Title:
**Automatic Detection of Geometric Features in CAD Models by Characteristics**

Authors:
Peter Chow, Peter.Chow@uk.fujitsu.com, Fujitsu Laboratories of Europe Ltd, UK
Tetsuyuki Kubota, Tetsuyuki.Kubota@uk.fujitsu.com, Fujitsu Laboratories of Europe Ltd, UK
Serban Georgescu, Serban.Georgescu@uk.fujitsu.com, Fujitsu Laboratories of Europe Ltd, UK

Keywords:
Feature detection, model simplification, Computer-Aid Engineering, CAD-to-CAE

DOI: 10.14733/cadconfP.2014.196-198

Introduction:
Since the introduction of computer for product design and development, computer-aided design (CAD) and computer-aided engineering (CAE), the time for design and simulation process is decreasing as computing performance increases. This is good news in time-to-market of product and saves on physical prototypes. Today, products are design and simulation validated in virtual space before fabrication in physical space. In the case of electronic products, the common simulations are: structural analysis, electromagnetic and thermal-fluid cooling. A major bottleneck to scalability (continue to decrease in time) in this process as computer performance continues to grow exponentially, is the CAD-to-CAE model preparation (CCMP) stage. The end result from the design stage is a CAD model that needs to be processed to create a model suitable for CAE stage. Using CAD model directly is possible but comes at high computational costs and long solution time. The common practice is to add a simplification process at the CCMP stage; this reduces the CAD model features relevant for the class of simulation without comprising solution accuracy. This results in big efficiency improvements in all downstream applications such as meshing and solving system of equations required for simulation. Figure 1 highlights the simplification process required of a server model for thermal-fluid cooling analysis, from the original CAD model to a simplified CAD model for CAE. The time given for each phase is time required for manual simplification. Automation need to be introduced in this process to scale with computer performance increase. Key elements are detection and processing of features in the CAD model. The latter can be solved with advanced geometric modelling kernels for CAD systems such as ACIS [1] and Parasolid [2].

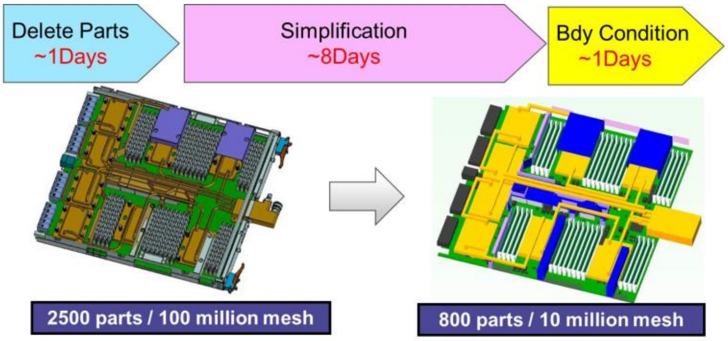


Fig. 1: CAD-to-CAE simplification process for a server model.

As for feature detection, there are methods proposed and studies conducted on simplification for complex 3D CAD models [3-6,9-10]. Basic features of circle holes, blends and chamfers can be detected automatically and available in geometric modelling kernels such as ACIS. For general features, for example arbitrary holes and bumps, it is thought to be difficult for these methods to detect [6-8].

Main idea:

In this article we propose a new approach to more generic feature detection. We call this "detection by characteristics". We start from a CAD model that is a solid model (no parametric feature-based records), for example CAD model in STEP format read into a geometric modelling kernel for processing. The entity elements in this case are vertex point, edge, surface and body. Edges are derived from vertex points. Surfaces have topology based on edges. In ACIS geometric modelling kernel, edges are classified into lines, arcs, curves, etc. Surfaces are classified into planar, cylindrical, sphere, helix, and so on. Based on these entities we can start describing characteristics in a feature in a generic way. The more characteristics we provide the more precise of identifying the right feature we what to detect. With such approach, there is balance between performance and accuracy – more characteristics checking means accuracy at the expense of performance, and vice versa.

