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LRS data analysis methods for the detection of lunar subsurface echoes

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Lunar Radar Sounder (LRS) is an instrument onboard KAGUYA(SELENE), the Japanese lunar explorer. The scientific objective of LRS is to investigate the geologic structures of lunar subsurface. LRS transmits radio waves from 100 km altitude orbit and receives the signals which are reflected from boundaries between different electrical property materials. As a result of observation of the Maria, subsurface reflection can be identified besides surface reflection. However, they are not clear in many cases. On the other hand, a large number of hyperbolic echoes were seen in highland regions. They are reflected echoes from isolated points such as steep walls of small craters facing to KAGUYA. We have to remove them because they prevent us from detecting subsurface reflections. This study aims to enhance subsurface boundaries and to suppress hyperbolic echoes by using the image processing techniques.

In order to enhance subsurface boundaries, two techniques were used, the area division by using the probabilistic relaxation that removes the noise and indistinctness in the image, and the VanderBrug's line detection operator. The relaxation is generally known as a numeric method of the simultaneous equations. The relaxation method is widely used as a technique for decreasing local contradiction such as noise and difference of line direction compared with surrounding lines and vagueness like indistinctness of contrast and uncertainness of edge direction by parallel repetition processing. In this study, the probabilistic relaxation was applied to the LRS data. Firstly, the LRS image was divided into the space and subsurface areas. Secondary, the subsurface area was further divided into subsurface boundary candidates and other areas. Consequently, the noises decreased and the image was binarized. Therefore, it became easy to extract the lines as candidates of subsurface boundaries.

In a digital image, continuousness of a dark pixel in a bright background can be regarded as a line. In this study, dark lines were detected as subsurface boundaries because they are darker than the surroundings. A typical technique for detecting lines in various directions is to use a template that has directionality and to rotate it. We used VanderBrug's line detection operator, which is resistant to noises and can be operated in high-speed. 16 templates for 16 different directionalities are employed in this technique. As a result, lines as candidates of subsurface boundaries were successfully extracted.

In order to remove the hyperbolic echoes, we adopted the migration method that is popular in seismic data processing. LRS observation which explores lunar subsurface by radio waves and seismic sounding which explores earth's underground by elastic waves are based on similar principles, but are greatly different in the velocity of transmitting waves. Therefore, preprocessing was applied before adopting the migration processing to LRS data. As a result, each hyperbolic curve focused to an original reflected point in the image, and was removed from the LRS image to some degree.