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GPU-accelerated vector-form particle-element method for 3D elastoplastic contact of structures

Key words:

Graphics processing unit (GPU); Parallel acceleration; Elastoplastic contact; Contact search; Finite particle method (FPM)

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Motivation

☐ Research background

- The **strong nonlinearities** involved in **elastoplastic contact** of **structures** make it difficult to get accurate solutions.
- The contact calculation processes are usually very **time-consuming** for **large-scale contacts**.
- An **effective** and **efficient method** is urgently needed to solve the elastoplastic contact of structures.

☐ Contact algorithms for elastoplastic contact

- Finite element method (FEM):

  effective, ***not efficient*** *for large-scale contacts*

- Finite particle method (**FPM**):

  effective, ***efficient*** *for large-scale contacts*

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Method

☐ Hexahedral elements in the FPM

- Motion equations of particles

$$m\ddot{\boldsymbol{d}} = \boldsymbol{F}_{\text{ext}} - \boldsymbol{F}_{\text{int}} - \boldsymbol{F}_{\text{dmp}} + \boldsymbol{F}_{\text{c}}$$

- Elemental internal forces

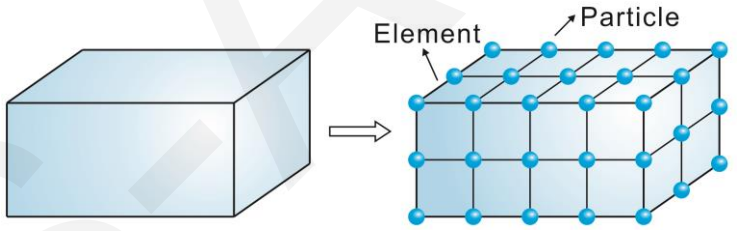
Fictitious reverse motion

⇩

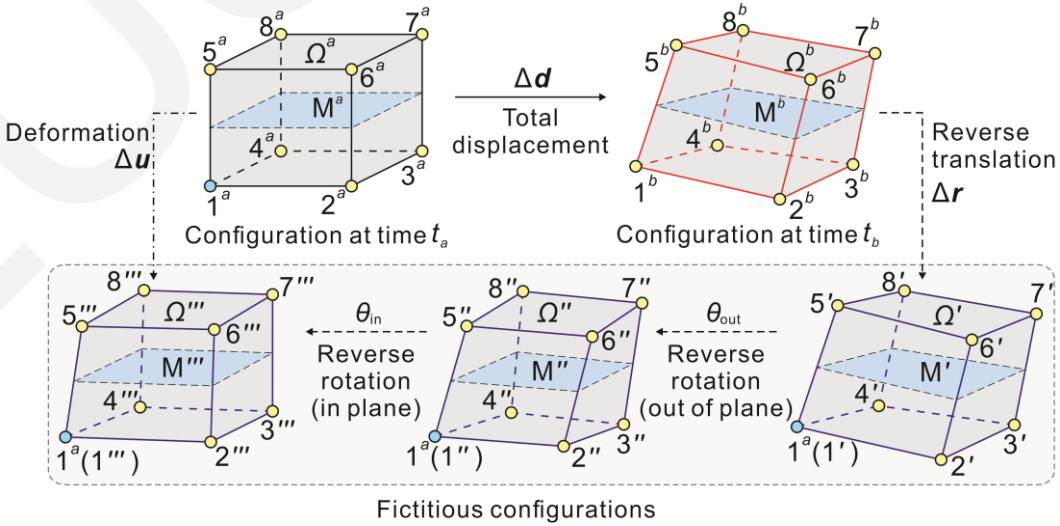
Constitutive theory

⇩

Internal forces



Discretization of a structure



Fictitious reverse motion

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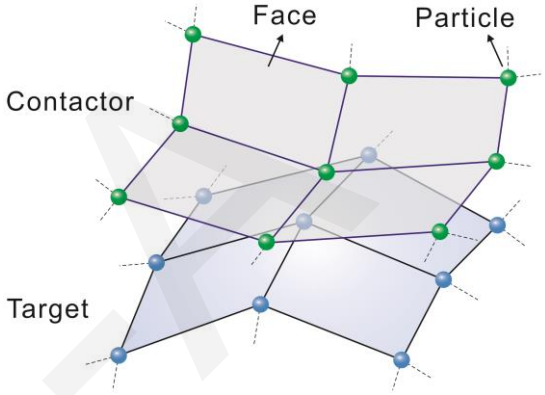
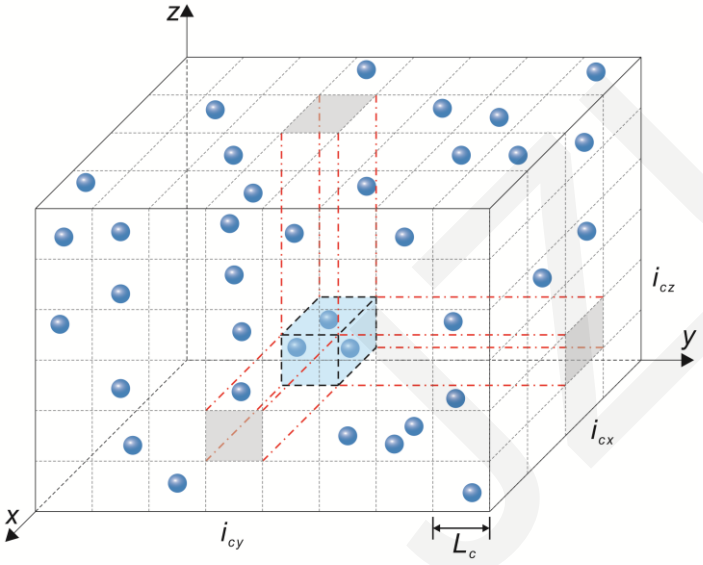
Method

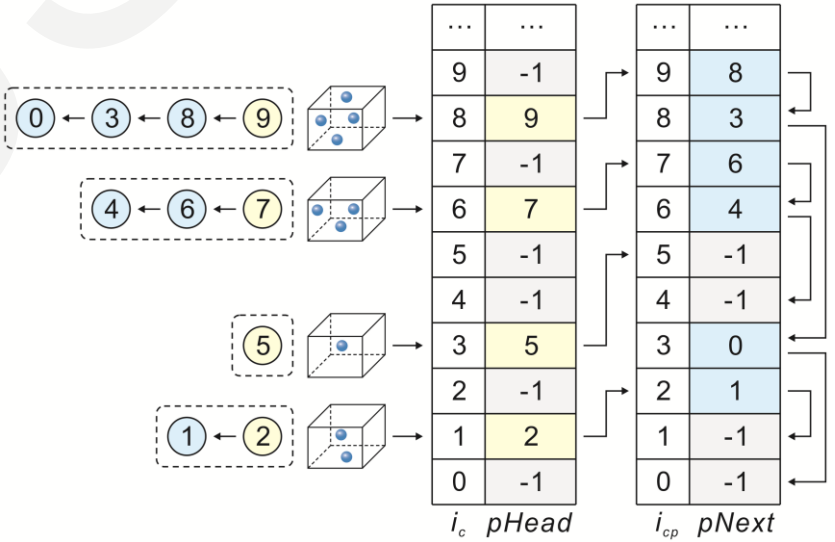
- Parallel contact algorithm
  - Discretization of contact surfaces
  - Parallel contact search
  - Enforcement of contact constraints



