Simplify Your 3D Models

Collaborative Engineering Based on Lightweight CAD Data

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In collaborative engineering environments, handling of large size 3D CAD models with a high level of detail is becoming more and more challenging. Especially sharing of 3D CAD models between OEMs and suppliers as well as utilization in downstream processes require file size reduction for sufficient performance and IP (Intellectual Property) protection while maintaining the initial design intent. In this context, simplification of 3D geometry provides a valuable solution to companies through enveloping, defeaturing and extraction of inner/outer surfaces. Lightweight CAD models enable the efficient sharing and communication of relevant 3D product information as the storage of redundant and confidential data is avoided. This is an important basis for an efficient collaborative engineering in globally distributed development.

Why Simplification

Increasing digitalization and global value-added networks have a strong impact on collaborative engineering. Companies are facing large amounts of data that need to be stored securely, transferred efficiently between partners, customers, suppliers etc., and handled in various tools in defined business and engineering processes. 3D data is playing an important role as communication medium throughout the entire product lifecycle – from conceptual design to downstream processes including CAE analyses, manufacturing and after-sales – and therefore requires reliable IP protection. The value of 3D product information is even increased through approaches like Model-Based Enterprise and Model-Based Systems Engineering [5].

Simplified 3D models serve as a key-enabler for successful digitalization in heterogeneous system landscapes and efficient reuse of CAD data in downstream processes as only the necessary information is processed. The ratio of users authoring 3D CAD data and users consuming 3D CAD data is approximately one to ten. Additionally, the consumption of 3D data and the required type of information heavily depend on each downstream process itself. Most of the downstream processes require only a reduced amount of information from the original CAD model, leading to potential cost savings and faster processing times [2]. Lightweight formats like the ISO standard JT [4] have already paved the way and are still contributing to that trend, opening up further areas of application that go beyond engineering.

The rapid evolution of hardware contributes to the performant handling of data, but the growth of 3D models is even faster. A large number of 3D models – original CAD models as well as derivatives – are produced every day and the amount of information stored in 3D models is extensively increasing. This information is not limited to 3D geometry and PMI, but also includes a lot of metadata. In the rise of Industrie 4.0, more and more entities have to be represented in 3D, one digital 3D model for each physical part or product [3]. Design CAD models of whole products are usually complex and large in file size. The complete 3D model of a mid-range car can easily exceed 10 GB. Sharing of large size CAD models with high level of detail in collaborative engineering environments, e.g., between an OEM and a supplier, often leads to performance issues and long loading times in CAD systems, CAE tools and other systems used in downstream processes. In the worst case, large size 3D models cannot even be opened in the desired application. The transfer of these complex models to a different system landscape or CAD format may also result in issues with product data quality. Besides, there is a consistent need to protect design intent and intellectual property when sharing detailed 3D models beyond company boundaries.

Simplification Methods for Your Needs

Today there are several tools for simplification of 3D models available in native CAD systems and commercial 3D interoperability software solutions. Depending on the scope and objective of simplification, different methods and processes on how to simplify 3D models can be applied. There are four major simplification methods available on the market. Engineers can choose a method, or often multiple methods in combination, that best-suit their simplification needs.

Approximation

Approximation is an easy and efficient method for simplification. The outer surface of a 3D model is tessellated usually by triangulation. The resulting outer shape of the 3D model can be strongly alienated or still be very close to the original geometry, depending on the number

