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FROM:

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REVIEW OF DOCTORAL DISSERTATION OF MR. MARCIN SIENIEK

To Whom it May Concern

In the following, I provide my evaluation assessment of the Doctoral Dissertation of Mr. Marcin Sieniek with title: "Adaptive Strategies for Multiscale Problems" 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. Marcin Sieniek proposes a number of approaches to use adaptive strategies for multiscale problems. The adaptive strategies are

all based on adaptive finite elements: h-adaptive finite elements (higher density of smaller size elements where error is higher) and hp-adaptive finite elements that combines h-adaptive finite elements with p-adaptive finite elements (use of higher polynomial order on large size finite elements where error is high but a smooth function of the spatial coordinates). The field of applications is pretty wide. In the dissertation, results of its application to material science with material properties extracted from Magnetic Resonance Imaging (MRI) scans are shown. Problem of linear elasticity with thermal expansion coefficients is analyzed in the dissertation but techniques proposed are suitable for many other physical problems.

It is show that by performing a preprocess stage (before the analysis of the physical problem) in which in an adaptive fashion (using hp self-adaptive techniques) a continuous representation of the material data (originally available as discontinuous digital data) is extracted, performance of the numerical method used afterward is significantly improved.

An algorithm that re-uses identical parts of the mesh is developed. This is of crucial importance when dealing with adaptive methods but also on other problems such as those that have some sort periodicity. Furthermore, the multi-frontal algorithm together with the reuse techniques is expressed with graph grammar productions.

An hybrid algorithm combining analysis at the macroscale and nanoscale is also presented. Furthermore, the switch between macro and nano scales is allowed while performing an adaptive analysis of the problem at hand.

Details of the mathematical formulations and computer implementations of the algorithms are given in the corresponding appendices.

Main Accomplishments

Mr. Marcin Sieniek applies for the first time hp-adaptive algorithms to preprocess discontinuous data coming from digital data acquired from, for example, Magnetic Resonance Imaging (MRI) scans. By performing this preprocess step, convergence of the ulterior numerical method (also a hp-adaptive procedure) is significantly improved.

Also, Mr. Marcin Sieniek develops a re-use algorithm for multi-frontal solvers that saves computational resources for periodic-type and adaptive meshes.

The above mentioned novel contributions are sufficient to grant a Ph.D. degree in applied Computer Sciences.

Scientific Aspects of the Doctoral Dissertation

Some suggestions/remarks and elements for scientific debate follow:

- The literature review is correct; nevertheless, it is not very extensive and seems to be very narrow in terms of the research groups referenced. I believe it should have been broaded to better reflect the state of the art in the field.
- Section 2.1.5.2: h-version of FEM does converge algebraically, but not exponentially, fast.
- Section 2.1.5.3: The "apparent" contradiction that the original h-adaptive FEM for the elasticity problem is incorrect since he presents other h-adapted FE grids (produced via a Projection-Based Interpolation operator) that deliver better error results with a lower number of unknowns (compare Table 3 vs. Table 2) should be explained.
- Section 2.5.4: Memory saving is close to 70 %. However, it is not easy to understand where the saving comes from if one follows the schematic diagram of Figure 22. I guess that for the regular case the elimination tree is basically reduced to one leaf. A diagram that clarifies how the algorithm performs would have helped the reader.
- Section 2.7: Please, include some intuitive explanation about the method on the introduction of this section. Otherwise, it is quite challenging to follow it. On the other hand, only one numerical result (Figure 37) seems to be too less to illustrate the method.
- I would rather have preferred actual conclusions that a mere summary in Section 3.
- I agree with the skilled choice of material moved from main core of the dissertation to the appendices.

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 generally adequate quality of figures, tables, equations and algorithms also facilitates the readability of the document.

- A half, or one, page abstract is missing. It helps to the visibility of the dissertation; and it helps the reader.
- Basically, the whole dissertation is condensed in one chapter (Chapter 2) with many sections and subsections. That makes difficult to the reader to appreciate the structure of the whole work presented in this dissertation. I would rather have chosen a structure with more chapters; e.g., separate chapters with sections 2.1-2.2, 2.3-2.5, and so on.
- I do not like too lengthy dissertations. However, dissertations should be, up to some point, self-contained. Therefore, I consider there are too may "for details see [ref]" within the explanations.
- Page numbering is missing.
- Table 2 is cut into two pages. Not sure if is on purpose.
- It is weird to use the term four-face element to refer to a tetrahedron.
- Some typos: *detais*, *base functions*.
- Figure 40 does not exist.
- Reference to Figure 37 is wrong.
- Section 2.6.2: The first paragraph seems unrelated to the previous section and make it hard to follow.

Main Scientific Achievements of Mr. Marcin Sieniek

- Mr. Marcin Sieniek has published five articles in peer-reviewed Journals, two more are accepted for publication, and one additional article is under review. He has also published other articles in more local journals.
- In addition, he has published numerous proceedings and has participated in multiple presentations.
- He is the first author of two of his main three publications as well as from the paper that is under review.

- I find the number and quality of "first class publications" adequate and satisfactory for his career stage. His large number of "proceedings" and "second class publications" is a bit excessive and strange for his career stage.
- He has a good number of local co-authors, which I find quite positive for his career. I also recommend him to further expand his research network to other international collaborators during the next few years.

Final Recommendations

In conclusion, it is my belief that Mr. Marcin Sieniek's 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 Polish law (Ustawa z dnia 14 marca 2003 r. o stopniach naukowych i tytule naukowym oraz o stopniach i tytule w zakresie sztuki —Dz.U. Nr 65, poz. 595, z późn, zm.—). Therefore, **I recommend his Dissertation to be considered for the highest possible recognition on the field** and to be admitted for further procedural stages.