Abstract

In engineering, visualization of huge volumes of design data at the system level in immersive experiences helps during the design validation and verification phase. It enables quick decision making by reducing the dependency on a physical prototype and helps in understanding complex designs and associated mechanisms, training, maintenance and quality inspection through advanced visual simulations.

Rendering complex engineering CAD data with many convex polygons on XR devices is resource-intensive. Each mesh is drawn on the screen by Graphic API, and in turn, these draw calls add to the performance overhead on the processor. It is essential to optimize the CAD data for the least number of convex polygons without losing the accuracy of the model. So, data preparation plays a significant role in the performance of the application and quality of experience.

There are many 3D data preparation products available in the market, such as PiXYZ STUDIO, 3DEXCITE from Dassault Systems, Simplygon from Microsoft and 3DS Max from Autodesk. Infosys has developed an automatic framework for optimal 3D data preparations using PiXYZ STUDIO algorithms. Further, the current approach can be implemented across any other commercial product too.
Introduction

Infosys provides a broad range of engineering services for various industries, including aerospace, automotive, oil and gas and power globally. Using CAD tools to create a 3D representation of the designed products is a standard practice in these industries. Infosys has demonstrated expertise in developing product designs using various CAD tools. With the advent of AR and VR, the use of digital models for real-time visualization is growing. These digital models are massive in size and require data preparation before using them in AR/VR.

Raw CAD data needs to be tessellated (converted into convex polygons) to be made usable for immersive experiences. Several convex polygons and simplified meshes play a vital role in the stability and performance of the XR applications. They have a direct impact on the downstream processes, such as lighting and texturing, which further reduces the performance exponentially. Hence, it is essential to follow a systematic and pragmatic approach for 3D data preparation when creating tessellated models from CAD models.

There are many tools available to convert CAD data into tessellated data. In the current Infosys framework, PiXYZ STUDIO tessellation is used to create high quality and low-density meshes from the CAD model. PiXYZ STUDIO provides efficient and fast tessellation while also significantly reducing and optimizing the number of convex polygons. It also embeds a Python API allowing advanced users to create powerful scripts to automate complex data preparation tasks by giving access to a large set of features and algorithms.

In this document, we aim to define a 3D data preparation framework and implementation details for a few scenarios along with their results.

Scope

Many techniques are used for 3D data preparation in the fields of engineering, architecture and entertainment. Photo realism is critical in the architecture and entertainment industries compared to engineering, as those industries are focused on providing rich experiences. In engineering, most applications are related to training, maintenance and remote monitoring and are rich in content with optimal photorealism of 3D assets. This document focuses on 3D data preparation related to engineering applications with optimal photorealism.

The current approach demonstrates the use of native CAD data (CATIA V5, Navis works, PTC Creo, etc.) and PiXYZ Studio 2019.1. The approach is agnostic to the underlying CAD and tessellation environment and can be implemented in an equivalent environment.

CAD Data Preparation Framework

Native CAD surfaces (NURBS, NURMS) must be converted into convex polygons to view in immersive experiences and meet performance and accuracy requirements. There are two main polygon shapes in a typical mesh - quads and triangles. The number of convex polygons (triangles/ quads) of CAD data depends on the complexity of the CAD surfaces. Quads are preferred while creating 3D assets and triangles are used in gaming engines. In live rendering, the "cost" of rendering is essential and is based on speed (FPS – frames per second) and device resources (CPU, GPU). The triangular mesh helps achieve better FPS as it is planar. The number of polygons in a mesh is another key factor that impacts CPU and GPU performance. Optimizing the polygon count to suit the targeted device processor is hence important. Devices like HTC Vive that possess a good GPU capability can handle a large number of polygons easily; however, optimizing the polygon count is especially critical for applications built for mobile devices where CPU and GPU power is limited.

There are many steps involved in CAD data preparation, and it is easy to miss a few when schedules are tight. It is therefore necessary to follow a methodical approach for data preparation.

Common mistakes include incorrect grouping or merging of meshes and processing polygons without optimization, wrong surface normal orientation and missing UV maps. These mistakes lead to...
the rework of data and related applications and reimporting the reworked 3D data into the application development engine. At this stage, most animation components and other related fields are to be relinked, and this is a tedious process, especially when the number of animations is high.

One way of mitigating this risk is by creating a checklist with a proper order of actions. However, even following a checklist with detailed actions can become monotonous, resulting in manual errors.

