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Presentation Title	Automatic Hexahedral Meshing for Structures using the 3D Medial Axis
Relevant Themes / Keywords	Automatic hex mesh, medial object

Abstract (plain text)	Shakeel Seebooa International TechneGroup Limited (ITI) There are several ways to mesh 3D solids for performing structural simulations. Despite progress in methods using tetrahedral and cartesian meshes, a hex mesh remains a very desirable mesh type, and is the most difficult to produce. Hex meshes typically require fewer degrees of freedom to represent a finite element problem than an equivalent tetrahedral mesh. By also allowing for anisotropy, a hex mesh can further greatly reduce the number of nodes required for a given accuracy, leading to faster computation times and lower memory requirements. Coupled with the higher accuracy of solutions offered, high quality hex meshes can be essential for advanced simulations such as complex thermomechanical and non-linear contact analyses. Several methods have been explored for automatically generating hex meshes, for example plastering, octree based approaches, and frame fields. However, problems such as element quality and robustness with such methods force users to resort to manual hex meshing, using a structured multi-block approach. This can be a lengthy process requiring skilled engineers and specialist geometry manipulation software. Automatic hex meshing has been researched for over 40 years and it is still a major problem in the industry. In this paper, we pursue an approach based on the 3D Medial Axis Transform (MAT). The MAT was introduced by Blum as a method of analysing shapes, and has seen recent applications in mixed dimensional modelling, as well as previous work on hexahedral mesh generation. Our approach is an extension of previous work on hybrid meshing for CFD , and is based on the 3D medial axis algorithm available in our CADfix software. The MAT of a CAD model can be thought of as the skeleton of the shape, and captures key geometric information such as proximity. This information guides the decomposition of a general object into small hex meshable blocks, without user input. The MAT of a CAD model is held as a non-manifold CAD structure known as a Medial Object (MO). Within thin regions, the MO faces can be treated as a local mid-surface. This allows for the partitioning of these regions into sweepable blocks, thereby reducing the problem to 2D quad meshing. In the more complicated thick regions of the model, the MO faces act as interior walls in the volume, and they bear a 1-1 mapping with the boundary. This allows the partitioning of the thick regions into hexahedral or sweepable blocks. Finally, hex blocks are constructed along the outer edges of the MO structure. This process provides a fully automatic way to generate a high quality, fully structured, hex mesh, with hexahedra well aligned to the boundaries, without prior knowledge of the model. However, a fully structured hex mesh is not always ideal, as singularities can propagate from one boundary face to another, thereby adding constraints such as element size and shape to the mesh. For applications such as contact analysis, this can be problematic, as a full hex mesh can interfere with the quality of the mesh in the contact region. To avoid compromise to the mesh quality in the region of interest, we use the MO to generate a partitioning which produces hex meshes over the skin of the object, leaving behind a core meshed with unstructured tetrahedra. This provides high quality structured hexahedra where the simulation needs them most, with the flexibility of unstructured tetrahedra elsewhere. This presentation will review the method of hex partitioning using MAT, the challenges faced and those yet to be addressed, and present the achievements to date.
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