Automatic Detection and Characterization of Impact Craters

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May 2010
Detection of Craters

from images

**advantages**
- Imagery data is most readily available.
- Some imagery data has fine resolution.

**disadvantages**
- Quality of images varies.
- No high resolution global mosaic.
- Fundamental limitation of 2D data.
- Illumination effects.

from topographic data

**advantages**
- DEM provides a direct, 3D representation of craters.
- Possibility of calculating more parameters, such as crater depth.
- No problems associated with visibility.
- Global mosaic for Mars.

**disadvantages**
- Low resolution.
Detecting Martian Craters from Topography - Content

- Global auto-detection of craters from MOLA topography
- Comparison to “standard” Barlow global catalog of craters
- Implication for extent of cryosphere
- Where are the deepest craters on Mars?
- Where are the shallowest craters on Mars?
Detection of Martian Craters from Topography

Global dataset

MOLA facts:
- 640 million measurements
- 300 m along the track
- 1 km between tracks

DEM facts:
- 46,080 x 22,528 pixels
- 128 pixels/degree
- 40% pixels interpolated
Detection of Craters from Topography

Algorithm for detecting craters from topography

Depressions finding transform

Input: elevation field (DEM)

Core idea

Output: “depressions” field

Focus point in the center of depression (++)

Focus point on the wall of depression (+)

Focus point outside depression (-)
Depressions finding transform: an example

- Classifier is constructed using 5 features of each depression: radius, depth, radius/depth ratio, two shape coefficients.
- Initial training set was labeled by human expert. It consists of 4702 samples for small-sized craters, 894 samples medium-sized, and 403 samples for large-sized craters.
- Accuracy of the classifier is 95% for small craters, for larger size craters > 85%. Accuracy is determined by averaging over 10 x 10-fold cross-validation.

- CRATERMATIC software.
  - Fast, written in C++
  - Produces catalog of crater candidates.
  - Results can be used as an input to the machine learning-based selection algorithm.
  - Free!
  - Available at cratermatic.sourceforge.net
Global Auto-Survey of Martian Craters from Topography

300 overlapping “equatorial tiles
Additional 56 “polar” tiles

Dr. Erik Urbach
doc
Detected craters

- 75,919 craters
- diameter
- depth
Comparison to Barlow Catalog

Comparison to Barlow Catalog

D < 5 km

15 < D < 20 km

5< D < 10 km

20< D < 25 km
Knowledge Discovery: Martian Cryosphere

Global distribution of crater "depth/diameter provides "observational" support for existence of cryosphere with varying depth of upper boundary.

How so?
Geographical Distribution of d/D

smaller craters are relatively deeper in equatorial regions

no correlation between Latitude and d/D for large craters
Explanation in Terms of Viscous Relaxation

small craters

- D <= 10 km
- z >= 1 km
- no ice regime
- equatorial regions
- large z/D regime
- z >= 1.6 km
- high latitude regions

larger craters

- D > 10 km
- z <= 4 km
- small z/D regime
  - equatorial regions
  - D > 10 km
  - small z/D regime
  - high latitude regions

- no ice – no shallowing
- z/D large – shallowing
- z/D small – no shallowing

100 Deepest Craters on Mars

133 craters with $d/D \geq 0.18$
Average $D = 7$ km

J. Boyce et al., (2006), Deep impact craters in the Isidis and southwestern Utopia Planitia regions of Mars: High target material strength as a possible cause, GRL., 33, L06202
Conclusions

• Auto-detection of craters from topography has arrived! New types of analysis are possible for surfaces represented by elevation grids (Mars, Moon, Mercury).

• Geographical distribution of d/D on Mars supports the existence of cryoshpere and provides constraints on its extent.

• Deepest craters on Mars are concentrated in two or three locations. Strong target materials?
Detection of Craters from Images

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**Key insight**

High resolution images for Mars:
- HRSC (up to 12.5 m/pixel)
- CTX (up to 5m/pixel)
- HIRISE (> 1m/pixel)

Other planets:
- Moon LROC (1m/pixel)
- Mercury Dual Imaging System MDIS, (500m/pixel global)
Detection of Craters from Images

1. Identifying shadow & highlight regions
2. Combining shadow & highlight pairs
3. Haar-like feature catalogs of smaller construction
4. Crater detection by supervised learning

Dr. Wei Ding
collaborator

Dr. Erik Urbach
postdoc

Lourenco Bandeira
graduate student

Detection of Craters in Nanedi Valles

- HRSC image, 37X56 km
- 3050 craters manually identified
- crater size 40m to 6600m

- Training 211 craters + 422 non-craters
- 7% of all craters in the site
- 20% area of the site
Detection of Craters in Nanedi Valles

Bandeira, L. et al. 2010, 41st LPSC # 1144
Conclusions

• Auto-detection of craters from images is still a work in progress.

• Shape-based algorithm provides an efficient means of finding crater candidates.

• Recognizing true craters from amongst the candidates on the shapes alone is challenging. Combining shape-based algorithm for fast identification of crater candidates with texture-based algorithm for recognition of true craters may improve the overall quality of detection.