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Eulerian finite volume method for capability and capacity computing of structure dynamics with supercomputer Fugaku

Koji Nishiguchi*

Department of Civil and Environmental Engineering
Nagoya University, Nagoya, Japan
* E-mail: kojinishiguchi@civil.nagoya-u.ac.jp

Extended Abstract

This paper presents a novel numerical method for the elastoplastic simulation of vehicle component structures under large deformation problems, such as crash-worthiness analysis. Elastoplastic simulation of vehicle structures is essential for designing safer and more efficient vehicles but poses significant challenges for a conventional finite element method (FEM) due to the limitation of parallel performance and mesh distortion at large deformations. To overcome these challenges, we propose using the cell-centered finite-volume method (CCFVM) in the Eulerian description [1] and the building-cube method (BCM) [2].

The Eulerian CCFVM is a robust scheme for solving large deformations of the continuum by spatially fixed collocated Cartesian mesh, which enables a simpler data structure than conventional FEM. The BCM is a hierarchical Cartesian mesh approach in which the computational domain is divided into cubic regions with adaptive refinement suitable for parallel computing. The combination of Eulerian CCFVM and BCM enables us to perform high-fidelity simulations of vehicle component structures. We demonstrate the validity and scalability of the present method by computing a three-point bending test of vehicle component structures using different geometries, such as impact beams. The numerical results show good agreement with the reference results obtained by LS-DYNA, a commercial FEM code. We also achieve a weak scaling of 73.5% in an elastoplastic simulation of about 540 million cell mesh using 131,072 cores of supercomputer Fugaku, the flagship supercomputer of Japan.

The proposed method is expected to contribute to developing geometrically complex crushable structures by giga-casting and 3D printing, which are emerging manufacturing techniques for vehicle structures. The Eulerian CCFVM, which uses a spatially fixed orthogonal mesh, enables the automatic and fast execution of elastoplastic analysis for tens of thousands of cases. Therefore, we have generated a dataset of pairs of three-dimensional shapes and mechanical parameters by performing elastoplastic analysis for more than 10,000 cases using the Eulerian CCFVM. We have been conducting a feasibility study of a deep generative model that can generate three-dimensional shapes from mechanical parameters by training it on DeepSDF, a probabilistic auto-decoder-type deep generative model. We also plan to report on the latest progress of this study at the workshop.

References

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2. Nishiguchi, Koji, et al. "Full Eulerian deformable solid‐fluid interaction scheme based on building‐cube method for large‐scale parallel computing." *International Journal for Numerical Methods in Engineering* 117.2 (2019): 221-248.