The influence of CLAHE on the accuracy stability of the automatic classification of Mars surface lineament structure based on DEM image

Ziyi Li¹, Pengcheng Yan², Jiarui Liang¹ and Xiaolin Tian¹,²,*

¹Faculty of Information Technology, Macau University of Science and Technology, Macau
²Lunar and Planetary Science Laboratory/Space Science Institute, Macau University of Science and Technology, Macau
*Corresponding author email: xltian@must.edu.mo

Abstract. This article introduces training ResNet to automatically classify the lineament structure of Mars surface (DEM image), and then use CLAHE to pre-process the samples to improve the stability of accuracy. The linear structure of Mars surface is mainly divided into two types: dorsum and vallis, and crater is added as a representative of non-lineament structure. We have prepared a sample set of 300 samples for each class, divided into training set, test set, and validation set at 6:2:2. Without pre-processing, the highest accuracy rate reached 98.33% (for crater), 100.00% (for dorsum), 98.33% (for vallis), 89.44% (for total). However, the accuracy of Dorsum fluctuates greatly and frequently. After CLAHE pre-processing, the fluctuation of the accuracy of dorsum is significantly reduced.

1. Introduction
On the surface of Mars, there is Valles Marineris, the largest group of fractured canyons that people have observed on other stars in the entire solar system. It is located near the equator in the western hemisphere of Mars. [1] Lineament structure is one of the most important landforms on the surface of Mars. [2] More in-depth study of these landforms can further explore the reasons for their formation and restore the process of landform changes on Mars. And more in-depth research is inseparable from the support of a large number of samples.

Compared with the light and shadow information carried on the CCD (Charge Coupled Device) image, the altitude information on the DEM image can more directly reflect the biggest difference between Vallis and Dorsum (the two main lineament structures on the surface of Mars). However, DEM images also have some unique problems, that is, the contrast in some areas is very low.

Regarding to the above shortages of DEM image, the pre-processing of histogram equalization would be more effective, for example AHE [3] etc. [4], and we selected CLAHE.

2. Data Set Preparations

2.1 DEM Image Source
We used Mars MGS MOLA-MEX HRSC Hybrid DEM Global 200m v2 from USGS Astrogeology Science Center. The resolution is 200 meters per pixel (mpp).
2.2 Single Sample

Samples are classified as three types: Dorsum, Vallis, Crater, as shown in Figure 1~3. In this research, there are 900 images used in total, which are 300 images from each type.

Eliminated those images of high latitude dorsum (the resolution of the poles is higher, but there’s image distortion since the image is taken around the equator) and too small dorsum (The lineament structure is too small to find on DEM image due to the resolution of DEM image is lower than the CCD image), there are 13 dorsum selected out of the 34 named dorsum of Mars to conducted 60 original samples. While there are 31 original samples (51.67%) are not visible to the naked eyes before pre-treatment, as show in Figure 4.

Based on the same selection standard as above, there are 25 vallis selected in 156 named vallis of Mars to create 60 original samples, which there are 24 original samples (40%) are invisible to the naked eyes before pre-processing, as show in Figure 5.

Crater is the representative of the non-lineament on Mars. According to the same selection principle as above, 60 craters are selected from 1138 named craters to produce 60 original samples, and there are 4 original samples are invisible to naked eyes before pre-process, as show in Figure 6.

2.3 The Problem of Invisibility

This problem is due to the low contrast of some samples. Physically, it is because the linear structure in the highlands or lowlands of Mars has a relatively small height difference with the surrounding area (the relatively short dorsum or the relatively shallow vallis).
2.4 Sample Expansion
Based on 3D transformation with x-axis rotation of ±15° and y-axis rotation of ±15°, each original samples, produced 4 extra samples and so each type extended from 60 to 300 samples in order to expand the sample pool and create the simulation of deformation occurred during a non-vertical shooting angle.

2.5 Samples Division
Samples are divided into training set, test set and valid set randomly, based on the proportion of 6:2:2.

3. Network Architecture

3.1 Abbreviations and Acronyms
The main difference between ResNet and traditional convolutional neural networks is that ResNet has an additional structure called residual block unit (as shown in Figure 7), which is designed to deal with the problem of gradient disappearance. In other words, this unit makes the network sensitive to small changes in gradient.

3.2 Parameter Setting

The selection of parameter setting was based on the best performance one in the automatic classification of Mars lineament structure in the CCD image.[5] The detailed parameters are as follows:

- Learning rate: 1*10^{-5}
- Epoch: 1200
- Gradient Algorithm: SGD
- Weight Decay: 5*10^{-4}
- Batch Size: 30 for train set and 15 for test set
- Residual block unit structure: Pre-Bottleneck

3.3 Accuracy Calculation
The accuracy of each category is calculated from the predicted corrects divided by the correct answers. And the total accuracy is the average of the three categories. The calculate formular is shown in Equation (1).[5]

\[ Acc_{Label} = \frac{Num_{Predicted}}{Num_{Correct}} \]  

(1)

