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HEURISTIC METHOD OF DYNAMIC STRESS ANALYSIS IN MULTIBODY SIMULATION USING HPC

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A parallel method of stress-strain simulation of single body in multibody dynamic model is proposed in this paper. Method is based on heuristic discrete elements approximation of deformable body and domain decomposition.

The main disadvantage of static analysis stress anlaisys methods is the ambiguous constraints. A car suspension arm stress analysis requires to constraint several degrees of freedoms before applying the Finite Element method [1]. There are multiple ways to constraint the arm that gives up to 2 times difference of stress maximal value in solution. In proposed method the body is free of constraints. Instead of the constraints there are real reaction forces in joints from full multibody simulation [2]. The reactions forces in joints are put in equilibrium so the solution is unambiguous.

Flexible body is represented as linked discrete elements. Discrete are formed from solid body geometry by regular orthogonal meshing. All cube elements are uniform links with adjacent by flexible joint. In this way flexible body is a large multibody system and can be solved by multibody approach. The correctness of the proposed model achieved by defining stiffness and damping factors of flexible joints and mass-inertia properties of discrete elements from real materials properties. Flexible body has a rigid counterpart in multibody model which is called reference body. The inertia forces and reaction forces in joints are obtained from multibody solution.

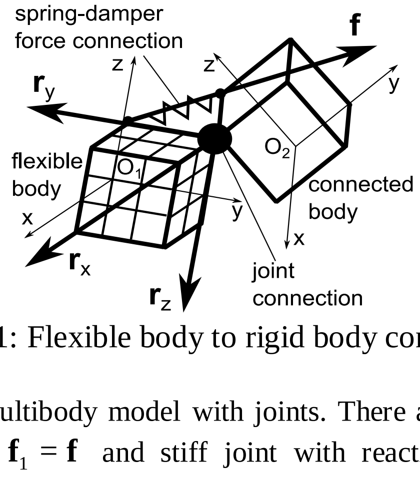

Figure 1: Flexible body to rigid body connection

Flexible body is connected to multibody model with joints. There are two kinds of joints shown in Figure 1: spring-damper force $\mathbf{f}_1 = \mathbf{f}$ and stiff joint with reaction force $\mathbf{f}_2 = (\mathbf{r}_x, \mathbf{r}_y, \mathbf{r}_z)$. The equation of motion for boundary discrete element has a following form in case of uniform distribution of reaction force along boundary:

$$\mathbf{M}_i\ddot{\mathbf{y}}_i = \mathbf{f}(t)/|F| + \mathbf{q}_i(\dot{\mathbf{y}},\mathbf{y},t) - \mathbf{M}_i\mathbf{a}_i(t) + \mathbf{s}_i(\dot{\mathbf{y}},\mathbf{y}),\ i \in F \qquad (1)$$

where $\mathbf{y}$ is a vector of discrete elements coordinates, $\mathbf{M}$ is a matrix of inertia for set of discrete elements, $\mathbf{a}$ is a vector constructed of reference body acceleration vector components, $\mathbf{s}(\dot{\mathbf{y}},\mathbf{y})$ is a stabilizing component. Reference body acceleration is obtained from multibody model. The function $\mathbf{q}(\dot{\mathbf{y}},\mathbf{y},t)$ describes the forces between rigid elements. Stress values are computed based on the values of the forces on each iteration, F is a set of node indices of boundary with applied reaction $\mathbf{f}$. The solution of Eq.(1) gives the displacements of discrete elements. The stress is calculated based on the displacements.

The uniform discrete elements allow to efficiently use parallel computing. The system of discrete elements is decomposed to overlapping subdomains using graph partitioning method (3). Similar methods are used in finite element procedure (4). The efficient parallel algorithm is developed to solve the decomposed discrete element model. The proposed method gives quite good speedup on shared memory platform with NUMA. Efficiency decreases with increasing of number of threads but the speedup of 10 is achieved on 32 cores. Parallel simulation efficiency analysis of different mesh sizes is carried out in proposed work. A custom thread handling significantly reduces overheads on NUMA-architecture in comparison with OpenMP. Parallel stress-strain simulation method is also applicable to distributed memory system such as clusters and can be implemented using MPI.

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