Multi-GPGPU Tsunami Simulation at Toyama-bay

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Abstract. Accelerated multi General Purpose Graphics Processing Unit (GPGPU) calculation for Tsunami run-up simulation was achieved at the wide area (whole Toyama-bay in Japan) by faster computation technique. Toyama-bay has active-faults at the sea-bed. It has a high possibility to occur earthquakes and Tsunami waves in the case of the huge earthquake, that’s why to predict the area of Tsunami run-up is important for decreasing damages to residents by the disaster. However it is very hard task to achieve the simulation by the computer resources problem. A several meter’s order of the high resolution calculation is required for the running-up Tsunami simulation because artificial structures on the ground such as roads, buildings, and houses are very small. On the other hand the huge area simulation is also required. In the Toyama-bay case the area is 42 [km] x 15 [km]. When 5 [m] x 5 [m] size computational cells are used for the simulation, over 26,000,000 computational cells are generated. To calculate the simulation, a normal CPU desktop computer took about 10 hours for the calculation. An improvement of calculation time is important problem for the immediate prediction system of Tsunami running-up, as a result it will contribute to protect a lot of residents around the coastal region. The study tried to decrease this calculation time by using multi GPGPU system which is equipped with six NVIDIA TESLA K20xs, InfiniBand network connection between computer nodes by MVAPICH library. As a result 5.16 times faster calculation was achieved on six GPUs than one GPU case and it was 86% parallel efficiency to the linear speed up.

Keywords: MGPGPU, Tsunami, Simulation, High Performance Computing

INTRODUCTION

High resolution and high speed wave simulation was implemented on multi Graphics Processing Unit (GPU) system. The wave is assumed as Tsunami which is generated by earthquake at the seabed. Tsunami is one of the most dangerous phenomena for human life because it sometimes damaged at coastal region and runs-up on ground, moreover the speed of the wave is very fast.

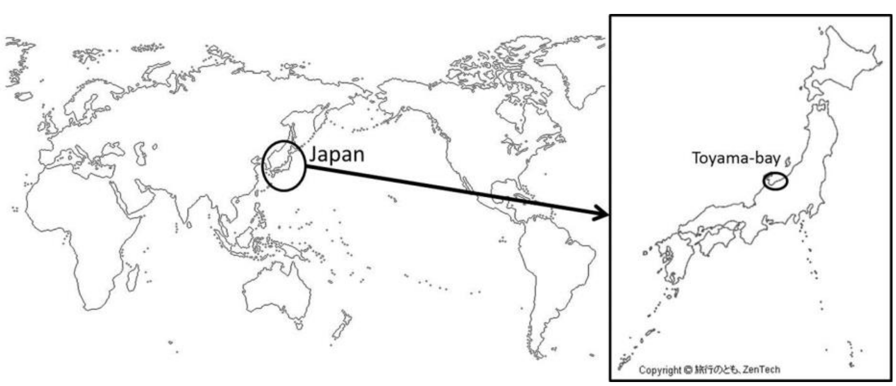

Figure 1 Target Area (Toyama-bay, Japan)

Toyama-bay which is the target area of the simulation is shown as Figure 1. The bay is located in middle of main island of Japan and faces the Sea of Japan. Almost of all area is over 1,000m in depth and it is one of the deepest bays in Japan and the bathymetry is suddenly dropped near the coast.

Tsunami has very long wave length and the speed is approximated by $\sqrt{gh}$, here g is gravitational acceleration and h is depth. When the earthquake is occurred in the Toyama-bay, very fast Tsunami will hit the coastal area immediately and run-up on residential areas around the bay. It is very serious scenario because of Toyama-bay has some active faults in the seabed.

A Tsunami simulation is one of the important technologies for protecting human life around coastal area. It predicts the Tsunami height at the coast and also provides the running-up area of the wave. Furuyama & Maihara simulated Tsunami wave at the part of Toyama-bay [1,2,3]. They got 78.5 times faster computation speed by using GPGPU than normal CPU calculation. However the simulation was not sufficient for the real phenomena because their target area was only around Toyama New Port and the initial wave was assumed as simple conditions. Therefore the purpose of this study is to extend the objective area and to use multi GPU system for the fast calculation of larger target area, i.e. whole Toyama-bay.

RESULT & DISCUSSION

Figure 2 shows tsunami situation at 75 seconds after the earthquake is occurred. The high wave propagates circles (75 seconds) and hits the coastal region. The running-up waves (a couple of meters) are observed at land regions where are residential areas.

