High-Performance Computing in Industry

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Abstract

In 1993, a list of the top 500 supercomputer sites worldwide was made available for the first time. Since then, the TOP500 list has been published twice a year. The list allows a detailed and well-founded analysis of the state of high-performance computing (HPC). This article summarizes the recent trends in application areas of HPC systems, focusing on the increase in industrial installations and applications. A detailed analysis with respect to the geographical distribution, the market share of manufacturers and the architectures used for different application areas is presented.

1 Introduction

Within the TOP500 project we are collecting information about the 500 most powerful computer systems, ranked by LINPACK performance. Since June 1993

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we have been publishing the TOP500 lists twice a year [1]. Because these lists record a variety of different data, they furnish an excellent basis for studying the high-performance computing (HPC) market (see, for example, [2], [3], [4] and [5]). Moreover, such lists can provide valuable insights about changes over time; see, for example, a study on the technologies used in HPC systems [6].

In this article, we analyze the type of customer and applications of the HPC systems in the TOP500 since 1993. During this time there has been a strong growth in the number of industrial users, and a comparable increase in the number of computer installations at industrial sites. One reason for this increase is that companies such as IBM and SGI have offered binary-compatible systems, from single workstations up to full-scale parallel systems. These companies thus have been able to sell a large number of systems to commercial customers; in turn, their systems often are selected for new supercomputer application areas. Another reason for the increase in industrial installations is that industrial customers have gained the needed experience to use medium-sized parallel systems (with up to 128 processors, and in some cases even more) and are now pressuring their companies to purchase high-performance supercomputers.

The variety of applications areas represented in the TOP500 has also been increasing during this time. The most important examples of new areas are database applications and image processing.

2 Performance Measure

For practical reasons we are using the LINPACK [7] performance for all systems listed in the TOP500 regardless of the application. LINPACK provides an adequate unit of measurement if one is interested in floating-point performance of computer systems. It is certainly not adequate for systems used for database applications, however. More useful benchmarks such as the TPC benchmarks are available for such applications[1]. By using the LINPACK benchmark, we miss all "pure" database systems, such as those from Teradata or Tandem, since no adequate LINPACK performance values are available for them (most likely, even a Fortran compiler would not be available). Therefore, we cannot produce statistics for the different vendors in the database market. Nevertheless, since we can track a reasonable sample of this market, we can see the fundamental trends, and we can compare the importance of these new applications for parallel systems with the more traditional numerically intensive applications.

3 Type of Customer

The year 1995 was a remarkable one for the TOP500 in several respects. In addition to new technologies used for HPC systems [6], there were considerable

[1] http://www.tpc.org/

changes in the distribution of the systems in the TOP500 for the different types of customer (academic sites, research labs, industrial/commercial users, vendor installations, and confidential sites) (see Fig. 1).

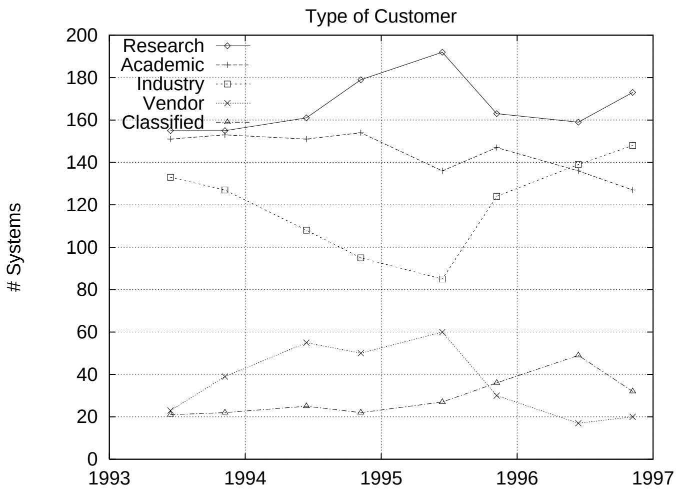

Figure 1: The number of systems on the different types of customers over time.

Until June 1995, the major trend seen in the TOP500 data was a steady decrease of industrial customers, matched by an increase in the number of government-funded research sites. This trend reflects the influence of the different governmental HPC programs that enabled research sites to buy parallel systems, especially systems with distributed memory. Industry was understandably reluctant to follow this step, since systems with distributed memory have often been far from mature or stable. Hence, industrial customers stayed with their older vector systems, which gradually dropped off the TOP500 list because of low performance.

