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A method of accelerating seismic Pre-stack time migration by GPU

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Summary

General Purpose GPU technology has being becoming mature, it has been applied in many industry area. However, due to the differences of computing feather between CPU and GPU, the study of GPU in petroleum industry application should be developed effectively. In this article, we introduce the General Purpose GPU technology and propose a method to realize pre-stack time migration software on GPU. Compared with traditional pre-stack time migration running on Personal Computer (PC) or PC-Cluster, the new programming method greatly improves computational efficiency, and then dramatically save power and maintenances cost. the actual tests in real seismic data illustrate that high performance computing based on General Purpose GPU technology(GPGPU)is a important direction of developments to meet the requirements of large scale computing in petroleum industry.

Introduction

Recent ten years,the transformation from single desktop to large-scale PC-Cluster stands for a hard and successful history. In this history, we have been aware that only increasing the number of computing nodes or the frequency of single computing node to improve the total performances will cost hugely. In Oil and Gas exploration, 3D pre-stack time migration running on PC-Cluster still cost a lot of time, so the situation that the computing results cannot meet the requirements of production schedule often takes place.

Fortunately, while the technology of PC-Cluster have been developed rapidly, another high performance computing technology, the General Purpose GPU, is becoming mature. In 2001, NVIDIA Company released the new production, programmable GPU chips as high effective computing chips building in 960 SPs (sequential processors). With the development of flexibility and floating computing ability of GPU, the trend of using GPU to complete the tasks which CPU did in the past is inevitable.

Advantages of GPU computing

General Purpose GPU technology already can use graphic card to general computing, not only to draw image. The floating-point operation performances reach trillion per second,namely correspond to ten times faster than the x86 CPU. But GPU itself after all is not general purpose chip and just can proceed some specific tasks through graphics application program interface(API), such as 3D romance, thus GPU had no means of processing general purpose computing yet. The appearance of GPU general purpose computing technique is directed to utilize powerful computational ability of GPU for speeding up general task, due to the characteristic of high parallelism and density computing. Compared with GPU, CPU is designed for low latency and complicate control, so it have little computing unit and low bandwidth; on the other hand, GPU is a processor with single instructor multiple data (SIMD) and include enormous processing unit and very high bandwidth to DRAM. These features give GPU so greatness potential to parallel processing and high density computing that it is valuable to expend GPU computing technique in Oil and Gas industry.

The travel time calculation of Pre-stack time migration

Well-known, the travel time calculation of seismic wave is a key aspect of Pre-stack time migration. There are three kinds of methods: straight ray, bending ray and un-symmetry travel time calculation. Straight ray method is

based on homogenous media assumption. The bending ray method is based on horizontally layered media assumption which can be described by a serial interval velocity. This method cannot be described by resolving expression. And using ray tracing method to compute travel time may lead to accumulative error, instability and low computational efficiency. In 1969 according to time-distance relation and the theory of paraxial approximation, Taner and Koehler declared the equation of time distance relation in horizontally layered media which has widely applied in practice. The expression as following:

$$T^2 = \sum_{k=0}^{m} c_{k-1} R^{2k} = T_0^2 + c_2 R^2 + c_3 R^4 + c_4 R^6 \cdots\cdots \quad (1)$$

where $R^2 = x^2 + y^2$. The two methods mentioned above never considered the horizontal velocity variety. In 2007 basing on the idea of the keeping structure algorithm, Lie group mathematics and exponential of pseudo-differential operator, Hong Liu discovered that the equation expression of travel time should include odd degree terms for the medias with horizontal velocity variety [2-4].

$$\begin{aligned} T^2 &= T_0^2 + \sum_{i=2}^{m} \sum_{j=2}^{i} c_{j,i-j} x^j y^{i-j} \\ &= T_0^2 + c_{2,0}\left(x^2 + y^2\right) + \left(c_{3,0} x^3 + c_{2,1} x^2 y + c_{1,2} x y^2 + c_{0,3} y^3\right) \\ &+ \left(c_{4,0} x^4 + c_{3,1} x^3 y + c_{2,2} x^2 y^2 + c_{1,3} x^1 y^3 + c_{0,4} y^4\right) \cdots\cdots \end{aligned} \quad (2)$$

In this way a kind of un-symmetry travel time Lie algebraic integral algorithm has been formed without the limits of horizontally layered media assumption. We programmed this algorithm and Kirchhoff integral pre-stack time migration. In actual test, we obtained good effects.

Parallel algorithm and efficiency

The computational efficiency of the flow of migration is a key symbol of estimating the industrial value. Besides the way of optimizing the algorithm itself, increasing parallelism of the method should be another way of improving efficiency.

