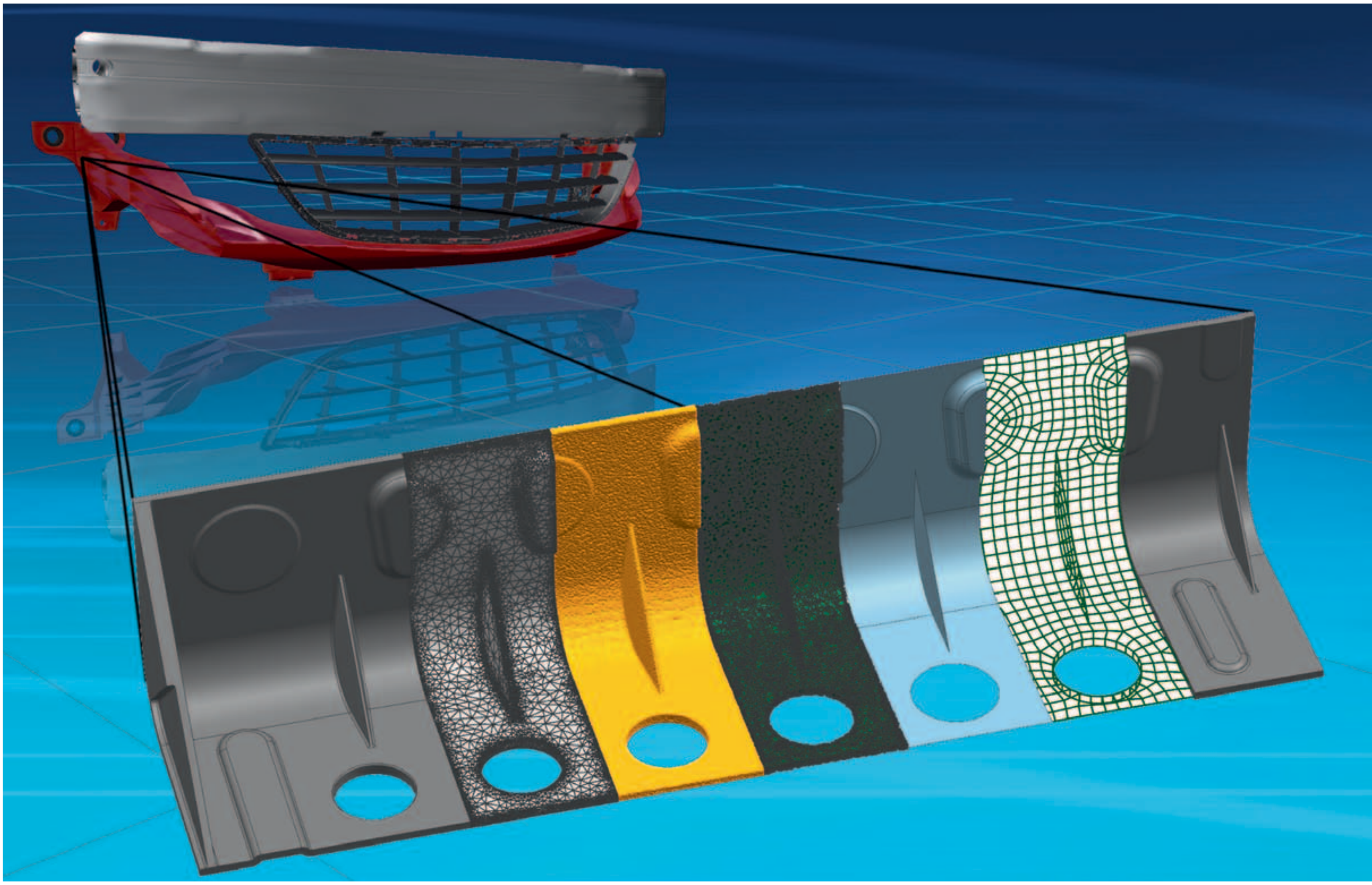

COMPLEXITY

Virtual processes and simulations have been a matter of course in the automotive development process for many years. Yet, certain types of components still pose a challenge. This especially counts for thin-walled components, which play an important role in crash simulations and NVH analyses. These components are modelled by computational engineers by using so-called mid-surfaces.

Mid-surfaces of many components can be calculated very reliably with currently available commercial software solutions. However, this only works in about 90 to 95 % of all cases. The geometries of the remaining 5 to 10 % are so complex that computational engineers must generate them manually, which involves much effort. The overhead for these mid-surfaces accounts for about 70 to 90 % of the entire meshing time. Depending on the complexity, the meshing time for one single component might require a complete day or in some cases even up to 14 days.

