COMPUTING A WELL-CONNECTED MIDSURFACE

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ABSTRACT

Computer-aided Design (CAD) models of thin-walled parts such as sheet metal or plastics are often reduced dimensionally to their corresponding midsurfaces for quicker and fairly accurate results of Computer-aided Engineering (CAE) analysis. Generation of the midsurface is still a time-consuming and mostly, a manual task due to lack of robust and automated techniques. Midsurface failures manifest in the form of gaps, overlaps, not-lying-halfway, etc., which can take hours or even days to correct. Most of the existing techniques work on the complex final shape of the model forcing the usage of hard-coded heuristic rules, developed on a case-by-case basis. The research presented here proposes to address these problems by leveraging feature-parameters, made available by the modern feature-based CAD applications, and by effectively leveraging them for sub-processes such as simplification, abstraction and decomposition.

In the proposed system, at first, features which are not part of the gross shape are removed from the input sheet metal feature-based CAD model. Features of the gross-shape model are then transformed into their corresponding generic feature equivalents, each having a profile and a guide curve. The abstracted model is then decomposed into non-overlapping cellular bodies. The cells are classified into midsurface-patch generating cells, called 'solid cells' and patch-connecting cells, called 'interface cells'. In solid cells, midsurface patches are generated either by offset or by sweeping the midcurve generated from the owner-feature's profile. Interface cells join all the midsurface patches incident upon them. Output midsurface is then validated for correctness. At the end, real-life parts are used to demonstrate the efficacy of the approach.

***K*eywords** CAD · Sheet Metal Features Taxonomy · Defeaturing · Model Simplification · Feature Abstraction · Topological Validation · Cellular Decomposition · Midsurface · CAE.

1 Introduction

Getting a quicker validation of the proposed product is crucial in the era of fierce competition and faster obsolescence. Digital product development, which includes, modeling by CAD (Comouter-aided Design) and analysis by CAE (Computer-aided Engineering) plays a crucial role in quicker "Time to market". For thin-walled models such as sheet-metal/plastic products, a quicker and fairly accurate CAE analysis is possible by idealizing them to their equivalent surface representations, called "Midsurface". Midsurface can be envisaged as a surface lying midway of a thin-walled solid, mimicking its shape. In CAE analysis, instead of using expensive 3D solid elements, 2D surface elements are used on the midsurface for fairly accurate results in lesser computations/time. Even in the age of scalable and near-infinite computing power, it is still desirable to have a robust, well-connected midsurface, so as to be able to run more design iterations, quickly. Because of such advantages, the midsurface functionality is widely used and is available in many commercial CAD-CAE packages.

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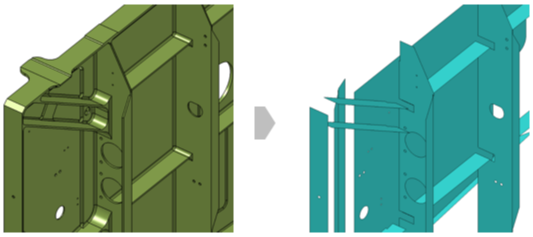


Figure 1: Midsurface Errors (Source: [1])

In spite of its demand and popularity, the existing techniques of computing the midsurface fail to compute a well-connected midsurface, especially for non-trivial shapes ([2, 3]). Failures manifest in the form of gaps, missing patches, overlapping surfaces, not lying midway, not mimicking the input shape, etc. (Figure 1). Correcting these errors is mostly a manual, tedious and highly time-consuming task, requiring hours to days. This correction time can be nearly equivalent to the time it can take to create the midsurface manually from scratch ([4]).

Automated and robust technique for computing midsurface is a crucial need and this work is a step in that direction. Simplification, abstraction and decomposition are the core themes of the proposed approach.

2 Proposed Approach

The input (Figure 2) is a feature-based CAD model represented by $(\cup_q f^3)$, where '$\cup$' denotes a collection, of 'q' features ('f') having dimensionality '3' (solids). In practice, the thin-walled CAD models come in various types, such as mesh, solid, feature-based CAD, etc. This research, as it leverages feature information [5], expects a feature-based CAD model as input. This, at times can be deemed as limitation, in case of unavailability due to format restrictions, proprietary data etc. But, techniques such as segmentation, feature recognition (FR), can be used effectively to convert the non-feature-based model to a feature-based one.