Discretization of contact surfaces



Decomposition of three-dimensional space

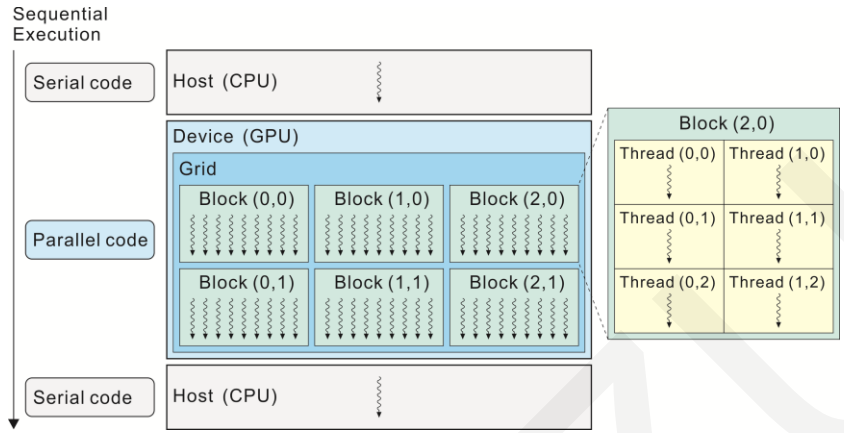


Connected list data structure

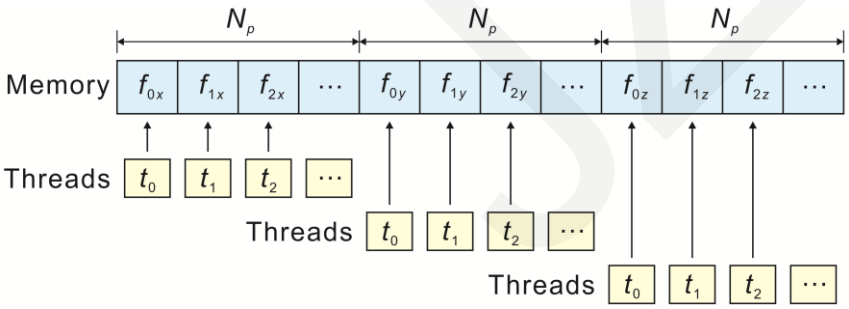
Method

☐ Parallel implementation

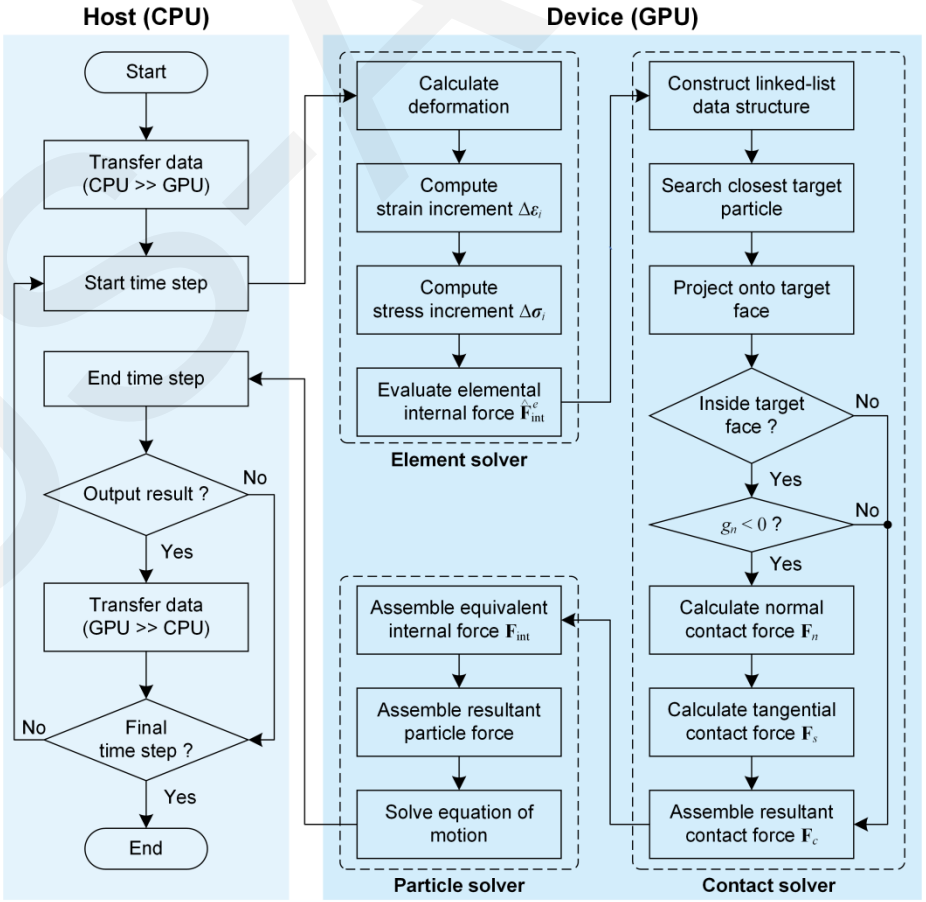
- ➢ Parallel FPM solvers
- ➢ GPU memory optimization