AUTOMEX RESEARCH PROJECT

In the jointly initiated research project „Automex – Automatic Extraction of Mid-surface Descriptions from 3-D CAD Volume Models“, Tecosim, a CAE development partner, and the RheinMain University of Applied Sciences have conducted extensive analyses in order to generate mid-surfaces. The objective of the project sponsored by the German State Hessen was the development of a software solution that automatically generates mid-surface models of complex geometries that can be found in plastic or metal moulded parts – especially in cases that previously required manual follow-up work.

The research project team combined a high level of media information technology and technical competencies and was made up of Tecosim employees and specialists in mechanical engineering and computer science from the RheinMain University of Applied Sciences. The two departments of the university provided just the synergies that were needed to run the project successfully. Tecosim ensured practical orientation.

USE OF MID-SURFACES – AN ADVANTAGE AND A CHALLENGE

Tecosim performs most of its calculations and simulations for examining properties and behaviours based on the Finite Element Method (FEM). For complex thin-walled components so-called surface models are used as a rule because a more extensive mapping would be too involved for every-day project needs. Generally, the component is represented by a surface located along its middle. This is the mid-surface referred before. The mid-surface represents all the essential features of the component and its material and appears

AUTOMATIC MID-SURFACE GENERATION AS A BASIS FOR TECHNICAL SIMULATION

Thin-walled components play a more and more important role in the context of lightweight construction. Nevertheless, they still are a major challenge for technical simulations. Tecosim and the RheinMain University of Applied Sciences have developed an innovative method for the automatic generation of mid-surfaces in the Automex project. The objective of this cooperative project is the replacement of the time-consuming manual design of this type of surfaces which is still in place up to now. Using an example of highly ribbed components like a radiator grill it is shown that the effort for meshing can be reduced enormously.

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in the actual simulation as a two-dimensional mesh. To ensure that meaningful, predictive simulation results are returned, the 2-D meshes must fulfil various quality criteria related to edge length, element angle and curvature of the quadrilateral elements.

Typically, the mid-surfaces of thin-walled components are not delivered by the component designers. They must be generated at the beginning of the simulation processes. Special software packages are available for this purpose. These programmes calculate the mid-surface of a component by subdividing the component geometry into surface geometry and edge geometry. Here, the applied criteria are symmetry properties and the direction of thinness of the wall. As noted previously, this method provides satisfactory solutions for about 90 to 95 % of all components.

More complex components, such as metal cast and plastic injection moulding parts, often have no usable symmetry and thus it is not possible to make an unambiguous division into edge and surface. Therefore the commercial software solutions currently available on the market are often unable to calculate any usable mid-surfaces for these parts. In that case, the mid-surfaces must be designed manually by experts.

THE MEDIAL AXIS

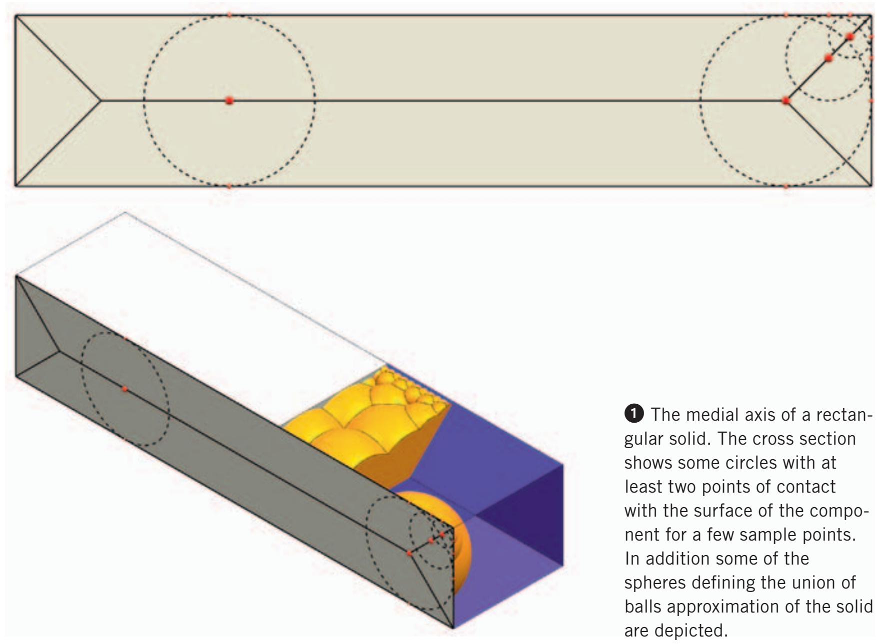
The partially ambiguous definition of the mid-surface of a component hampers its automatic determination. This problem can be avoided by substituting the mid-surface by the so-called medial axis. The medial axis of a volumetric object consists of all points within the object that have at least two nearest points to the border of the object, ❶. Thus, the medial axis of a volumetric object is a skeletal surface that reduces the dimensionality of the object while preserving its actual shape. Medial axes were used for the first time in 1967 by Blum to describe biological shapes [1]. Since then they have been used in numerous applications, for example for object classification, robot path planning and generating FE meshes [2].

