Framework for Hull Form Reverse Engineering and Geometry Integration into Numerical Simulation

A brief Summary of the Dissertation

by

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Computer Aided Design (CAD) has a widespread and ubiquitous application and every specific downstream application dealing with 3D geometry has its own quality requirements that restrict the direct usage of CAD models. In fact the modern CAD systems have attained a certain degree of maturity, but their efficiency, reliability, and compatibility with subsequent analysis tools remain an active research topic. At the heart of this problem lie some mathematical issues, concerned with the computation, representation, and manipulation of complex geometries, which have stubbornly resisted the best efforts of the research community to formulate rigorous and efficient solution procedures.

These problems are usually introduced during reverse- or forward engineering processes and often need to be analyzed and processed towards downstream applications that typically have strict requirements on the quality and integrity of their input. In practice, these requirements are often not met by models originating from either forward- or reverse engineering processes. Forward engineering process with regards to CAD model development is relatively stable and matured compare to reverse engineering because it is a daily basic product development phenomena and far more has been done over years. However reverse engineering involves many error-prone processes and no straightforward recipe how to obtain a good quality model is available especially when it comes to complex shapes.

Indeed, the 3D CAD models obtained through forward- or reverse engineering are usually the starting point for downstream application such as computational fluid dynamics, computational solid dynamics, computational electromagnetic analysis, specification, verification of product design, automatic manufacturing, inspection, maintenance and assembly operations. The model should fulfill certain requirements of downstream applications in order to obtain feasible and quality results. The adapting process usually involves tedious, time and resource consuming tasks.

Over the years, different techniques were proposed by CAD, meshing and computer graphics communities to solve CAD model inconsistencies. However, it is rather vast and complicated to device a common strategy which ables to adapt a CAD model to downstream application input requirements. In addition, such an attempt would be inevitably incomplete as particular cases and new applications arise too frequently.

Therefore, it is important to develop application specific reverse engineering and CAD repairing technique to improve their reliability, accuracy, efficiency and compatibility with subsequent analysis tools. In addition, it helps to include expertise knowledge in reverse engineering process as well as in CAD repairing, region identification and domain preparation steps. The goal of the thesis is to develop a framework which efficiently bridges a point cloud data from real world object (i.e. hull form) to downstream applications specifically for hydrodynamic simulation. The developed framework comprises three alternative reverse engineering processes namely curves network, direct surface fitting and triangulated surface methods. In addition, it includes CAD repairing, region identification and further domain preparation strategies as shown in Figure 1.

In addition to the CAD model reconstructed from existing objects, the framework also includes the possibility to adapt the CAD model represented in parametric surfaces read from Initial Graphics Exchange Specification (IGES) and triangulated surfaces read from STereoLithography (STL). The thesis aims not only the development of suitable RE processes but also the adaptation for downstream application so that the process is complete and time saving.

