Title:
Interactive Rendering and Modification of Massive Aircraft CAD Models in Immersive Environment

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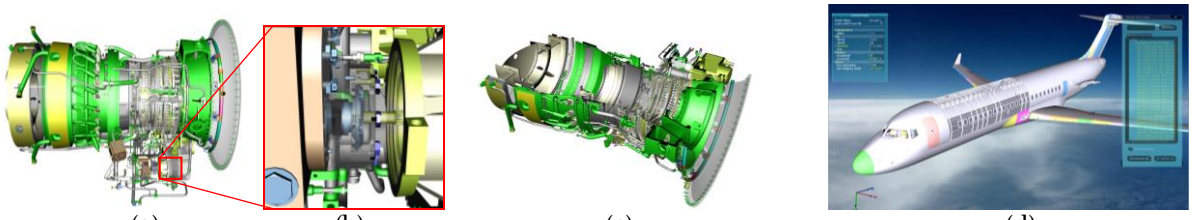
Introduction:
Aircraft CAD models have been recognized as one of the most complex and largest datasets in the world which consist of millions of parts and have complicated topology. The model data storage can be up to gigabyte and the number of the triangular faces within the visualization geometry can be hundreds of millions. For example, the Boeing 777 model has over 6 million parts and connectors, 350 million triangular faces, 12GB geometry data storage, which has far more exceeded the performance of common visualization methods.

Many research works have been done towards real-time visualization of such massive models. In general, they contain two phases: preprocessing and rendering. A preprocessing phase is required to do model format converting, model simplification and partition, LOD generation, etc. Depending on the scale of the model data and the performance of computing systems, preprocessing can take between few hours up to several days. The rendering phase ensures the high fresh rate of the graphics display and functions of transparency, clipping, node picking and manipulating and the model assembly tree information display. The visualization system can be used in different phases of the aircraft lifecycle, such as design review, assembly simulation, and maintenance training. During these applications, the CAD part/product design may need to be modified due to the identification of potential design problems. Every time the CAD design changed the preprocessing procedure must be conducted to synchronize the modifications into visualization system. Particularly in the case of small modifications to large and complex models, this is really a time-consuming and tedious work. The concept of direct modification of CAD models in VR environment can be an attractive alternative.

Several research efforts in such CAD-VR integration have been directed toward virtual reality approaches for immersive design [1], in which, CAD-VR framework [2] is combined with multimodal immersive interaction to gain direct and intuitive deformation of the objects' shapes within a VE [3]. These approaches, however, lack genericness, flexibility, most importantly the large-scale model dataset visualization ability. Existing research on massive model visualization mainly deal with interactive ray tracing [4], scalable rendering architecture [5] and parallel visualization and graphics clusters [6], few of them have involved the integration of interactive modification of the models and the non-geometric data loss in the model preprocessing phase. In our research, we combine together the massive model visualization with VR based CAD model modification, and ensure the real-time interactive feature.

Main idea:
Massive CAD model visualization has been a traditional topic in both CAD and computer graphics research field. Many institutions have made great achievement on this, such as Utah University's Manta system, Saarland University's real-time ray tracing system. However, few of them have addressed the problem of model tree list information loss in the preprocessing phase.



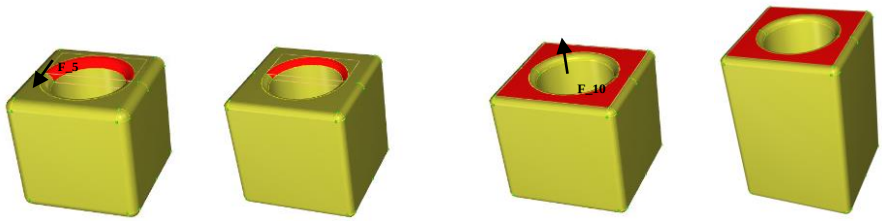
(a) (b) (c) (d)

Fig. 1: Interactive rendering of an engine model (4,502,793 TRI) and aircraft model (19,445,309 TRI): (a) Node transparency, (b) Detail of the transparency, (c) Clipping with transparency, and (d) Aircraft model visualization with model tree list.

Model tree list is important for part location especially in real-time visualization of large models like aircraft models, which have millions of parts and they may occlude with each other. We want a lossless transmission of the model tree list information from the original CAD models to the polygon models throughout the preprocessing phase. We also introduce a novel interactive rendering framework which make it easier to explore massive aircraft models. With which KD-tree of the model scene graph can be built to improve the time complexity in the node picking selection. Transparency and clipping effect with dynamic adjustment ensure the inner of the aircraft model can also be easily examined.

In VR or other visualization applications, polygon models especially the triangular-face form models are mostly used because the display hardware are designed to render triangles more efficiently. But the problem is that these models can be difficult to be further modified. The conventional way is to modify the original model with CAD software and then do a lot time-consuming preprocessing work and finally render them.

In our research, to implement the combination of massive models visualization with VR based CAD model modification, the original CAD model can be loaded and then modified directly in VE with NURBS methods. The B-Rep meshes of the new model can be applied to replace the old polygon meshes in the virtual scene. And with the VR devices, such as, an ART flystick or data glove, intuitive and interactive modification of the models can be enabled in an immersive way, such as extruding a curve, making holes on a model, or even editing control points of a model, etc. Therefore there is no need for a preprocessing phase to modify massive aircraft models, which is much more efficient than the conventional way. The new model generated in our virtual environment can also be exported for other use.



(a) fillet value = 0.75 (b) fillet value = 0.5 (c) height = 10 (d) height = 15

Fig. 2: Modeling parameters modifications in VR. (a) Pick the fillet face (highlighted) and drag inward, (b) The fillet value is reduced and new model is generated, (c) Pick the top face (highlighted) and drag upward, (d) The extruding hight is increased and new model is generated.

Conclusions:

The experimental results using our approach and system, show that high FPS can be gained with CAD models consist of 20M triangles on a commodity PC. The VR based CAD model interactive modification can save a lot of time compared with the traditional way of updating model changes in VR by preprocessing. The interactive rendering feature make it more efficient to inspect the aircraft models. Our approach has demonstrated that an interactive rendering and modification of massive

aircraft models is feasible, and that it can improve the efficiency of the creation of aircraft visualization system and benefit the aircraft design and manufacturing cycle.

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