Chrono: a multi-physics high performance modeling and simulation framework. Part 2: Applications and Validation

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ABSTRACT

In this contribution we demonstrate the use of Chrono [1], a multi-physics high performance modeling and simulation framework, in two real-world applications and report on a validation study that seeks to assess its predictive attributes.

The first application is tied to the issue of ground vehicle mobility. Specifically, the interest is in gauging the mobility of large vehicles during fording operations when the riverbed is made up of deformable terrain and there is a three-way coupling between the dynamics of the vehicle, the deformation of the rock bed, and the dynamics of the fluid. The computer-based analysis of vehicle mobility on deformable terrain remains a challenging endeavor particularly when the terrain is made up of a large number of elements introduced to capture sandy or muddy soils. This type of simulation capability has anticipated use in the virtual design of large wheeled vehicles that cannot be tested in practice owing to costly and/or difficult testing conditions. Several different types of materials were simulated, including fluid, mud/clay, gravel and rocks in a multi-body dynamics framework designed to handle millions of degrees of freedom. In this framework, the multitude of objects making up the terrain interact mutually, through contact, friction and cohesion, as well as with complex mechanical systems that comprise joints and linkages. A nine body HMMWV (Humvee) vehicle model with an accurate suspension is used to demonstrate the simulation capability and illustrate how the vehicle performs during several fording scenarios.

The second problem relates to the use of modeling and simulation in the field of 3D printing and additive manufacturing. In many cases the dimensions of the printing volume are smaller than the dimensions of the part of interest. In this case, the printed part is clothing that is comprised of tens of thousands of linked rings. We rely on simulation to take the un-deformed configuration as it was designed and simulate compression and folding so that it fits within the printing volume. Upon printing, the article of clothing can be pulled apart to its full size. Results will show the effectiveness of the simulation of chainmail fabric and the final 3D printed result.

The third part of the contribution concentrates on the validation of Chrono. To this end, a direct shear test is used to measure the shear strength properties of a soil such as the cohesion, angle of friction, and shear modulus. We carry out a simulation of a sandy soil sample contained in a shear box, which is aligned under a load cell that applies a normal force to the soil. The top of the shear box is clamped so that the lower half can be translated horizontally by a specified displacement. The horizontal force required to displace the soil is measured to produce a plot of the shear stress as a function of shear displacement with results validated against experimental measurements.

We close with a summary of a select set of benchmarking experiments that demonstrate some of the high performance computing challenges posed by Chrono at a time of tumultuous changes in the parallel computing software and hardware paradigms. We will discuss the computational bottlenecks of Chrono and report on benchmark tests that explain its flop and bandwidth performance.

REFERENCES

[1] H. Mazhar, T. Heyn, A. Pazouki, D. Melanz, A. Seidl, A. Bartholomew, A. Tasora, and D. Negrut. Chrono: a parallel multi-physics library for rigid-body, flexible-body, and fluid dynamics. Mechanical Sciences, 4(1):49–64, 2013.