Performance Evaluation on the ALE Formulation in MPP LS-DYNA

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Abbreviation:
ALE Arbitrary Lagrangian Eulerian
CPU Central Processing Unit
EPIC Explicitly Parallel Instruction Computing
MPP Massive Parallel Processing

Keywords:
ALE Formulation, MPP Performance, Intel® Itanium™ Processor Family

ABSTRACT

The ALE fluid-structure coupling capability in LS-DYNA has become the main tool to accurately simulate the airbag-inflating process. However, it is very time-consuming: Running serially, it has been observed to take more than ten days on various computer platforms. Hoping to obtain speedup by parallelization, LSTC has been making efforts to implement the ALE formulation with MPP LS-DYNA. In this paper, the scalability of this implementation, with the number of processors up to 64, is investigated on an HP Superdome. While the result indicates the current scalability of MPP LS-DYNA is inadequate and its improvement is needed, a preliminary study predicts the McKinley processor of the Intel® Itanium™ Processor Family will make the goal of simulating a full airbag-inflating process within 24 hours possible.

INTRODUCTION

The traditional Lagrangian finite element formulation, in which the computational mesh follows the material boundaries and moves with the material deformation, is known to be efficient and accurate for problems with moderate deformation. For problems with large deformation, evolving topology and chemical reactions (e.g. airbag inflating), the Lagrangian formulation is, however, not adequate because of its low accuracy and small stable time steps caused by distorted elements. An adequate approach is the multi-material Eulerian, or Arbitrary Lagrangian Eulerian (ALE), finite element formulation, in which the mesh is fixed in space and the material flow through the mesh (Livermore Software Technology Corporation, 1998). With the mesh being fixed in space, the numerical difficulties caused by the distortion of elements are eliminated, and so the ALE has become the chosen method to accurately simulate the airbag inflating process.

However, the ALE formulation for the simulation of airbag inflating process is very compute-time intensive. Running serially, it has been observed to take more than ten days on various computer platforms. And in fact until a couple of months ago, LS-DYNA offered only the serial capability of the ALE formulation. Hoping to obtain speedup by parallelization, LSTC has been making efforts to implement the ALE formulation with MPP LS-DYNA. In this paper, the question of scalability of this implementation is answered with a performance study on a 64-CPU HP Superdome. While the result indicates that the scalability is inadequate and needs improvement, we will show in this paper that the goal of simulating a full airbag inflation-process within 24 hours will be achievable with the newly introduced McKinley processor of the Intel® Itanium™ Processor Family. Furthermore, we will discuss the reason why the McKinley processor can achieve such a good performance.

SCALABILTY OF AIRBAG SIMULATION

In this investigation, we use HP's current largest, and most powerful, single-image system, the 64-CPU Superdome with the 750 MHz PA8700 Processor. The airbag model consists of about 120,000 elements. The MPP DYNA version used is 970. To avoid a prolonged testing, we first obtain the timings for the short simulation time of 3 milliseconds for the cases of 1, 2, …, 32, 64 CPUs. The result is shown in Table 1 and Figure 1. This result clearly indicates the scalability of the ALE formulation in MPP-LSDYNA needs improvement.

Number of CPUs	**1**	**2**	**4**	**8**	**16**	**32**	**64**
Elapsed Time in Seconds	31448	19324	10402	8294	5987	4872	3794
Speedup	1.00	1.63	3.02	3.79	5.25	6.45	8.29

Table 1. The scalability of MPP LS-DYNA simulating the airbag inflating process for 3 milliseconds.

