World Academy of Science, Engineering and Technology
International Journal of Computer and Information Engineering
Vol:6, No:11, 2012

Study on Crater Detection Using FLDA

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Abstract**—**In this paper, we validate crater detection in moon surface image using FLDA. This proposal assumes that it is applied to SLIM (Smart Lander for Investigating Moon) project aiming at the pin-point landing to the moon surface. The point where the lander should land is judged by the position relations of the craters obtained via camera, so the real-time image processing becomes important element. Besides, in the SLIM project, 400kg-class lander is assumed, therefore, high-performance computers for image processing cannot be equipped.

We are studying various crater detection methods such as Haar-Like features, LBP, and PCA. And we think these methods are appropriate to the project, however, to identify the unlearned images obtained by actual is insufficient.

In this paper, we examine the crater detection using FLDA, and compare with the conventional methods.

Keywords**—**Crater Detection, Fisher Linear Discriminant Analysis , Haar-Like Feature, Image Processing.

I. INTRODUCTION

SLIM (Smart Lander for Investigating Moon) project aiming at the pin-point landing to the moon surface is examined in JAXA(Japan Aerospace Exploration Agency) and SLIM Working Group[1]. Therefore, a technique about autonomous navigation subsystem based on the image processing becomes the important element. Real-time image processing needs high performance computational resources. However, SLIM project is planning to lighten the weight of a lander, it is difficult to equip and use high-performance computers. So, rapidly crater detection method is needed.

Traditionally, we have been studying various methods to detect crater, such as Haar-Like features [2], LBP [3] and Adaboost algorithm [4]-[6]. In the conventional methods, the simulation performance has been satisfied. However, there is a concern that the characteristics of moon surface image taken by the actual lander during the performance may exceed the characteristics of images that are learned. If this situation happens, we cannot deny the possibility of crater detection performance is degraded.

To avoid the problem, we have focused on PCA (Principal Component Analysis)[7]. According to its validation [8], the main components are discovered as a common trend between the different satellites images. Also, the main components of crater are different from those of non-crater. We have concluded if the appropriate boundary between crater and non-crater is provided, the method using PCA can detect crater [8].

Therefore, in further investigation of object detection using PCA method, interesting results have been written by P. N.Belhumeur[9]. This paper said the Fisherface method which is using FLDA (Fisher linear discriminant analysis) appears to be the best method to face detection at simultaneously handling variation in lighting and expression [9]. Based on this result, we infer that the FLDA method is more suitable than PCA method for crater detection because brightness change is likely to occur at moon surface.

In this paper, we report the crater detection using FLDA, and the performance is compared with crater detection using Haar-Like features which is assumed best method in our conventional experiments.

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II. FLDA (FISHER LINEAR DISCRIMINANT ANALYSIS)

FLDA [9]-[10] is a sort of a class specific method, in the sense that it tries to shape the scatter in order to make it more reliable for classification. This method selects $\boldsymbol{W}$ in such a way that the ratio of the between-class scatter and the within-class scatter is maximized. The $\boldsymbol{W}$ makes best axis for classification because data in different classes are clearly divided.

$$y = \boldsymbol{W}^T \boldsymbol{x} \tag{1}$$

- $\boldsymbol{W}$: Translation matrix.
- $\boldsymbol{x}$: Input data.
- y : Projection point.

A. Comparing FLDA with PCA

According to the result [8], we are thinking PCA can detect many craters. Although PCA finds components that are useful for representing data, there is no reason assume that these components must be useful for discrimination between data in different classes. PCA might discover directions that are efficient for representation; discriminant analysis seeks directions that are efficient for discrimination [11]. So, we assume that FLDA is better than PCA for crater detection system which judges weather now scanned image window is crater or not.

In this paper, we experiment with FLDA method for crater detection in moon surface images.

B. Introducing FLDA Adapting Crater Detection

We use FLDA to make best directions for classification in two classes.