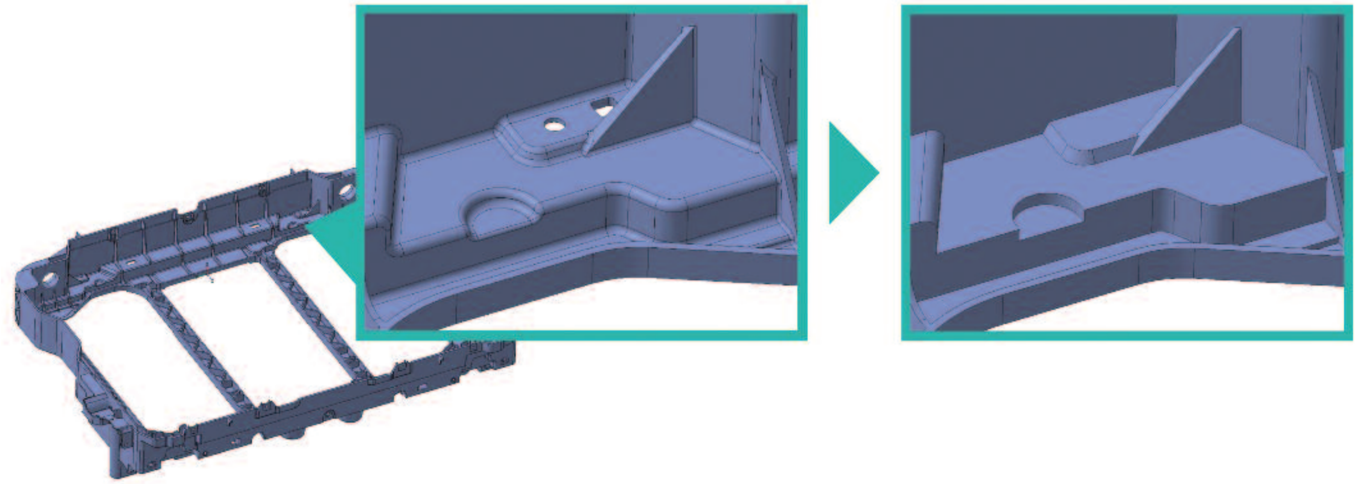

Figure 1: *Defeaturing for CAE model preparation (Removal of small fillets and holes)*

and size of triangles used. Tessellated models are often deployed in manufacturing processes, e.g., additive manufacturing. Besides polygonal simplification, approximation can be used for B-spline curves and surfaces to reduce the number of control points to merge faces or to remove tiny edges and faces.

Removal of Technical Design Details
A more sophisticated method of geometry simplification is the removal of technical design details and features like holes, fillets, grooves etc. Defeaturing is ideal for the optimization of 3D models to create high-quality meshes for CAE analyses, which leads to higher performance and accuracy in CAE analyses (see Figure 1). Ideally, the feature recognition is performed by geometry and not by the modeling history, so that any CAD data can be simplified. Feature recognition is the more generic approach as identical shapes can be recognized independent of the actually used features. Also risk of failures can be reduced, e.g., resulting from the suppressing of fillets for complex 3D models.

Replace by Simple Shapes
Instead of removing dedicated features completely from the 3D model, they can also be replaced by primitive shape objects, like cuboid, cylinder or extruded shape. This is often used for handling large size 3D models in plant engineering or for digital mock-ups. The substitution of parts with lower level of detail, e.g., replacing screws by cylinders, reduces file sizes and enables performant visualization.

Enveloping
Enveloping is a technology to merge complex products and large assemblies into a single solid model while deleting inner parts. Gaps are filled with small volumes and united by Boolean operations. The precise outer shape of the 3D model remains while file size is reduced and intellectual property is protected. Alternatively, exterior surfaces can be extracted if a surface model is sufficient.

Simplification Use Cases in Collaborative Engineering

Simplification is a valuable contribution to several use cases in collaborative engineering. Simplification of 3D models reduces lead time, enables reliable IP protection and improves 3D interoperability in heterogeneous engineering environments. Three major use cases can be distinguished.

File Size Reduction
Main purpose of file size reduction is to create lightweight 3D models of complete products or major assemblies. The development of products by multiple partners using different CAD systems and the transfer of 3D CAD data based on neutral formats often leads to large file sizes. Major issues are storage of redundant information within CAD models, unnecessary information for the dedicated engineering task as well as increase of file sizes by each export and transfer process between partners.

The simplification technologies described above and sophisticated compression algorithms enable the creation of simplified 3D models with reduced file sizes (see Figure 2). They are utilized for visualization, digital mock-ups of complete products and fixture design. For large products and in plant engineering, the substitute of frequently occurring parts by simple shape objects is used. Simplification for file size reduction serves also as a key-enabler for augmented and virtual reality as specific devices cannot display heavy parts.