CUDA Programming model



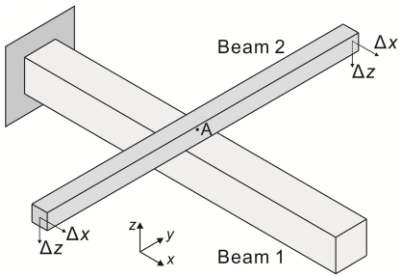
SoA memory layout



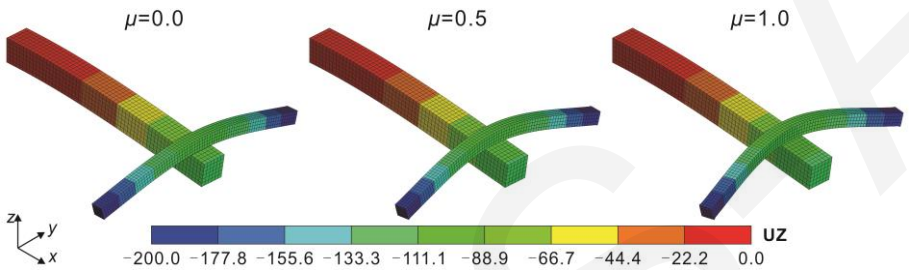
Flowchart of parallel FPM solvers

Verification

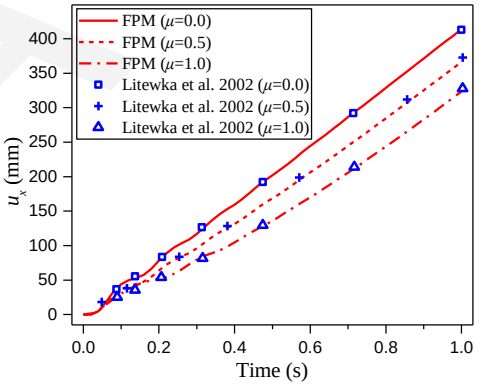
Elastic contact



Geometry

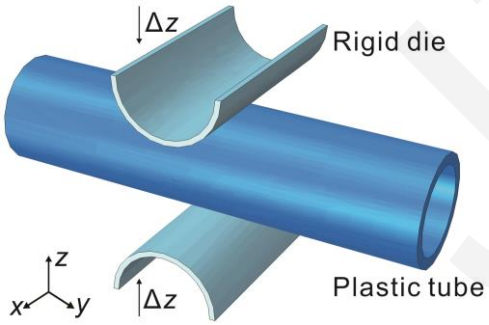


Displacement contour



Displacement

Elastoplastic contact



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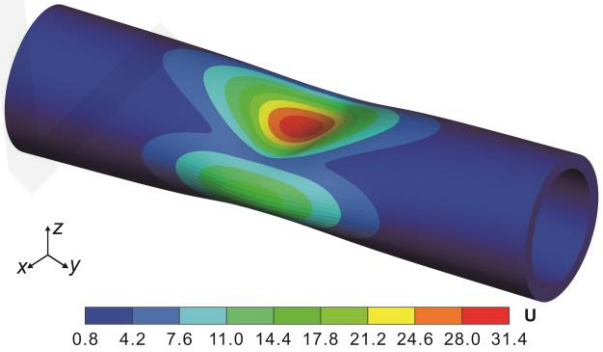
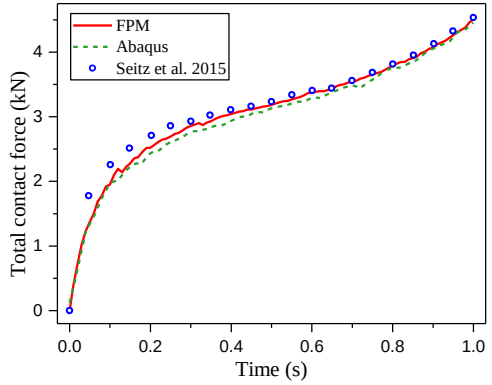