4. CLAHE

4.1 CLAHE Operation
Contrast Limited Adaptive Histogram Equalization (CLAHE) is one of contrast enhancement algorithm. The method operates on small individual patches of the image. The contrast transform function for each patch is computed and will be applied in order to enhance the contrast between patches. Then, the neighbouring patches are then combined base on bilinear interpolation to rule out artificially induced boundary [3]. It can weaken the noise [6]. The function is below

\[ S = \text{hist}(i) \times \frac{255}{W \times W} \]  

where \( S \) is the slope of the local mapping function, \( W \times W \) is the size of sliding window, \( \text{hist}(i) \) is the local histogram of sliding window. Maximum histogram is \( H_{\text{max}} \) and corresponding to \( S_{\text{max}} \).

\[ H_{\text{max}} = S_{\text{max}} \times \frac{W \times W}{255} \]  

\[ \text{hist}'(t) = \begin{cases} \text{hist}(i) + L, & \text{hist}(i) < T \\ H_{\text{max}}, & \text{hist}(i) \geq T \end{cases} \]

where \( T \) is a threshold, equal to \( H_{\text{max}} = T + L \). Any counts of the same gray value, larger than \( H_{\text{max}} \), would be truncated to \( H_{\text{max}} \) and truncated part would be evenly distributed to all gray scales.

4.2 Parameter Setting

64 tiles in 8 columns and 8 rows is a common choice [7], that is \( W \times W = 8 \times 8 \). And \( T = 3 \).

5. Results and Analysis

5.1 Without Pre-Processed Sample Set

5.1.1 Test Set Results. The following graphs (Figure 8–9) show the accuracy curve and loss curve we got based on 1200 epoch. And Table 1 representing highest & average accuracy, and variance.

![Figure 8. Accuracy through 1200 Epoch with test set (without pre-processed)](image)

![Figure 9. Loss through 1200 Epoch with test set (without pre-processed)](image)
Table 1. The highest accuracy of test set (without pre-processed)

| Types | The highest accuracy | Average | Variance |
|-------|----------------------|---------|----------|
| Crater | 98.33%               | 75.08%  | 135.08   |
| Dorsum | 100.00%              | 86.70%  | 208.07   |
| Vallis | 98.33%               | 69.40%  | 53.94    |
| Total  | 89.44%               | 77.06%  | 39.14    |

5.1.2 Valid Set Results. The following graphs show the accuracy curve and loss curve (Figure 10–11) conducted from 1200 epoch; and Table 2 illustrates the detailed data.

Figure 10. Accuracy through 1200 Epoch with valid set (without pre-processed)

Figure 11. Loss through 1200 Epoch with valid set (without pre-processed)
Table 2. The highest accuracy of valid set (without pre-processed)

| Types   | The highest accuracy | Average | Variance |
|---------|----------------------|---------|----------|
| Crater  | 100.00%              | 97.02%  | 22.17    |
| Dorsum  | 100.00%              | 86.80%  | 160.70   |
| Vallis  | 100.00%              | 90.83%  | 62.76    |
| Total   | 99.44%               | 91.55%  | 39.18    |

5.2 Pre-processed Sample Set

5.2.1 Test Set Results. The following graphs (Figure 12~13) show the accuracy curve and loss curve we got based on 1200 epoch. And Table 3 representing highest & average accuracy, and variance.

Table 3. The highest accuracy of test set (pre-processed)

| Types   | The highest accuracy | Average | Variance |
|---------|----------------------|---------|----------|
| Crater  | 96.67%               | 78.11%  | 69.91    |
| Dorsum  | 100.00%              | 94.01%  | 59.74    |
| Vallis  | 81.67%               | 68.93%  | 33.35    |
| Total   | 87.78%               | 80.35%  | 20.44    |
5.2.2 Valid Set Results. The following graphs show the accuracy curve and loss curve (Figure 14~15) conducted from 1200 epoch; and Table 4 illustrates the detailed data.

![Figure 14. Accuracy through 1200 Epoch with valid set (pre-processed)](image)

![Figure 15. Loss through 1200 Epoch with valid set (pre-processed)](image)

| Table 4. The highest accuracy of valid set (pre-processed) |
|-----------------|--------------|-------------|-------------|
| Types           | The highest accuracy | Average   | Variance   |
| Crater          | 100.00%        | 92.26%     | 19.19       |
| Dorsum          | 100.00%        | 89.16%     | 63.16       |
| Vallis          | 100.00%        | 82.20%     | 46.51       |
| Total           | 94.44%         | 87.87%     | 14.06       |

5.3 Results Analysis
Compared with the “non-pre-processed” sample set, the highest accuracy of the sample set pre-processed by CLAHE is not improved. However, there is a very significant reduction in variance. The range of fluctuations in the accuracy of dorsum and the frequency of large fluctuations have significantly decreased. It can be said that CLAHE has a very significant effect on improving the stability of accuracy. Judging from the loss curve, there is no overfitting in both groups.

6. Conclusion
The ResNet50 has a very good performance in the highest accuracy. Without pre-processing, the highest accuracy rate reached 98.33% (for crater), 100.00% (for dorsum), 98.33% (for vallis), 89.44% (for total). And after using CLAHE for pre-processing, the stability of the accuracy has also been greatly improved. The variance reduced from 135.08 to 69.91 (for crater), from 208.07 to 59.74 (for dorsum), from 53.94 to 33.35 (for vallis), from 39.14 to 20.44 (for total).
7. Acknowledgement
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