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Chrono: An Open Source Parallel Simulation Framework for Many-Body Dynamics Applications

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We present a parallel computational framework, called Chrono, for the modeling, simulation, and visualization of many-body dynamics and fluid-solid interaction problems. This simulation capability has a modular structure built on top of five foundation classes that provide support for: modeling, numerical solution, contact detection, domain decomposition, and pre- and post-processing.

The modeling component provides support for the automatic generation of the equations of motion. This is achieved in a fashion transparent to the user who need only provide high-level model and solution parameters. Examples include: the equations of motion for granular flow simulations, using either a Differential Variational Inequality (DVI) or a penalty approach; the equations of motion for flexible multibody dynamics; the Navier-Stokes equations for fluid-solid interaction problems, etc.

The numerical solution component provides the parallel algorithmic support required to solve the set of equations governing the dynamics of interest. Depending on the underlying physics, various parallel solvers are employed for: optimization problems arising in the DVI approach for handling frictional contact; solving nonlinear problems arising in the context of implicit numerical integration; SPH-based methods for fluid-solid interaction problems, etc.

The domain decomposition and inter-domain communication component manages the splitting of large problems into subdomains and provides support for the required inter-process communication. This enables the MPI simulation of granular flow problems with millions of particles interacting through frictional contact, conducted on hundreds of distributed nodes.

Finally, the pre/post-processing component supports the task of setting up a model using the Chrono API and provides support for efficient visualization of simulation results from problems involving millions of states resolved at frequencies of hundreds of Hertz.

Chrono is open source and available under a BSD license. It leverages heterogeneous parallel computing architectures, including GPU and multi-core CPU processors, as well as MPI distributed architectures, to accelerate the simulation of systems with tens of millions of degrees of freedom. Examples applications include granular flows, where the number of interacting elements can be in the millions, and fluid-solid interaction simulations involving millions of fluid markers and tens of thousands of solid bodies.

In this talk, we demonstrate the use of Chrono for terrain modeling and simulation. Representing the terrain as a large set of discrete elements enables the analysis of vehicle mobility on deformable terrain, anchoring in granular material, and bulldozing of loose clay-type terrains.

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