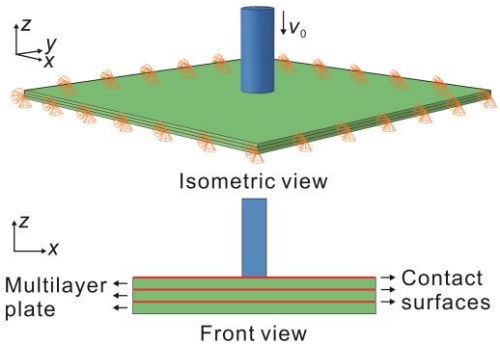
Displacement contour



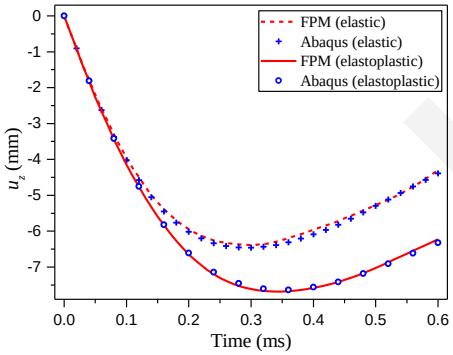
Contact force

Efficiency test

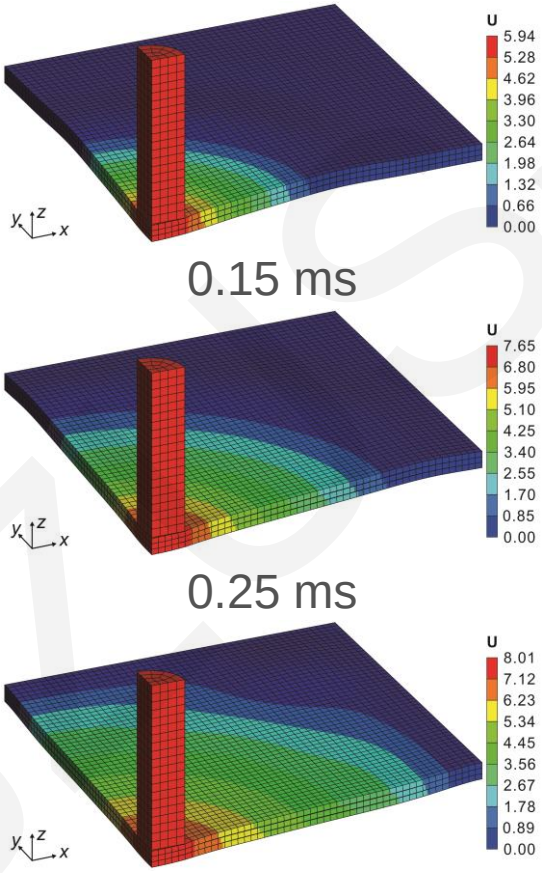
☐ Elastoplastic contact



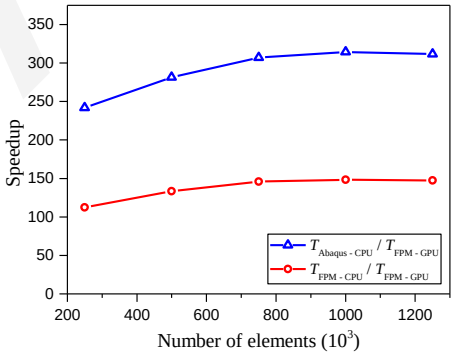
Geometry



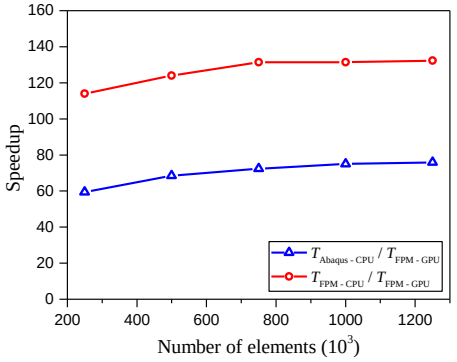
Displacement



Displacement contour



Speedup of contact calculation



Speedup of overall computation

Conclusions

- Two verification examples that involve elastic and elastoplastic frictional contacts are investigated. The proposed method is shown to be **effective** in both **elastic** and **elastoplastic contacts**.
- The efficiency of the GPU-accelerated FPM is investigated. It is shown that the proposed method is **efficient** in both **elastic** and **elastoplastic large-scale contacts**.
- The GPU-accelerated FPM is approximately **130~140** times faster than the serial one, and **70~80** times faster than Abaqus. Specifically, the GPU-accelerated FPM contact solver is approximately **110~140** times faster than the serial FPM contact solver, and **310~340** times faster than the Abaqus contact solver.

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