LS-DYNA PERFORMANCE
ON ULTRASPARCTM -III
SERVERS AND WORKSTATIONS

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ABSTRACT

Sun Microsystems recently announced a new line of high-performance Sun FireTM Midframe servers and Sun BladeTM 1000 workstations based on 750-MHz UltraSPARC-III microprocessors. These new computers offer exceptional performance for numerically intensive MCAE applications at reasonable prices. This paper presents single- and multi-processor performance and scalability results of LS-DYNA running on these systems. Results of both OpenMP and MPI binaries are compared to those of existing server platforms. Scalability and performance results are presented for the OpenMP binary that has been built with Sun's native OpenMP compiler extension. Comparisons with a previous version using libraries from KAI show significant improvements both in the absolute execution time and the scalability. The MPI executable tuned for the new Sun Fire server resulted in a 40-60% improvement in execution time over the entire range of processor counts.

BENCHMARK SYSTEMS

In this paper, performance data of LS-DYNA are reported for Sun Blade 1000 workstation and Sun Fire 6800 server, both based on UltraSPARC III (US-III) processors.

Sun Blade 1000 is 2-CPU deskside workstation based on US-III processors [1]. It features a high-performance crossbar-switch system interconnect that provides high bandwidth for high-speed processors and graphics subsystems, and a 64-bit PCI bus for fast I/O. It has up to 8 GB memory, two 18/36-GB disks, and five high-end 3D graphics options. The benchmark system had two 750-MHz processors with 8 MB E-cache, 8 GB of memory and 150 MHz system bus.

Sun Fire 6800 is a Midframe server with up to 24 US-III processors, 192 GB memory, 4 dynamic system domains, 9.6 GB/s sustained I/O bandwidth, and is fully hardware redundant [2]. The benchmark system had 24 750-MHz processors with 8 MB E-cache, 49GB of memory and 150 MHz system bus.

Executables tested were LS-DYNA SMP version 950c, 950e and MPP version 940.2a, and uniprocessor binary based on 950e source. Baseline executables had been compiled with Sun Performance Workshop CompilerTM version 5.0 F77 compiler. The newly tuned executables used ForteTM 6 update 1 compiler [3]. For SMP executable that uses OpenMP library used Sun's F90 along with OpenMP version 1.0 that are part of the Forte 6 update 1 compiler suite.

Test cases used were mostly public-domain benchmarks from FHWA/NHTSA National Crash Analysis Center[7] -- except for one customer benchmark which is the side impact of a truck into a lamp post.

Table 1 summarizes the configuration of the benchmark systems used.

Table 1. Configuration of the benchmark systems.

Executables	LS-DYNA-SMP v.950c, 950e	LS-DYNA-MPP v.940.2a
Hardware	Sun Blade 1000	2x750 MHz US-III, 8 MB E-cache, 8 GB memory
	Sun Fire 6800	24x750 MHz US-III, 8 MB E-cache, 49 GB memory
Operating System	SolarisTM 8	
Parallel Environment	Forte OpenMP v.1.0	SunTM HPC ClusterToolsTM 3.1, CRE
Compiler	Forte 6 update 1 F90	Forte 6 update 1 F77

PERFORMANCE RESULTS

• Sun Blade 1000

With the introduction of workstations based on the new US-III processors, extensive tuning of LS-DYNA for the new hardware were executed. Table 2 shows the results of the tuning performed. The test case is the rp_lsd93, a small car impact with a rigid pole of 6,000 nodes, from Professor Malcolm Ray at Worcester Polytechnic Institute [4]. The first executable tuned for UltraSPARC processor did not show satisfactory performance on US-III processors. But after tuning targeted at the new processor, the new executable recovered its performance to achieve a speed-up that scales almost up to the clock-speed increase, resulting in 1.60x speed-up where the clock-speed increase is 1.67x compared to the existing Ultra 80.

Table 2. Tuning results of small car impact on US-II and US-III workstations.

Executables	Hardware	Elapsed Time(sec)	Speed-up
v.950c uniprocessor (Tuned for US-II)	Ultra 80, US-II, 2x450MHz, 4MB E-Cache	5376	1.0x
	Sun Blade 1000, US-III, 2x750MHz, 8MB E-Cache	4256	1.26x
v.950e uniprocessor (Tuned for US-III)	Sun Blade 1000, US-III, 2x750MHz, 8MB E-Cache	3355	1.60x

• Sun Fire 6800

This section describes performance results on Sun Fire 6800 system with various test cases.

