation profiles and cross-section profiles particularly to measure topographic relief and mark the geomorphic units in the study area. The mosaiced CTX images can also be used in morphometric analysis [14] of Martian drainage basins, particularly in identification, characterization, and classification of landforms to know their origin, *i.e.*, fluvial, volcanic, or structural

4. Conclusions

To determine the different aspects of Martian studies widespread, satellite data sets are required. The images provided by different cameras on different satellites present a small-scale coverage image; a unification of numerous images is required. The present study documents the processes that are used to create a single large-scale regional and global mosaic. It discerns:

1) A new method wherein the ERDAS Imagine platform is used to make mosaics from thousands of Context Camera (CTX) images onboard Mars Reconnaissance Orbiter (MRO) spacecraft to visualize the large-scale areas.

2) The mosaic generated will be applicable for mapping of martian geomorphological features, 2D mapping of the linear feature with high resolution, crater counting, and morphometric analysis.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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