A GPU Based Time-Domain Raw Signal Simulator for Interferometric SAR

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Interferometric Synthetic Aperture Radar (InSAR) has been widely proposed as a technique in many fields such as topographic survey, estimation of ocean currents, moving targets detection and location, etc. The importance of simulation in radar system design and algorithm analysis is noticeable for its controllable parameters and predictable results. Generally speaking, three different levels of InSAR simulation can be categorized: the raw signal level [1], [2], the single-look-complex image level [3] and the interferometric phase level [4]. Among these levels, a raw signal simulator can generate the received SAR signals, which is much more practical than the other two levels. In recent years, some works on InSAR raw signal simulation have been published, where two simulation methods are used. If an ideal straight line motion hypothesis without mechanical oscillation concerning the SAR platform is concerned, calculating the raw signal in a frequency-domain is computationally efficient [1]. A time-domain raw signal simulator, however, can easily consider the real orbit of the platform and other effects such as mechanical structure oscillation and the target backscattering coefficient variation during the integration time [2]. The main drawback of a time-domain simulator is its high computational complexity [2]. Therefore, conventional SAR/InSAR raw signal simulations are performed at the expenses of accuracy (in frequency-domain) or time (in time-domain).

In order to overcome these limitations, a novel time-domain raw signal simulator for InSAR (also for SAR) is proposed in this paper. Considering the high computational complexity of a time-domain simulator, some kernel calculations are achieved in a programmable graphics processing units (GPU) by using CUDA language [5]. Nowadays, NVIDIA CUDA is a general purpose parallel computing architecture that leverages the parallel compute engine in NVIDIA GPUs to solve many complex computational problems in a fraction of the time required on a CPU. CUDA considers the arithmetic logic units in GPU as grids, which is divided into blocks for parallel computation. Each block can be further divided into many threads as defined in OpenMP of CPU computation. Therefore, for InSAR

raw signal simulation in time-domain, each transmitted radar impulse of one pulse repetition frequency (PRF) is mapping to one block, and each echo from a scattering point is parallel calculated and stored in the local memory with a thread in this block. Meanwhile, the orbit ephemeris, target backscattering coefficients and other system parameters are stored in the constant and texture memory for threads' reading. Finally, the InSAR raw signals are transferred from the RAM of GPU to the RAM of the computer system.

Table I shows the simulation time for different facets (scattering points) by CPU and GPU calculation, respectively. It is clearly seen that the GPU based simulation is much faster.

Figure 1 shows a focused image of our simulator under an ideal condition, where the three-dimensional terrain is constructed by using fractal algorithm. Figure 2 shows the interferogram of our simulator when mechanical structure oscillation occurs. Figure 3 shows the simulated interferogram (use the SRTM DEM) and the corresponding real interferogram (acquired by JERS) near the Fuji Mountain where the real orbit is considered.

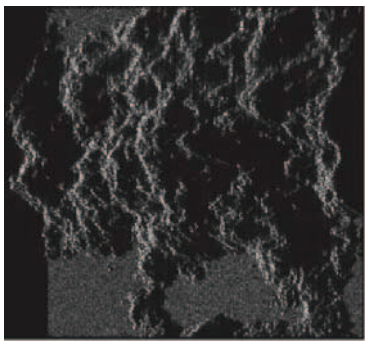

Figure 1: Image of man-made terrains of 4 km × 4 km with a resolution of 4m.

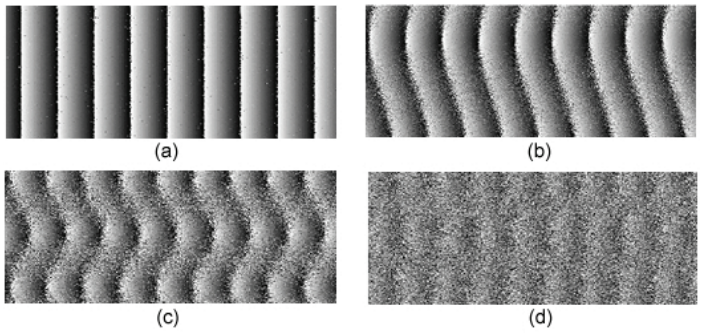

Figure 2: Interferogram of a flat earth. (a) ideal; Oscillation of (b) 0.01°, 1Hz, (c) 0.01°,2Hz, (d) 0.05°, 2Hz. Near range is on the left.

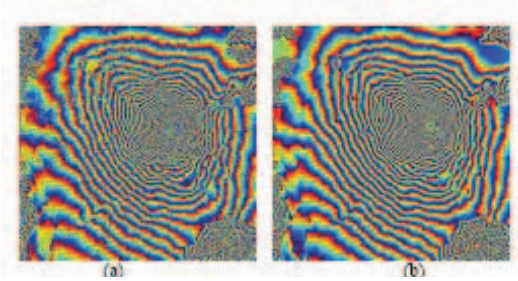

Figure 3: Interferogram of Fuji, (a) real; (b) simulated. Real orbit is considered in the time-domain simulation.

Table 1 Simulation Time Comparison

Facets	Time (hours)	
	CPU	GPU
10000	0.26	0.016
250000	6.50	0.450
1000000	26.00	1.800

References

[1] G. Franceschetti, A. Iodic, M. Miglianccio and D. Riccio, "A novel across-track SAR interferometry simulator," *IEEE Trans. Geosci. Remote Sensing*, vol. 36(3), pp. 950-962, May 1998.
[2] A. Mori and F. De Vita, "A time-domain raw signal simulator for interferometric SAR," *IEEE Trans. Geosci. Remote Sensing*, vol. 42(9), pp. 1811-1817, Sep. 2004.
[3] W. Xu and I. Cumming, "Simulator for repeat-pass satellite InSAR studies," *IEEE IGARSS'97*, pp. 1704-1706, 1997.
[4] R. Kun, V. Prinet, X. Shi, G. Wu, "Simulation of interferogram image for spaceborne SAR system," *IEEE IGARSS'03*, pp. 3824-3826, 2003.
[5] NVIDIA CUDA Programming Guide. [Online]. Available: http://www.nvidia.com/object/cuda_develop.html.