Beginning in 1994, however, companies such as SGI, Digital, and Sun started to sell symmetrical multiprocessor (SMP) models of their major workstation families. From the very beginning, these systems were popular with industrial customers because of the maturity of these architectures and their superior price/performance ratio. At the same time, IBM SP2 systems started to appear at a reasonable number of industrial sites. While the SP initially was sold for numerically intensive applications, the system began selling successfully to a larger market, including database applications, in the second half of 1995. Subsequently, the number of industrial customers listed in the TOP500 increased from 85, or 17%, in June 1995 to about 148, or 29.6%, in November 1996.

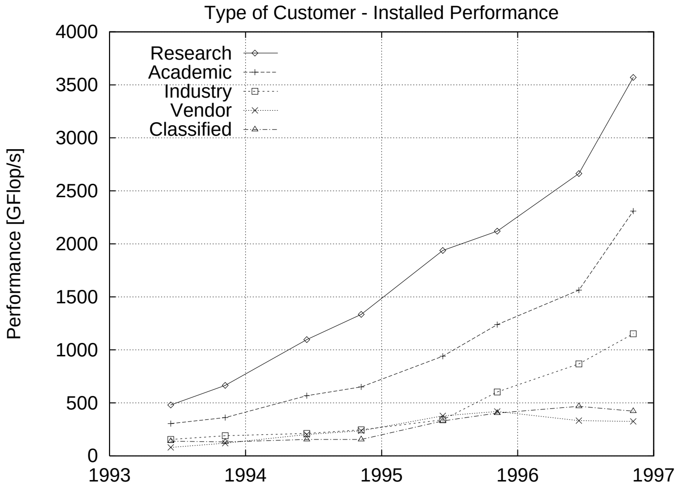

Figure 2: The accumulated performance of the different types of customers over time.

Figure 2 shows that the increase in the number of systems installed at industrial sites is matched by a similar increase in the installed accumulated performance. The relative share of industrial sites rose from 8.7% in June 1995 to 14.8% in November 1996. Thus, even though industrial systems are typically smaller than systems at research laboratories and universities, their average performance and size are growing at the same rate as at research installations. The strong increase in the number of processors in systems at industrial sites is another major reason for the rise of industrial sites in the TOP500. The industry is ready to use bigger parallel systems than in the past.

4 Geographical Distribution of Industrial HPC Systems

The United States clearly leads the world, both as producer and as consumer of high-performance computers [6]. Analyzing the geographical distribution of the customers in the TOP500 we see that this leadership pattern is reflected in industrial siting of high-performance computers. As Table 1 indicates, in the United States, 38% of the systems are installed at industrial sites compared with 23% in Europe and only 11% in Japan. In the United States, there are more systems at industrial sites than at governmental research labs or at academic

Table 1: Geographical distribution of type of customer as of November 1996.

TOP500 Statistics — Number of Systems Installed					
	U.S.	Europe	Japan	Others	Total
Research	81	52	39	1	173
Academic	44	44	28	11	127
Industry	104	31	9	4	148
Classified	28	3		1	32
Vendor	14	2	4		20
Total	271	132	80	17	500

Table 2: Geographical distribution of the accumulated performance for the different types of customers as of November 1996.

TOP500 Statistics — Installed R_{max} [Gflop/s]					
	U.S.	Europe	Japan	Others	Total
Research	1622.0	940.7	1105.8	6.6	3675.1
Academic	586.2	500.2	1171.1	111.0	2368.5
Industry	801.7	220.3	119.7	25.9	1167.6
Classified	362.7	53.4		5.9	422.0
Vendor	218.9	24.2	111.2		354.2
Total	3591.5	1738.8	2507.8	149.3	7987.4

sites. While having installed 54% of all systems worldwide, the United States holds 70% of all industrial sites.

Table 2 shows that the United States is also a market leader for the accumulated installed performance; where the United States has 45% of the overall performance and 69% of the total industrial performance worldwide.

5 Distribution of Industrial HPC Systems by Manufacturer

SGI with it's new subsidiary Cray Research is the clear leader market leader with respect to the number of systems (see Table 3) and the accumulated installed performance (see Table 4). Focusing on the industrial market segment we see however that IBM is ahead of SGI/Cray with respect to the number of systems as with the accumulated installed performance. The major reason for this is

Table 3: Geographical distribution of type of customer as of November 1996.

TOP500 Statistics — Number of Systems Installed						
	Research	Academic	Industry	Classified	Vendor	Total
SGI/Cray	80	50	58	24	10	222
Cray only	62	23	23	15	8	131
SGI only	18	27	35	9	2	91
IBM	28	29	67	1	1	126
Fujitsu	12	14	2		3	31
NEC	20	3	4		1	28
TMC	8	5	6	4		23
Hewlett-Packard	3	9	7	1	2	22
Intel	12	4	1	1		18
Hitachi	4	6	1		2	13
Others	6	7	2	1	1	17
Total	173	127	148	32	20	500

Table 4: Geographical distribution of the accumulated performance for the different types of customers as of November 1996.

