Improvement of domain decomposition of LS-DYNA MPP R7 and R8

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1 Introduction

In order to get the accurate results by crash analysis, the large models with fine meshes are generally used. The increase of computational time by the large models is improved by the MPP version of LS-DYNA.
The domain decomposition is one important technique to get the good performance by MPP version. LS-DYNA MPP R7 and R8 improve the domain decomposition.

2 What is domain decomposition?

MPP version is the parallel processing. The model divided to several domains, and each domain assigned to the each core in cpu. The elements and nodes on the boundary of domain are transfer the information to those in the other domain. In order to get the good performance, the following two items are important:

- Load balance; the calculation cost of each domain should be the same
- Communication: The communication cost between domains should be small

The calculation of LS-DYNA is mainly divided to two parts: element processing and contact algorithm.

2.1 Domain decomposition from the view point of element processing

Since the communication of element processing occurs only on the boundary of domain, the amount of communication is small. The load balance is important for element processing.

For element processing, LS-DYNA knows the element formulation and material type from input data, and can estimate the cost of element calculation. By using these information LS-DYNA can distribute the elements to each domain as the calculation cost are the same. In other words, by any domain decomposition, element processing should be the same calculation time during the early stage of job.. However, at the later stage of job the change of element cost during the calculation, for example, material change from elastic to plastic, or element deleted by failure of elements, has to be considered for domain decomposition.

2.2 Domain decomposition from the view point of contact algorithm

For Contact Algorithm, both load balance and communication are important. For highly parallel case(more than 200), communication is more important, since the many data have to transfer between domain.

Choice of domain decomposition is large effect for the performance.

In this paper we use the 10-million element model with deformable offset barrier and refined NCAC Taurus model until 10ms. [1]

3 LS-DYNA MPP R6

Three type of domain decomposition as show in Fig.1 is tested.

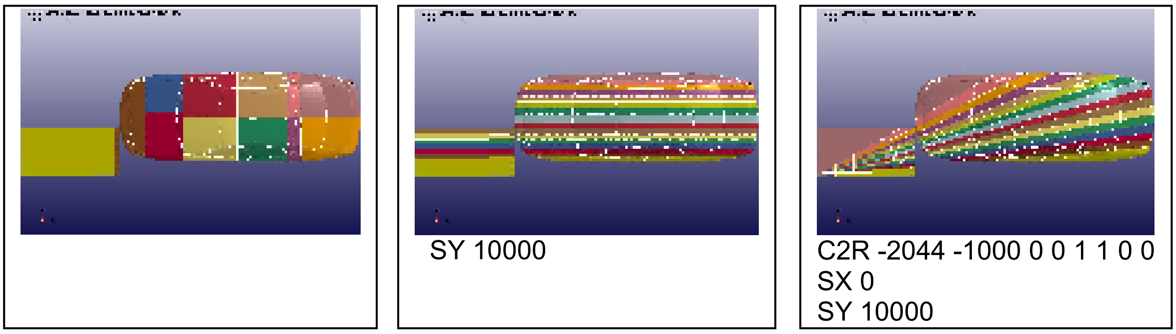

Fig.1: Three type of domain decomposition (a) default, (b) sy and (c) C2R

In the following figures, the performance is the wall clock time of 24cores SY decomposition divided by the each wall clock time, and the abscissa is the number of cores. As shown in Fig.2, the performance of default decomposition (R6-default) is lower than the other two domain decomposition(R6-SY and R6-C2R).

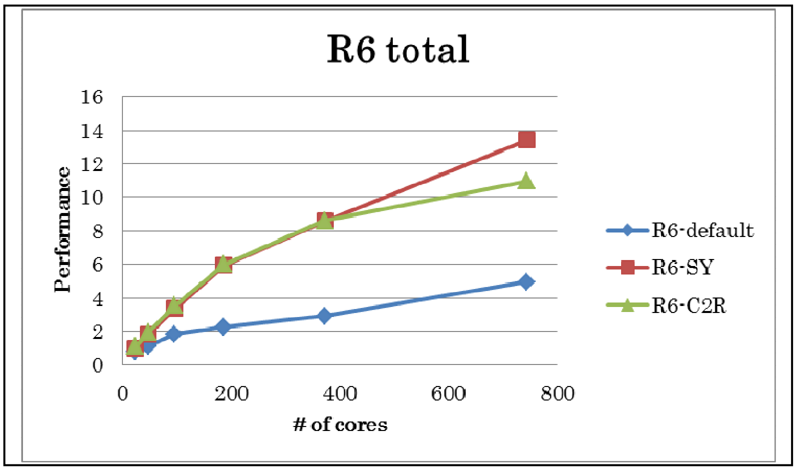

Fig.2: The total performance of R6.