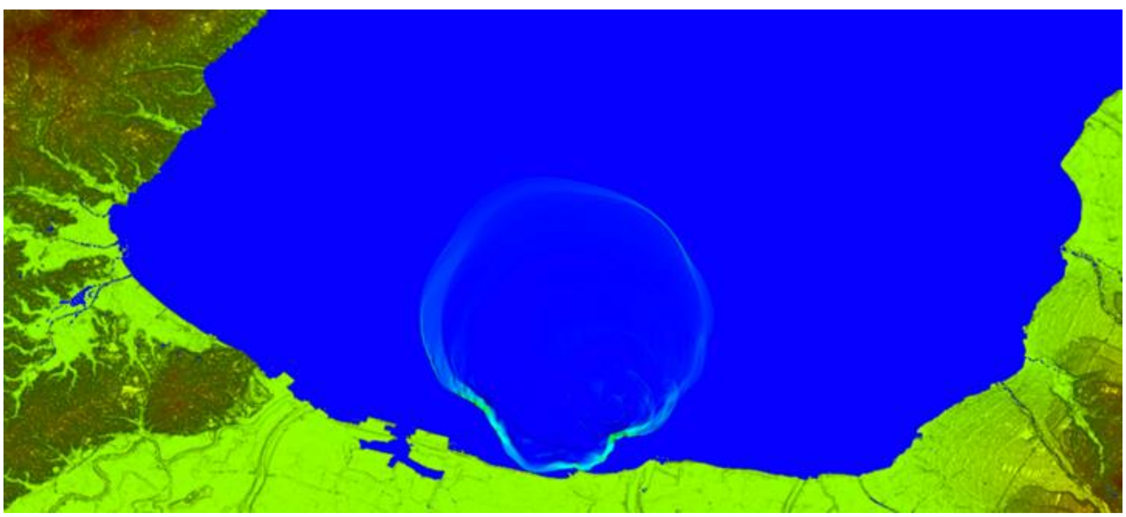

Figure 2 Simulation Result, 75 seconds after Earthquake (Toyama-bay, Japan)

Table 1 shows the results of total calculation time, calculation time for each parts (water level and flux) , the message passing time and parallel efficiency with the some number of GPU devices. The simulation achieves 91.8 and 176.1 seconds calculation time by six and three GPUs which are the faster time than the real phenomena (200 seconds). The parallel efficiency means the ratio of the calculation time to the linear speed up. The high parallel efficiencies are achieved such as 90% and 86% to the linear speed up (ideal performance) in the cases of three and six GPUs parallel computing.

The simulation result shows tsunami hits coastal area around Toyama-bay within 200 seconds after an earthquake occurs at Kurehayama active fault. The calculation time for the simulation is achieved in 91.8 seconds by using six GPUs. The parallel efficiency is high even in the case of six GPUs. The part of water level calculation, distributed well balanced load in each GPU.

Table 1 Calculation Time and Parallel Efficiency to Linear Speed Up

# of GPUs	1	3	6
Total Calculation Time [sec.]	473.3	176.1	91.8
Calc. for Water Level [sec.]	61.8	20.0	10.2
Calc. for Flux [sec.]	410.7	152.2	76.3
Message Passing Between Domains [sec.]	0	2.7	4.9
Parallel Efficiency (%)	N/A (100%)	90%	86%

Figure 3 shows the water level calculation time at each time steps in each GPU. All GPUs' calculation time is around 1 [ms] and it shows the well balanced load distribution. As a result the speed up ratio is almost linear in the part. In the part of flux calculation, the calculation time at each time steps in each GPU is shown in Figure 4. There is 50% difference calculation time between GPU1 which has shortest calculation time and GPU2 which has longest one. The part has process of tsunami running-up calculation. Because of tsunami running-up areas (computational cells) are dynamically changing in the simulation, as a result the unbalanced load in each GPU influences the calculation performances. Moreover the flux calculation part occupies 83–87% of total calculation time and the load balancing affects directly the performance. However a high efficiency of parallel calculation was kept in the study. InfiniBand contributed the performance with its high speed data transfer ability between nodes and the data transfer time was only about 5 % of the total calculation time in the case of six GPUs were used. As the result the high performance of parallel efficiency was achieved. The result also indicated that the simulation time is shorter than the time of the real time phenomena (200 second). It will be able to apply the method to a real time (after earthquake occurring) tsunami disaster simulation in future.

