A Code Coupling Application for Solid-Fluid Interactions and Parallel Computing

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A code coupling strategy is introduced for solution of multidisciplinary problems involving multiple codes. Coupling of a Computational Fluid Dynamics (CFD) code with a Computational Structural Dynamics (CSD) code is demonstrated as an application for prediction of aeroelastic phenomena. A third-party library, MpCCI, is used for coupling of the codes and their corresponding computational meshes. The CFD solver is based on an unsteady, unstructured and parallel finite-volume algorithm for solution of large-scale fluid dynamics problems [1, 2]. The CSD solver is based on the time integration of modal dynamics equations extracted from full finite-element analysis of structures [3]. The solutions of the flow and the structure are coupled by MpCCI [4]. The coupling scheme is depicted in Figure 1. The unsteady CFD solver with a moving mesh algorithm is used to calculate the dynamic response of aeroelastic systems. A virtual mesh approach used for exchanging information between the meshes of solid and fluid media is illustrated in Figure 2. The nodal pressures of fluid flow are transferred from CFD mesh to CSD mesh, while surface displacements of solid are transferred from CSD mesh to CFD mesh. The solid mesh in this application is a mid-surface shell mesh of quadrilateral elements, while the fluid mesh is a three-dimensional tetrahedral elements. CFD computations are performed on a three-dimensional aircraft wing test case shown in Figure 3, where tetrahedral finite-volume cells are used. The virtual surface mesh of quadrilateral elements used for the wing is shown in Figure 4. Flutter predictions obtained by the coupled CFD-CSD code are compared with those reported by others and the available experimental data.

With the parallel computational features of the code, the computational task is distributed to several computers making metacomputing and multidisciplinary code coupling across different computer clusters possible.

In this research, I-Light, which is a high-speed optical fiber network connecting Indiana University Bloomington (IUB), IUPUI, and Purdue University West Lafayette, is used as the communication medium which transfers the coupling information across the solution blocks and the CFD-CSD interfaces. As a test case, the use of the resources of the Computational Fluid Dynamics Laboratory (CFDL) at IUPUI together with the resources at IUB are considered. Shown in Figure 5 is the comparison of parallel speedups obtained by solving the coupled problem using: 1) IBM Unix workstations at CFDL, 2) IBM SP2 system at IUB, and 3) CSD solver at CFDL and CFD solver at IUB with two codes communicating via I-Light. As may be seen, the penalty for using I-Light versus solving the problem entirely at IUB computers is minor. The superior performance of the IUB system is due to the parallel architecture of SP2, while the workstation cluster at CFDL is networked via Ethernet. Thus, the fast transmission speed of the I-Light, which connects our computer cluster at the Computational Fluid Dynamics Laboratory

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and the SP2 computer cluster in Indiana University Bloomington makes the concurrent utilization of both resources possible for large-scale computations.

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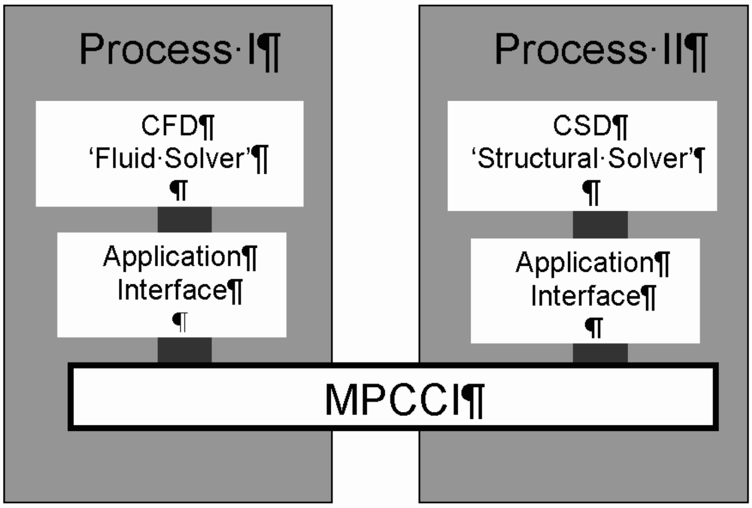

Figure 1. CFD-CSD coupling scheme.