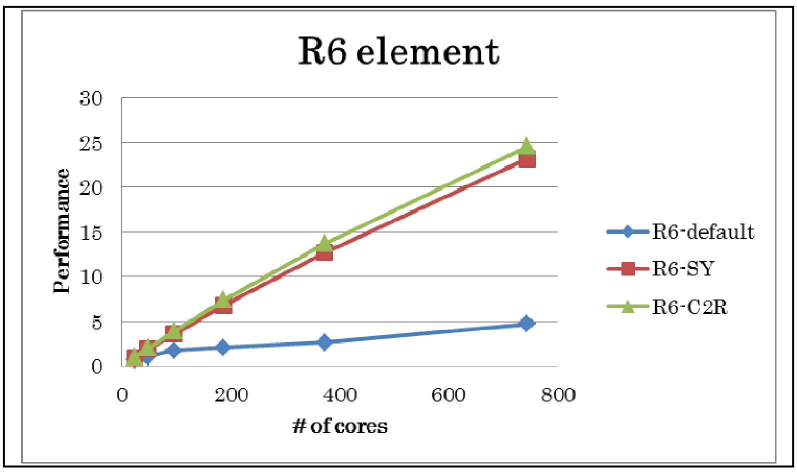

Fig.3: The element performance of R6.

Figures 3 and 4 show the performance of element processing and contact + rigid body. respectively. Although the performance of contact + rigid body for default decomposition is better than the other two decomposition, the performance of element processing is lower than the others. The low performance comes from element processing as shown in Fig.3.

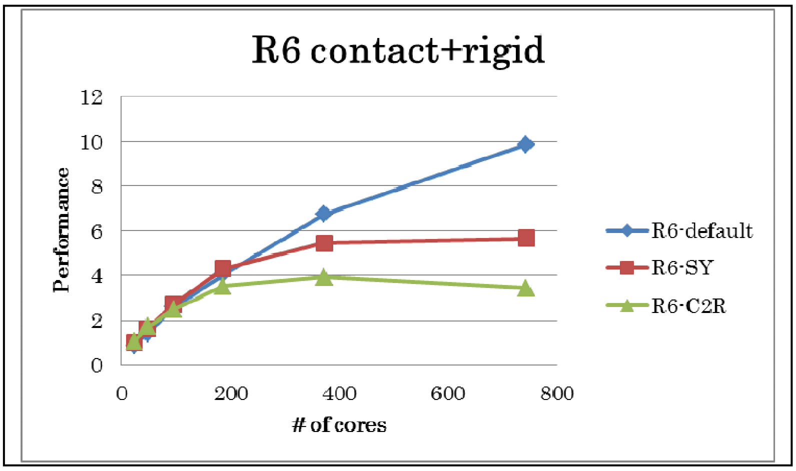

Fig.4: The contact+rigid performance of R6.

4 LS-DYNA MPP R7

Figures 5 and 6 show the performance of element and other, respectively, by LS-DYNA MPP R7.. Figure 5 shows the performance of element processing. The performance of all decomposition are the almost same , and the performance of default decomposition looks improved. However, from LS-DYNA MPP R7, the output of the timing information is changed. The element processing output in LS-DYNA MPP R6 is split to the element processing and OTHER. As shown in Fig. 6, the performance of OTHER for default decomposition is still lower than other decompositions.