Calculating the exact medial axis of a volumetric object is very involved. It mainly depends on the description of the edge of the object. Complex algebraic methods are needed even for objects with an edge that is piecewise linear. Since these methods result in long computing times, they are only used for processing simple objects in practical applications [3].

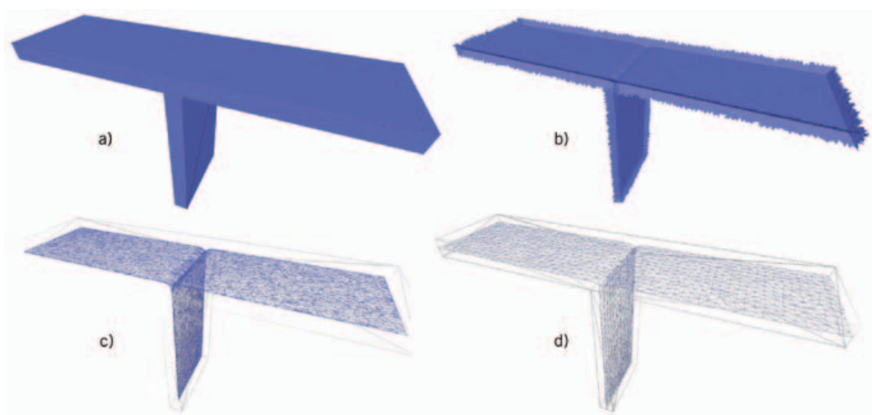
One possible solution to this problem is to calculate not the exact medial axis, but rather an approximation of it. In fact, technical components often can be described more properly by this kind of approximation than by the actual medial axis. A suitable approximation can be calculated, for example, by using non-

Euclidean distance metrics [3, 4]. The metrics can be selected so that all calculations occur in the field of rational numbers, which will lead to numerically stable algorithms. However, the objects must be converted into a special volumetric representation. This is particularly time-consuming for complex components, especially if the error that occurs has to be very small.

Another way to approximate the medial axis of an object is the scale axis [6]. In this case, the entire object is approximated by spheres [7]. The centres of all of these spheres then define the scale axis. Thereby, the approximation of the medial axis can be controlled by prescribing the radius of the smallest permitted spheres. The smaller the spheres, the more details of the actual objects will be recovered. A disadvantage of this method is that it may generate surface fragments with incorrect topology. These fragments must then be filtered out in a subsequent step.



❶ The medial axis of a rectangular solid. The cross section shows some circles with at least two points of contact with the surface of the component for a few sample points. In addition some of the spheres defining the union of balls approximation of the solid are depicted.



❷ From component to technically usable mid-surface: a) initial geometry, b) scale axis mesh, c) scale axis after fraying has been removed from the edges, d) extended, smoothed and fused mid-surface elements

THE TECHNICAL MID-SURFACE

As part of the Automex project, in a first step the medial axis of an object is approximated by a scale axis. The starting point for this step is a polygon mesh of the component surface, which is created based on the original CAD geometry. The scale axis also is represented as a polygon mesh. In the next step this mesh must be processed in such a way that a technically usable mid-surface emerges. To produce this technical mid-surface, the fragments with incorrect topology must be removed from the polygon mesh of the scale axis initially. Subsequently, the fraying at the edges of the scale axis must be removed. Finally, the remaining surface has to be extended to the surface of the component. ❷ depicts each of these steps.

FEM simulations, which are based on the mid-surface of a component, demand a mesh of triangles and rectangles that meets high quality requirements. Quality characteristics include edge length, element angle and curvature of quadrilateral elements. In order to ensure reliable simulation results, these parameters of the FE mesh must correspond to the predefined standard values. Another major aspect for the generation of an FE mesh consists of the so-called feature lines of the component. They define significant lines in the geometry and represent characteristic component features. These feature lines must be considered in the FE mesh in such a way that the characteristic geometric features of the component are well reproduced in the simulation. For example, the element nodes on component edges have to lie exactly on the edges. Thus, one challenge in generating mid-surfaces is extracting the feature lines from the object geometry and transferring them in a suitable manner to the technical mid-surface, ❸.

