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Valparaíso, August 30, 2017

To whom it may concern

Subject: PhD thesis of MACIEJ WOZNIAK

Dear Sir or Madam,

Hereby find my review report of the PhD thesis of MACIEJ WOZNIAK called "Trace theory based isogeometric solvers for different parallel architectures", presented at the Department of Computer Science at the AGH University of Science and Technology in Krakow, and whose supervisor is Dr. Maciej Paszynski.

Summary

The Doctoral Dissertation of Mr. Maciej Wozniak proposes a parallel algorithm for the solution of isogeometric L2 projections. This problem has multiple applications, including: explicit dynamics simulations; image processing; or smoothing of material data for smooth execution of numerical simulations with isogeometric analysis. In all the mentioned applications, the isogeometric L2 projection problem has to be solved multiple times, for large amount of input data. Thus, efficient algorithms are necessary, and in my opinion this topic of research is important and deserves the investigation.

Main Accomplishments

Mr. Maciej Wozniak for the first time analyses the computational complexity and memory usage for a classical multi-frontal algorithm. This analysis concerns both the sequential version of the algorithm as well as its parallel counterparts, targeting shared-memory and distributed memory parallel machines. The task of analyzing the computational complexity requires deep understanding of the numerical operations performed by the solver algorithm in the context of different architectures of the parallel machines. Both, mathematical background and technical knowledge about parallel programming and architectures is needed here. He concludes that beside parallelization on modern parallel supercomputers, the classical multi-frontal solver approach is limited and some alternative solutions are necessary. He finds one alternative solution in the alternating directions method, factorizing the tensor product structure Gramm matrix in a linear computational cost, using only a single processor. Worth mention that this algorithm, in its sequential version, is not an achievement of the Ph.D. candidate. It has been proposed in 2014 by Longfei Gao. However, the parallel version of this algorithm, and the derivation of its computational cost and memory usage, is the main original achievement of Mr. Maciej Woźniak. The algorithm was then tested on modern parallel supercomputers, including distributed memory machines, and shared memory large graphic cards, destined for scientific computing. Outstanding performance of the proposed algorithm is proven numerically.

In my opinion, the previously mentioned novel contributions are sufficient to grant a Ph.D. degree in applied Computer Sciences.

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Scientific Aspects of the Doctoral Dissertation

Some suggestions/remarks and elements for scientific debate:

- The Ph.D. candidate derived some computational complexities, but not computational costs. What are the constants in front of the derived computational complexities? Does these constants depend on the implementation? Does depend on the architecture of the parallel machine? What is the order of these constant?

- The main application of the isogeometric L2 projection solver concerns explicit dynamics. But while performing simulations with explicit dynamics solvers, we are constrained by the Courrant-Fredrichs-Levy condition. What is the limitation of this condition in terms of the computational problem that can be simulated? How large computational grids for the problem of non-linear flow in heterogenous media can be processed? Is it possible to implement similar strategy for implicit simulations?

- What is the implementation language for the shared-memory version of the solver? What was the motivation behind this technology?

- What about hybrid memory parallel machines? Did the author run the simulations of the mixed formulation, over distributed memory Linux cluster node with multiple running cores?

Non-Scientific Aspects of the Doctoral Dissertation

The organization of the document together with some properly written key sections makes this Doctoral Dissertation easy to follow and understand for the most part. The quality of figures, tables, equations and algorithms also facilitates the readability of the document. The dissertation has been correctly prepared in LaTeX and the Figures seem to be generated with gnuplot technology. There are some minor mistakes in the parts of the dissertation containing mathematical formulas, for example:

- Eq. (1.1) should start with \frac{du}{dt} instead of \frac{\partial u}{\partial l};
- The operator L in Eq. (1.1) and after is not defined formally.
- Which are the required regularities of the solution and right-hand-side in the weak-form? Same for the test-space V.

The derivation of the alternating directions algorithm in Appendix A is unnecessary complicated. It would be better to define the Kronecker product operator and use its properties to get the two (or three) banded linear systems to be factorized.

The author often confuses computational cost with computational complexity, e.g., in the title of Section 5.1.3.

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Main Scientific Achievements of Mr. Maciej Woźniak

The main scientific achievements of Mr. Maciej Woźniak can be listed as follows:

- The derivation of computational complexities of parallel multi-frontal solver algorithm for different architectures (and its numerical verification).
- The formulation of a parallel algorithm for the alternating direction solver, including the expensive integration of the right-hand-sides.
- Exemplary application to explicit dynamics simulations.

Final Recommendations

In conclusion, it is my belief that Mr. Maciej Wozniak Dissertation and Scientific Achievements constitute a significant contribution to the field of computer science and fulfills the requirements for a Doctoral Degree according to the current Polish law.

Therefore, I recommend his Dissertation to be considered for the highest possible recognition on the field and to be admitted for further procedural stages.

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