Using edge and surface entities we can describe an arbitrary hole with three characteristics:

1. A list loop of edges exist inside a surface boundary and all have the convex characteristic;
2. Surfaces connected to the list loop of edges is a closed-loop;
3. Top and bottom surfaces, each with outward normal vector pointing away from each other.

A list loop of surfaces can be derived from edge-surface relationship with respective list loop of edges. The edges here all have the convex characteristic; the two surfaces on either side have outward normal vector pointing way from each other.

Adding an extra characteristic that all surfaces in the list loop are cylindrical, we can detect circle holes. To detect rectangular holes, four planar surfaces in the list loop. Hexagon holes, six planar surfaces in the list loop. And so on for different kind of holes. Small holes can be detected by characteristic of size, for example, compare the volume of the arbitrary shape to the small feature volume parameter value.

Similarly, we can describe an arbitrary bump with three characteristics:

1. A list loop of edges exist inside a surface boundary and all have the concave characteristic;
2. Surfaces connected to the list loop of edges is a closed-loop;
3. Bump surfaces forms a solid body.

A list loop of closed surfaces can be derived from edge-surface relationship with respective list loop of edges. The edges here all have the concave characteristic; the two surfaces on either side have outward normal vector pointing toward each other. Bump surfaces forms a solid body means closure, no holes; this can be derived from surface adjacency topology. Like holes, adding extra characteristics can detect various classes of bumps such as cylinder and rectangular.

Conclusions:

With the new approach, detection by characteristics, we are able to detect features in a generic way; the flexibility to expand and build on existing feature detection functions. So far for the server model, Figure 1, the 10 days period for CAD-to-CAE model preparation has been reduced to 6 days.

References:

[1] ACIS, http://www.spatial.com, Spatial Corporation.
[2] Parasolid, http://www.plm.automation.siemens.com, Siemens PLM Software.
[3] Zhu, H.; Menq, C.H.: B-rep model simplification by automatic fillet/round suppressing for efficient automatic feature recognition, Computer Aided Design, 34 (2), 2002, 109-123. http://dx.doi.org/10.1016/S0010-4485(01)00056-2

[4] Woo, Y.: Automatic simplification of solid models for engineering analysis independent of modeling sequences, Journal of Mechanical Science and Technology, 23(7), 2009, 1939-1948. http://dx.doi.org/10.1007/s12206-009-0509-y
[5] Mounir, H.; Nizar, A.; Abdelmajid, B.: CAD model simplification using a removing details and merging faces techniques for a FEM simulation, Journal of Mechanical Science and Technology, 26(11), 2012, 3539-3548. http://dx.doi.org/10.1007/s12206-012-0869-6
[6] Thakur, A.; Banerjee, A.G.; Gupta, S.K.: A survey of CAD model simplification techniques for physics-based simulation applications, Computer Aided Design, 41(2), 2009, 65-80. http://dx.doi.org/10.1016/j.cad.2008.11.009
[7] Rezayat, M.: Midsurface abstraction from 3D solid models: general theory and applications, Computer Aided Design, 28(11), 1996, 905-915. http://dx.doi.org/10.1016/0010-4485(96)00018-8
[8] Quadros, W.R.; Owen, S.J.: Defeaturing CAD models using a geometry-based size field and facet-based reduction operators, Engineering with Computers, 28(3), 2012, 211-224. http://dx.doi.org/10.1007/s00366-011-0252-8
[9] Lee, S.H.: A CAD-CAE integration approach using feature-based multi-resolution and multi-abstraction modelling techniques, Computer-Aided Design, 37(9), 2005, 941-955. http://dx.doi.org/10.1016/j.cad.2004.09.021
[10] Belaziz, M.; Bouras, A.; Brun, J.M.: Morphological analysis for product design, Computer-Aided Design, 32(5-6), 2000, 377-388. http://dx.doi.org/10.1016/S0010-4485(00)00019-1