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APPLICATIONS OF PARALLEL PROCESS HIMAP FOR LARGE SCALE MULTIDISCIPLINARY PROBLEMS

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Since the initiation of the HPCC Project at NASA early in 90s, several computational tools have been developed under the computational aerosciences(CAS) area[1]. One such tool is HiMAP, a supermodular, 3-level parallel, portable high fidelity, tightly coupled analysis process[2,3]. This process is designed using the state-of-the-art information technology tools such as MPIRUN[4], an efficient protocol to allow groups of processors to communicate with other groups of processors for mutltidisciplinary type computations. MPIRUN is based on IEEE standard Message Passing Interface (MPI)[5] that is currently supported by most major computer vendors.

The modularity in HiMAP is based on the function of the individual discipline module. In general, an analysis process in HiMAP is divided into independent and dependent modules. Independent modules are those dealing with specific physics and can be used in stand alone mode as a single discipline code. For example, the fluids module is an independent module. Dependent modules are usually required for multidisciplinary computations.They depend on more than one module for their function. A typical example of a dependent module is thermal loads module in aero-theromoelastic computations. This module requires temperature data from the fluids module and also structural data from the structures module to convert temperature to thermal loads. Figure 1 shows a typical process chart for HiMAP.

The three level (intra-discipline, inter-discipline and multiple run) parallel capability is built into HiMAP using MPI and MPIRUN protocols. On a typical massively parallel super-computer, a set of processors are assigned to each discipline as needed. Communication within discipline is accomplished using MPI. Between disciplines and cases communications are achieved using MPIRUN. Figure 2 shows the multi level parallel capability of HiMAP.

The hybrid coarse-fine grain parallelization achieves the goal of load-balanced execution provided that there are enough processors available to handle the total number of blocks. On the other hand, the load-balancing does not guarantee the efficient use of the computational nodes. The computational nodes might be working with less than the optimal computational load and performing a lot of expensive inter-processor communications, hence data-starved. Both problems are alleviated by introducing domain-coalescing capability to the parallelization scheme. In domain coalescing, a number of blocks are assigned to a single processors resulting in economy in number of the computational resources and also a more favorable communications-to-computations ratio during the execution. This process which is illustrated in Fig. 3 is described in Ref. 6 that was presented at SC97.

HiMAP is suitable for large scale multidiscipinary analyses. It incorporates Euler/Navier-Stokes based flow solvers such as ENSAERO[7], USM3D[8] and finite element based structures solvers such as NASTRAN[9]. To-date HiMAP has been demonstrated for large scale aeroelastic applications that required 16 million fluid grid points and 20,000 structural finite elements. Cases have been demonstrated using up to 228 nodes on IBM SP2 and 256 nodes on SGI Origin2000 computers. Typical configurations analyzed are full subsonicand supersonic aircraft.

Figure 4 shows the 34 block grid for the sub-scale wind tunnel model of an L1011 transport aircraft[10,11]. The total grid size is 9M points. Due to geometric complexity grid sizes vary significantly from block to block. The ratio of smallest to largest grid size is 0.07. This distribution can lead to inefficient computations on MPP. An algorithm based on node filling is currenly incorporated in HiMAP. This algorithm assigns multiple grids to a single processor. Using the node filling algorithm that will be explained in detail in the full paper, the 34 block grid was mapped on to 24 Origin-2000 processors. Figure 5 shows the original grid distribution by assigning one block per processor and modified block distribution by using the node-filling algorithm. The computational efficiency is increased by 30% with the new distribution. Further research is ongoing in using neural networks approach to the load.

Fig 6 shows one of the 5 structural modes from the finite element computations. One O2000 node was assigned to the modal data. Computations were made using GO3D (Goorjian-Obayashi Streawise Upwind Algorithm) fluids solver[12] and ENSAERO modal solver[13] along with MBMG(MultiBlockMovingGrid)[11,14] moving grid module available in HiMAP process. A typical aeroelastic solution is shown in Fig 7. The stability and convergence of GO3D algorithm was not affected by re-distribution of patched grids to different processors. Results will be further tested on a case with 108 blocks and 13 million grid points. Figure 8 shows a plot of current grid size versus grid blocks. This grid is for a complex state-of-the-art aircraft.

HiMAP is multi-platform middleware. It has been tested on IBMSP2, SUN HPC6000 and SGI O2000 systems. Scalable performance and portability is shown in Fig 9. Work is in progress to port HiMAP to other platforms and will be reported on in the full paper.

More details of HiMAP and its latest applications including its suitabilty for PSE (Problem Solving Environment) and IPG (Information Power Grid) will be presented in the final the paper. The results from neural network based load balacing algorithm will be demonstrated for a large DARPA/NASA aerospace problem that needs large number of nodes. Computations will be demonstrated on NASA’s new 512-node Origin 2000 supercomputer Lomax.

