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REPORT by Prof. Umberto Cugini
ON THE PhD THESIS:

“Modification of semantically enriched FE Mesh models: application to the fast prototyping of alternate solutions in the context of industrial maintenance”

by **Ruding LOU**

This report reflects my opinion about the thesis of Mr. Ruding LOU.

This work starts from a very specific industrial problem to propose and validate with a prototype implementation a very interesting and innovative approach to the typical cycle of engineering design, consisting in modeling (with CAD systems in terms of geometric models) the result of the design phase, convert these models in meshes for FEA and, on the basis of the results of numerical simulation, iteratively modify the geometric model and consequently the FE mesh model to reach an optimal result.
The aim is to provide, at the mesh level, a set of operators and procedures allowing the designer to modify easily his current design without loosing all the semantics included into the CAD model and the FE mesh model already generated.
The work presented is centered on a multi-layered framework, based on semantically enriched meshes, which appear to be the most interesting basis for reconsidering the present approach based on the strict separation of the model, ideally representing the design result, and the models, goal oriented, needed for each validation to be done by simulation.

The thesis is organized in two parts and six chapters.

The first part (High-level manipulations of Finite Elements meshes: state of the art) is relative to the state of the art of the existing models, methods and tools classically adopted for FEA, and is organized into two Chapters.

In particular Chapter 1 (Models, methods and tools for industrial studies) presents a very accurate and precise description of the various representation schemes for geometric modeling used to model 3D shapes, with a particular reference to the basic mesh techniques. A description of the classical CAD-FEA loop for the optimization of the design result follows, as well as a precise description of some industrial examples provided by EDF R&D, and curiously described as maintenance problems, defining the framework in which the work was developed.

In Chapter 2 (Modification of enriched FE meshes) a state of the art on mesh modification methods is presented. In order to maintain the semantic information attached to the meshes, the modification is analyzed from geometric and semantic criteria point of view, and in particular the following modifications are examined: meshes intersection, crack insertion, cutting operation, mesh filleting and semantics manipulation.

The second part (CAD-less geometric modeling operators) presents the approach, methods and tools developed for the geometric and semantic treatments of enriched FE meshes; a generic operator and its instantiations, as well as some test cases relative to the application environment proposed, and is organized into four Chapters.

In Chapter 3 (Generic CAD-less approach for fast preparing of FE meshes) is proposed a multi-layered framework defining a hierarchical subdivision of : semantics, groups and geometry, and is introduced the concept of a generic CAD-less modeling operator acting at three stages: information exploitation, geometric modification and semantics transfer.

Chapter 4 (Basic methods and tools for the geometric treatment of enriched FE meshes) describes various methods and tools relative to shape recognition, sharp feature identification and topological modification, mesh deformation under constraints and mesh quality control. All methods and tools are very clearly described and analyzed in terms of pros and cons and tested with very well illustrated examples.

Chapter 5 (Basic models, methods and tools to handle semantics) deals with the different needs for semantics treatments, in particular in the mesh and group's manipulation for semantics transfer, introducing the concept of Virtual Group Boundary. At the end rules for high-level semantics transfer are proposed.

In Chapter 6 (A generic CAD-less mesh modeling operator and its instantiations) are described several instances of the generic CAD-less mesh modeling operator aimed at answering the needs in mechanical engineering posed in Chapter 1. In particular the various instances implement: mesh merging, mesh cracking, mesh drilling and mesh filleting. All operators are very clearly described in full detail with a lot of very well illustrated examples and performance results.

A final Chapter (Synthesis, conclusion and perspectives) synthesizes the work done and presented in the thesis and examines challenges of faster, easier and accurate modeling, perspectives of the methods and tools proposed also outside the narrow boundaries proposed at the beginning by the industrial problems taken as a starting point. In the analysis of the limits and shortcomings of actual engineering, a more open analysis of the general situation, taking into account the approaches and software suites based on topological optimization, should have indicated interesting application domains for the novel developed methodologies.

The thesis is very accurate, well written, and very well illustrated and documented. The results obtained relative to the industrial examples used to validate the approach, methods and tools developed, demonstrate the value of the excellent work done, but, personally, I think the most interesting domain in which to apply the methods and tools developed, could be in new frameworks for knowledge driven product development.

The ideas and work presented in the thesis are original and a step forward in the research domain. In my opinion this work appears to represent an important improvement in the field of semantic driven shape description and manipulation.

With great pleasure I fully support to award the title of Docteur de L'Art et Métiers ParisTech and Dottore di Ricerca della Università degli Studi di Genova to Ruging LOU.

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