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GPGPU-Accelerated Digital Signal Processing Method for Detection and Analysis of Repeating Earthquake

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Repeating earthquakes are occurring on the similar asperity at the plate boundary. These earthquakes have an important property; the seismic waveforms observed at the identical observation site are very similar regardless of their occurrence time. The slip histories of repeating earthquakes could reveal the existence of asperities: The Analysis of repeating earthquakes can detect the characteristics of the asperities and realize the temporal and spatial monitoring of the slip in the plate boundary. Moreover, we are expecting the medium-term predictions of earthquake at the plate boundary by means of the Quantitative analysis of repeating earthquakes. Detailed information of stress concentration at quasi-static slip area and mechanism of energy deposition is indispensable to prediction of earthquake. Nowadays, GPS observation network also gives the peculiarity of quasi-static slip area. It is, however, not enough for analysis of ocean trench-type earthquakes.

Although the previous works have shown the existence of asperity and repeating earthquake and relationship between asperity and quasi-static slip area, the stable and robust method for automatic detection of repeating earthquakes has not been established yet. Furthermore, in order to process the enormous data (so-called big data) to speed up the computation of digital signal processing is an important issue.

Recently, GPU (Graphic Processing Unit) is used as an acceleration tool in various study fields. This movement is called GPGPU (General Purpose computing on GPUs). In the last few years the performance of GPU keeps on improving rapidly. The use of GPUs contributes to a significant reduction of the execution time in the digital signal processing of the huge seismic data.

In this study, we examine the high-speed signal processing of huge seismic data using the GPU architecture. We employ two signal processing methods: First, the band-limited Fourier phase correlation is applied as a fast method of detecting repeating earthquake. Secondly, we employ coherence function using three orthogonal components (East-West, North-South, and Up-Down) of seismic data as a detailed analysis of repeating earthquakes. These methods give us the correlation between two seismic data. Then, we evaluate the effectiveness of these methods. Moreover, we also examined the GPGPU acceleration technique for these methods. We compare the execution time between GPU (NVIDIA GeForce GTX 580) and CPU (Intel Core i7 960) processing. The parameters of both analyses are on equal terms. In case of band limited phase only correlation, the obtained results indicate that single GPU calculation is ca. 8.0 times faster than 4-core CPU calculation (auto-optimization with OpenMP). In case of coherence function using three components, GPU is 12.7 times as fast as CPU. It was found that both band-limited Fourier phase correlation and coherence function using three orthogonal components are effective, and that the GPGPU-based acceleration for the temporal signal processing is very useful. On the other hand, these methods also have some problems in the present; acceleration of data transfer between RAM to VRAM, time reduction of input/output operations. We are going to examine multi-GPU computing algorithm for more acceleration of signal processing framework.

Keywords: Repeating Earthquake, GPGPU, CUDA, Fourier phase correlation, Coherence