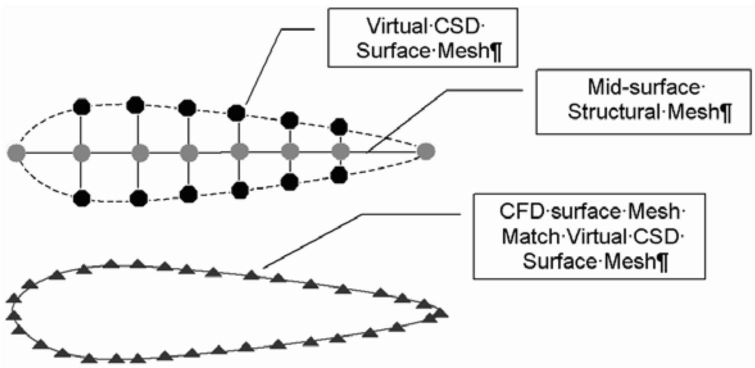

Figure 2. CFD surface mesh, CSD virtual surface mesh and structural mesh.

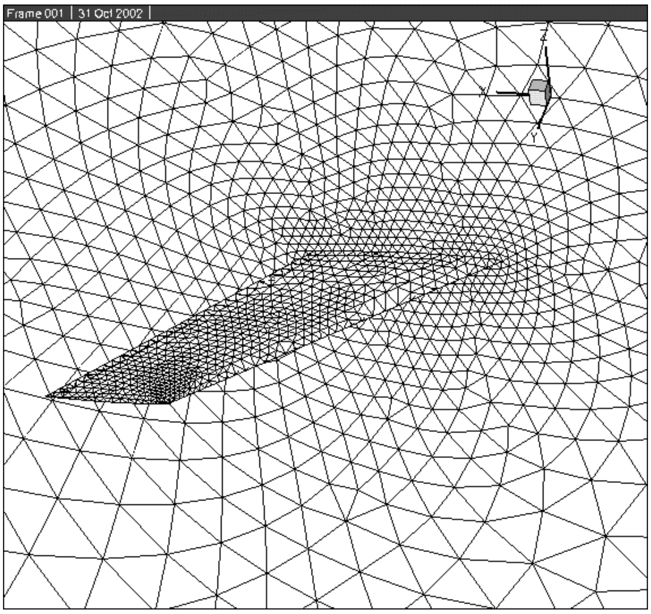

Figure 3. CFD Mesh around the aircraft wing.

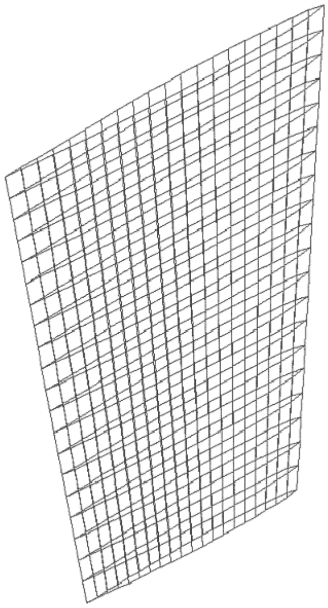

Figure 4. Virtual CSD mesh on the wing.

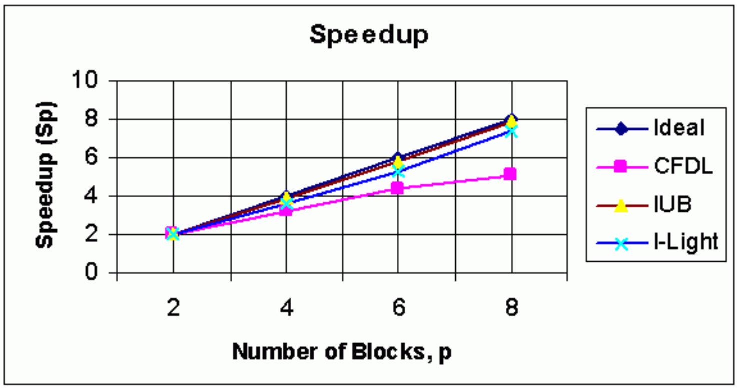

Figure 5. Parallel speedup using CFDL, IUB, and combined CFDL and IUB resources via I-Light.