Optimisation and Parallelisation of 3D Explicit Dynamic Material Point Method in CPU - GPU Computing Architectures

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Material Point Method

The material point method is one of the meshfree methods which discretizes a continuum body with finite set of material points in the original configuration that are tracked throughout the deformation process on the underlying grid. MPM algorithm naturally combines advantages of both Lagrangian and Eulerian formulation and avoids mesh distortion problem present in Lagrangian formulation and numerical diffusion due to non-symmetric convective terms present in Eulerian formulation.

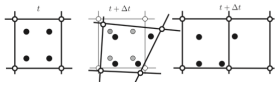

Figure 1: Deformation in Lagrangian and MPM Scenarios

MPM Algorithm

Each incremental step in the MPM includes a Lagrangian stage and Eulerian stage.

1. Initial configuration of particles, grid cells, nodes and material properties.
2. Interpolation from material point particles to nodes.
3. Calculate nodal velocities and accelerations.
4. Update stresses and material properties of particles.
5. Movement of particles to new position.
6. End of time step.

Joint Industry Project SIMON

Deltares is working on simulating the driving of monopiles, steel tubes with diameters of up to 11 meters and length of more than 60 meters, into the seafloor for the construction of offshore wind farms. Doing such simulations will give a better understanding of underlying mechanical processes and accelerate installation process of monopiles.The project can be found on http://www.tki-windopzee.nl/project/simon-jip.

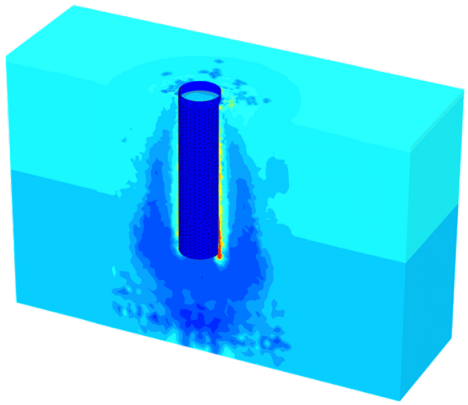

Figure 2: Variation of soil density during driving pile into the seabed

Conclusion and Future Work

The material point method proves to be an efficient and promising numerical technique for simulating large deformation problems in Geotechnical Engineering but poses huge computational challenges for simulations involving large number of material points and degrees of freedom. The focus of this master thesis jointly done with Deltares and EZNumeric will be on parallelization and optimisation of currently implemented two phase MPM unstructured 3D finite element code. Speed-up using shared memory, distributed memory parallelization and optimising the underlying data structure will be main theme of this project and scope of GPU computing for MPM will also be explored towards the end.

References

[1] P. Huang, X. Zhang, S.Ma and H.K. Wang *Tech Science Press*. Shared Memory OpenMP Parallelization of Explicit MPM and its Applications to hypervelocity Impact(2008).

[2] Y Dang,D Wang, M.F. Randolph *Computers and Geotechnics*. A GPU parallel computing strategy for material point method(2015).

[3] I.K.J AL-Kafaji *Phd Dissertation-Stuttgart University* Formulation of a dynamic material point method (MPM) for geomechanical problems (2013)

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