Mars Craters Research Report

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*Abstract* — The following report provides an overview of the research being conducted within the Mars Craters Research as part of the Remote Earth Observation Sensing class, held at ETI Faculty of Gdańsk University of Technology. This report covers an overview of the craters phenomena, their origins and creation process. The primary goal of the project was to identify satellite photos of Mars surface and identify craters on them. This report provides description of the methods used. A discussion about strong and weak points of various approaches applied conclude this paper.

Keywords —mars, craters, satellite, observation, opencv.

# Introduction

Mars is the most similar planet to Earth in our Solar System. Its sidereal day is 24h 37min, which is roughly 40 minutes longer than Earth’s. Mars gravity is weaker and equals to 37% of Earth’s gravity. Its atmosphere is probably the most distinct feature that sets Mars and Earth apart. Its average density (11.55 hPa) is around 0.6% of Earth’s (101.3 hPa). The atmosphere consists of 96% of carbon dioxide, 1.93% of argon and 1.89% of nitrogen. Oxygen is present only in trace amounts (0.174%). For more details, see [2].

Asteroids occupy various orbits throughout the whole Solar System, but the area behind Mars orbit has the highest concentration. Therefore it often nicknamed “an asteroid belt”. As of Nov. 2019 there are over 851.000 minor bodies known in the Solar System [3]. Earth is naturally protected from incoming minor bodies by its thick atmosphere and a large Moon that can alter the trajectory of incoming objects. Neither of those mechanisms as present on Mars. Also, the close proximity to main asteroid belt contributes significantly to the amount of surface impacts. As such, Mars is a very attractive place for meteorite research.

The goal of the research conducted was to study evidence of incoming bodies. Since the Mars’ atmosphere is so thin, most of the incoming meteors end up hitting the surface and becoming a meteorite. The primary goal of this research was to study the data available, experiment with various techniques and come up with the most reliable method for detecting craters.

# Methodology

There are currently 6 orbiters providing orbital photos from Mars: 2001 Mars Odyssey (2001), Mars Express (2003), Mars Reconnaissance Orbiter (2006), Mars Orbiter Mission (2014), MAVEN (2014) and ExoMars orbiter (2016). Year of reaching Mars orbit specified in parentheses.

Several imagers are particularly useful:

**THEMIS -** precision better than 10m on India territory and 20m on surrounding sea.

HiRISE – describe HiRISE here.

# Results

## Initial data selection

During our research we noticed that some impact craters have very bright edges on images from infrared sensor at night from THEMIS mission. NASA provide the global mosaic from these images in with a resolution of 100m. Several experiments proved that it’s a good source data for craters recognition. Using this data has one limitation, however. Not every crater has a bright edge. Crater must to have a specific minimal depth (at least 0.4-0.5 km) and the radius cannot be too big (< 15km).

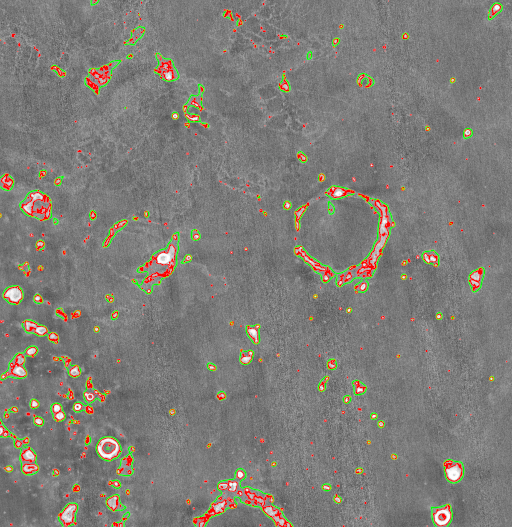
Another difficulty was introduced with an observation that craters are not the only objects that have a bright edges. Other terrain forms, such as hills, may show similar behavior. Fortunately, we came up with a way to filter them out.

## Early experiments

Initial experiments were conducted with GIMP [4], a general purpose image editing software with powerful plugins collection. The image selected for this experiment was coming from THEMIS and had a resolution of 300m. Two methods were investigated. The first method uses subtle Gauss blur, thresholding (with pixels within range 160-170 treated as white), dilate filter [5] that widened and enlarged the detected areas. Finally, the resulting white pixels were used as a mask. An example result of this method has been presented in Fig. 1, denoted red.

The second, alternative approach assumed somewhat similar approach, albeit the details were different. The first step used aggressive Gaussian blur, thresholding at the value 160, detecting edges using Gaussian differences and the second thresholding. The resulting white pixels were used as a mask. An example result of this technique is depicted in Fig. 1, denoted in green.

Several conclusions emerged from those experiments. Initial blur is necessary to remove minor noise distributed throughout the whole image. The blur parameters must be adjusted to the size of the craters being searched. This implies that to find craters of any sizes, several passes of the algorithm are necessary. Too aggressive blur performs poorly, even for large craters. They’re being merged with smaller craters in the area, resulting in unusable blobs of pixels. Small hills can distort the results. With increasing latitude, craters’ circumference become less pronounced and hills becoming more visible, thus making detection more difficult.