- Neon test case:

In a previous paper [5], the Sun E10000 StarfireTM server proved to be a platform suitable for large-scale crash simulations, demonstrating superb scalability and efficiency with LS-DYNA-MPP especially at large CPU counts. Here, the same test case has been used to make comparisons for the scalability of the new server versus Starfire. Table 2 shows execution times and scalability of base and optimized executables running on Sun Fire 6800. The table also includes times from [5] of base executable running on the E10000 server with 64 400-MHz US-II CPU's and 8 MB E-cache. The same decomposition has been used as in [5] for both cases, using pfile of :

```
decomp { expdir 2 expsf 15; silist 2,6 }
```

The base MPI executable (v.940.2a) had been compiled with Sun Workshop 5 being tuned for US-II processor, while the optimized one was based on the v.940.2 source and was compiled with Forte 6 update 1 F77 compiler. Parallel environment used for the optimized runs was Sun HPC ClusterTools v.3.1 with Sun Cluster Runtime EnvironmentTM (CRE).

Table 2. Run results of MPI executables on Sun Fire 6800. Neon frontal impact case (286K nodes). Simulation time of 10 msec. Numbers in square brackets are interpolated from Figure 2.

NCPU	Opt. Exec (sec)	Opt. Scale	Efficiency (%)	Base Exec (sec)	Speed-up (Opt/Base)	E10K Exec (sec)	E10K Scale	Speed-up (Opt/E10K)
1	40862	1	100			68599	1	1.68x
2	18946	2.16	108			31735	2.2	1.68x
4	9417	4.34	109			15406	4.5	1.64x
8	4885	8.36	105	7032	1.44x	8077	8.5	1.65x
16	2889	14.1	88	3994	1.38x	4493	15.3	1.56x
22	2217	18.4	84	3298	1.49x			
24	2154	19	79			[2983]	[23.0]	[1.38x]
32						2310	29.7	

Figure 1 shows the improvement in absolute run time achieved with the optimized executable on Sun Fire 6800 as compared with the the best number obtained with E10000 running the base executable. The speed-up achieved ranges from 1.56x to 1.68x up to 16 processors. Clock frequency ratio was 1.88 - that is, the ratio of 750 MHz divided by 400 MHz.

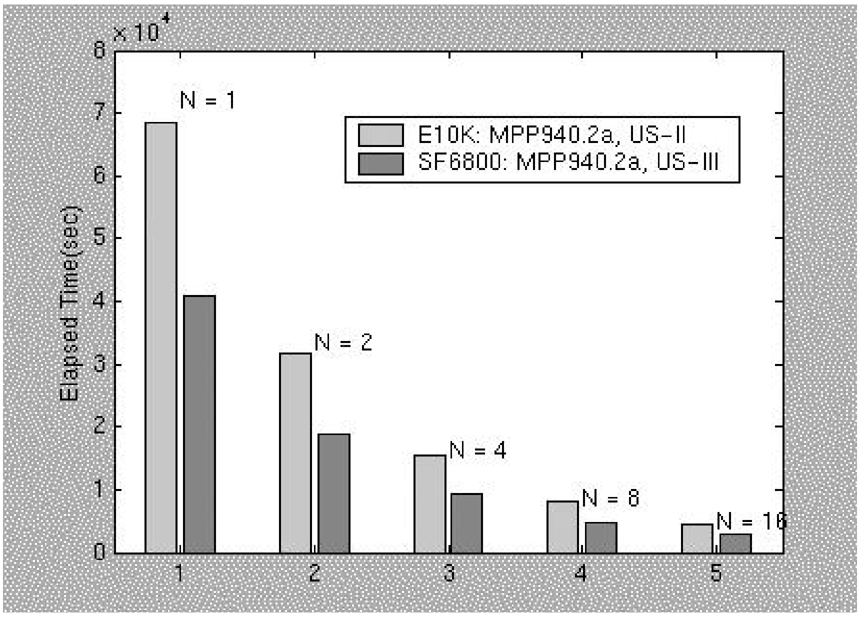

Figure 1. Absolute timing for Neon test case up to 10 msec.
Sun Fire 6800 numbers were obtained with MPP v.940.2a optimized for US-III;
E10000 numbers with MPP v.940.2a optimized for US-II.