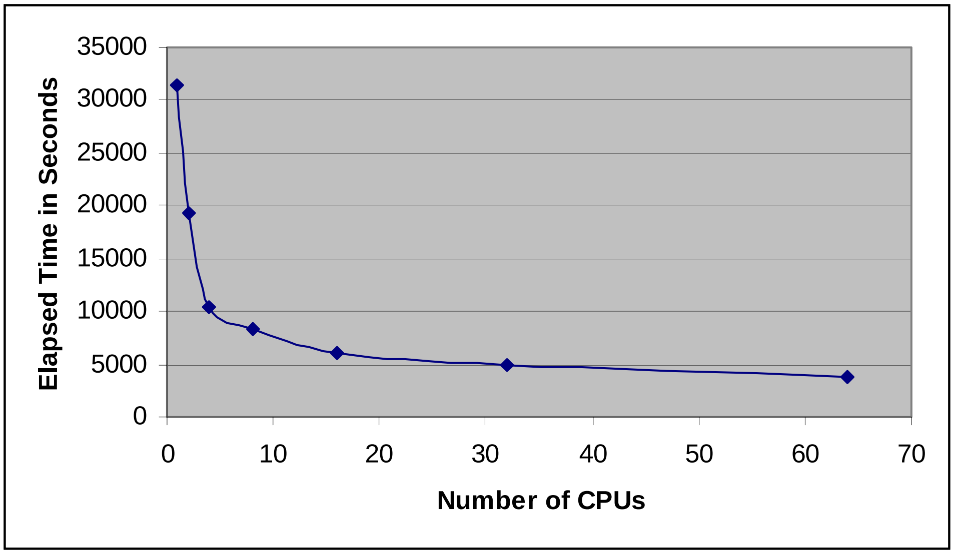

Figure 1. The scalability of MPP LS-DYNA simulating the airbag inflating process for 3 milliseconds.

HOW LONG DOES IT TAKE FOR A FULL AIRBAG SIMULATION?

It takes about 60 milliseconds for the airbag inflating process to complete. At the time of investigation, MPP LS-DYNA has numerical problems that caused the simulation to fail beyond 50 milliseconds. So we ran the simulation to 50 milliseconds with 16, 32, and 64 CPUs on the HP Superdome to measure how long it takes for a full airbag simulation. The result is shown in Table 2. It is worthwhile to note that it takes more than one and half a day to finish the simulation even with 64 CPUs.

While this result, as well as the result shown in the previous section, clearly points to the need to improve the scalability of MPP LS-DYNA, preliminary study indicates that the newly introduced McKinley processor of the Intel® Itanium™ Processor Family will reduce the times here by a factor of more than 1.5. This would reduce the elapsed time to less than 24 hours with a cluster of 64-CPU McKinley processors, as shown in Table 3.

Number of CPUs	**16**	**32**	**64**
Elapsed Time in Hours	47.05	36.98	33.47

Table 2. Measured times for simulating the airbag inflating process for 50 milliseconds with 16, 32, and 64 CPUs on an HP Superdome.

Number of CPUs	**16**	**32**	**64**
Elapsed Time in Hours	<31.4	<24.7	<22.3

Table 3. Predicted times for simulating the airbag inflating process for 50 milliseconds with 16, 32, and 64 CPUs on clusters of McKinley processors.

THE INTEL® ITANIUM™ PROCESSOR FAMILY

In this section, we will discuss briefly why the McKinley processor can achieve a performance of at least 1.5 times faster than the PA8700 processor. The McKinley processor belongs to the Intel® Itanium™ Processor Family, which is based on a new parallel architecture—Explicitly Parallel Instruction Computing (EPIC). The EPIC architecture is co-developed by Intel and Hewlett-Packard. Other current architectures suffers from the following problems:

- Poor instruction level parallelism
- Inhibition of performance by branches
- High memory latency

The EPIC architecture addresses these problems by the following approaches:

- Advanced software (compiler) techniques
- Designing hardware that allows the compilers to tell hardware how to improve parallelism, remove branches, and decreases latency effects
- Prediction
- Speculation

All evidences that we have gathered so far indicate the EPIC architecture has achieve superior performance gain relative to other architecture. And we are confident the Intel®Itanium™ Processor Family will become the industry's leading processor family.

SUMMARY

First, using a cut-short simulation time of 3 milliseconds, we present the scalability, up to 64 CPUs, of MPP LS-DYNA with the ALE approach to simulate the airbag inflating process. Second, we present the measured elapsed times to simulate the inflating process fully, to 50 milliseconds. The result indicates that presently no platform, regardless of how many processors it has, is able to finish the full simulation within 24 hours. It points to the needs to improve both the scalability of the software, MPP LS-DYNA, and the performance of the hardware. The latter challenge will soon be met with the newly introduced McKinley processor of the Intel® Itanium™ Processor Family.

ACKNOWLEDGEMENT

As the capability of ALE formulation in MPP LS-DYNA is newly implemented, it inevitably has problems. During this investigating, I appreciate Dr. Jason Wang's extra effort to make this capability work so that I have the opportunity to present this paper.

REFERENCES

Livermore Software Technology Corporation (1998). LS-DYNA Theoretical Manual, pp. 14.1-28.