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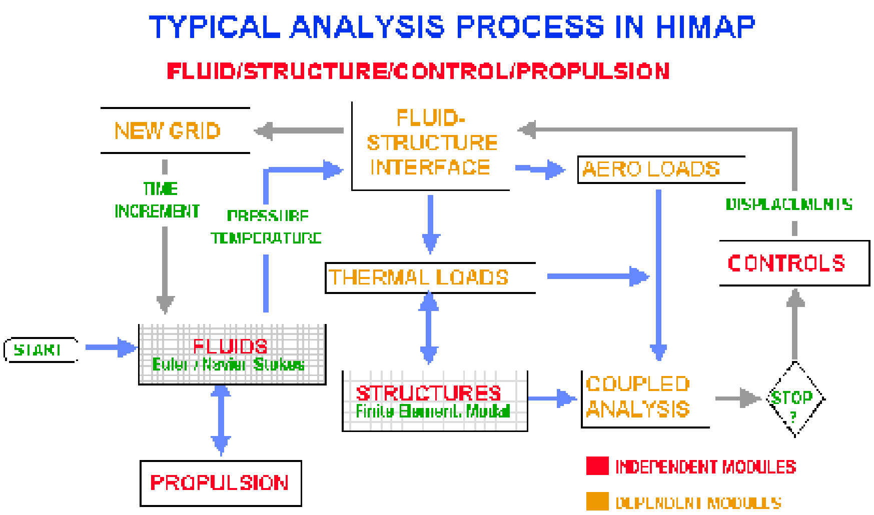