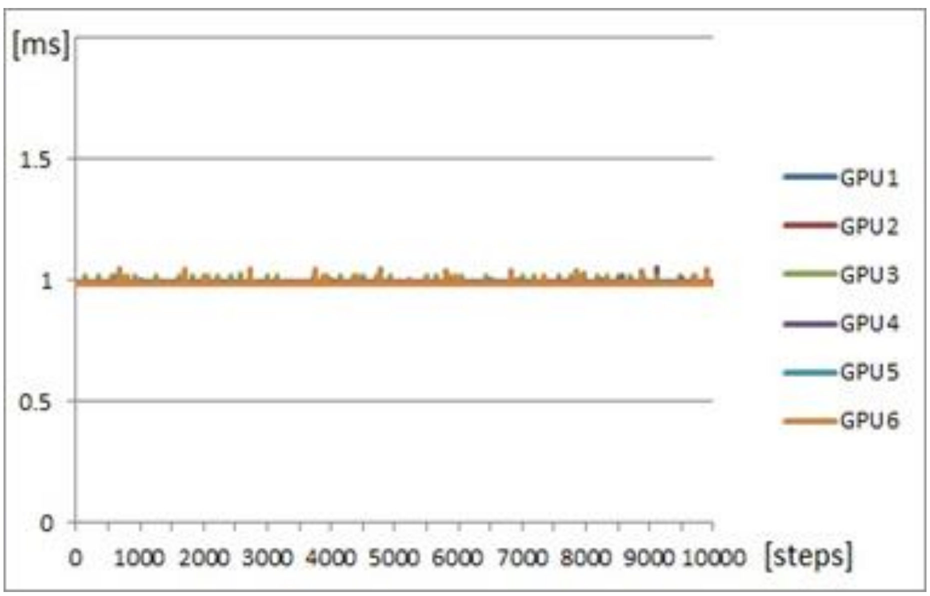

Figure 3 Calculation Time for Water Level at each GPU unit

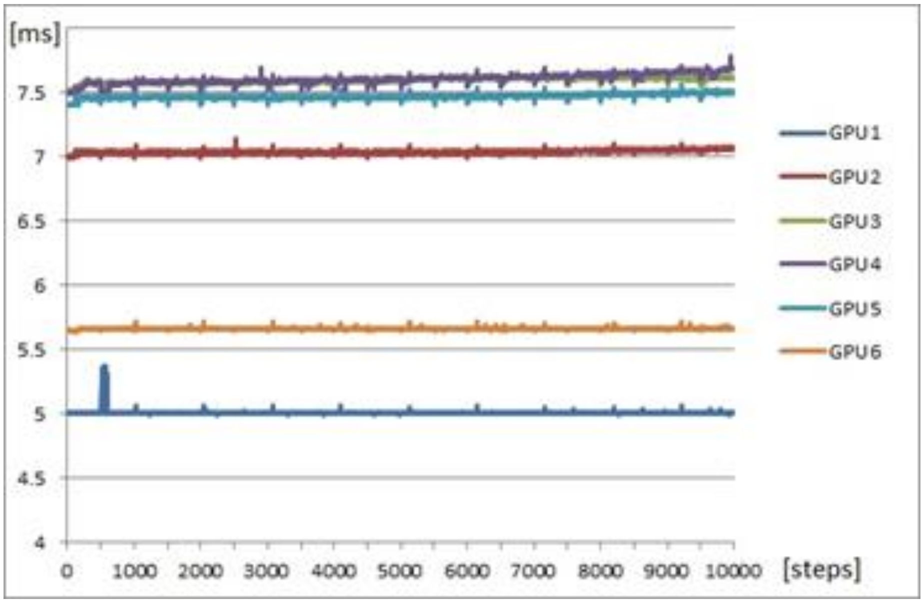

Figure 4 Calculation Time for Flux at each GPU unit

CONCLUSION

Accelerated multi GPU Tsunami run-up simulation was realized at Toyama-bay in Japan with faster computation technique. The huge area simulation is required such as 42[km] x 15[km] area with fine computational cells of 5[m] x 5[m], as a result the simulation uses over 26,000,000 computational cells. To achieve the simulation, multi GPGPU system (NVIDIA TESLA K20x, InfiniBand, MVAPICH) was used for the calculation. The result was 5.16 times faster calculation on six GPUs than one GPU and it is 86% parallel efficiency to the linear speed up. The result also indicated that the simulation time is shorter than the time of the real time phenomena (200 second). It will be able to apply the method to a real time (after earthquake occurring) tsunami disaster simulation in future.

ACKNOWLEDGMENT

This study has been supported by JSPS KAKENHI Grant-in Aid for Scientific Research C (Grant Number 24510260).

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