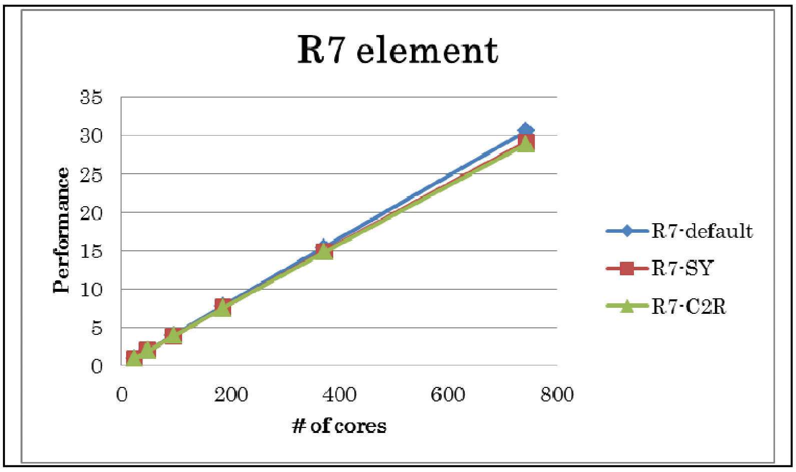

Fig.5: The element performance of R7

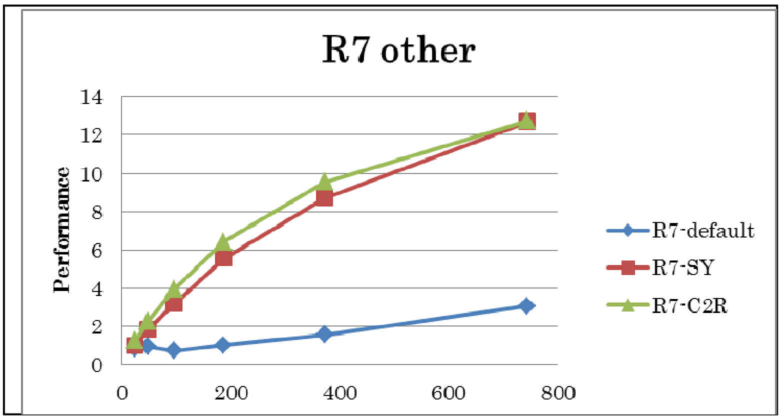

Fig.6: The oter performance of R7

5 Element cost evaluation

In order to know the lower performance of OTHER, LS-DYNA MPP R8 is used, because LS-DYNA MPP R8 output the timing information more detail, and the OTHER in LS-DYNA MPP R7 is split to time step size, OTHER and misc1,2,3,4. From these information of LS-DYNA MPP R8, the most time consuming part is time step size. The time step size is mainly timing of load imbalance of element calculation. The low performance of default decomposition comes from the load imbalance of element calculation. We improve the performance of element processing by the following procedure.

The new element cost evaluation is developed in LS-DYNA MPP R8.

5.1 Preparation for element cost evaluation

The element cost evaluation is done by several steps.

First the set of simple test data with the following lines is prepared. The set of simple test data include the all element formulation and the all material type.

```
*CONTROL_MPP_PFILE
decomp { timing_start 10 timing_end 5000000 }
```

Fig.7: Collecting timing information of element formulation and material

By executing the set of simple test data, DECOMP_TIMINGS.OUT and DECOMP_TIMING.PARMS is created. These data include the timing information data depend on the element formulation and the material type from timing_start cycles to timing_end cycles defind in pfile as shown in Fig.7.

After we have DECOMP_TIMINGS.OUT and DECOMP_TIMING.PARMS, execute the tool decomp_timings, which will be provided with LS-DYNA MPP R8.

```
decomp_timings *.OUT
```

This command generated shell_costs.inc_New and solid_costs.inc_NEW, which include calculation time information of one element per one cycle for each the element formulation and material type.

As shown in Fig 8, by adding the lines of newcost, shellcosts and solidcost in pfile decomp section, we can use the new element cost for decomposition.

```
decomp {
  newcost
  shellcosts shell_costs.inc_NEW
  solidcosts solid_costs.inc_NEW
}
```

Fig.8: New costs defined in pfile

5.2 Results of new element cost

Figure 9 shows the OTHER, which accumulated the detailed information of LS-DYNA MPP R8 and equivalent to OTHER of LS-DYNA MPP R7.