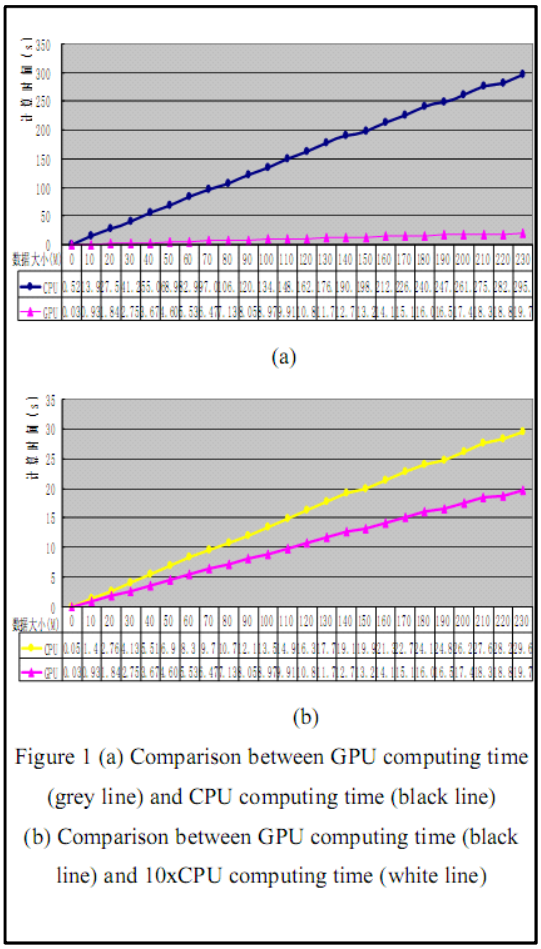
When it comes to CPU PC-Cluster, there are two programming models: output model and input model. If we use GPU to realize the algorithm of pre-stack time migration, the wide bandwidth cuts off the consummations of network transformation; each thread can address the shard memory and decrease the times of reading datasets. In this way, the requirements of output model can be met. In this article we combine input model with output model to realize un-symmetry travel time migration. Anti-aliasing and migration run on GPU.

Seismic data tests

The hardware environments of tests as following: GPU NVIDIA GForce 8800GT, the frequency of GPU is 1.5GHZ, including 128 SPs; CPU Xeon Dual Core Processor 3.0GHZ; PC-Cluster include 10 CPUs Xeon Dual Core Processor 3.0GHZ. Each node run 4 processes totally 40 processes. Compile with the flag -O3 to optimize CPU applications. The seismic datasets in our experiments are from an east survey of china.

Analysis of speedup

The speedup between single GPU and CPU and the speedup between single GPU and 10 CPU Cluster are respectively shown in figure 1. Pre-stack migration of seismic data 230MB running on GPU only consumes 19 seconds. It is 15~16 times faster than single CPU and 1.5~2.0 times faster than 10 CPU Cluster.



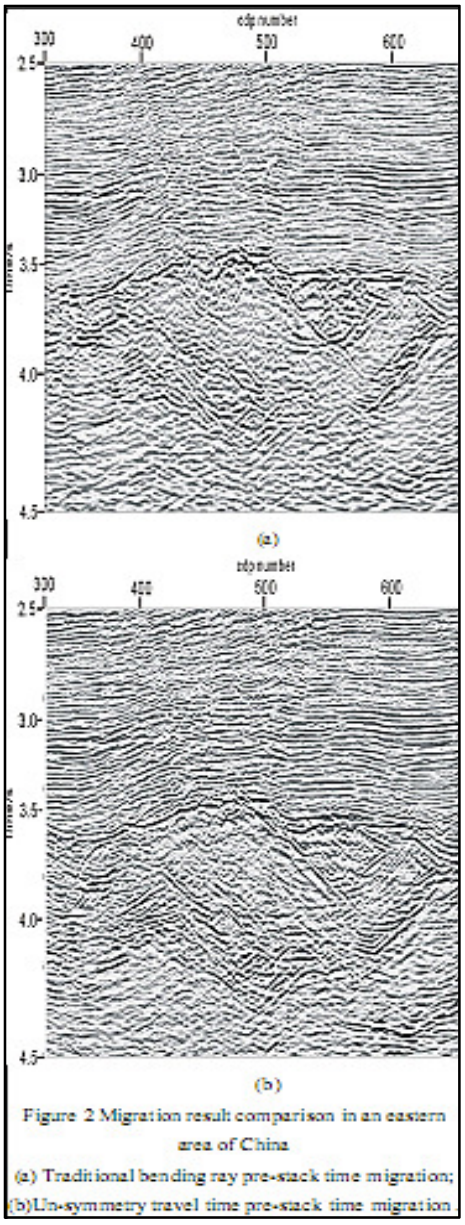
(a)

(b)

Figure 1 (a) Comparison between GPU computing time (grey line) and CPU computing time (black line) (b) Comparison between GPU computing time (black line) and 10xCPU computing time (white line)

The image quality comparison

The image results of traditional bending ray method and un-symmetry travel time migration are shown in figure 2. Compared with bending ray method results, the results of un-symmetry travel time migration can be characterized by clear faults, reasonable structures, high signal-noise ratio, and better image. That also means the precision of GPU don't affect the image results.



(a)

(b)

Figure 2 Migration result comparison in an eastern area of China

(a) Traditional bending ray pre-stack time migration; (b)Un-symmetry travel time pre-stack time migration

Conclusion

Combined with GPU computing technology, pre-stack time migration has been improved efficiently. Further considering the cheap price and huge market, GPU can be characterized by cute size, saving power and portable. So your pre-stack datasets can migrate by your desktop or personal computer with GPU. Other huge time consuming algorithm, such as the pre-stack depth migration, can be transplanted onto GPU. That means a new developmental stage is coming for 3D seismic data pre-stack imaging and multifarious mass data preparation.

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