ASSIGNMENT 0: PROFILE & PARALLEL APPLICATION PROBLEM

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1. Profile

I am a first year M.S./Ph.D. student in the Computational Materials Research Lab lead by Prof. T.I. Zohdi, in the Mechanical Engineering department. My research area is in the simulation of subterranean blasts, in regards to developing better methods of protecting military vehicles. Recent research developments have been building a discrete element code to model the behavior of soil particles.

2. Parallel Application Problem

2.1. **Explosive Simulations, in Finite Element Enviornments.** Of chief concern when one is concerned with the safety and durability of military vehicles during an explosion, one ins concerned with the blast pressure wave's interaction with the hull of the vehicle. At first glance one can see how this is a complex multi-physics, coupled fluid-structure interaction (F.S.I.) problem. FSI, is frequently handled using the finite element method, in order to handle the potentially large deformations of the solid components of the system.

2.2. **Use of Parallelism.** Finite elements have been one of the most popular methods for the past several decades, due to their ability to handle complex geometries and boundary conditions. Thus the Finite element method, has been the subject of a lot of parallel studies, and attempts. In our specific study, it is likely to be important that the element mesh be able to adjust itself to reduce the local error at locations of severe change. This adaptivity in the mesh and the following solve pose problems for parallelism because of the necessity for communication between different processing elements.[1]

In the adaptive meshing process, one divides up larger elements into smaller elements. However this task needs to be done carefully, as to produce valid elements, as in a new element does not require a node to be located along the edge of an other element (among other conditions). In parallel application of mesh adaptation, one processing element is assigned a local block of elements to adapt, and will follow a splitting algorithm, which often involves the interaction with elements outside of that processor's assigned group. This can pose synchronization problems. For if each processor is splitting its local elements, and then after all are completed, the different processors order their neighboring blocks to split accordingly and can cause poorly conditioned elements, as well as a possibility for invalid elements. In addition, since often an element can only be split once, if an element boarders several blocks it can get instructions to split multiple times, and in many situations this becomes an impossible goal, and the whole mesh adaptation can be rendered useless.[1]

To solve this problem with parallel mesh adaptation, as posed by N. Jansson, is to use a type of voting system for the 'boundary' elements of the distributed blocks. So that when a block sees that it needs to split a boarder element, it rates necessity of the element split and then demands that the neighboring blocks do the same for their adjacent elements. Then the element that is deemed most necessary for splitting is split, and the others update their local meshes accordingly. This ad hoc synchronization, can reduce the effects of the complete invalidation of the adaptation, and improve the performance on large parallel machines.

3. References

(1) Jansson, N., Hoffman, J., and Jansson, J. Framework for Massively Parallel Adaptive Finite Element Computational Fluid Dynamics on Tetrahedral Meshes SIAM Journal on Scientific Computing 2012 34:1, C24-C41
(2) Hoffman, J., Jansson, J.. Unicorn: Parallel adaptive finite element simulation of turbulent flow and fluidstructure interaction for deforming domains and complex geometry Computers & Fluids 2012 0045-7930