- **Defeaturing** $(\cup_r f^3, r \leq q)$: Computes gross shape by removing irrelevant/superficial features [6], using Feature taxonomy and size-based Remnant feature approach ([7]).
- **Generalization** $(\cup_r L^3)$: "ABEL" transforms form-features to "Loft/Sweep" representations (L), making it simpler to develop a generic, portable algorithm ([8]).
- **Decomposition**: Cellular decomposition is performed at each feature step to form a graph of nodes having non-volumetrically-overlapping cellular bodies with respective owner-Sweep feature.
- **Midsurface Computation**: Using topology of the graph, the nodes are classified into midsurface-patch generating nodes (solid cells - $sCells$) and interaction-resolving nodes (interface cells - $iCells$). Midsurface patch is computed by, first, extracting the profile and the guide curve from the owner Sweep feature, then either offsetting the profile in case of shorter guide curve or sweeping the midcurve [9, 10] along the guide curve.
- **Validation**: Midsurface needs to mimic the input shape, faithfully. A novel topological method is used to validate correctness of the midsurface ([11]).

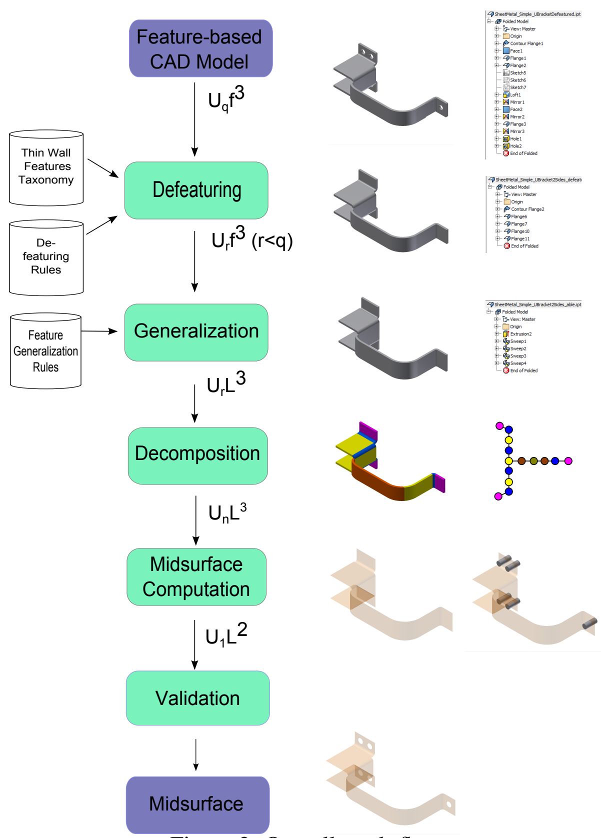
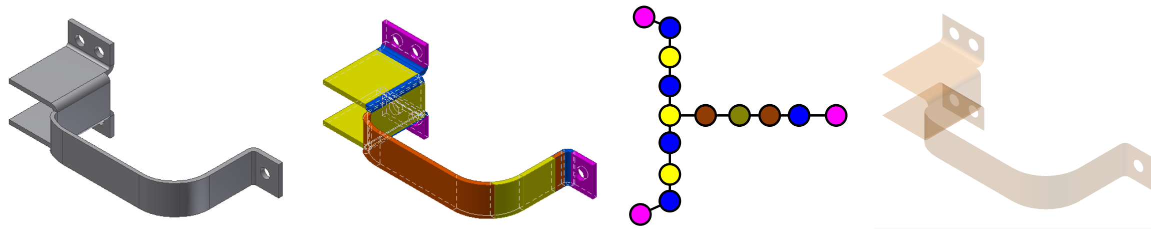


Figure 2: Overall work-flow

A well-connected output midsurface is then sent to downstream applications such as CAE analysis.

3 Conclusion

Computation of midsurface is one of the popular simplification techniques for CAE analysis of thin-walled models. In-spite of good demand, current methods (especially the popular Midsurface Abstraction - MA) suffer from problems such as gaps, overlaps, not lying midway, improper connections, etc. In MA, these failures are due to complexities of face-pair detection and interactions. In our approach uses feature simplification and abstraction to resolve face-pair detection problems and cellular decomposition to develop a generic logic to address interaction problems amongst midsurface patches.



(a) Original Part (b) Decomposition (c) Graph (d) Midsurface

Following is a comparative analysis of some relevant approaches vis-a-vis our approach:

Researcher	**Method**	**Shortcomings**	**Our Approach**
Chong et al. [12]	Uses concave edge decomposition. Mid-curves by collapsing edge pairs. If they form a loop, creates a midsurface patch	Hard-coded inequalities/values to detect edge-pairs. Connection logic is not generic and comprehensive	A generic treatment for the computation of midcurves, midsurface patches and their connections
Boussuge et al. [13]	Generative decomposition. Recognizes Extrudes of each sub-volume. Creates midsurface patches in each and connects them together.	• No fillets/chamfers. • Only Additive cells. • Only Extrudes with Analytical surfaces • Expensive MAT to detect thin profiles • Works only on Parallel and Orthogonal connections.	• No such restriction • Re-inserts -ve cells • Generic Sweep extend-able to Loft • Simple rules of size of profile/guide • Generic logic for any numbers/types of connections.

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