HIROSAKI UNIVERSITY

Radiation Environment and Medicine 2023 Vol.12, No.2 107–110

REM
Radiat Environ Med

Report

Expectation for Utilizing Supercomputers in Natural Radiation Research

Kazuki Iwaoka[1*], Masahiro Hosoda[2] and Shinji Tokonami[2]

[1]*National Institutes for Quantum Science and Technology, 4-9-1 Anagawa, Inage, Chiba 263-8555, Japan*
[2]*Hirosaki University, 66-1 Honcho, Hirosaki, Aomori 036-8564, Japan*

Received 30 August, 2022; revised 5 January, 2023; accepted 27 January, 2023

In Japan, there are 33 types of supercomputers with registered specifications. One of these is jointly owned by the National Institutes for Quantum Science and Technology (QST) and the Japan Atomic Energy Agency (JAEA). This supercomputer has been used in some studies, and information on using it in other research (i.e., natural radiation research) is limited. This supercomputer was used to perform two cases related to natural radiation research (Case 1–Monte Carlo radiation transport calculation and Case 2–Building Artificial Intelligence image recognition model) in this study. This study describes the expected benefits and drawbacks of using this supercomputer from the viewpoint of general natural radiation researchers.

Key words: natural radiation, supercomputer, radiation transport simulation, image recognition

1. Introduction

Supercomputers are developed by various institutions and are occasionally used for calculations in various researches. Recently, there are 33 types of supercomputers with registered specifications in Japan[1)]. One of these is jointly owned by the National Institutes for Quantum Science and Technology (QST) and the Japan Atomic Energy Agency (JAEA). This supercomputer has been used in some studies (e.g., atmospheric diffusion analysis) for various computational calculatuion[2, 3)]. This supercomputer could also be used in natural radiation research other than the above research, as follows.

Case 1–Monte Carlo radiation transport calculation: Although the dose rate (e.g., air kerma rate) for natural radiation sources is often evaluated using Monte Carlo radiation transport calculations, it generally takes time on a common PC. This supercomputer may be useful in reducing the processing time for its calculation.

Case 2–Building Artificial Intelligence (AI) image recognition model: Image recognition is often used in AI research and can be used in natural radiation research (e.g., a radiation phenomenon observed on an image, i.e., the tracks of nuclear particles on solid state detector). However, building an AI image recognition model on a common PC is a time consuming and complicated process. This supercomputer could be useful in reducing the processing time for building the model.

In this study, two cases related to natural radiation research (Case 1 and 2) were examined using this supercomputer to determine the practical benefits of using supercomputers, such as processing speed.

*Kazuki Iwaoka: National Institutes for Quantum Science and Technology, 4-9-1 Anagawa, Inage, Chiba 263-8555, Japan
E-mail: iwaoka.kazuki@qst.go.jp
https://doi.org/10.51083/radiatenvironmed.12.2_107
Copyright © 2023 by Hirosaki University. All rights reserved.

2. Materials and methods

2.1. Performance of supercomputer in this study

For this study, a supercomputer (known as HPE SGI8600)

Fig. 1. Photo of the supercomputer (HPE SGI8600) in this study.

Table 1. Expediential configuration of the radiation transport calculation.

Item	Configuration
Source	Type: point source
	Nuclides: ^{40}K of 1 Bq
	Emission direction: 4 π sr
	Particle: photon
Tally	Position: distance of 1 m from a source
	Target: fluence
Material	Whole space: air
Calculation	Monte Carlo tool: PHITS version 3.26[5]
	History per batch: 10000000
	Batch number: adjusted to be 5 processes
Remarks	Operational validation: It was confirmed in advance that the air kerma rate obtained from the fluence under these configurations was 1.85×10^{-5} nGy/h, which was 99% or more identical to that in the literature[6].

jointly owned by the QST and the JAEA and has been in operation since 2020, was used (Fig. 1). According to the explanation for the performance of this supercomputer[4], this supercomputer mainly comprises a General-Purpose computing on Graphics Processing Unit (GPU) and Central Processing Unit (CPU) sections for normal use. The total theoretical peak performance for the GPU section is 9.739 Peta Floating-Point Operations Per Second (PFLOPS), total number of computing nodes is 272, total number of cores is 13056 based on Intel Xeon Gold 6248R (3.0 GHz and 24 core), total number of units is 1088 based on NVIDIA Tesla V100 SXM2 (32 GB), and total RAM capacity is 102 TB. The total theoretical peak performance of CPU section is 2.801 PFLOPS, total number of computing nodes is 706, total number of cores is 28240 based on Intel Xeon Gold 6242R (3.1 GHz and 20 core), and total RAM capacity is 132.375 TB. The CPU section is used for all operations, such as calculation, whereas the GPU section is effective for specific operations such as image recognition.

