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High-Speed Digital Signal Processing Method for Detection of Repeating Earthquakes Using GPGPU-Acceleration

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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 analysis of repeating earthquakes.
Although the previous works mostly clarified 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) the speedup of the signal processing is an important issue.
Recently, GPU (Graphic Processing Unit) is used as an acceleration tool for the signal processing 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. That is, a PC (personal computer) with GPUs might be a personal supercomputer. GPU computing gives us the high-performance computing environment at a lower cost than before. Therefore, the use of GPUs contributes to a significant reduction of the execution time in signal processing of the huge seismic data.
In this study, first, we applied the band-limited Fourier phase correlation as a fast method of detecting repeating earthquake. This method utilizes only band-limited phase information and yields the correlation values between two seismic signals. 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. This method gives us the correlation between two seismic data at each frequency. 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 is ca. 8.0 times faster than 4-core CPU (auto-optimization with OpenMP). On the other hand, GPU is times as fast as CPU. And in case of coherence function using three components, GPU is 12.7 times as fast as CPU.
This study examines the high-speed signal processing of huge seismic data using the GPU architecture. 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. We will employ the multi-GPU computing, and expand the GPGPU-based high-speed signal processing framework for the detection of repeating earthquakes in the future.