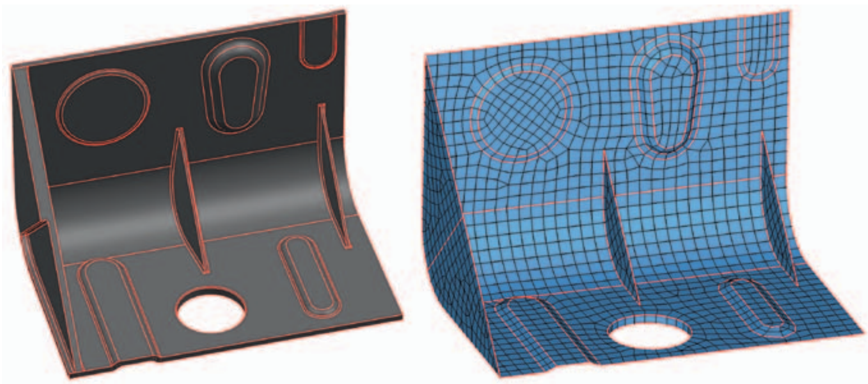
THE AUTOMEX PROCESS

The Automex process chain starts with a triangulated component surface, which can be generated with sufficient accuracy based on the original CAD geometry. ❹ illustrates the essential individual steps. They consist of the following tasks:

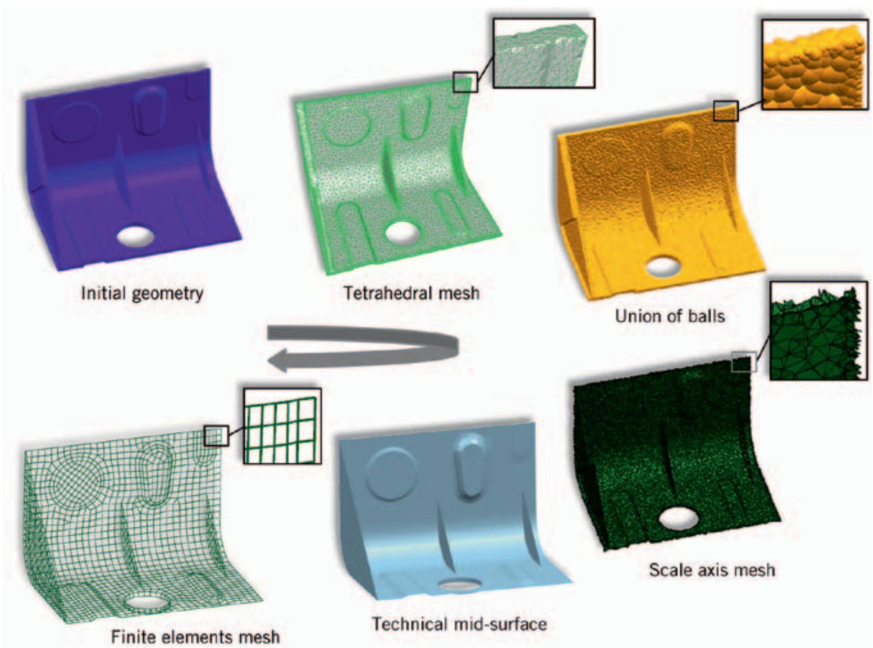
- Tetrahedralisation of the component
- Scale axis calculation and control
- Topology correction
- Fusion or extension and smoothing of sub-areas.

In the final generation of a problem-oriented FE mesh, Tecosim is already able to use its own established processes together with Automex.

As mentioned before, the technical mid-surfaces to be determined are not always unambiguous. Their shape depends on the problem investigated in the simulation, the relevant customer requirements and the subjective perception of the engineer.



❸ Feature lines (red) in the component (left) and on the technically usable mid-surface (right)



❹ Automex process steps: Component, component immediately after meshing with tetrahedrons, union of balls, scale axis mesh, technically usable mid-surface and resulting FE mesh

Automex uses simple, formally defined strategies to generate a mid-surface. Based on the mathematical medial axis this surface can be used in the simulation.

RESULTS

Within the Automex project, a software system was developed for automatically generating technically usable mid-surfaces, including also highly ribbed, volumetric components. The mid-surfaces that are generated can be used as FE meshes for the technical simulation. A polygon mesh of the relevant component serves as the input data for the developed system. In a first step, the scale axis is generated as an approximation of the medial axis.

Subsequently, this surface is smoothed in the next step. In particular, fraying at the ends is removed. Next, the filtered surface is extended to the edges of the actual object geometry. In the last step this surface must be re-meshed to generate a technical mid-surface with sufficient quality for the FEM simulation. Here especially the feature lines must be taken into consideration and attributes must be assigned to the individual surface elements, for example material properties or component thicknesses.

CONCLUSION AND OUTLOOK

The Automex research project was successfully concluded at the end of 2013. Currently the method that was developed is being integrated into the Tecosim simulation process. Tecosim has plans to use the software during the first half of 2014 in numerous applications areas in project business. The CAE development project partner is expecting important competitive advantages from this process for automating mid-surface generation. Automation simplifies internal processes considerably, thereby saving significant time and money.

The fast processing time and project implementation as well as lower costs are decisive competitive arguments for customers. Creating mid-surfaces automatically also makes it possible to track simulation results objectively, as well as preventing errors that can occur with manual processing.

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