2.2. Case and condition

Two simple cases for natural radiation research, i.e., Case 1–Monte Carlo radiation transport calculation and Case 2–Building AI image recognition model, were performed by the CPU and GPU sections, respectively.

Case 1–Monte Carlo radiation transport calculation: In one case, for convenience, a simple calculation of photon fluence in the air at a distance of 1 m from the natural radiation source was assigned ^{40}K of 1 Bq in this supercomputer. Details on expediential configuration are shown in Table 1. The CPU section of this supercomputer with the above configuration ran under various supercomputer's job conditions. The total number of cores was adjusted by setting the number of nodes. A common local computer was also used as a reference case. To avoid the effects of unexpected initial extra work during the first process, the processing time of the second process was used for performance comparison.

Case 2–Building AI image recognition model: In one case, for convenience, a simple build of a two-dimensional (2D) image recognition model for squares, triangles, circles, and hexagons was assigned to this supercomputer. Details on expediential configuration are shown in Table 2. The GPU section of this supercomputer with the above configuration ran under two supercomputer's job conditions, namely, GPU enabled and GPU disabled. The GPU environment was built using Compute Unified Device Architecture (CUDA), a platform and program on NVIDIA GPUs that can accelerate computing applications[9]. A common local computer was also used as a reference case. For performance comparison, the processing time in the second loop (epoch) was used to avoid the effects of unexpected initial extra work during the first loop.

3. Results and discussion

Case 1–Monte Carlo radiation transport calculation: The results of this supercomputer and a common local computer are shown in Table 3. As shown by the results in each supercomputer's job condition, it was possible to speed up by increasing the number of Open Multiprocessing (OMP) threads, but this was not a significant difference compared with increasing the number of Message Passing Interface (MPI) processes.

Table 2. Expediential configuration for building a simple model.

Item	Configuration
Images	Size: 100×100 pixels
	Color: blue and white
	Number: square 1000, triangle 1000, circle 1000, and hexagon 1000 (90% for learning images and 10% for test images)
Leaning	Platform: TensorFlow version 2.4.3-gpu[7)]
	Loop number (Epoch): 20
	Containerization: singularity[8)]
Remarks	Operational validation: It was confirmed in advance that the accuracy of the recognition ability under these configurations was ≥ 99%.

Table 3. Results of supercomputer and a common local computer.

Job name		SPC1	SPC2	SPC3	SPC4	SPC5	Reference[2] (Local computer)
Job condition	Processing section[1]	CPU	CPU	CPU	CPU	CPU	-
	Total core number[3]	1	10	20	20	80	-
	MPI process number	1	1	1	20	80	8 (Maximum performance)
	OMP thread number	1	10	20	1	1	-
Result	Processing time per one batch	34 s	15 s	14 s	1.9 s	0.50 s	14 s

1: Allocation was set to be exclusive. 2: A common notebook (Let's note CF-LV7, Panasonic Corp., Japan) was used for the local computer. 3: Total core number = OMP thread number×MPI process number.

Table 4. Results of supercomputer and a common local computer.

Job name		SPG1	SPG2	Reference[2] (Local computer)
Job condition	Processing section[1]	GPU	GPU	-
	Operation of CUDA	Yes (i.e., GPU enabled)	No (i.e., GPU disabled)	No (i.e., GPU disabled)
Result	Processing time per one epoch	0.72 s	8.5 s	49 s

1: Allocation was set to be exclusive. The number of GPU, core, MPI, and OMP is 1, 20, 1, and 1, respectively. 2: A common notebook (Let's note CF-LV9, Panasonic Corp., Japan) was used for the local computer.