IP Protection
Reliable protection of company intellectual property plays an important role in collaborative engineering and is increasing in response to a growing awareness of Industrie 4.0 and the Internet of Things

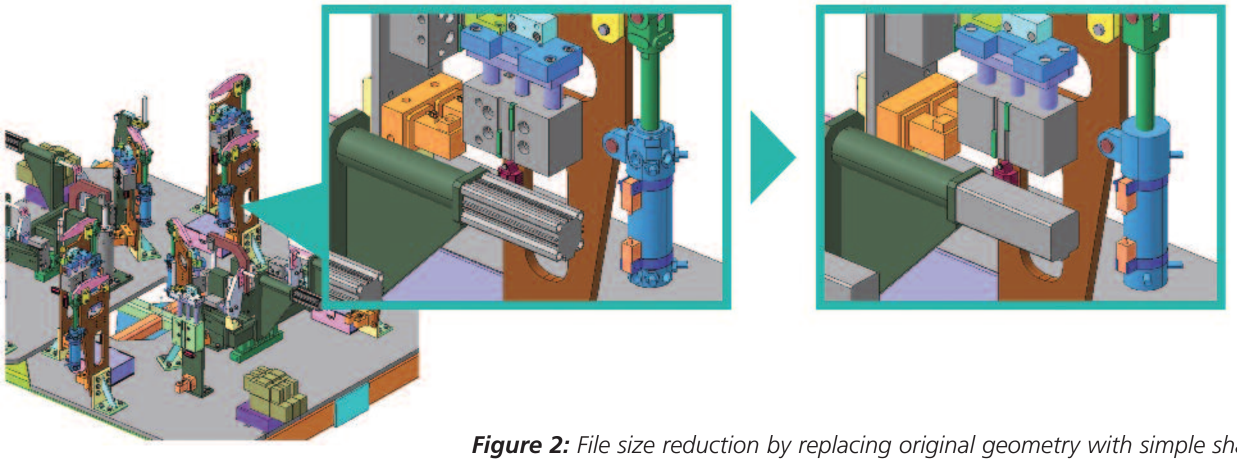

Figure 2: File size reduction by replacing original geometry with simple shapes

(IoT). As more and more 3D engineering data is shared between OEMs and suppliers, inside value added networks and finally with customers, IP protection gets relevant starting in the early design phase. The exchange of 3D models is essential, but the level of detail has to be controlled when a 3D model crosses a company boundary. Simplification of 3D models is a powerful and industry proven solution. In most of the downstream processes, a simplified representation with reference geometry is sufficient for engineering applications.

When exchanging assembly models, instead of deleting confidential parts completely, best practices are removal of technical design details on part level as well as enveloping for the removal of inner geometry (see Figure 3). This eliminates any confidential information and safeguards the design know-how, even for sectioning of simplified models in target applications. The outer surface can be maintained as accurate as in the original input 3D model, but could also be further alienated through approximation. The resulting 3D model may be represented only by a single solid model or as a surface model.

CAE Model Preparation

Shortening lead time for manufacturing companies and having robust results available in early design phase are main drivers for deployment of virtual simulations and utilization of CAE tools [1]. Efficient preparation of 3D data for CAE simulations is one of the key enablers to save entire days by design and simulation engineers. Failures or inaccurate simulation results are avoided through efficient mesh generation based on the extracted, simplified 3D model. This improves accuracy of CAE analyses and prevents long iteration loops. Suppressing small features like holes or bosses will improve quality of mesh because those small features often introduce relatively tiny meshes that will lead to increased number of mesh, and moreover, inaccurate result of simulation.

For fluid analysis, as another example, a significant amount of manual work is required due to the high number of clearance gaps in assembly models. Enveloping enables automated identification and filling of gaps in large and complex assemblies by improved Boolean operations and further advanced technologies (see figure 4).

