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PARALLEL SPECTRAL ELEMENT METHOD FOR SIMULATION OF ELASTIC WAVES IN SMART STRUCTURES

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Smart structures with embedded network of piezoelectric transducers have been widely investigated in the last decade. The aim of such network is monitoring of the state of material during operation of a structure. Among various monitoring methods are those based on anomalies in propagating Lamb waves.

Due to complexity of smart structures as well as electromechanical coupling effect, modelling requires application of approximated methods. One of the best method for wave propagation modelling excited by piezoelectric transducer is the time domain spectral element method [1]. The method is suitable for wave propagation modelling in composite materials and has the same flexibility as conventional finite element method but it is computationally much more efficient. Nevertheless, it is still challenging to modell accurately high frequency elastic waves in complex and large structures. It is because of the condition of at least five nodes per wavelength assuring accurate wave crest representation. Resulting mesh has usually milions of degrees of freedom. In order to solve dynamic coupled equations of motion it is necessary to use powerfull workstation.

The problem of large number of degrees of freedom and in consequence long computation time can be alleviated by using multicore processors. However, special code implementation is necessary. Two strategies can be applied: division of mesh into subblocks at the element level or at the degree of freedom level along with appropriate parallel computing implementation.

The latter approach is proposed in this research. It is selected because spectral element meshes have more nodes than elements. Thus, finer computational granularity is achieved. It is especially beneficial in case of using Compute Unified Device Architecture (CUDA) developed on modern Graphical Processing Units (GPU). Such devices have 128-2688 processors resulting in high computational efficiency up to 4290 GFLOPS (Nvidia Tesla K40). Hence, it is great alternative to standard computers equipped with multicore processors of much less number of Central Processing Units (CPU).

CUDA is parallel computing platform which is also available in Matlab by Jacket software. It allows GPU-based matrix manipulation and implementation of algorithms. Matlab Jacket software has been used for parallel spectral element method implementation.

Proposed spectral element method implementation is based on storage of local shape function derivatives calculated at Gauss-Lobatto-Legendre points in sparse matrix. The algorithm utilizes two basic operations: multiplication of sparse matrix by vector and element by element vectors multiplication. All operations are performed for equation of motion derived at the degree of freedom level of 3D isoparametric spectral elements. Final assembly is performed at the force vector in such a way that adding operations are divided into 12 stages. These stages are related to predefined sets of unique nodes in each set. This is the only serial part of algorithm. Therefore, atomic operations, the number of threads that must wait for the lock to be released, are minimized.

The algorithm has been tested on old Nvidia Tesla C1060 GPU. The results have been compared to classical serial code implementation in Matlab at 8 core workstation. It has been found that about ten times speed up is achieved.

REFERENCES

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