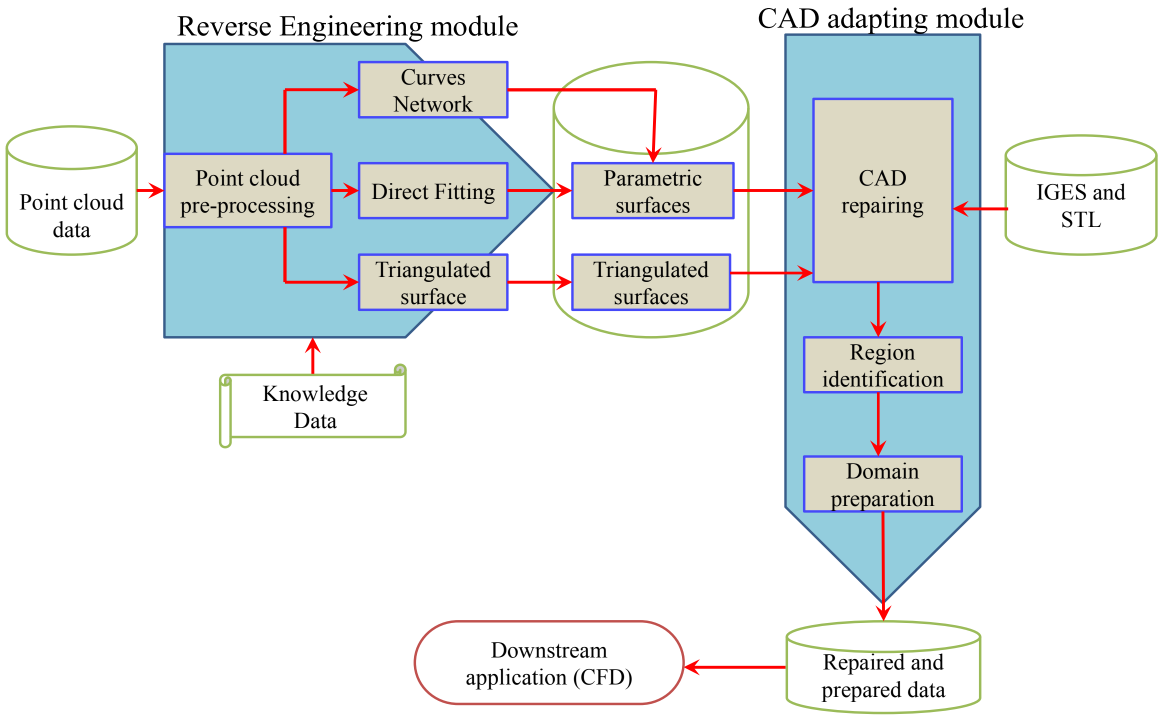

Figure 1: The main components and integration of the developed framework

The achievements of the thesis can be summarized as follows:

- A comprehensive review of state-of-the-art techniques in reverse engineering, knowledge based reverse engineering, CAD repairing, region identification and domain preparation strategies are presented.
- Time saving and efficient ship hull form specific reverse engineering and geometry integration into numerical simulation tools framework is developed.
- The developed framework is integrated with three suitable reverse engineering techniques (curves network, direct surface fitting and triangulated surface methods) and CAD repairing, region identification and domain preparation methods. It also introduces several structured and integrated numerical processing algorithms to perform the reverse engineering tasks such as point cloud pre-processing, segmentation, normal estimation, geometric fitting, etc.
- The developed curves network reverse engineering technique reconstructs hull form section B-spline curves from an unorganized point cloud. With a receipt of consistently aligned point cloud from various patches of 3D point cloud data views, it is efficient and time saving strategy.
- The direct NURBS surface reconstruction from an unorganized point cloud usually requires a thorough point cloud pre-processing. Hence, the framework includes suitable pre-processing techniques which avoids prior triangulation and NURBS patch networks and develops a computationally efficient and time saving strategy.
- In some cases using curves network or direct NURBS surface fitting is not efficient because the process is in a sense of repeating itself and comes back to where it is started but with deviations or inaccuracies far in excess of the original scanned point cloud. On the other hand, it is the most employed method with many techniques proposed over the last decades. As a matter of these facts, existing triangular surface reconstruction approaches are studied and evaluated against quality, capability and usability criteria, and implemented in such a way that they are suitable and efficient for hull form reconstruction.

- Prior knowledge (i.e. data, algorithm spatial and scene) are integrated into the developed framework in order to increase the usability and accuracy of different algorithms.
- An automatic CAD inconsistencies detecting and repairing approach which aims to reduce the amount of time and cost associated with repairing CAD geometric data is developed and integrated into the framework.
- Ensuring error-free CAD models alone does not guarantee a good mesh or good computational analysis results. Most downstream applications have their own input geometry requirements from which geometric consistency and error-freeness are usually common. However, several requirements are application specific and need to be fulfilled based on individual bases. Therefore, the region identification, and domain preparation strategies are developed aiming to further decrease the CAD model processing time.

The framework offers different ship hull form specific reconstruction approaches with pre- and post-processing functionalities including knowledge integration. These make the developed framework effective and time saving. The surface healing, region identification, and domain preparation strategies of the developed framework are applied to ensure the consistency of the CAD model constitutes (i.e. geometry, topology and tolerance). It does not only provide consistent output representations but also saves time and resources.