POTENTIAL LANDING AREAS SELECTION FOR CHINA'S CHANG'E-4 PROBE. Bo Li ${ }^{1,2^{*}}$, Jiang Zhang ${ }^{1}$, Peiwen Yao ${ }^{1}$. 1 Shandong Provincial Key Laboratory of Optical Astronomy and Solar-Terrestrial Environment; Institute of Space Sciences, Shandong University, Weihai, China. 2 State Key Laboratory of Remote Sensing Science, Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences. Beijing 100101

## Introduction

China's Chang'e-4 (CE-4), the first in-situ exploration of lunar farside, will explore the South PoleAitken (SPA) basin in 2019. The preselected landing area $\left(45^{\circ} \mathrm{S}-46^{\circ} \mathrm{S}, 176.4^{\circ} \mathrm{E}-178.8^{\circ} \mathrm{E}\right)$ for CE-4 is located on the southeastern floor of the Von Kármán crater (Fig.1). Lunar landers are sensitive to PNTs (including rocks, craters, ridges, troughs and secondary crater chains), which represent an obvious hazard to landing spacecraft. The more exactly PNTs on a landing area can be recognized, the better the potential hazards to the lander can be described and avoided. Identifying the PNTs through remote sensing data is thus critical for the success of landing tasks.

## Double-threshold Otsu method

Each PNT consists of two parts (dark and bright areas) in lunar images under the sunlight. Because of low complexity in time and space of lunar images, image segmentation algorithm is especially suitable for recognizing and extracting lunar features. Here we used an image segmentation algorithm to identify PNTs and extract flat areas on CE-4 preselected landing area based on the mosaic NAC image.

Let $\{0,1,2, \ldots, L-1\}$ denote the $L$ distinct intensity levels in a digital image of size $M \times N$ pixels, and let $n_{\mathrm{i}}$ denote the number of pixels with intensity $i$. The total number, $M N$, of pixels in the image is $M N=n_{0}+n_{1}+$ $n_{2}+\ldots+n_{L-1}$, where $p_{\mathrm{i}}=n_{\mathrm{i}} / M N$. For three classes consisting of three intensity intervals (which are separated by two thresholds) the between-class variance $\left(\sigma_{\mathrm{B}}\right)$ is given by [1]:

$$
\begin{gathered}
\sigma_{B}^{2}=P_{1}\left(m_{1}-m_{G}\right)^{2}+P_{2}\left(m_{2}-m_{G}\right)^{2}+P_{3}\left(m_{3}-m_{G}\right)^{2} \\
P_{1}=\sum_{i=0}^{k_{1}} p_{i} \quad P_{2}=\sum_{i=k_{1}+1}^{k_{2}} p_{i} \quad P_{3}=\sum_{i=k_{2}+1}^{L-1} p_{i} \\
m_{1}=\frac{1}{P_{1}} \sum_{i=0}^{k_{1}} i p_{i} \quad m_{2}=\frac{1}{P_{2}} \sum_{i=k_{i}+1}^{k_{2}} i p_{i} \quad m_{3}=\frac{1}{P_{3}} \sum_{i=k_{2}+1}^{L-1} i p_{i}
\end{gathered}
$$

The two optimum threshold values, $k_{1}{ }^{*}$ and $k_{2}{ }^{*}$, are the values that maximize $\sigma_{\mathrm{B}}{ }^{2}=\left(k_{1}, k_{2}\right)$. In other words, we find the two optimum thresholds by finding:

$$
\sigma_{B}^{2}\left(k_{1}^{*}, k_{2}^{*}\right)=\max _{0<k_{1}<k_{2}<L-1} \sigma_{B}^{2}\left(k_{1}, k_{2}\right)
$$

The thresholded image is then given by $g(x, y)=a$, if $f(x, y)<=k_{1}{ }^{*} ; g(x, y)=b$, if $k_{2}{ }^{*}<f(x, y)<=k_{2}{ }^{*} ; g(x, y)=$ $c$, if $f(x, y)>k_{2}{ }^{*}$. where $a, b$ and $c$ are the values standing for the dark area, flat area and bright area separate-
ly. The image segmentation results of CE-4 preselected landing area were shown in Fig. 2. The black and white colors represented the dark and bright areas which were uneven areas, while the light green color stood for the flat areas.

Safety assessment for CE-4 preselected landing area

We divided the CE-4 preselected landing area into regular square grids with size of 0.01 degree. Then, the Fap (flat area percentage) of each grid was calculated.

In order to obtain the Fap threshold for the safe landing and travelling for CE-4, here we calculated the Faps at the landing sites of past successful lunar missions, including CE-3, Apollo, Surveyor and Luna series. If CE-3 landing site was excluded, the average Fap increased to $60.6 \%$. Therefore, we thought it was safe for CE-4 landing in a grid if its Fap was bigger than 0.6.

According to the Fap of CE-4 preselected landing area, the divided square grids can be classified into safe grid (Fap>0.6) and unsafe grid (Fap<=0.6). In Fig. 3 , the grids with blue and light blue colors were safe for CE-4 landing, while the grids with red and light red colors were unsafe for CE-4 landing. And the adjacent safe grids were merged, so that the range of CE-4 preselected landing area can be greatly reduced. As shown in Fig. 4, five potential landing areas (PLAs, yellow polygons marked with number 1-5) were labeled (Fig.3).

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## References:

[1] Otsu, N. N., 1979. IEEE Trans. syst. man. \&Cybern, 9(1), 62-66.


Fig. 1 (a) LRO WAC mosaic of Von Kármán crater. The white box shows the CE-4 preselected landing area. (b)
The troughs (yellow arrows) in the floor of Von Kármán crater


Fig. 2 (a) LRO NAC mosaic of CE-4 preselected landing area marked with a white box in Fig.1. (b) The image segmentation results of CE-4 preselected landing area through a double-threshold Otsu method.


Fig. 3 The Fap of each divided square grid with a size of 0.01 degree in CE-4 preselected landing area, superposing on the NAC mosaic image. The five potential landing areas (PLAs, yellow polygons) are marked with number 15, while the three least safe landing areas (LLAs, red polygons) are marked with A-C.