Fig.1 Parallel Process

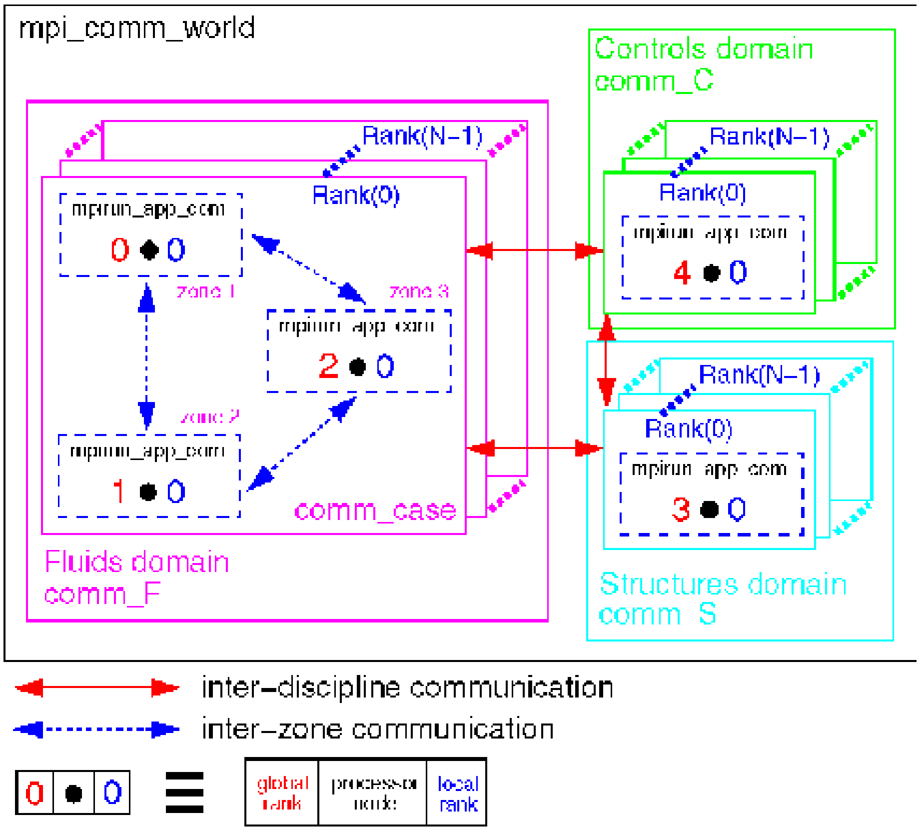

Fig.2 Multilevel process

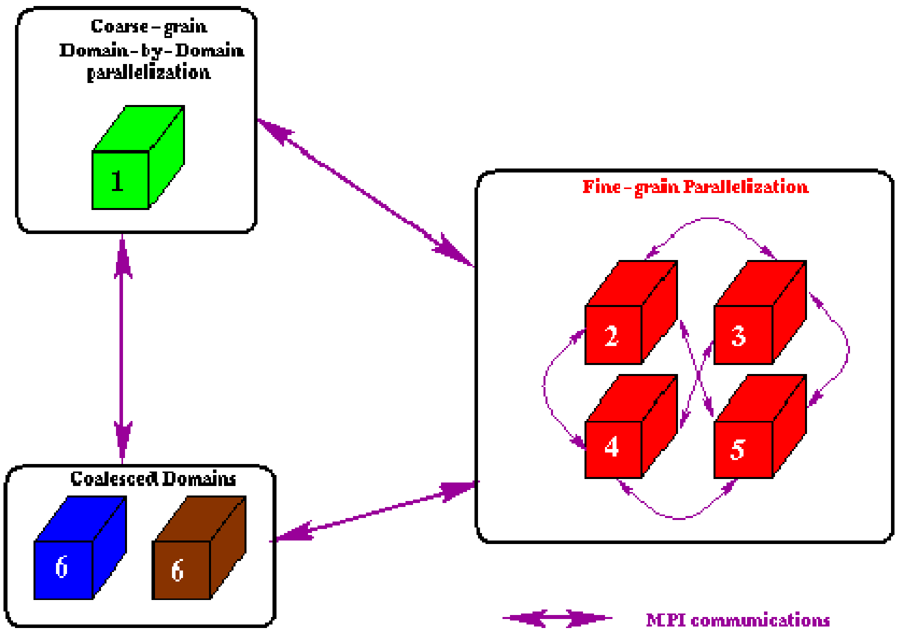

Fig.3 Load balacing approach in HiMAP

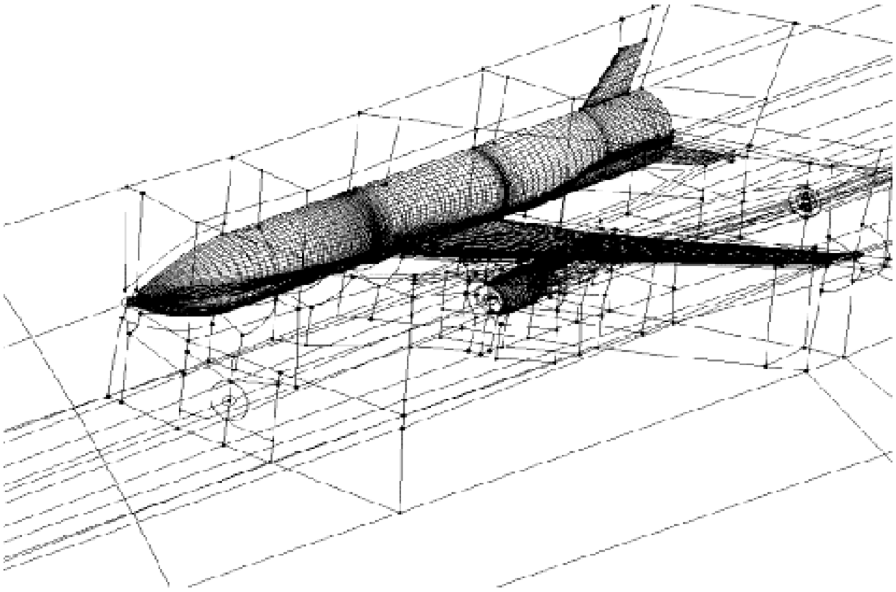

Fig.4 Grid Blocks for L1011 wind tunnel mode

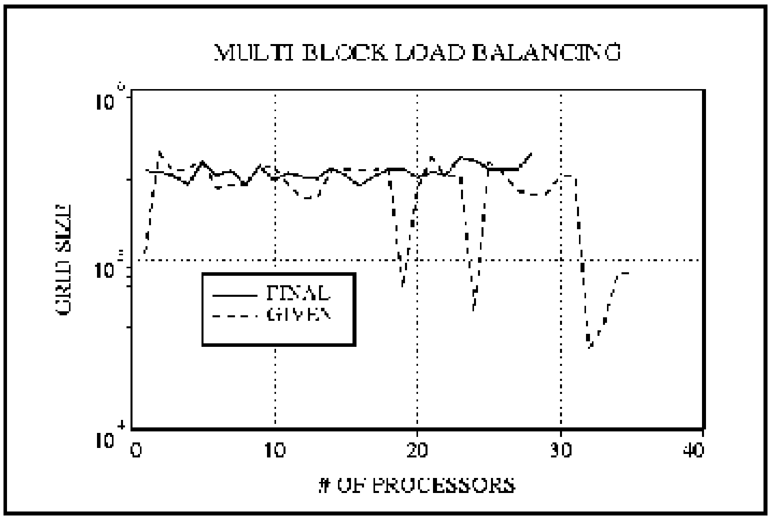

Fig.5 Results load balancing

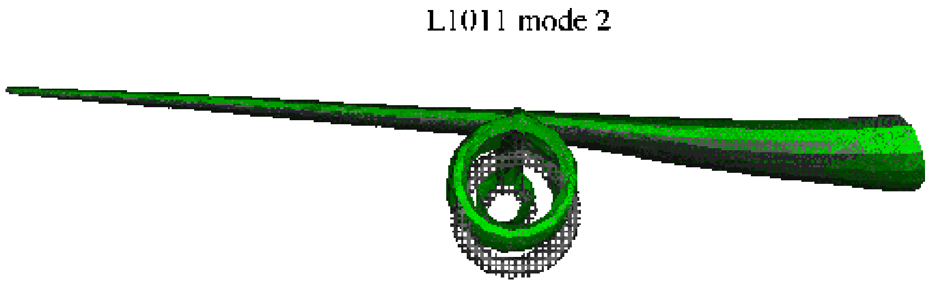