There are many parameters to be set carefully based on the target platform. PiXYZ exposes several of these functions for automation (Python API). Some process steps like merging meshes and verifying surface normals are to be performed manually, as these requirements vary across scenarios and customers.

Exhaustive checklists must be created for data simplifications tasks. However, each model requirement varies; hence, instead of creating an exhaustive checklist with the Infosys Framework, tasks were categorized as manual and automatic. We identified forty tasks for automation and created three automation scripts. Other tasks were categorized as manual and four manual steps were identified.

**Repair CAD**: Automatically repairs native CAD surfaces by assembling faces within given tolerance value and removes duplicate faces.

**Tessellate**: Generates mesh representation for each given CAD part. The maximum sag value defines the surface deviation from the native CAD surface during tessellation.

**Repair Mesh**: Automatically repairs tessellated meshes by stitching disconnected edges within given tolerance limits and orients faces automatically.

**Decimate**: Reduces convex polygon count (mesh density) on the selected parts by removing some vertices. Surface, normal and line tolerance values define the quality of the resulting surface.

**Merge Static Meshes by Material**: Identify all the static meshes in the scene and group them manually by material; this reduces the number of draw calls while rendering.

**Generate UV**: UV maps are 2D representations of unwrapped 3D models. The UV map is generated by unwrapping or projecting the texture on geometry objects like a box or sphere.

**Repack UV**: Repack all UV islands to fit into the given map resolution. The automated framework is utilized for a frame assembly, which has seven separate meshes. The graph in Figure 2. indicates the effort savings for this assembly. On average, even considering bigger assemblies, a quality output can save over 90% of the effort.
In many cases, mesh optimization may lead to gaps between the adjacent meshes. Hence, it’s vital to repair the mesh after every modification operation. Also, it’s essential to convert convex polygons to triangles as they render faster. The mesh optimization techniques, along with the repair mesh, is automated in the Infosys framework.

Some of the CAD data contains hidden meshes which are not part of the rendering. These meshes make the model heavy and impact performance. Some of the CAD models also have unused material information, which resides in the FBX file. Deleting hidden meshes and extra material information are automated in the Infosys framework.

In the event of missing UV maps, artists cannot apply required textures and hence fail to achieve the desired results. Repacking of generated UV maps to a resolution same as that of the texture map is also an important step, else it requires the artist to tweak parameters like tiling, spacing during development. The Infosys framework automates these steps and saves considerable effort.

It’s necessary to reduce the mesh count along with convex polygon reduction to achieve better performance. Each mesh is drawn on the screen by Graphics API, and these draw calls are often resource-intensive, adding to the performance overhead on the CPU. The Infosys Automated Framework reduces the time required for data preparation and generates optimal convex polygon count.

**Figure 3:** The Infosys Framework applied to a frame assembly

"Through an automated framework, Infosys can reduce the data preparation time by ~92% with optimal convex polygon count and desired quality of the mesh."

**Figure 4:** A sample scenario showing a reduction in convex polygon count
Every part or mesh requires a different treatment based on the importance of the part in the entire application or experience. “By following a defined framework for the sample wheel data, we reduced the number of convex polygons by 87% without compromising the quality of the mesh.”

**Best Practices**

The Infosys Automated Framework includes best practices to optimize render performance and further decrease convex polygon count without compromising mesh quality. Some of the best practices are:

**Holes Removal**

The brush wheel in the image below has bristles and holes. When rendering the bristles, it’s not required to render the holes on the wheel. By removing these holes, the convex polygon count is reduced by 86%, from 48,084 to 6,552 convex polygons.

**Hidden Mesh Removal**

The frame in Figure 6 is fabricated out of thick tubes. There are convex polygons inside the tube, which are not visible but are being rendered. By removing these convex polygons, the count is reduced by 51%, from 36,778 to 17,957 convex polygons.
Proxy Mesh

The tower assembly in Figure 7 has four towers. The details of the tower assembly are not relevant, and it’s a static object. By creating a proxy mesh of the highest quality, the convex polygons count reduced by 95%, from 515,416 to 25,924.

**Figure 7: Best practice: Creating a proxy mesh**

Level Of Detail (LOD)

Rendering high-quality models affect FPS, especially if the scene is large. A detailed model is relevant for a close-up view while it’s not so critical for a faraway object. Here is where the level of detail (LOD) plays an important role.

A good approach is to create multiple versions of each model with differing quality and rendering the right version based on the mesh distance from the camera. This approach makes rendering high fidelity models easier.