In Figure 2, the scalabilities of the two servers are compared. Although the E10000 shows overall superior scalability, the Sun Fire 6800 still exhibits 88% efficiency at 16 processors, maintaining still high scalability at the full CPU count. Interpolation from the figure would give 23x at 24-CPU for E10000, which would in turn account for 1.38x faster execution time for the Sun Fire 6800 at full 24-CPU as displayed with square brackets in Table 2.

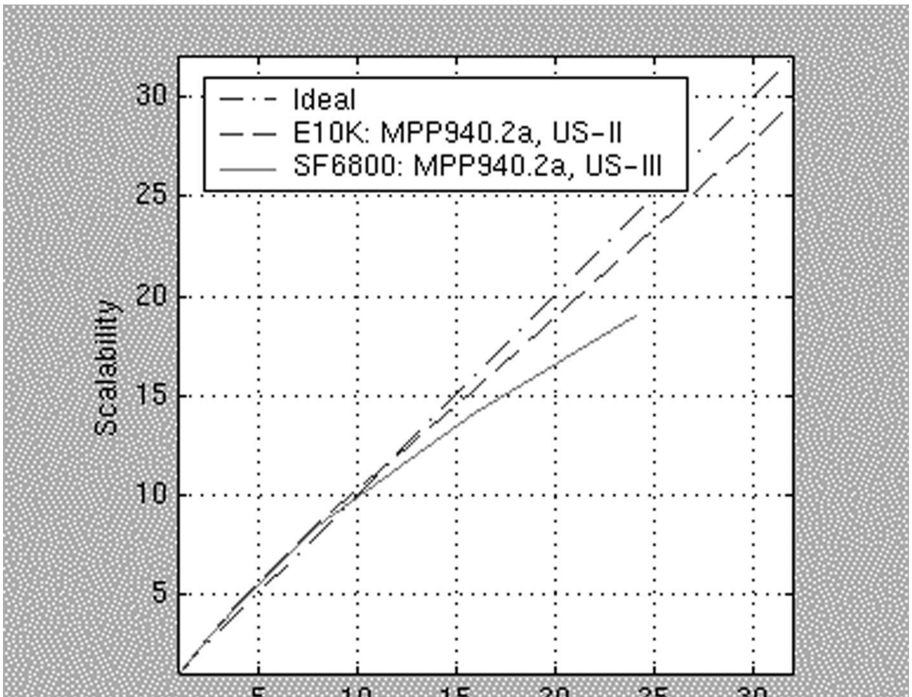

Figure 2. Scalability of Sun Fire 6800 compared to E10000 server. Neon test case.
Sun Fire 6800 numbers were obtained with MPP v.940.2a optimized for US-III;
E10000 numbers with MPP v.940.2a optimized for US-II.

- Taurus test case:

Table 3 and Figure 3 shows the MPI performance improvement on the Sun Fire 6800 server from the runs of Taurus frontal crash up to 150 msec simulation time. The model and decomposition used were same as in [5]. Both base and optimized executables are the same ones as used in the Neon test case. Execution speed-up achieved was ranging from 1.38x to 1.61x where at lower processor count was the larger speed-up. This speed-up is comparable to the ones achieved for the Neon test case, 1.38x to 1.49x over 8 to 22-CPU range.

Table 3. Performance improvement of MPI executable on Sun Fire 6800.
Taurus frontal impact case (27K nodes) up to 150 msec.

NCPU	Opt. Exc. (sec)	Opt. Scale	Base Exc. (sec)	Base Scale	Speed-up
4	9990	1	15969	1	1.61x
8	5836	1.71	8723	1.85	1.49x
16	3401	2.94	4729	3.41	1.39x
22	2802	3.57	3878	4.15	1.38x