Fig.6 Modal data from finite element analysis

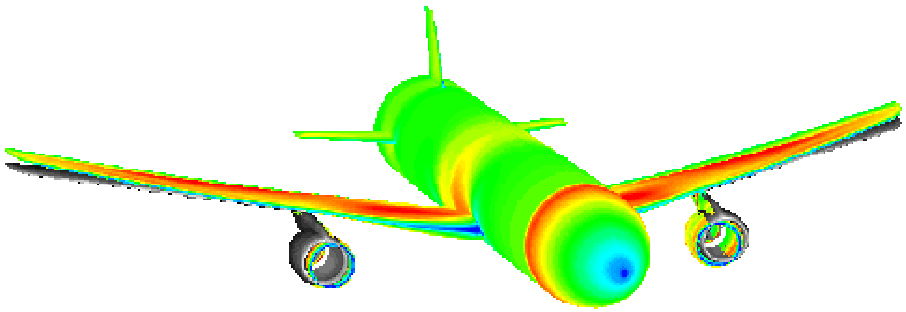

Fig.7 Typical aeroelastic results for L1011 sub-scale wind tunnel model

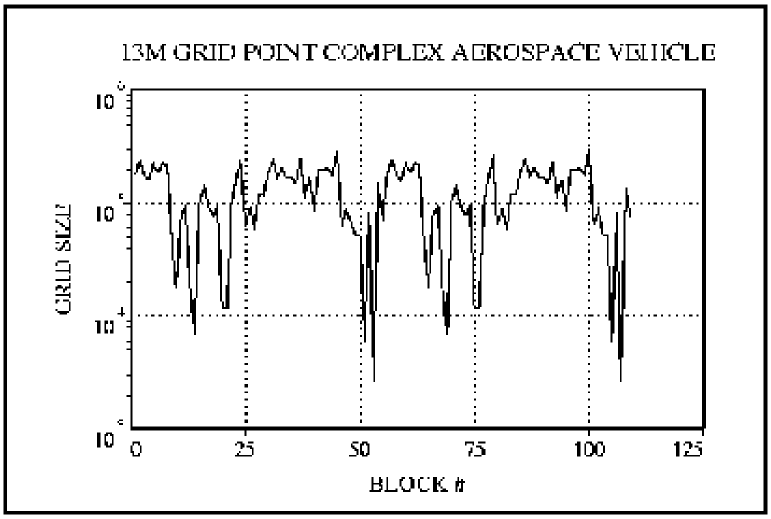

Fig.8 Grid distribution for a complex aerospace vehicle

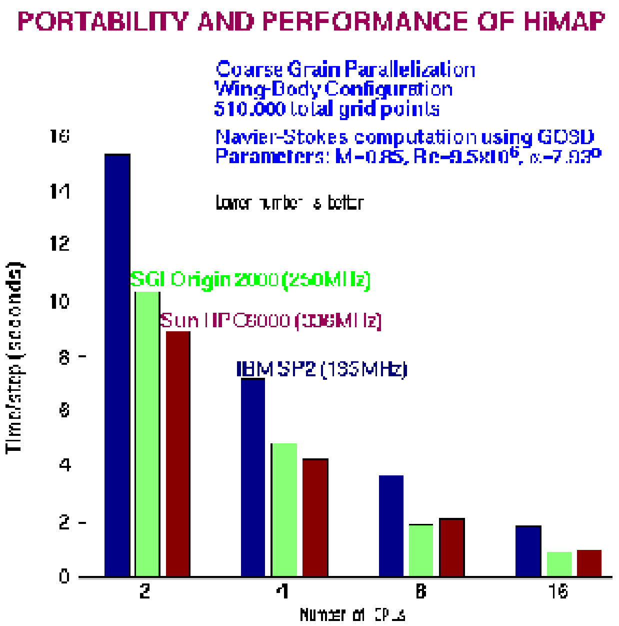

Fig.9 Demonstration of Portability of HiMAP