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Next-generation Multi-mechanics Simulation Engine in a Highly Interactive Environment

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Abstract

We describe the development of a highly interactive approach to simulation of engineering multi-mechanics problems, using the smoothed particle hydrodynamics mesh-free method as the computational engine, for applications including ship survival, medical devices and Pelton turbines.

Keywords: Smoothed particle hydrodynamics; Computational fluid dynamics; Distributed shared memory

1. Introduction

A paradigm shift in computational fluid dynamics (CFD) is required to simulate complex processes (multi-mechanics, moving and deforming solids in fluid flow) for demanding industrial applications such as Pelton turbines, ships and medical devices. In the NextMuSE project [1] we aim to achieve this using Smoothed Particle Hydrodynamics (SPH), a mesh-free computational mechanics method, as the computational engine running on a HPC system behind a highly interactive visualisation frontend. In the present work we address both the intrinsic performance of SPH numerical algorithms to achieve sufficient accuracy and robustness for engineering applications, and the development of an interactive analysis and visualisation environment that will support user interactions with multi-million-particle simulations.

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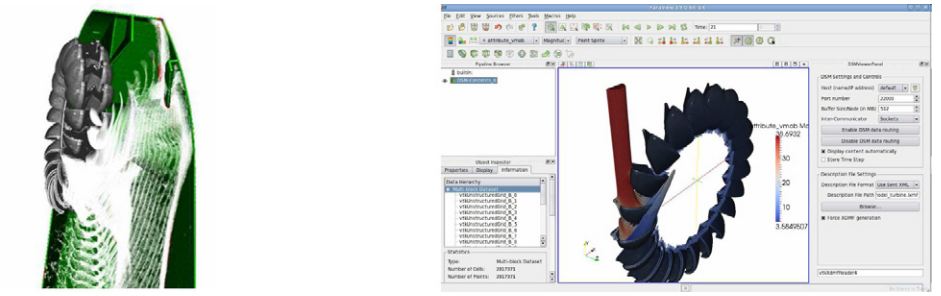

Fig. 1. (a) SPH simulation of flow in a Pelton hydraulic turbine; (b) The interactive ICARUS display.

2. Numerical Algorithms

Issues of numerical accuracy and computational cost are being addressed by fundamental algorithm development and evaluation on canonical benchmark test cases, leading towards more complex and realistic applications. Figure 1(a) is a visualisation of a SPH simulated water flow in a Pelton turbine, a device widely used in hydroelectric power generation, in which high-speed water jets impinge on rotating blades. Work is underway to develop optimised HPC SPH implementations, evaluating shared-memory, distributed-memory and GPU architectures. Large progress has been made in improving scale-up efficiency, especially by using dynamic update of the domain decomposition as particles move in a Lagrangian manner across subdomain boundaries.

3. Initialize, compute, analyze, render, update and steer (ICARUS)

ICARUS is the solution under development to enable a SPH user-engineer to visualise and interact with a very large running SPH simulation. The user may interact with the model while it is running, as shown in Figure 1(b), for example to assess the effect of a change in design or operating condition. An open-source virtual file driver, H5FDdsm [2], has been developed for this purpose, based on parallel communication to transfer data using the HDF5 IO API and a distributed shared memory buffer.

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