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TO: AGH University of Sciences and Technology, Krakow, Poland

RE: Review Report of PhD Dissertation of Konrad Jopek, entitled:
        "Parallel Multi-thread Multi-frontal Solvers Using Element Partition Trees"

Dear Members of the Ph.D. Programme of AGH University of Sciences and Technology,

In the following, I provide my review report of the Ph.D. Dissertation of Mr. Konrad Jopek.

Summary
When performing an LU factorization of a sparse matrix, it is critical to properly order such a matrix. Indeed, different ordering methods give rise to significantly different fill-ins on the L and U factors, thus seriously affecting the factorization´s performance both in terms of time and memory. Most existing multi-frontal solvers use the matrix structure to generate a graph that is later optimized with the aim at minimizing the resulting fill-in of the L and U factors. Unfortunately, since this problem is NP (nondeterministic polynomial) complex, the encountered solution is often far away from the optimal one.
Mr. Konrad Jopek proposes to improve some of these ordering algorithms by using additional information associated with grid-based methods that is often ignored by traditional solvers: element based elimination trees. By using this extra piece of information, one can improve the resulting ordering. This improvement is more notorious in matrices associated with certain heavily-refined grids since it is known that existing algorithms based on nested dissection are quasi-optimal in uniform grids. The author illustrates several advantages and limitations of using element based elimination trees for matrix reordering during LU factorization with different numerical examples and applications.

Main Accomplishments

The main accomplishments of this PhD Dissertation are:

- **Mr. Jopek is able to clearly show the advantages of using element based elimination trees to decide the ordering of a matrix for LU factorization**.
- Mr. Jopek provides a scientifically profound and in-depth discussion of how to use element based partition trees to perform LU factorization, as well as to design discretizations that minimize the cost of LU factorization.
- Mr. Jopek shows a large number of numerical examples illustrating the performance of LU factorization with different ordering algorithms. These results are enlightening.
- Mr. Jopek has published several articles in the topic and has delivered several presentations in recognized conferences and venues worldwide.

In my opinion, the previously mentioned novel contributions are sufficient to grant Mr. Jopek a Ph.D. degree in Technical Computer Science and Telecommunication.

Other Aspects of Mr. Jopek Ph.D. Dissertation

In the following, and based on the submitted Ph.D. Dissertation, I provide a list of suggestions and ideas that aim at helping Mr. Jopek with his future career.

1. The abstract is well-written, clear, and concise. Other sections, however, exhibit important grammatical mistakes. I recommend Mr. Jopek to preserve well-written pieces in future works and to use some grammar corrector (like grammarly) in written documents.
2. The introduction is for the most part well-written. In particular, he dedicates a subsection for open questions, where Mr. Jopek clearly states the questions he tries to answer in his dissertation. I find this to be a great idea that facilitates the reading and explains the motivation of his work. I suggest the author to preserve similar structures in his future works.
3. It is clear that it is possible to obtain the nonzero pattern of a matrix from the element based elimination trees together with additional info about the selected basis functions. What about the opposite? Since one of the main assumptions of this dissertation is that the opposite is not easily achievable, a discussion about it could enrich this work. In particular, to know if this is possible, and if it is, if the computational cost would be affordable (of lower order as compared to the subsequent LU factorization) or not.
4. The comment on page 4 of the introduction stating that matrices are banded is incorrect. This only occurs in one-dimensional problems.
5. Some parts of the Dissertation, like the detailed description of the basis functions, seem unnecessary to me. It is only necessary to know the support of those functions.
6. Some formulas like Eq. 29 seem too descriptive to me. Why do you need to know the lower order terms? I similarly observe a plethora of details in the examples and graphics (e.g., Fig. 17). Are all these details necessary?
7. I miss a more profound literature review. I think it could have been beneficial for this Dissertation. I suggest Mr. Jopek to perform a more detailed literature review in future works.

8. The section where Dr. Jopek computes/estimates FLOPS should be better motivated. This is a critical section since it allows to select cutting planes when designing, for example, refined Isogeometric Analysis (rIGA) discretizations. However, I find this is not so clearly explained in the beginning of the section about estimating FLOPS.

9. The possible need of pivoting to prevent round-off error or simply to be able to perform the LU factorization for the case of indefinite problems is little discussed. I think this could be a major constraint on the proposed ordering method based on element elimination trees. A section dedicated to this would enrich the presented work or, alternatively, could be envisioned as future work.

10. I miss a more detailed acknowledgment section. A Ph.D. dissertation is supposed to be a task that entails great work and dedication, and as such, writing a detailed list of acknowledgments is a good thing to do.

11. Please, double check the format of the references. In particular, they all should include the year number.

12. The quality of the graphics is dissimilar. Some exhibit high quality (e.g., Fig. 10) while others lack axis labels (e.g., Fig. 63) or look of poor quality (e.g., Fig. 61).

13. I suggest Mr. Jopek to focus his publication efforts on publishing in high-ranked (Q1) journals. Also on being the leading author of some of his publications.

Final Recommendation

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

Sincerely,

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