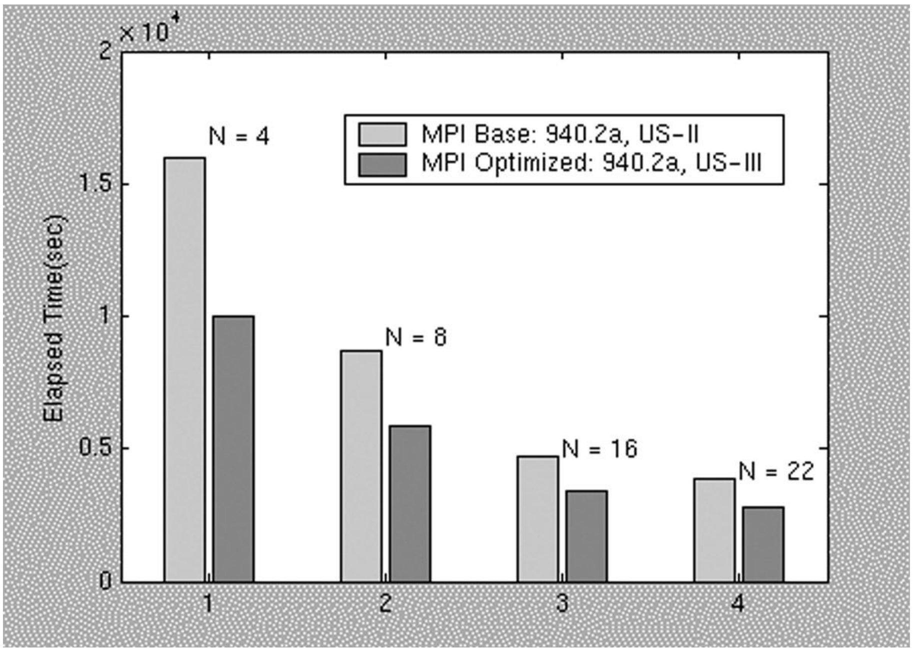

Figure 3. Effect of MPI optimization: Taurus frontal crash on Sun Fire 6800.
Base executable is MPP v.940.2a optimized for US-II with Workshop 5.0 compiler;
Optimized executable based on MPP v.940.2a with US-III tuning with Forte 6 update 1.

- Customer benchmark case:

Table 4 shows the performance data for a customer benchmark test case. The model is a truck side impact crashing into a lamp post, and it consists of 70,000 nodes. The new executable tuned for US-III shows 1.7x speed-up with respect to the base executable, achieving an equivalent level of improvement for the Neon and Taurus cases.

Table 4. Performance improvement of MPI executable on Sun Fire 6800.
Customer benchmark case (70K nodes) of truck side impact into a lamp post.

NCPU	Opt. Exc. (sec)	Opt. Scale	Base Exc. (sec)	Speed-up
4	15060	1		
8	10490	1.44		
12	8880	1.7	15163	1.71x
16	5534	2.72	9191	1.66x
20	5870	2.57	10022	1.71x

COMPARISON BETWEEN OpenMP AND MPI

Starting with v.950e, the SMP version of LS-DYNA became available that uses Sun's native OpenMP library. The OpenMP capability is available through Forte 6 update 1 F90 compiler as a suite of OpenMP libraries [3]. In this section, two OpenMP binary versions, 950c and 950e, were first compared. V. 950c had been compiled with Sun Workshop 5.0 F77 compiler with OpenMP functionality from Guide library version 3.6 from KAI [6]. Version 950e was compiled with Forte 6 update 1 F90 compiler with Sun-native OpenMP library version 1.0. The timing data were obtained from an E10000 server with 64 333-MHz US-II processor and 4 MB external cache. The test case used was NCAC Taurus frontal crash model used in [5] with the simulation time of 5 msec.

Table 5 shows the timing comparison between OpenMP and MPI executables. The three columns after the processor number column relates to OpenMP timing. The second column numbers are obtained with v.950e native OpenMP and Forte 6 compiler, while the third with v.950c KAI OpenMP executable. Over the range of processor counts up to 16, the Sun-native OpenMP executable shows better performance over the one using Guide library in absolute timing except for the single processor run where the difference is within noise level. The new executable also shows better scalability. The difference between the two executables are not limited to the OpenMP performance, since the source code and compilers used are different. But it is safe to say that when used properly, the Forte Fortran compiler and its OpenMP extension provide an appropriate toolset for parallel processing development environment for SMP LS-DYNA.

The second group of columns, fifth to seventh, show optimization results for the MPI executable. Both MPI executables used the same v.940.2a source, while the old one used Performance Workshop 5 compiler and the new Forte 6 compiler. MPI library used were HPC ClusterTools 3.0 and 3.1, respectively. The optimization was targeted at US-II processor, mainly focused on the compiler-based tuning. The result was a consistent improvement up to 16-CPU's.