TOP500 Statistics — Installed R_{max} [Gflop/s]						
	Research	Academic	Industry	Classified	Vendor	Total
SGI/Cray	2488.0	607.1	452.3	332.7	110.5	2831.5
Cray only	1192.8	449.9	262.7	265.7	88.1	2259.2
SGI only	136.0	157.2	189.6	67.0	22.4	572.3
IBM	456.5	331.9	500.9	14.4	88.4	1392.1
Fujitsu	728.0	357.5	14.2		27.2	1126.9
NEC	428.6	144.5	72.9		60.7	706.6
TMC	125.2	98.6	53.8	58.2		335.8
Hewlett-Packard	17.1	60.1	50.6	5.5	18.2	151.4
Intel	496.2	52.1	5.8	6.3		560.4
Hitachi	64.6	674.4	7.1		42.6	788.7
Others	30.1	42.3	10.1	5.0	6.7	94.1
Total	3675.1	2368.5	1167.6	422.0	354.2	7987.4

IBMs success in selling the SP2 system as parallel database system.

6 Application Areas

For research sites or academic installations, it is often difficult—if not impossible—to specify a single dominant application. The situation is different for industrial installations, however, where systems are often dedicated to specialized tasks or even to single major application programs. Since the very beginning of the TOP500 project, we have tried to record the major application area for the industrial systems in the list. We have managed to track the application area for almost 90% of the industrial systems over time.

Since June 1995 we see many systems involved in new application areas entering the list. Figure 3 shows the total numbers of all industrial systems which is made up of three components: traditional engineering applications, new emerging applications, and unknown application areas. Figure 4 shows the accumulated performance for these components. It is evident that the new emerging applications show a strong rise since mid 1995 in the number of systems and in the installed performance as well.

In 1993, the applications in industry typically were numerically-intensive applications, for example,

- geophysics and oil applications,
- automotive applications,
- chemical and pharmaceutical studies,
- aerospace studies,
- electronics, and
- other engineering including energy research, mechanical engineering etc.

The share of these areas from 1993 to 1996 remained fairly constant over time, as can be seen in Figure 5 and Figure 6. The possible exception was the electronics industry: the number of recorded systems continuously decreased from 14 in June 1993 to 5 in November 1996 and the installed performance shows no substantial increase over time. It is unclear to us if the recent drop of the numbers for the chemical industry are only a temporary effect or a signal that this industry no longer need the very high end supercomputers.

Recently industrial systems in the TOP500 have been used for new application areas. These include

- database applications,
- finance applications, and

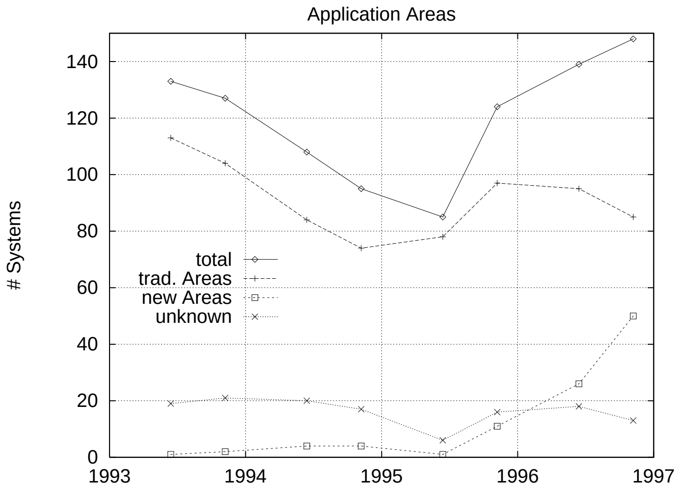

Figure 3: The total number of systems at industrial sites together with the numbers of sites with traditional engineering applications, new emerging application areas and unknown application areas.

