

Computing a well-connected Midsurface

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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 (Computer-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.

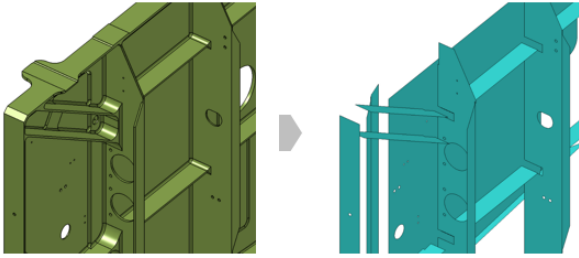


Figure 1: Midsurface Errors (Source: [1])

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 ([13, 2]). 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 ([12]).

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 [6], 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.

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- **Defeaturing** ($\cup_r f^3, r \leq q$) : Computes gross shape by removing irrelevant/superficial features [5], using Feature taxonomy and size-based Remnant feature approach ([10]).
- **Generalization** ($\cup_r L^3$) : “ABEL” transforms form-features to “Loft/Sweep” representations (L), making it simpler to develop a generic, portable algorithm ([7]).
- **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 [8, 9] 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]).

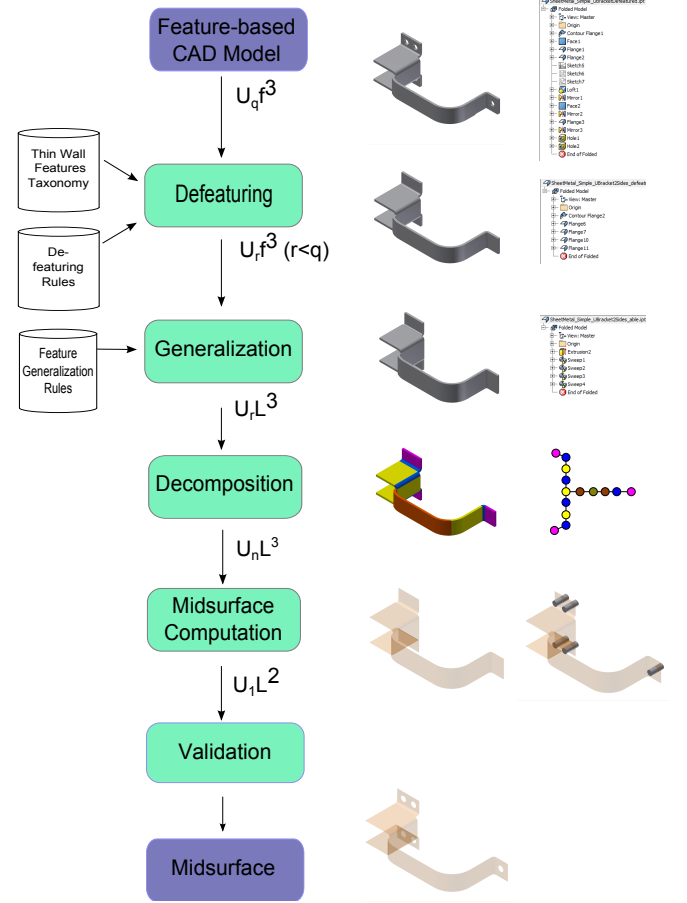
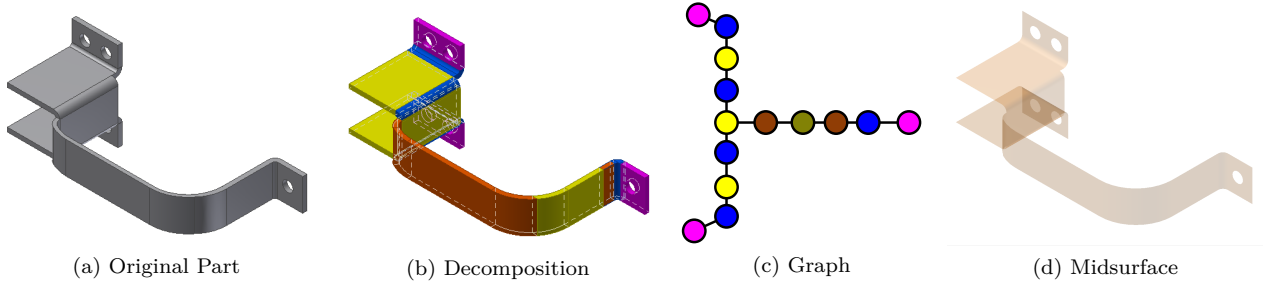


Figure 2: Overall work-flow

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.



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

References

- [1] C. Aparicio. 3 steps to create midsurface geometry, Sept 2015. (Last accessed Oct 2015).
- [2] A. Backes, C. Glockner, and U. Schwanecke. Automatic mid-surface generation as a basis for technical simulation. *ATZ Worldwide*, 116(2):20–23, 2014.
- [3] F. Boussuge. *Idealization of CAD assemblies for FE structural analyses*. PhD thesis, University of Grenoble, 2006.
- [4] C. S. Chong, A. S. Kumar, and K. H. Lee. Automatic solid decomposition and reduction for non-manifold geometric model generation. *Computer-aided Design*, 36:1357–1369, 2004.
- [5] Y. Kulkarni, A. Sahasrabudhe, and M. Kale. Strategies for using feature information in model simplification. In *Proceedings of International conference on Computer Aided Engineering, IIT Madras*, 2013.
- [6] Y. Kulkarni, A. Sahasrabudhe, and M. Kale. Using features for generation of midsurface. In *Proceedings of International Conference on Advances in Mechanical Engineering (ICAME)*, pages 141–145, 2013.
- [7] Y. Kulkarni, A. Sahasrabudhe, and M. Kale. Formulating midsurface using shape transformations of form features. In *5th International and 26th All India Manufacturing Technology, Design and Research Conference*, 2014.

Re-searcher	Method	Shortcomings	Our Approach
Chong et al. [4]	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. [3]	Generative decomposition. Recognizes Extrudes of each sub-volume. Creates midsurface patches in each and connects them together.	<ul style="list-style-type: none"> • No fillets/chamfers. • Only Additive cells. • Only Extrudes with Analytical surfaces • Expensive MAT to detect thin profiles • Works only on Parallel and Orthogonal connections. 	<ul style="list-style-type: none"> • 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.

- [8] Y. Kulkarni, A. Sahasrabudhe, and M. Kale. Midcurves generation algorithm for thin polygons. In *National Conference on Emerging Trends in Engineering and Science (ETES)*, pages 76–82, 2014.
- [9] Y. Kulkarni, A. Sahasrabudhe, and M. Kale. Dimension-reduction technique for polygons. *International Journal of Computer Aided Engineering and Technology*, 2017. Inderscience.
- [10] Y. H. Kulkarni, R. K. Gupta, A. Sahasrabudhe, M. Kale, and A. Bernard. Defeaturing sheet metal part model based on feature information. *Proceedings of CAD’15*,, pages 297–302, 2015.
- [11] Y. H. Kulkarni, A. Sahasrabudhe, and M. Kale. Topological validation of midsurface computed from sheet metal part. *Computer-aided Design and Applications*, 6:663–673, 2015.
- [12] R. Stolt. Reusing cad models for die-casting products for fea. *Proceedings of 2nd NAFEMS seminar: prediction and modelling of failure using FEA*, May 2006.
- [13] Y. Woo. Abstraction of mid-surfaces from solid models of thin-walled parts: A divide-and-conquer approach. *Comput. Aided Des.*, 47:1–11, 2014.