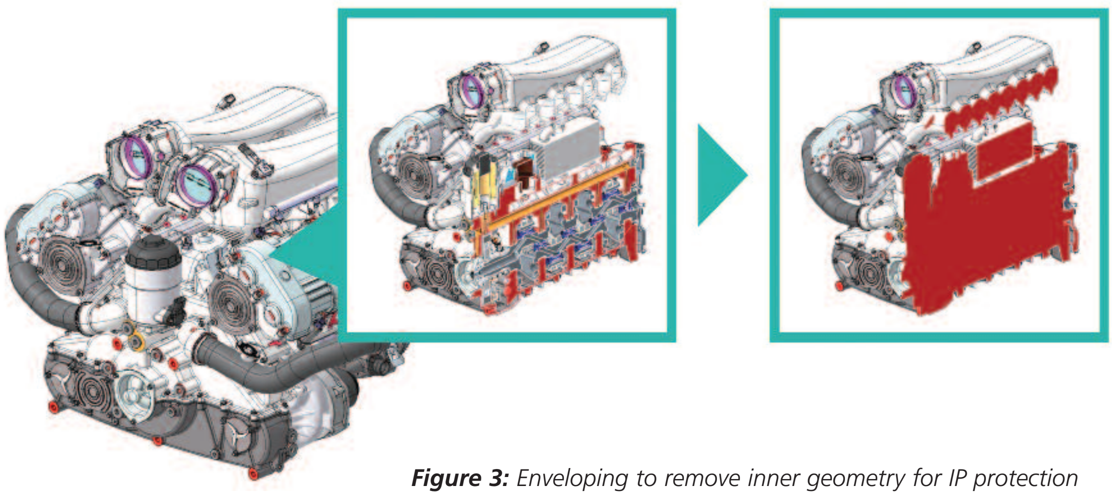

Figure 3: Enveloping to remove inner geometry for IP protection

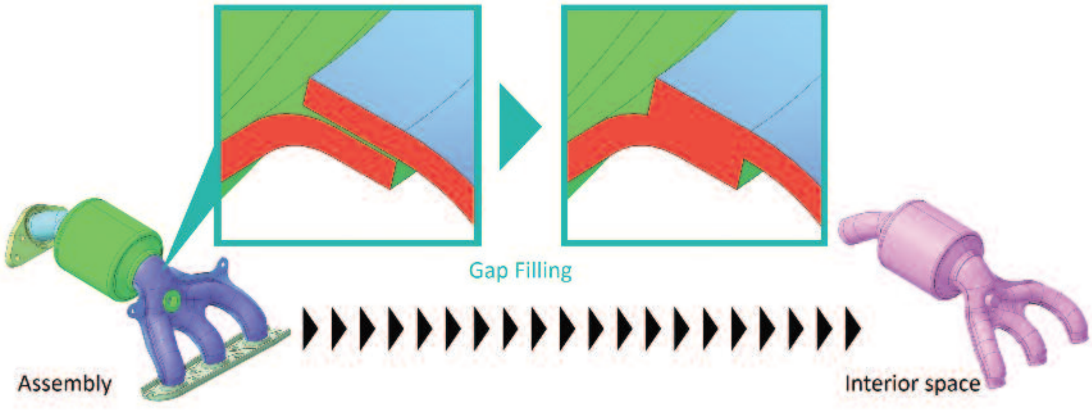

Figure 4: *Enveloping to extract interior space for fluid analysis*

Conclusion

Efficient collaborative engineering on a global scale needs the right amount of information at the dedicated location at the right time. Simplified 3D models serve as information carrier that are reduced to the essentials and can be created automatically. Therefore, they are easy to share and heavily utilized as lightweight models in several downstream processes. Simplified 3D models improve 3D interoperability in heterogeneous system landscapes and communication, based on 3D data in value added networks, e.g., data exchange between OEMs and suppliers or in supplier internal collaboration. They enable time savings in engineering and lead time reduction for manufacturing companies. Engineers are freed from tedious manual tasks, so that they can invest their valuable time in true innovation. Simplification methods like approximation, defeaturing and enveloping secure reliable IP protection in data exchange across company boundaries and allow the customized preparation of 3D models for CAE analyses. Simplified 3D models can be visualized faster and more easily than original CAD models due to reduced amount of information and smaller file sizes.

Future developments will focus on a higher degree of automation for the creation of simplified 3D models. Especially for large-scale and complex models like those in plant engineering, manual effort for repetitive simplification tasks and testing of the ideal procedure has to be reduced. Best practices from different simplification use cases need to be consolidated to provide optimal simplification strategies. Additionally, dedicated simplification capabilities might be isolated from specific tools and offered on engineering platforms to reach a larger user base in shorter time. With this, simplification of 3D models will continue to enhance collaborative engineering based on lightweight CAD data. ■

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