- Class-number:1 Crater

- Class-number:2 Negative

To calculate best directions, within-class scatter and between-class scatter are needed. Their definitions are shown below.

$$\boldsymbol{m} = \frac{1}{N}\sum_{i=1}^{N}\boldsymbol{x}$$

$$\boldsymbol{m}_i = \frac{1}{N}\sum_{x\in D_i}^{N}\boldsymbol{x}$$

$$\boldsymbol{S}_B = \sum_{i=1}^{2}\frac{(\boldsymbol{m}_i-\boldsymbol{m})(\boldsymbol{m}_i-\boldsymbol{m})^T}{N_i}$$

$$\boldsymbol{S}_W = \sum_{i=1}^{2}\sum_{x_i\in D_i}\frac{(\boldsymbol{x}-\boldsymbol{m}_i)(\boldsymbol{x}-\boldsymbol{m}_i)^T}{N_i}$$

$$J_s(\boldsymbol{W}) = \frac{\boldsymbol{W}^T\boldsymbol{S}_B\boldsymbol{W}}{\boldsymbol{W}^T\boldsymbol{S}_W\boldsymbol{W}}$$

- $\boldsymbol{m}$ Average of brightness among all images
- $\boldsymbol{m}_i$ Average of brightness in class i
- N_i Class:i's picture
- $\boldsymbol{S}_B$ Between-class scatter
- $\boldsymbol{S}_W$ Within-class scatter
- $J_s(\boldsymbol{W})$ Within-class scatter between class scatter ratio

Therefore, directions for classification $\boldsymbol{W}$ are computed when $Js(\boldsymbol{W})$ is maximized[10]-[11].

III. Proposed Method

In a object detection, a detection window is scanned by the whole image and detects the target property calculating FLDA. However, it is time consuming to calculate FLDA at every scanned window. So, we prepare one preprocessing before FLDA calculation process.

Our proposed method is combination of FLDA and the pretreatment. The proposed method is successful in reducing processing time without degrading crater detection performance.

A. Preprocessing Using Integral Image

Integral Image is in the rapid method to obtain the luminance value of a particular area. A scanning window of brightness is rapidly computed by Integral Image. Integral Image is acquired by (2).

$$I(x,y) = \sum_{i=0}^{x}\sum_{i=0}^{y} v(i,j) \qquad (2)$$

where $v(i; j)$ is the brightness value of the pixel and $I(x; y)$ is the integral value of the image. By using the method, the sum of the detection window (A) in Fig. 1 can be obtained by Eq.(3) rapidly without depending on rectangle size.

$$(A) = \sum_{i=x1}^{x2}\sum_{i=y1}^{y2} v(i,j)$$

$$= I(x2,y2) - I(x1-1,y2)$$

$$- I(x2,y1-1) + I(x1-1,y1-1) \qquad (3)$$

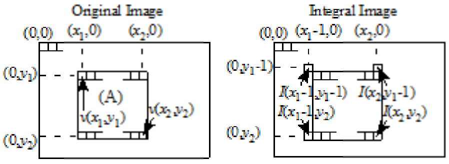

Fig. 1 Integral image for the rapid computation of the detection windows

We think this method useful to reject clearly non crater regions without calculating FLDA at now scanned window.

$$V1 = |A - B| \qquad (4)$$

$$V2 = |C - D| \qquad (5)$$

- $V1$: the absolute value of difference between the top and bottom of the scanning region.
- $V2$: the absolute value of difference between the left and right of the scanning region.
- $A \sim D$: luminance value of each area.

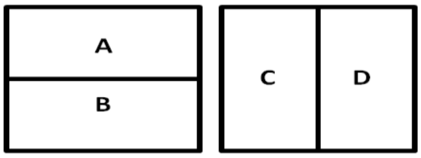

Fig. 2 Extracting V1 and V2 by using Integral Image

We extracted V1 and V2 of crater images and negative images. The graph shows the results. According to Fig. 3 and Fig. 4, there are a different trend between crater's parameters and negative's parameters. So, we set threshold of V1 and V2. When now scanned region's parameters are beyond threshold, FLDA process is adapting. This pretreatment helps to rapidly eliminate negative region.

