A Special-purpose Computer for the Monte Carlo Simulation using Random Numbers with an Arbitrary Distribution

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1. Introduction

The Monte Carlo method is now the powerful and commonly used technique for analyzing statistical problems in many fields⁽¹⁾. However, when high accuracy is required, the cost of performing the computation on a general-purpose computer including a supercomputer is prohibitive, because the accuracy obtained in the Monte Carlo calculation is proportional to $1/\sqrt{N}$, where N is the number of statistical samples. As an alternative to the general-purpose computer, several special-purpose computers for the Monte Carlo simulation have been constructed⁽²⁾. However, they handle only the Ising models by using random numbers with the uniform distribution. This paper develops a special-purpose computer which can handle a large class of the Monte Carlo problems by using random numbers with an arbitrary distribution.

2. Hardware design

It is clear that a completely hardwired system that can perform the same thing as a full program for the Monte Carlo simulation cannot be built. However, the part for generating random numbers can be realized by a common hardwired system, because all Monte Carlo simulations need random numbers. As the algorithm for the rest depends on the application which we want to study, it should be organized by software. In the present work, several transputers are utilized, because they can easily perform the parallel calculation. If we want to study a special application, the transputers can be replaced by a hardwired system.

Figure 1 shows the block diagram of the special-purpose computer which we have designed and built. Transputers are connected to a general-purpose host computer and to the random number generator(RNG) developed by the authors⁽³⁾. The host computer sends transputers a compiled program for the Monte Carlo simulation. The program is written in parallel C and/or parallel Fortran language avail-

able on the transputers. The transputers perform in parallel the Monte Carlo simulation using random numbers with the arbitrary distribution generated by the RNG. The topology of the array of the transputers should be decided according to the application.

The RNG is the system for the high speed generation of random numbers with the arbitrary distribution. It prepares two tables of random numbers and stores them in two memories, and then picks out two random numbers and assembles them, resulting a new random number. One of our originalities in the RNG can be found in the method to make the tables⁽³⁾. Figure 2 shows the block diagram of the RNG. ROMs X and Y store the tables. Counters #2 and #3 count one hundred from the value given by ROMs Hx and Hy in order to produce random numbers from ROMs X and Y.

3. Performance

We are currently using two transputers (30MHz T805) and EPSON personal computer (PC386) as the host computer. As the time of one cycle of the RNG is 200ns, this system can generate 5 million random numbers a second.

In order to show the basic performance of the developed computer, we calculate the following integration using the importance sampling:

$$I = \int_0^1 e^x dx. \quad (1)$$

This integration can be estimated as follows:

$$I = \frac{3}{2N} \sum_{i=1}^N \frac{e^{\eta_i}}{(1 + \eta_i)} \quad (2)$$

where η_i is a random number with the density function of $\frac{2}{3}(1+x)$ in $[0,1]$. Transputer #1 gets a random number η_i from the RNG and sends it to transputer #2. Transputer #2 calculates the equation (2). These two transputers perform in parallel the calculation. The computational time of the transputer #1 per random number is 15.0μsec, and

Fig.1 Block diagram of the computer.

Fig.2 Block diagram of the random number generator.

that of the transputer #2 is $44.8\mu\text{sec}$. The time to transfer data between two transputers is $4.6\mu\text{sec}$. Therefore, the computational time per random number is $49.4\mu\text{sec}$.

4. Conclusion

A special-purpose computer with the RNG and several transputers has been developed to compute the Monte Carlo method. It can handle a large class of the Monte Carlo problems. Some applications will be studied in the future.

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References

- (1) K.Binder and D.W.Heermann : *Monte Carlo simulation in statistical physics*, Springer-Verlag (1992).
- (2) M.Taiji, N.Ito and M.Suzuki : "Special purpose computer system for Ising models", *Rev. Sci. Instrum.* **59**, 2483 (1988).
- (3) T.Ishikawa et al. : "A method for the high-speed generation of random numbers with arbitrary distributions", *Comp. Phys. Comm.* **70**, 501 (1992).

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