CAD Data Format

We recommend working with native CAD formats instead of common CAD data exchange formats such as STEP, IGES. Common CAD data exchange formats are likely to lead to incorrect hierarchy, loss of metadata and inaccurate local pivots.

Tessellation Resolution

Keeping the least surface deviations (sag, length and angle) for tessellation is a sound approach. It is relatively easy to decimate (decrease the convex polygon count) rather than increase the convex polygon count at a later stage of the data preparation process.

Combine Meshes

Combining (merging) meshes is an essential process in data preparation as it directly impacts the number of draw calls and performance.

The artist must have clarity on the input CAD data and the animations and effects in ARVR experience. The incorrect merging of meshes leads to considerable rework, including splitting the mesh and relinking all the components in the game engine.

UV Maps

UV maps are a 2D representation of the 3D geometry. Textures are overlaid on the UV map to reflect texture on the 3D mesh. It is always recommended to maintain the same resolution for the UV map and texture to ensure the desired texture results.

Export Format

There are two widely used file export formats - FBX and OBJ. OBJ is a simple file format that holds only geometry (vertex, normal) and UV data. FBX is an advanced file format that can hold more complex information like geometry, UV data, materials, textures and animations. Theoretically, it can contain the complete scene data in a node-based structure.

If the requirement is to export only geometry and UV data, we suggest using OBJ format instead of the FBX format.
Conclusion

In conclusion, a systematic and optimal approach in CAD data preparation for immersive experiences is a critical success factor. Identifying and grouping each of the meshes play a vital role in performance improvement. The Infosys framework for data preparation resulted in reducing approximately 87% convex polygon count and saving 92% effort through automation of sample CAD data used so far, resulting in a high-performance immersive visualization experience.
Acknowledgments

The authors would like to thank Veerabhadram V for his continuous support during the development of the data simplification framework. Thanks to Swapnil Mehta for his valuable inputs and critical reviews. Thanks are due to the senior management of the engineering services practice Avinash Patil, Sriram Panchapakesan and Nitesh Bansal for their continuous support and encouragement.

Authors

Srinivas Devalla is an Engineering Lead with Infosys since 2007 and has 12 years of experience in product design and engineering data visualizations. His areas of interest are AR, VR and utilizing 3D data for industrial visualizations. His experience spans many leading projects in the Gas Turbine and Steam Turbine domains. He led multiple process and productivity improvement initiatives, PDCA and various CAD/Excel automation for a significant power sector OEM. He is currently leading the AR and VR team at Infosys’ engineering services.

Mayuresh Mhaiskar is a senior project manager with Infosys since 2012 and has over 20 years of experience in CAD and engineering data visualization. His areas of interest are CAD, 3D data rendering, augmented reality and virtual reality. He has experience with various leading CAD products development like PTC Creo, CATIA and ICEM DDN. Developing algorithms for parametric 3D modeling and history-free 3D modeling are his other interests. He leads the AR and VR practice for engineering services at Infosys and works on multiple areas like VR for training, AR-based maintenance and digital twins.

Dr. Ravi Kumar G. V. V. is Associated Vice President and Head Advanced Engineering Group (AEG). He has led numerous innovation and applied research projects over the past 20 years. His areas of expertise include mechanical structures and systems, knowledge-based engineering, composites, artificial intelligence, robotics, autonomous systems, AR, VR and Industry 4.0. He is involved in the development of commercial products like AUTOLAY (CADD-COMPOSITES) - a spin-off Indian LCA program, Nia Knowledge - a knowledge-based engineering platform and KRIT 4.0 - an operational excellence framework. He contributed to many Industry 4.0 implementation projects and played a key role in the development of Industry 4.0 maturity index under the umbrella of Acatech, Germany. He is also involved in various initiatives of the World Economic Forum (WEF) fourth industrial revolution technologies in production. He is a member of the HM 1 and G31 technical committees of SAE International. Dr. Ravi Kumar has published over forty-five technical papers, three patents - two granted and one filed. He has a Ph.D. and an M.Tech in applied mechanics from IIT Delhi, and a BE (Honors) from BITS Pilani, India.

For more information, contact askus@infosys.com

© 2019 Infosys Limited, Bengaluru, India. All Rights Reserved. Infosys believes the information in this document is accurate as of its publication date; such information is subject to change without notice. Infosys acknowledges the proprietary rights of other companies to the trademarks, product names and such other intellectual property rights mentioned in this document. Except as expressly permitted, neither this documentation nor any part of it may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, printing, photocopying, recording or otherwise, without the prior permission of Infosys Limited and/or any named intellectual property rights holders under this document.