*Fig. 1: GIMP experiment*

# Pattern recognition using OpenCV

The next step in our research was to use OpenCV library [6]. OpenCV is an open source computer vision and machine learning software library. To ease the development, we used the basic python bindings for OpenCV [7] as well as extra wrapper for it [8]. Several experiments were conducted.

Every OpenCV based experiment had some common characteristic. First, it used the cv2 wrapper, loaded the input image file, processed the image with the results both being displayed on the screen and written to file. JPEG format was used. In some cases the detected craters could be saved as a .CSV file and the detected shapes exported to .SHP file.

In all cases the primary mechanism for detecting craters was circle Hough transform (CHT) algorithm [9] with Hough Gradient detection method, available in OpenCV [10].

## OpenCV experiment 1

In this experiment, an image acquired by THEMIS was used. It was a night-time IR mosaic with 100m resolution. Exact photo identifier was THEMIS Night IR 100m Global Mosaic (v14.0)JM137.184-15.195\_256\_2048ppd.jpg.

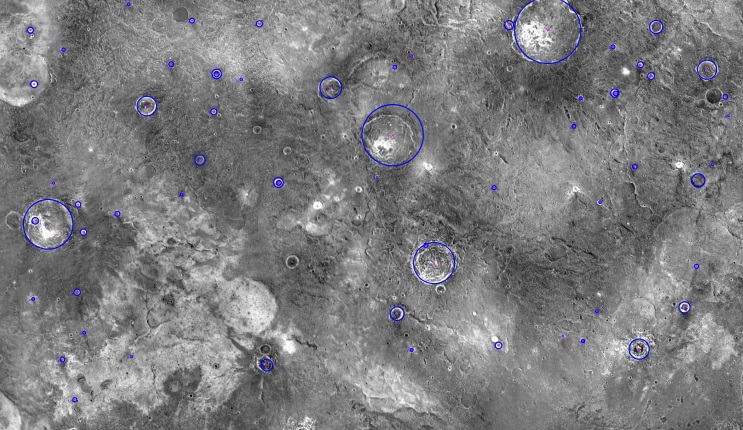
The algorithm used is as follows. First, the image is converted to grayscale. Second, a median blur is applied with the following parameters: Radius 12, Percentile 66, High precision. Then an edge detection mechanism is used with the following parameters: algorithm used: gradient, amount 1. The final step was to use Sobel edge detection algorithm.

The result of this experiment is presented in Fig. 2.

## OpenCV experiment 2

This experiment is an extension of the previous one. It Used the same approach as before, but the parameters of the circles being looked for are different. The parameters were (150, 10, 50) and (550, 50, 500), where the first parameter denotes minimal distance between the nearest detected circle, the second denotes minimal radius and the third one denotes maximal radius. All parameters expressed in pixels.

Results of this experiment are presented in Fig. 3 below.