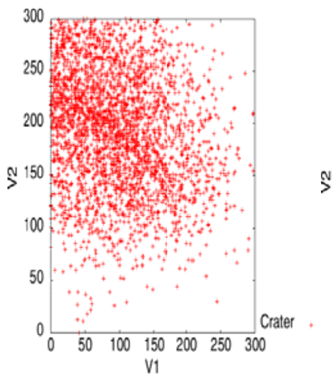

Fig. 3 Crater

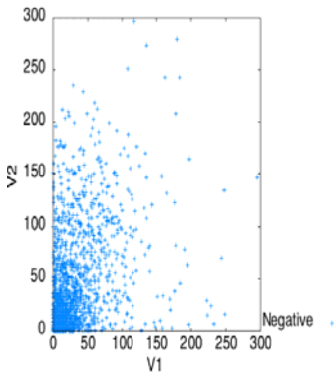

Fig. 4 Negative

B. Crater Detection of Various Sizes

There are various sized craters in moon surface image. Various dimension ***W*** are needed to detect various sized crater, because d-dimension ***W*** can only detect same size region. However, we don't prepare various dimension ***W*** but only one matrix ***W***(24 × 24).

Because SLIM project doesn't use high performance equipment. We save resource even a little. Therefore, the moon surface image is gradually shrinking and our proposed method is adapting. This process detects the craters of various sizes while saving resource.

C. Estimation of the Crater's Location

III-A and III-B process is computing many candidates of various sized craters. To estimate locations of each crater, one process which finds the best crater-location among near candidates is required. Because one region is recognized as candidates of crater tendency, other regions near the region are recognized as candidates too. Estimation crater-location is using y means distance to the classification boundary between crater and negative. y is more bigger, the possibility of crater at the region is higher. And, when y is beyond 60, the region is labeling crater detection due to robust crater detection.

Estimation process is consisting of three steps.

1) Forming group of crater candidates.
2) Comparing y values among each group.
3) Estimation

- The candidates which has highest y among each group are recognized as crater.
- Other candidates are deleted.

The two images Fig. 5 and Fig. 6 show this estimate crater-location process.

D. Flowchart

Fig. 7 is the flowchart of crater detection system using FLDA. If scanned window reach image-end, moon surface image is shrunken. Scanning starts in the shrunken moon surface image.

