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News & Highlights

More Super Supercomputers

Jane Palmer

Senior Technology Writer

In June 2018, the United States claimed the No. 1 position in supercomputing according to TOP500, which ranks the top 500 most powerful computer systems in the world [1]. The US Department of Energy's Summit machine (Fig. 1) [1] claimed this distinction, which previously had been held by China's Sunway TaihuLight supercomputer.

Web-based and open-access, TOP500 is published and updated every six months by the ISC Group, an advanced digital technology event and service provider owned by the private company Prometeus GmbH (Waibstadt, Germany). The company was founded in 1998 by the late Hans Meuer, a professor of computer science at the University of Mannheim and co-founder and organizer of what is now the annual International Supercomputer Conference and Exhibition. The list ranks these computers by the LINPACK Benchmark [2], which measures their ability to solve a dense set of linear equations using floating point arithmetic. Summit, built by IBM from commercial components for the Oak Ridge National Laboratory in Tennessee, can process 200 000 trillion floating point operations per second (FLOPS)—200 petaFLOPS, exceeding Sunway TaihuLight's performance by 107 petaFLOPS.

At the beginning of 2019, Summit still held the first place position in the rankings but another US machine, Sierra of the Lawrence Livermore National Laboratory reached the second place with a processing power of 94 petaFLOPS [3]. As reflected by the rapid change in rankings over the last year, countries worldwide are all working to build faster, and consequently more powerful, supercomputers. Their goals are inspired less by international prestige than the promise of machines that can speed advances in scientific discovery and economic competitiveness.

"Really it is about building machines to help solve problems that couldn't be solved before," said computer scientist Jack Dongarra, the director of the Innovative Computing Laboratory at the University of Tennessee, co-author of the TOP500 list, and originator of the LINPACK Benchmark. "Although there is pride associated with having the fastest computer."

In the early days of computing, personal computers performed only one function at a time, a procedure termed serial processing. Then it became possible to split problems or actions into several pieces and work on each piece simultaneously—a strategy termed parallel processing. This could be achieved by having more processors in a single machine, or by having many machines working in parallel. Today's supercomputers use both approaches.

Fig. 1. Housed in refrigerator-sized cabinets, the Summit supercomputer fills a floor space spanning 506 m^2, about the size of two tennis courts. Credit: Carlos Jones, Oak Ridge National Laboratory/US Department of Energy (CC BY 2.0).

Summit has 9216 central processing unit (CPU) chips and 27 648 graphic processing units (GPUs) [4], which are tightly connected. Dongarra explains that, to match what Summit does in 1 s, the entire population of Earth would have to compute continually for 305 d, performing one operation per second. To attain this level of performance, the scientists have added GPUs to the supercomputer model. Architecturally, CPUs are composed of several cores with cache memory that can handle only a few operations at a time. GPUs, however, can handle many operations simultaneously, and perform the same operation very quickly on huge batches of data. Using GPUs boosts acceleration while being more power-efficient than using CPUs [5]. "Using GPUs is the main driver of the increase in performance," said Hongzhang Shan, a parallel programming expert at the Lawrence Berkeley National Laboratory.

Supercomputers are typically used for complex, mathematically intense scientific problems, such as simulating the climate, forecasting the weather, or testing the strength of encryption codes. In the early 1990s, the US Department of Energy embarked on a campaign to raise the processing speed of the world's best computers by a factor of 10 000 [6] with the purpose of building machines that could model nuclear processes. Adding multiple GPUs to the supercomputer architecture boosts their performance for many computational problems, including for data mining and deep learning, Dongarra said.

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Although the United States now hosts the two fastest supercomputers in the world, China hosts the most supercomputers, claiming 227 systems in the TOP500 rankings in November 2018 [7]. Supercomputers can have so many applications, and be so useful, that having more of them can be a real advantage—potentially as valuable as having the most powerful supercomputer in the world. "Having the fastest supercomputer is not always required to solve many problems," Shan said. The United States claims 109 systems in the TOP500 rankings, the second largest number, and Japan is the third with 31 systems.

China also now has three prototypes for an exascale computer, which would be capable of one million trillion operations [8] per second, or 1000 petaFLOPS—five times more powerful than Summit. It is believed that the first exascale, or exaFLOPS, supercomputer will likely be the Tianhe-3, at the National Supercomputing Center in Tianjin, in 2020 [9]. All these new supercomputers will most likely make use of GPUs, but "going exascale" will also require radical changes in computing architecture, software, and algorithms, said Dongarra, who is also a co-Editor-in-Chief of *Supercomputing Frontiers and Innovations*, an open-access journal focused on these technical and computational challenges.

Other countries are also working to produce exascale computers. The United States is spending $1.8 billion USD to develop three exascale supercomputers, which should be completed in 2021–2022 [10], and both Japan and Europe are also investing billions of dollars to develop exascale computing [9]. Breakthroughs in chip technology could fuel further significant advances in supercomputer performance, but likely not in the near-term future.

These increasingly powerful computers will be most useful in helping researchers gain an improved understanding of the world we live in, Dongarra said. The increased speed of computation, the greater fidelity, and the higher memory capacity will result in more detailed models that will give scientists the ability to explore any situation in greater depth. Already Summit's power is being used in research areas ranging from fusion energy to advanced materials and human disease [11].

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