BIG DATA TOOLS COME TO MARS: CONTENT-BASED ANALYSIS OF MARS ORBITAL IMAGERY.

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Introduction: The volume of data that has been and continues to be acquired by Mars orbital imagers can be unwieldy for individual investigators, especially for studies that focus on a particular phenomenon that is only present in a subset of the data. Current methods for selectively downloading images provide contextual searches (e.g., image timestamp, location, viewing angle, etc.) but not *content-based* searches (what was captured in the image?). It is therefore possible to search for all images of Valles Marineris, but not for all images containing craters.

We have developed automated methods for analyzing and classifying the content of these images. The resulting characterization provides searchable metadata. For the first time, content-based image searching is possible. Further, because the analysis is done on a server, there is no need to download large image files or install any software to get the results. The investigator can then download the original image files only for those found to contain a feature of interest.

Image analysis services: The services we have developed include (1) given an existing image or a latitude/longitude point, return a list of images that overlap the same location; (2) given an image, find and classify all visually salient *landmarks* present [1]; (3) given two overlapping images, compare their landmarks to detect any changes over time [1]. The first and third services support scientific campaigns that seek to characterize surface changes over time, while the second service provides a catalog of interesting landmarks (craters, dark slope streaks, dust devil tracks, ridges, etc.). Figure 1 shows an example of the

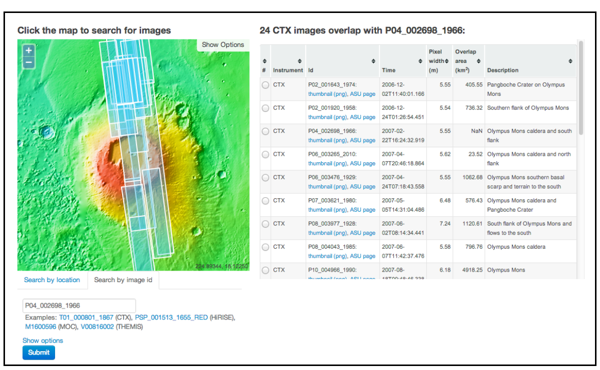
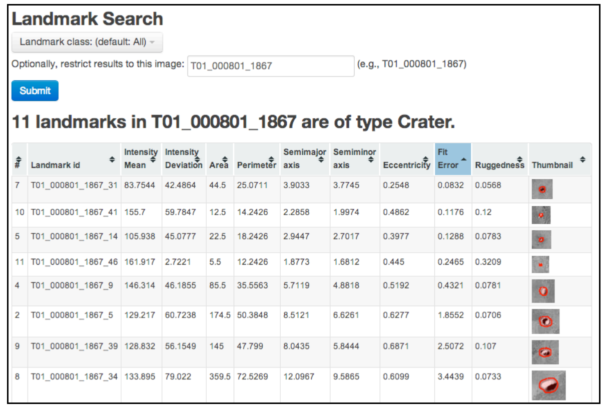


Figure 1. Results of a query for images that overlap with a given CTX image.



Landmark Search

Landmark class: (default: All)

Optionally, restrict results to this image: T01_000801_1867 (e.g., T01_000801_1867)

Submit

11 landmarks in T01_000801_1867 are of type Crater.

#	Landmark id	Intensity Mean	Intensity Deviation	Area	Perimeter	Semimajor axis	Semiminor axis	Eccentricity	Fit Error	Ruggedness	Thumbnail
7	T01_000801_1867_31	83.7544	42.4864	44.5	25.0711	3.9033	3.7745	0.2548	0.0832	0.0568	
10	T01_000801_1867_41	155.7	59.7847	12.5	14.2426	2.2858	1.9974	0.4862	0.1176	0.12	
5	T01_000801_1867_14	105.938	45.0777	22.5	18.2426	2.9447	2.7017	0.3977	0.1288	0.0783	
11	T01_000801_1867_46	161.917	2.7221	5.5	12.2426	1.8773	1.6812	0.445	0.2465	0.3209	
4	T01_000801_1867_9	146.314	46.1855	85.5	35.5563	5.7119	4.8818	0.5192	0.4321	0.0781	
2	T01_000801_1867_5	129.217	60.7238	174.5	50.3848	8.5121	6.6261	0.6277	1.8552	0.0706	
9	T01_000801_1867_39	128.832	56.1549	145	47.799	8.0435	5.8444	0.6871	2.5072	0.107	
8	T01_000801_1867_34	133.895	79.022	359.5	72.5269	12.0967	9.5865	0.6099	3.4439	0.0733	

Figure 2. Web-based search of image landmarks classified as craters within image T01_000801_1867.

overlapping image web service which displays the footprints of all images that overlap with CTX [2] image P04_002698_1966. Hovering over a footprint on the map highlights the corresponding image entry in the table at right, which reports imaging parameters. Likewise, hovering over a table row highlights the corresponding image footprint on the map. The overlap database contains images from MOC, THEMIS, CTX, HiRISE, and the Viking orbiter cameras.

Identifying overlapping images from multiple instruments enables the study of changes over decades, rather than only those phenomena captured during the lifespan of a single instrument. All detected landmarks are stored in a database that can also be queried through a web interface, which links to the original images. Figure 2 shows an example of searching the database for landmarks classified as craters, restricted to results from a particular CTX image.

Case study on fresh impact craters: We developed a prototype method to detect surface changes between a pair of images without human supervision. Based on the geometry of the image footprints, this method automatically identifies and crops overlapping areas. Next, it overlays and registers the areas using jitter correction and computes a difference image via image subtraction. True surface changes appear prominently in the difference image. Landmark identification [1] is applied to the difference image, the difference image is high-pass filtered, and classification of the landmarks separates shadows and other spurious changes from true surface changes.

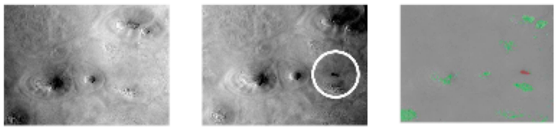


Figure 3. Detection of fresh impact crater ejecta from CTX images. Changes are classified by the system as fresh impact (red) or spurious/minor change (green) in the rightmost image, which is computed as the difference between the pre-impact and post-impact images.

We successfully applied this method to identify new impact ejecta in Context Camera (CTX) images [2], as shown in Figure 3. These rare impact events constrain the present-day impact cratering rate and occasionally expose near-surface ice [3,4].

Once the processing pipeline is implemented and the classifier fully refined, the system can operate in an entirely unsupervised fashion to analyze and down-select from the full set of available orbital imagery to focus on those images with fresh impact craters. Operationally, the system can automatically analyze the data received in each downlink and generate a report about interesting content contained within it. Features of particular interest can trigger email or other alerts. The analysis report can be used to assist with subsequent planning and targeting operations, e.g., to acquire repeat imagery of a location of interest.

Discussion: These web services and analysis algorithms offer several benefits to any scientific investigation that performs a selective study of Mars orbital images. They can provide a first-cut summary of the content of an image even before any humans have had a chance to examine the data. Currently, image summarization is generally limited to creating lower-resolution thumbnails of the original image. Landmark-based analysis provides a catalog of interesting features that are present, along with descriptive properties for each one (size, shape, albedo, etc.). Novel products enabled by this analysis include (1) automatically cropped sub-regions of interest and (2) information that informs data prioritization, for downlink or for manual review on the ground.

The web services described here are currently only available inside the JPL network. We are working with the Planetary Data System (PDS) to associate landmark content with images and make them publicly searchable through the Planetary Image Atlas interface.

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