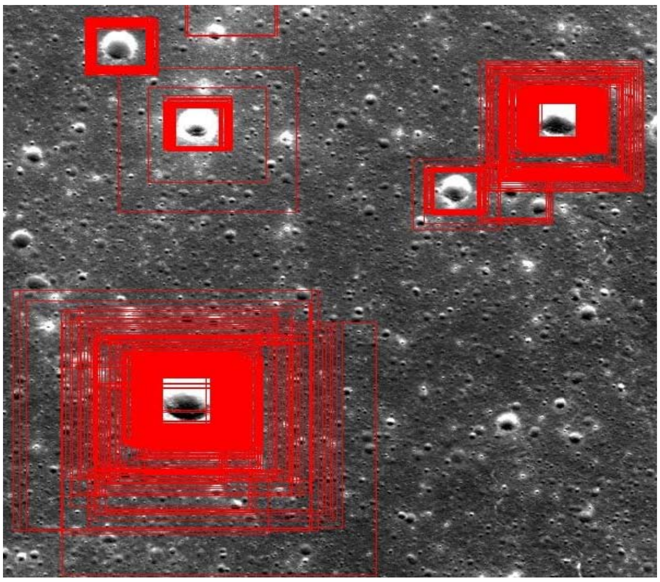

Fig. 5 Before estimation process

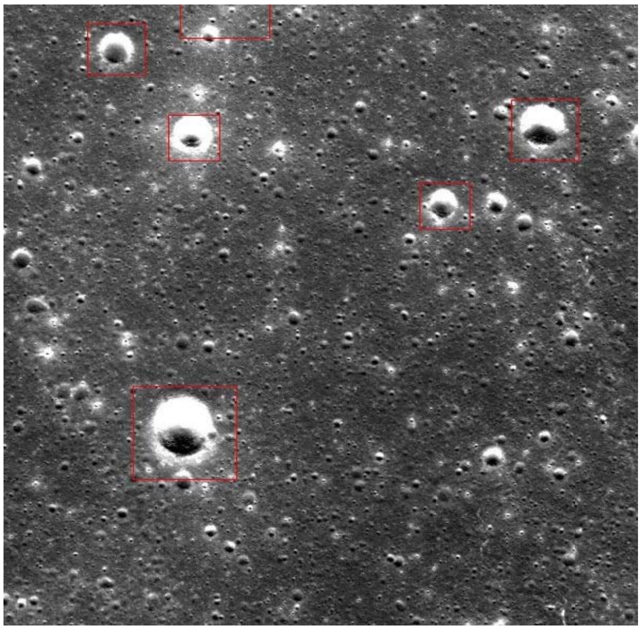

Fig. 6 After estimation process

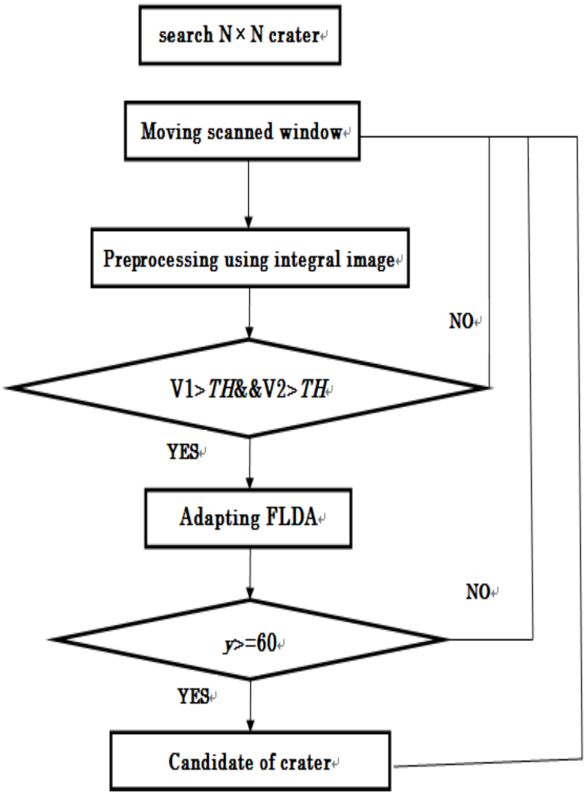

Fig. 7 Flowchart of proposed crater detection method

IV. RESULT

We experiment 10 moon surface images with our proposed method and Haar-Like features. Moon surface image size is 2400×2400 and scanning window size is 24×24.

There are four images Figs. 8-11 adapting Haar-Like features or proposed method. Each red rectangle region is recognized as crater. Table I shows each detection performance. Fig. 12 says each calculation time.