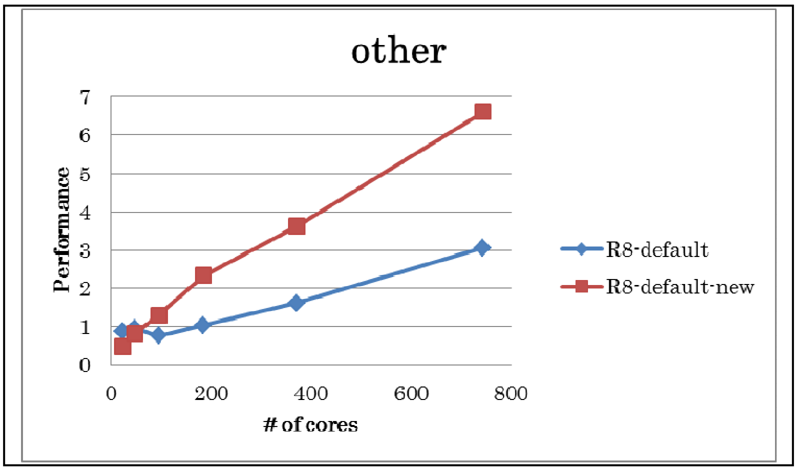

Fig.9: The OTHER performance of R8

R8-default is the results of default element cost of LS-DYNA and R8-default-new is the results of new cost defined in Fig.8. By using NEW cost, OTHER performance improved more than 2 times.

Figure 10 shows the total performance . R8-default-new is better than R8-defalut and more closer to R8-SY and R8-C2R.

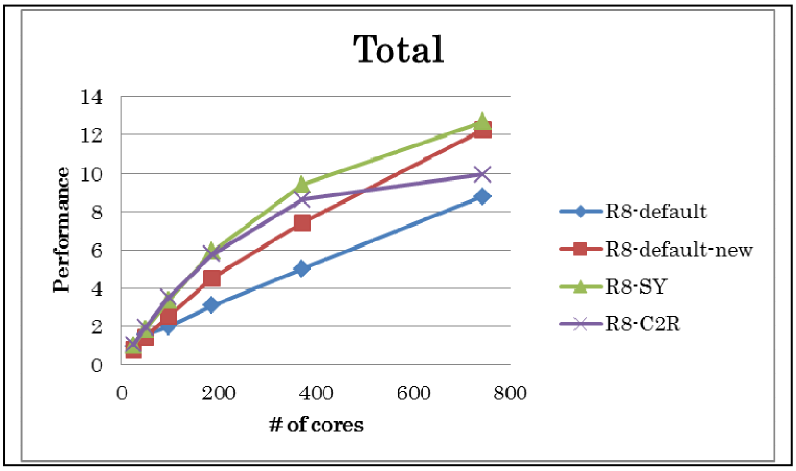

Fig.10: The Total performance of R8.

6 Summary

- In LS-DYNA MPP R8, user can define the element cost for domain decomposition.
- LS-DYNA MPP R7 can read the new element cost data shown in Fig.8, however, the new element cost data is created by LS-DYNA MPP R8.
- By using the new element cost data, the performance of default decomposition of ODB-10M is improved. The time step size of LS-DYNA MPP R8 is reduced 28.4% from 47.5%.
- The performance of other decomposition (SY and C2R) with new element cost data, which do not shown in this paper, is not improved at this time. Since the time step size of LS-DYNA MPP R8 has 11.9% and 8.8% for SY and C2R, respectively, we need more tuning of element test data, because the set of simple data for element cost is provided by LSTC, and this data is not complete.
- Thick shell element and beam element have not yet to define the new element cost. The new element cost routine will extend to these elements in future.

7 Acknowledgements

I would like to thank Mr. Brian Wainscott of LSTC for the development of new cost capability and fruitful discussions about MPP version. I also acknowledge Dr. John Hallquist for using the computer system..

8 Literature

[1] Makino,M, Yamada,S: "ODB-10M New topcrunch Benchmark Data", 8th European LS-DYNA Conference, 2019, session24-2