*Fig. 2: OpenCV experiment 1*

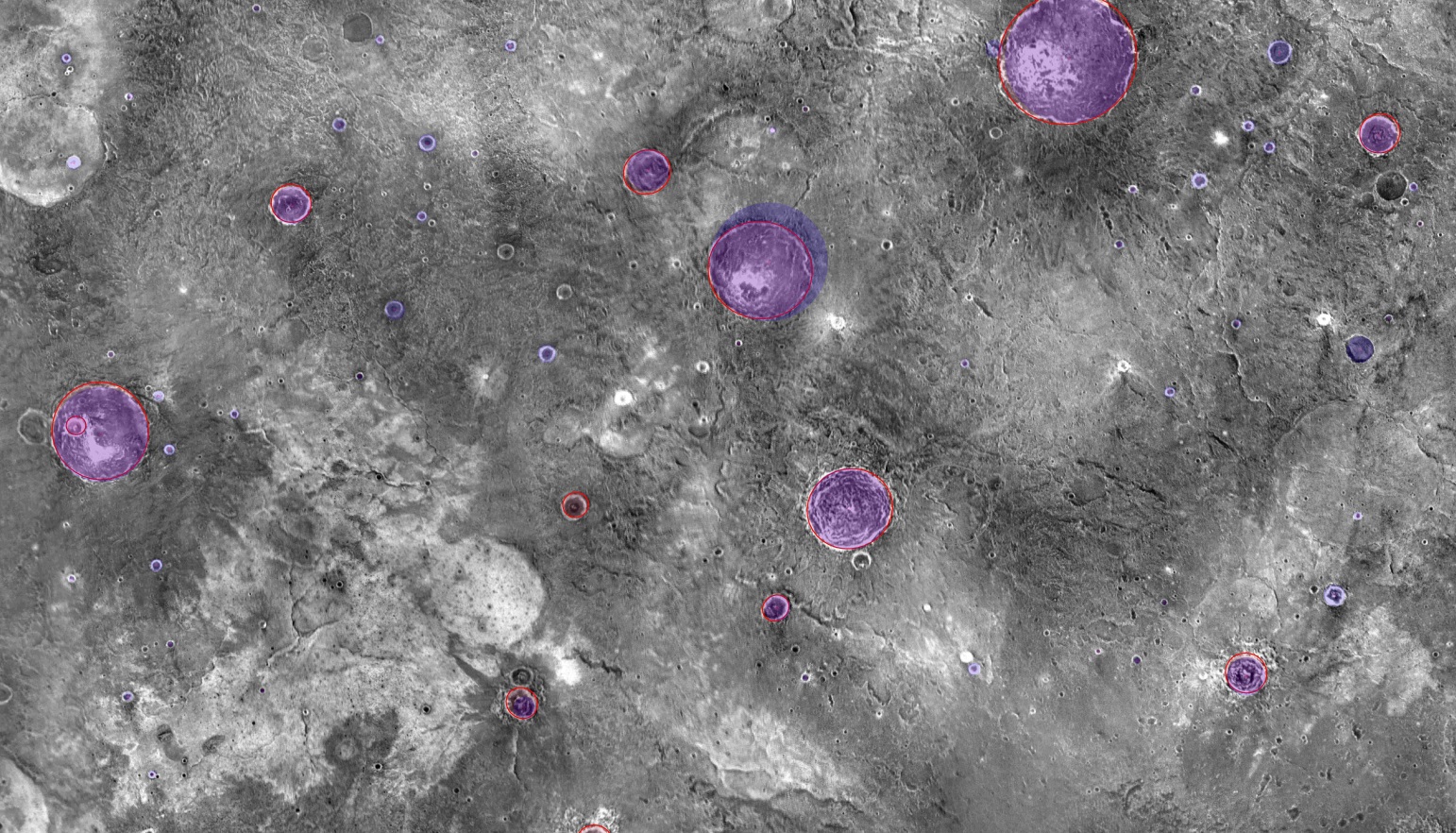


Figure 3: OpenCV experiment 2

# Strong and weak points

The following section attempts to assess the performance of the developed algorithms.

## Quantitative assessment

The data provided by JMars [11] was used a benchmark reference. For the image analyzed in OpenCV experiment 2, we got the results as presented in Table 1.

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| --- | --- | --- | --- |
| **Radius [km]** | **Actual** | **Recognized** | **Accuracy** |
| > 30 | 3 | 0 | 0 |
| 25-30 | 0 | 0 | 0 |
| 20-25 | 1 | 0 | 0 |
| 15-20 | 1 | 0 | 0 |
| 10-15 | 9 | 3 | 0.33 |
| 5-10 | 6 | 1 | 0.16 |
| 4-5 | 5 | 4 | 0.8 |
| 3-4 | 10 | 2 | 0.2 |
| 2-3 | 17 | 4 | 0.24 |
| 1-2 | 55 | 20 | 0.36 |
| < 1 | 240 | 30 | 0.13 |

*Table 1:Unbound evaluation  
This table compares detected craters (Recognized column) with information provided by J-Mars project. Accuracy denotes overall number of detected crates over all craters known.*

Assuming general, unrestricted search, the algorithm is able to reliably detect only certain class of craters: diameter between 2 and 15km and depth at least 500 meters.

Different craters have different characteristics. The good performance within those ranges and poor in others can be explained by the properties of the images being analyzed. We used data acquired by THEMIS Infrared Night sensor. On those photos, some craters have a very bright edge. This phenomena, however, is only observed in craters with specific diameter and depth. If radius was too large then the edge of crater has too low height and the edge was too damaged or otherwise not pronounced well enough. Also, if the crater was too shallow, the edge wasn’t distinctive enough and thus difficult to detect. This can be explained by the characteristics of the craters. Large craters, caused by impacts of bolides (large meteorites) or small asteroids are very uncommon and most large craters are millions years old. Even though erosion on Mars is much slower than on Earth due to lack of vegetation and almost complete absence of water, with sufficient time the erosion process can be almost as destructive as on Earth.

Therefore this method is best for recognize craters with radius lower than 15 km and depth higher than 0.5 km. Assuming the crater detection problem is limited to those criteria, the algorithm performs much better. The results for specific ranges has been presented in Table 2.

|  |  |  |  |
| --- | --- | --- | --- |
| **Radius [km]** | **Actual** | **Recognized** | **Accuracy** |
| 15-10 | 3 | 3 | 1 |
| 5-10 | 1 | 1 | 1 |
| 4-5 | 4 | 4 | 1 |
| 3-4 | 2 | 1 | 0.5 |
| 2-3 | 3 | 2 | 0.66 |

*Table 2:Parametrized evaluation*

# Conclusions

The inverse correlation between number of visible satellites and the GNSS accuracy has been clearly proven. Furthermore, another often neglected aspect – the satellites geometry on the sky – has been studied and was determined to have significant effect. Another important factor is the sky visibility and obstacles that can obstruct the line of sight. This problem, however, can be alleviated to a large degree by using more satellites.

The methodology developed During filtration you should remember that not whole edge will be bright for each crater. For old crater edge may be incomplete or edge may to have different structure and some parts are dark.

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