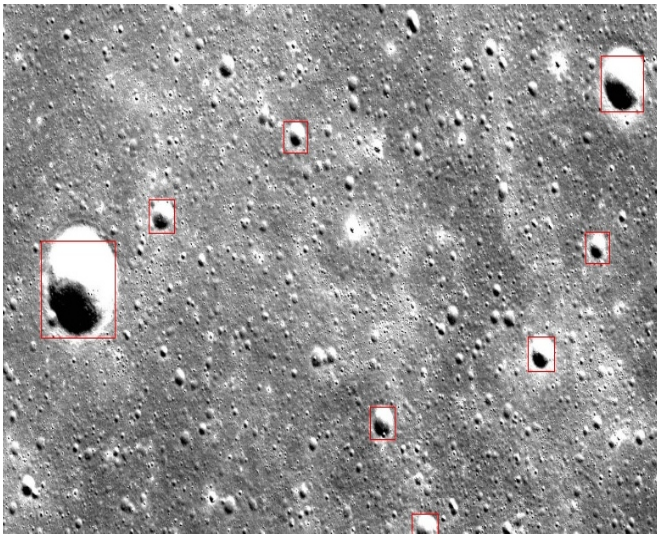

Fig. 8 Crater detection with Haar-Like feature in image A

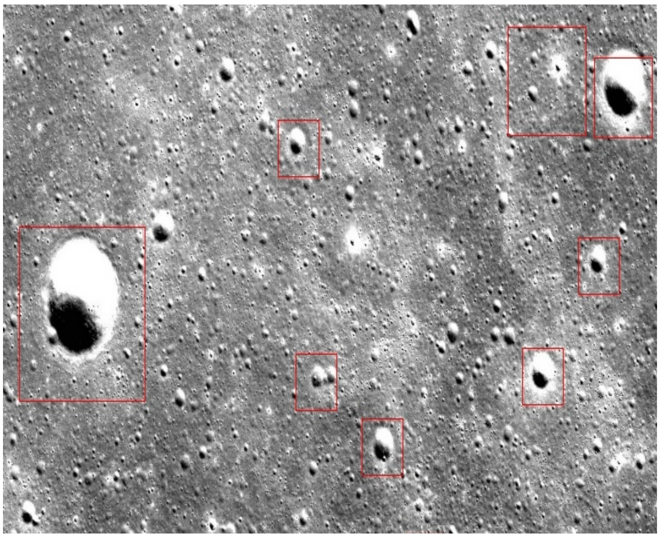

Fig. 9 Crater detection with proposed method in image A

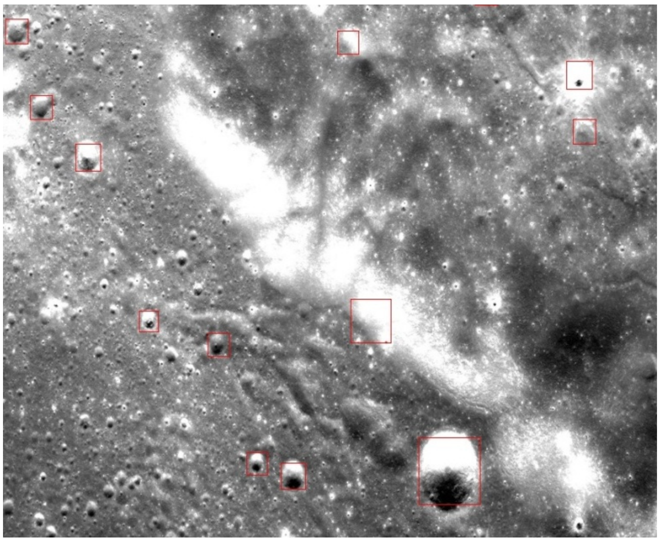

Fig. 10 Crater detection with Haar-Like feature in image A

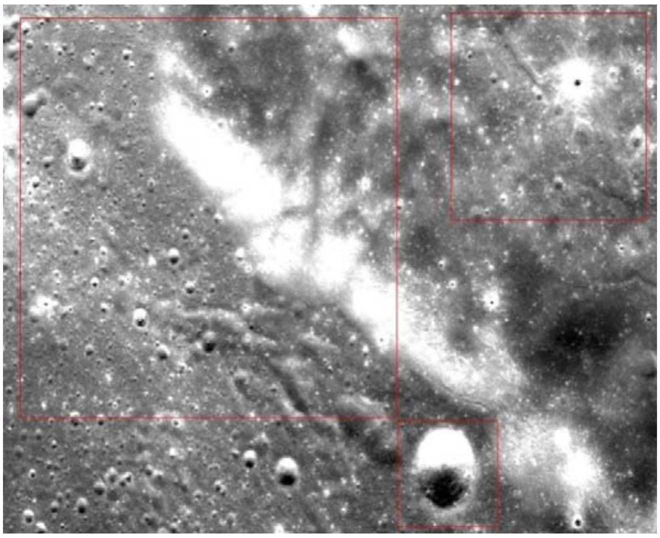

Fig. 11 Crater detection with proposed method in image B

TABLE I
CRATER DETECTION RATIO

	Detection	True crater	Positive ratio[%]
Proposed method	193	163	85.8
Haar-Like features	653	553	84.7

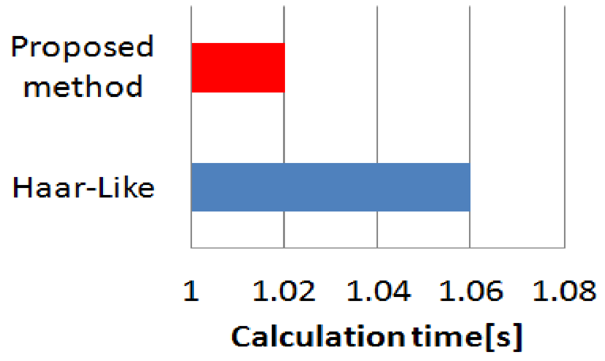

Fig. 12 Comparing calculation time

V. Discussion

Proposed method has different traits from Haar-Like features.

These are below.

1) True positive detection ratio is up.
2) Computing time is fast.
3) Saving resource.
4) Leaking crater is up.
5) There is big size false detection.