The last column compares parallel efficiency between the native OpenMP and the optimized MPI executable across the range of processor counts. The tests show increasing improvement in MPI performance as the processor count increases, resulting in better scalability for MPI executable, up to 50% better at 16-CPU. Figure 5 summarizes the scalability results of KAI and Sun OpenMP, and optimized MPI executables. The superiority of MPI over OpenMP in terms of scalability is quite obvious, verifying the well-known fact of MPI advantage in scalability coming from the higher, physical domain-level parallelism compared to the loop-level parallelism of OpenMP. For this specific test case, the cross-over point where MPI outperforms OpenMP were as early as at 2-CPU.

Table 5. Comparison of OpenMP and MPI executables running Taurus frontal impact case up to 5 msec. Runs were made on an E10000 server. Optimized executables are based on US-II.

NCPU	Sun OMP Exec (sec)	KAI OMP Exec (sec)	Speed-up OpenMP	MPI Opt. Exec (sec)	MPI Base Exec (sec)	Speed-up Sun MPITM	Speed-up MPI/OMP
1	3053	3012	0.99x	3109	3730	1.20x	0.98x
2	1712	1859	1.09x	1445	1771	1.23x	1.18x
4	971	1176	1.21x	712	788	1.11x	1.36x
8	563	678	1.20x	400	428	1.07x	1.41x
12	434	488	1.12x				
16	367	447	1.22x	246	246	1.00x	1.49x

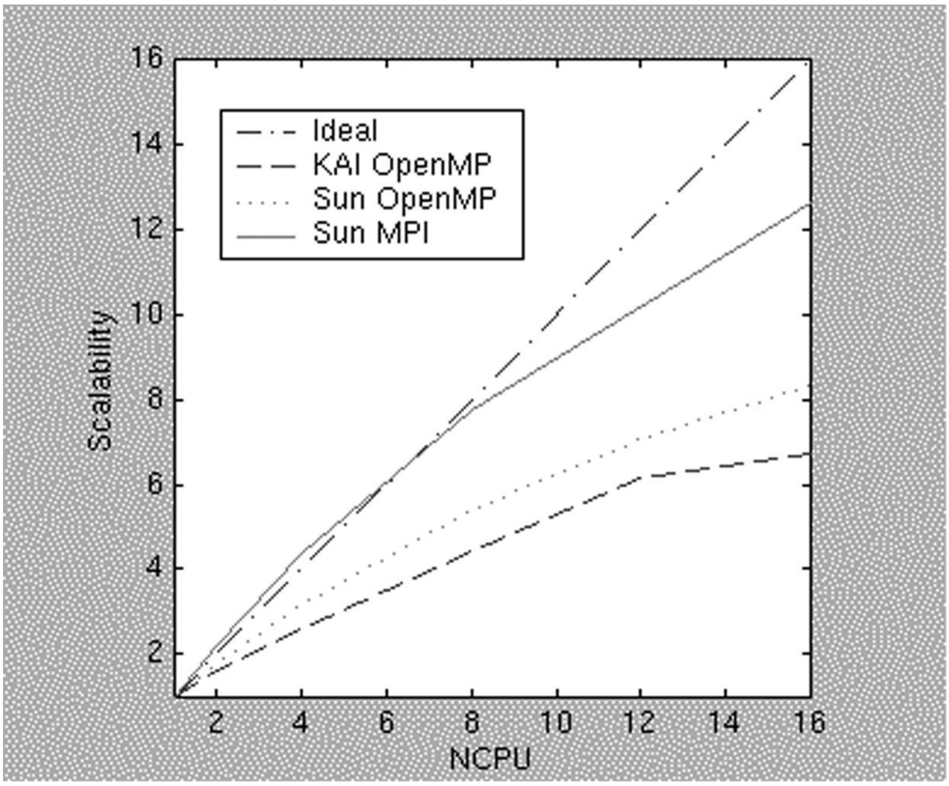

Figure 4. Comparison of scalability: OpenMP and MPI executables. Taurus frontal impact case, running on an E10000 server.

SUMMARY

The new Sun Fire 6800 Midframe server based on the new UltraSPARC III processor is thus an effective computational platform for LS-DYNA, for both OpenMP and MPP-executables. With the aid of the latest Forte compiler along with either OpenMP or MPI library, the tuned binaries targeted for the new processor exhibited a satisfactory run-time performance especially in the large processor counts. Sun's native OpenMP was successfully used to generate parallel executable for SMP machine, improving the performance of existing OpenMP binary. The MPI executable proved to be effective in large processor count for the test cases considered. This is due to the high-level parallelism obtained from MPI formulation as compared to the loop-level parallelism of OpenMP.

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