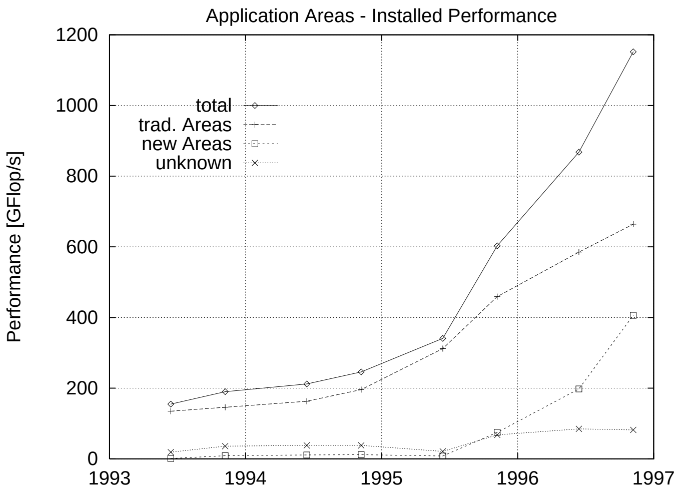

Figure 4: The accumulated performance of the different classes of industrial sites.

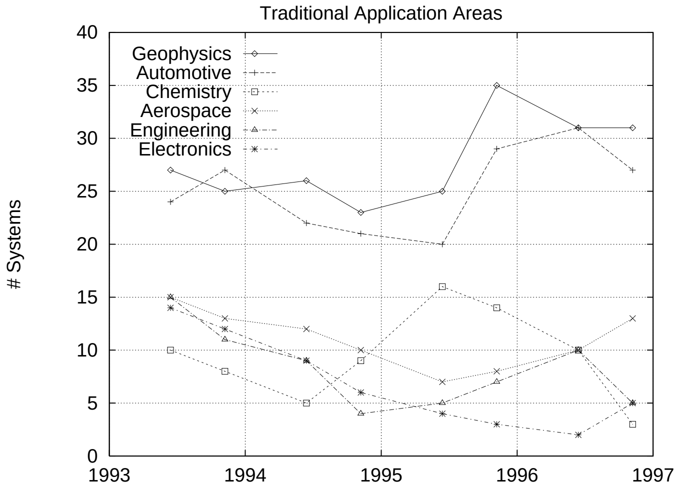

Figure 5: The number of systems at industrial sites used for traditional engineering applications.

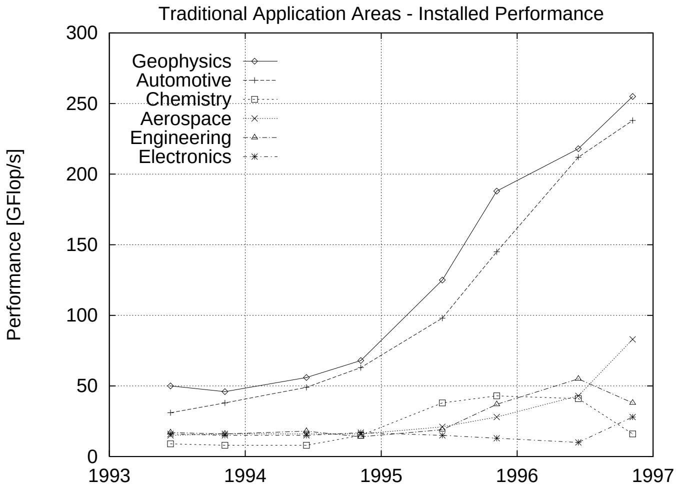

Figure 6: The accumulated performance at industrial sites used for traditional engineering applications.

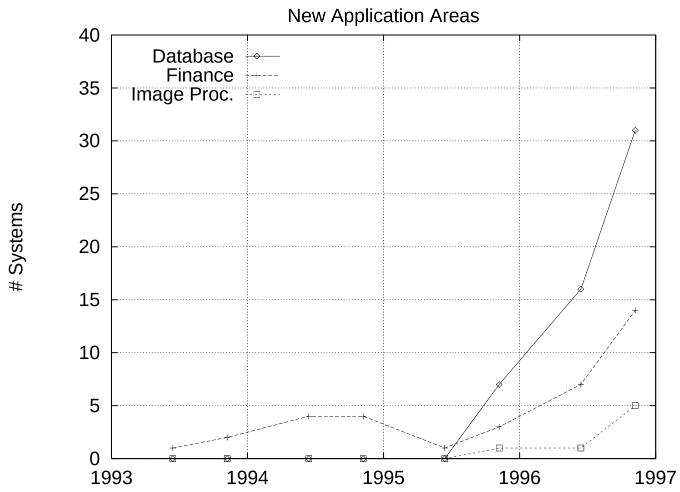

Figure 7: The number of systems at industrial sites used in new application areas.