When used for MPI processes instead of OMP threads, the cores can be more effective at speeding up. In this study, a limited number of MPI processes were used to prevent unnecessary competition among users. However, in theory, the number of MPI processes can be increased by increasing the number of cores and nodes in the CPU section of this supercomputer (approximately 7500 MPI processes as a maximum for general users), which would significantly speed up the calculation. This is a considerable advantage for shortening the calculation time for natural radiation research like this case because only a few MPI processes are available on common local computers (Table 3). However, this supercomputer has a disadvantage in that it requires additional work (e.g., command line operations, specific script preparation, and data transfer). These additional works are generally not troublesome, but some natural radiation researchers who are unfamiliar with computer literacy may consider these additional works as serious problems.

Case 2–Building AI image recognition model: The results of this supercomputer and a common local computer are shown in Table 4. As shown in the results in each supercomputer's job condition, the GPU environment with operation on CUDA (GPU-CUDA) could build the model at a higher speed than that without GPU-CUDA. Generally, local common PCs do not have a GPU-CUDA environment because GPU-CUDA is a specific and expensive option; it takes time for the common PC to build the model (Table 4). This supercomputer has a significant advantage in studies aimed at its application to natural radiation research, such as this case because the GPU-CUDA environment is available as the default state. However, this supercomputer also has a disadvantage in that a singularity container is required because users are restricted from installing any software on this supercomputer on their own. Some natural radiation researchers may have difficulty preparing the container.

4. Conclusions

For natural radiation research, such as this study, the use of this supercomputer can accelerate computer processing time. However, common natural radiation researchers, especially those in experimental fields, are unfamiliar with computer literacy, and mastering how to use, set up, and operate this supercomputer would take a long time. It is necessary to have opportunities to teach and share skills about this supercomputer with each other. The author is considering opportunities to hold study sessions, particularly for young researchers. These efforts are expected to increase the number of supercomputer users in the natural radiation research community, resulting in the production of new knowledge, technology and diversity in natural radiation research. In this regard, for example in terms of future technological development, since this supercomputer has many GPUs, consideration of improving GPU parallelization may be expected as an interesting research.

Acknowledgment

This work was partially supported by JSPS KAKENHI Grant Numbers JP17KK0162, JP18K07741, and JP21K12360, as well as Environmental Radioactivity Research Network Center F-22-46. The authors would like to thank Yuto Tomisaka for kind support regarding natural radiation research.

Disclosure

The authors declare that they have no conflicts of interest.

Author contribution

Kazuki Iwaoka performed the study and wrote the manuscript. All authors contributed extensively in the discussion of the work and the review of the manuscript.

References

1. TOP 500. [Internet]. The 59th TOP500 list [cited 2022 July 1]. Available from: https://www.top500.org/lists/top500/.
2. QST. Research Reports Using Supercomputer Systems in FY2020, QST-R-21. Chiba: National Institutes for Quantum Science and Technology; 2021. Japanese.
3. JAEA. Summaries of Research and Development Activities by Using Supercomputer System of JAEA in FY2020, JAEA-Review 2021-022. Ibaraki: Japan Atomic Energy Agency; 2022. Japanese.
4. JAEA. [Internet]. HPE SGI8600 [cited 2022 July 1]. Available from: https://ccse.jaea.go.jp/computer/index_eng.html.
5. Sato T, Iwamoto Y, Hashimoto S, Ogawa T, Furuta T, Abe S, *et al*. Features of Particle and Heavy Ion Transport code System (PHITS) version 3.02. J. Nucl. Sci. Technol. 2018;55:684–90.
6. JRIA. Radioisotope Pocket Data Book 11th edition. Tokyo: Japan Radioisotope Association; 2011. Japanese.
7. Abadi M, Agarwal A, Barham P, Brevdo E, Chen Z, Citro C, *et al*. [Internet]. TensorFlow: large-scale machine learning on heterogeneous distributed systems [cited 2022 July 4]. Available from: https://www.tensorflow.org/.
8. Kurtzer GM, Sochat V, Bauer MW. Singularity: scientific containers for mobility of compute. PLoS One. 2017;12:e0177459.
9. NVIDIA. [Internet]. NVIDIA developer [cited 2022 July 1]. Available from: https://developer.nvidia.com/cuda-zone.