1), 2) and 3) features are good for our objective.

1) feature is important to realize autonomous accurate navigation system based on image processing. 2) and 3) features are helpful to implement crater detection system on not-high performance PC.

However, 4) and 5) feature are poor. In particular, navigation system is affected by 5) feature. We think reasons what causes 5) feature.

- Not appropriate threshold of y.
- Shrunken image have noise.
- Beyond learning crater image.

Threshold of y is very important to reduce missing crater and increase true crater location. We need to examine the threshold by more experiment. Next, when shrink a moon surface image, some noise occur the image and these noise affect wrong. Therefore, there are varieties of crater in moon surface. For example, shadow shape, brightness, size and so on. So, we need to more crater images to learn crater information and extract $\boldsymbol{W}$.

Finally, the location which is recognized as crater by both proposed method and Haar-Like features are correct crater. We would like to examine an approach which combined these two methods.

VI. Conclusion

In this paper, we have studied on crater detection method based on FLDA. According to this result of validation, the proposed method combined one preprocessing with integral image and FLDA has good performance of crater detection almost equivalent to Haar-Like features. Besides, the proposed method needs low memory compared with Haar-Like features, so this is an advantage of proposed method to implement on FPGA.

In the future, we are going to examine to pursue a system that can be detected faster, more stable crater detection. For example, scanned window movement is more efficient and combination advantage of proposed method and Haar-Like features.

References

[1] Yoshikawa S., Kunugi M., Yasumitsu R., Sawai S., Fukuda S., MizunoT., Nakaya K., Fujii Y. and Takatsuka N. "Conceptual Study on the Guidance, Navigation and Control System of the Smart Landing for Investigating Moon(SLIM) ", Proc. of Global Lunar Conference 2010, paper ID 5644(2010).

[2] P. Viola and M. Jones, "Rapid Object Detection using a Boosted Cascade of Simple Features, Proc. CVPR, Vol. 1, pp.511-518, 2001.H. Poor, *An Introduction to Signal Detection and Estimation*. New York: Springer-Verlag, 1985, ch. 4.

[3] Matti Pietikainen, Guoying Zhao, Abdenour Hadid, Timo Ahonen, "Computer Vision Using Local Binary Patterns" , Springer-Verlag, 2011.

[4] H. Schneiderman, "Feature-Centric Evaluation for Efficient Cascaded Object Detection", Proc. CVPR, Vol. 2, pp.29-36, 2004.C. J. Kaufman, Rocky Mountain Research Lab., Boulder, CO, private communication, May 1995.

[5] S. Mizumi, H. Kamata, K.Takadama, "Study on crater dection system using Haar-Like features in japanese", 54h Proceedings of the Space Sciences and Technology Conference, paper ID 2A13, 2010.

[6] T. Tanaami, Y. Takeda, N. Aoyama, S. Mizumi, H. Kamata, K. Takadama, S. Ozawa, S. Fukuda and S. Sawai, " Crater Detection using Haar-Like Feature for Moon Landing System Based on the Surface Image ", Proc. 28th International Symposium on Space Technology and Science, 2011-d, 37, 2011.

[7] M. S. Bartlett, J. R. Movellan and T. J. Sejnowski, " Face Recognition by Independent Component Analysis", Trans. IEEE, Vol. 13, No. 6, pp.1450-1464, 2002.

[8] Y. Takeda, T. Tanaami, N. Aoyama, S. Mizumi and H. Kamata, " Study on preprocessing and postprocessing to improve crater deteciton performance in japanese ", 55th Proceedings of the Space Sciences and Technology Conference,paper ID 3H08, 2011.

[9] P.N. Belhumeur, J.P. Hespanha and D.J. Kriegman, "Eigenfaces vs. Fisherfaces: recognition using class-specific linear projection ", IEEE Trans. Pattern Analysis and Machine Intelligence, Vol. 19, No. 7, pp. 711-720, 1997.

[10] R.A. Fisher, "The Use of Multiple Measures in Taxonomic Problems", Ann. Eugenics, vol. 7, pp. 179-188, 1936.

[11] Richard O.Duda, Peter E.Hart, David G.Stork, "Pattern Classification (2nd.Ed.) ", John Wiley & Sons, Inc.(2001), pp.117-120.