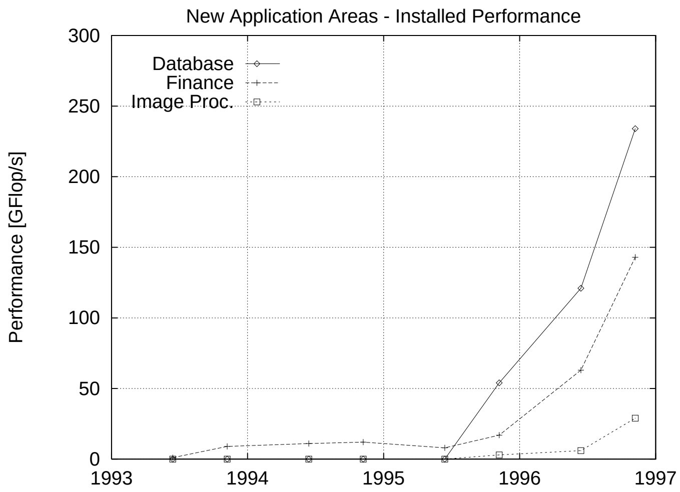

Figure 8: The accumulated performance at industrial sites used in new application areas.

- image processing.

The most dominant trend seen in Figure 7 and Figure 8 is the strong rise of database applications since mid 1995. These applications include on-line transaction processing as well as data mining. The HPC systems being sold and installed for such applications are large enough to enter the first hundred systems—a clear sign of the growing maturity of the systems and their practicality for industrial usage.

7 Architectures used in different Application Areas

It is also important to notice that industrial customers are buying not only systems with traditional architectures, such as the SGI PowerChallenge or Cray Triton, but MPP systems with distributed memory, such as the IBM SP2. Distributed memory is no longer a hindrance to success in the commercial marketplace. In Table 5 we see that only in the automotive industry vector processing is still dominating.

In all other industrial application areas such as aerospace, geophysics and new applications MPP have replaced the vector systems. In the automotive, geophysics and aerospace industry we also see a substantial number of SMP systems.

Table 5: The different architectures used in industrial systems as of November 1996.

TOP500 Statistics — Number of Systems Installed				
	MPP	PVP	SMP	Total
Aerospace	6	3	4	13
Automotive	3	14	10	27
Chemistry		1	2	3
Electronics	1		4	5
Engineering	3	1	1	5
Geophysics	22	1	8	31
Database	27		4	31
Finance	13	1		14
Image Proc.	1		4	5
others	1			1
Unknown	13			13
Total	90	21	37	148

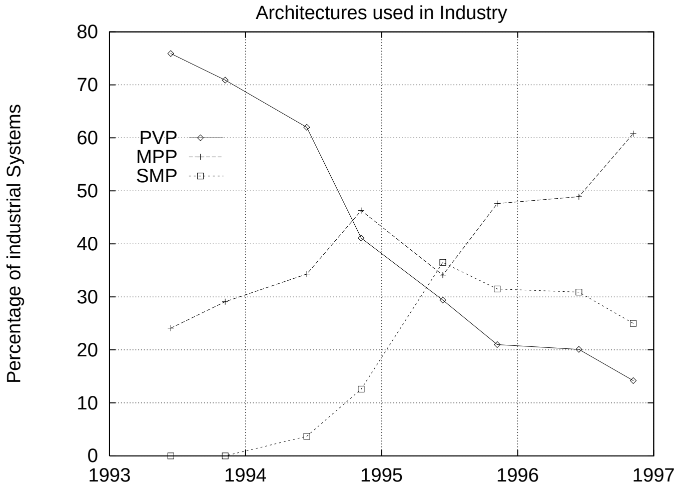

Figure 9: The percentage of the different architectures installed at industrial sites based on system counts.

In figure 9 we see the continuous replacement of the vector systems (PVP) by MPP systems and SMP systems over the last five years.

8 Conclusions

The success of massively parallel systems in commercial environments is not bound to any special architecture. Maturity of systems and availability of key application software in a standard Unix system environment are much more important than details of the system architecture. The use of standard workstation technology for single nodes is one key factor. This eases the task of building reliable systems with portable application software.

From the present eight releases of the TOP500 we see the following trends:

- The number of industrial customers in the TOP500 has risen steadily since June 1995.
- The most successful companies (IBM and SGI) are selling disproportionately well in the industrial market.
- The average system size at industrial sites is increasing strongly.
- Database applications is the most important and most successful new application area for supercomputers.

- Distributed-memory systems are being installed at industrial sites in reasonable numbers and have outnumbered shared memory vector systems in the meantime.
- Only in the automotive industry vector processing is still dominant.
- IBM is leading in the industrial market place ahead of SGI/Cray.
- The United States is the world leader in the industrial usage of HPC systems.

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