INTRODUCTION

Multi-temporal observations are key to detect and analyze surface changes and processes on Mars. Since the 1970s, spacecraft observations have revealed that the surface of Mars is very dynamic [e.g., 1–3]. The modifications are attributed to exogenic processes, including solar activity [4, 5], mass movement [6, 7], the growth and retreat of the polar caps [9, 10], and crater-forming impacts [11]. Observations of these variable features became possible by the increasing number of repeated image acquisitions of the same surface areas. MUTED comprises metadata of all major Mars missions and enables scientists to quickly identify the spatial and multi-temporal coverage of planetary image data from Mars. Images can be searched in temporal and spatial relation to other images at a global scale or for a specific region of interest.

ARCHITECTURE

MUTED is based on free and open source software, and consists of a three-tier architecture. Metadata of the planetary image datasets are included from NASA’s Planetary Data System (PDS) into PostgreSQL database. Additional information, e.g., the number and time span of overlapping images are derived for each image data respectively. A GeoServer translates the metadata stored in the relational database into web map services (WMS) and web features services (WFS). All services are combined and visualized in the web-based user interface (Fig. 1). The user interface was built using HTML, PHP, and Javascript and provides several features for data selection, filtering, and visualization. The multi-temporal coverage, as well as meta data and the spatial and temporal context of the images, are presented on the map or within a timeline.

DATASETS

Metadata pertaining to more than 1.3 million images from various instruments including the Viking Orbiter (VO) [12], the Mars Orbiter Camera (MOC) [13] on board Mars Global Surveyor (MGS), the High Resolution Stereo Camera (HRSC) [14] on board Mars Express (MX), the Thermal Emission Imaging System (THEMIS) [14] on board Mars Odyssey, the Compact Reconnaissance Imaging Spectrometer of Mars (CRISM) [17], the Context Camera (CTX) [18], and the High Resolution Imaging Science Instrument (HiRISE) [19] on board the Mars Reconnaissance Orbiter (MRO) are integrated into the database. The spatial resolution of the integrated images varies from ~25 centimeters to several kilometers per pixel. A global coverage analysis reveals that high-resolution images with a spatial resolution better than 25 meter/pixel cover 99.9% of the surface of Mars (Fig. 2).

DISTRIBUTION

Share areas of interest and data availability with others via a link. The automatically generated permanent link stores the user defined area, datasets as well as filter options. This enables a fast and convenient way to exchange research areas and orbital images with other scientists or save the current progress for future work. An interactive tutorial advises new users how to explore the multi-temporal coverage of Mars with MUTED and informs them about the available data sets.

SCIENTIFIC APPLICATIONS

MUTED supports the identification of orbital images and their spatial and temporal context as a basis for various change detection analyses. In particular, the definition of a timespan between repeated images enables users to discover surface changes caused by very short-term and temporally highly variable processes, e.g., dust devils [16]. The number of images within a certain time period can be specified according to solar longitude, for example to observe seasonal changes and processes [8, 9, 10]. The number of overlapping images can be defined to ensure data availability, e.g., long-term changes of the surface of Mars [16]. MUTED has been used in recent projects on past and recent changes of the martian surface [20, 21, 22]. In particular, the database has been used to identify multi-temporal high-resolution coverage and analyze the formation of slope streaks [20] and gullies throughout the martian year [21]. MUTED has also been used to support the data selection for geological mapping [22]. Due to continuous data acquisition by spacecraft, the amount of image data is steadily increasing and enables further comprehensive analyses of martian surface changes. The flexible structure of MUTED allows for a fast integration of upcoming data sets, e.g., from ESA’s ExoMars Trace Gas Orbiter (TGO) mission.

DATA-DRIVEN-SEARCH

The multi-temporal search enables users to find spatially overlapping images, which are separated by a user-defined temporal interval. Repeat images with a specified time interval (minutes, hours, days) or season (solar longitude) can be identified at a global scale. The spatial and temporal context of the images is presented on the map or within a timeline. Additionally, queries can be listed and exported as text files.

LOCATION-DRIVEN-SEARCH

Using global spectral, topographic or geological information, users are able to define a region of interest and explore the local image coverage. All available orbital images can be filtered by date, season or spatial resolution. By selecting image footprints, metadata, including, e.g., product ID, acquisition time, download links, as well as high-resolution preview images, are presented.

Fig. 2: Global coverage of high resolution images (spatial resolution better than 25 meter/pixel).

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