GPU-Accelerated Animated Volume Rendering of Isogeometric Analysis Results

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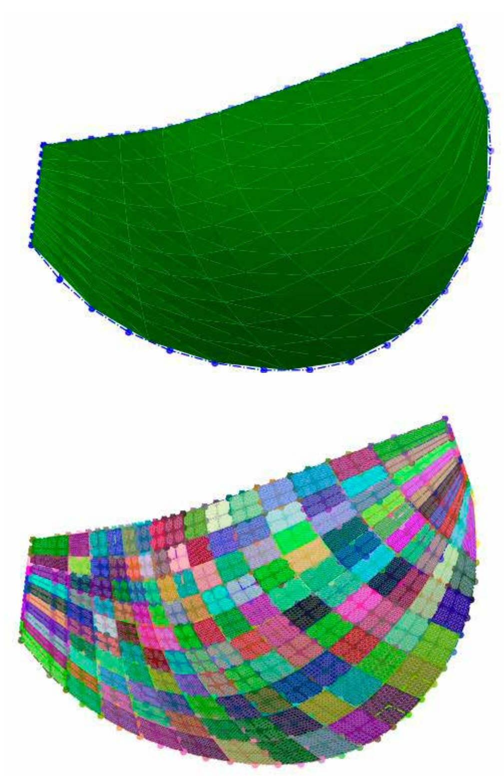
INTRODUCTION

Development of Isogeometric analysis(IGA) has enabled tighter integration of engineering design and computational analysis. The core idea of IGA is to use same NURBS (Non-uniform rational B-splines) basis functions for representation of geometry in CAD and the approximation of solution fields in FEA. However, visualizing the results of volumetric IGA is compute intensive and hence, current methods are not interactive. We have developed a modified ray casting and voxelization method for visualizing volumetric NURBS, which provides better interactive performance. This process has been highly parallelized using the GPU to produce interactive animated results in real time. We present an example of the utility of the approach in visualizing results of cardiac simulations.

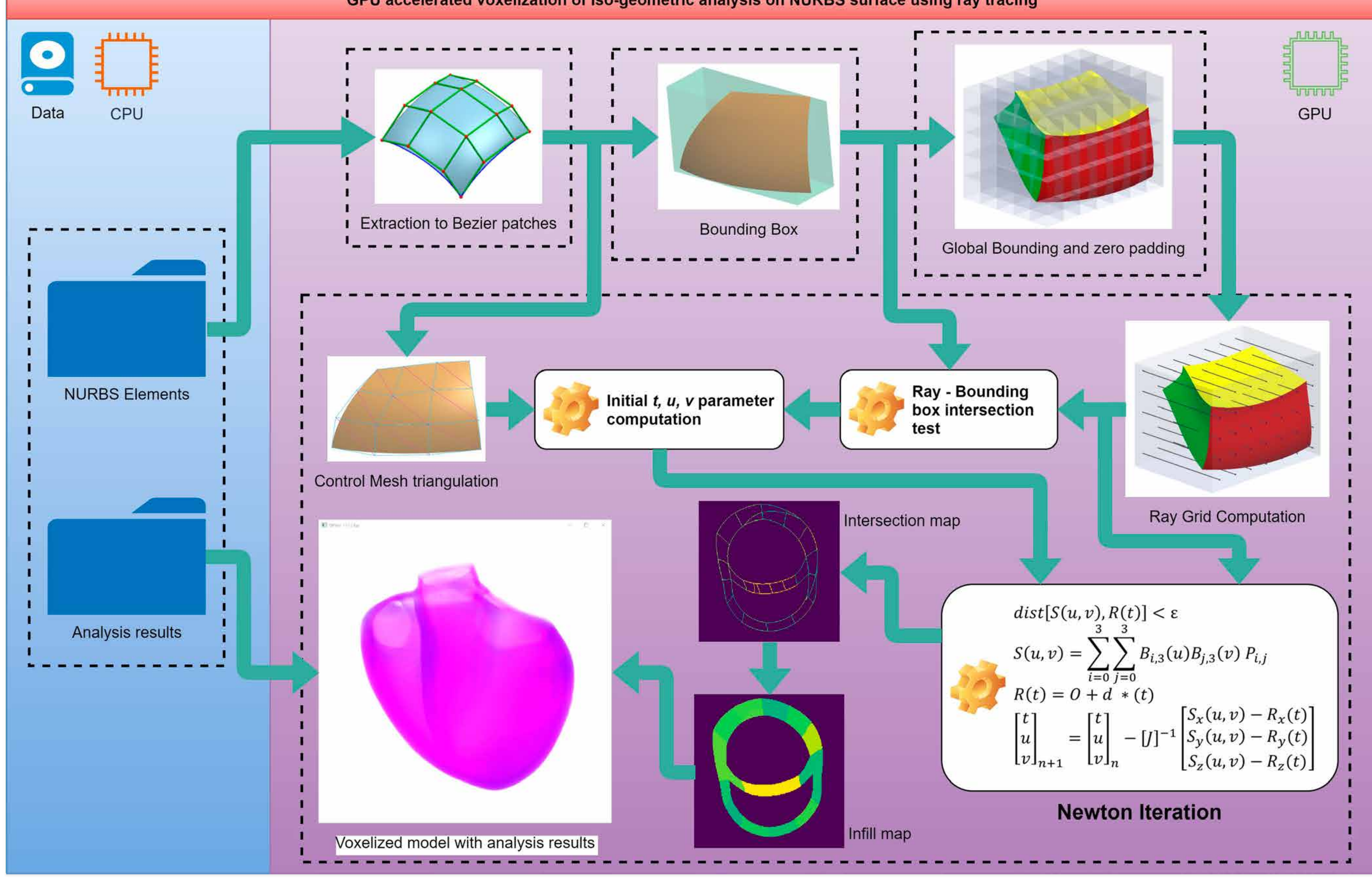
IMPLEMENTATION

- NURBS volume elements are decomposed into Bezier patches
- Bounding box of the patch is computed using the convex hull property
- A ray grid is computed based on a user-defined voxelization resolution
- Intersection point between the parametric ray and the Bezier patch is computed using a Newton iteration approach
- After obtaining surface patch intersection map, a multi-direction infill operation is performed using marching along the ray to create a voxelized model
- Value of the analysis results is computed based on the volumetric position of the voxel in the containing element



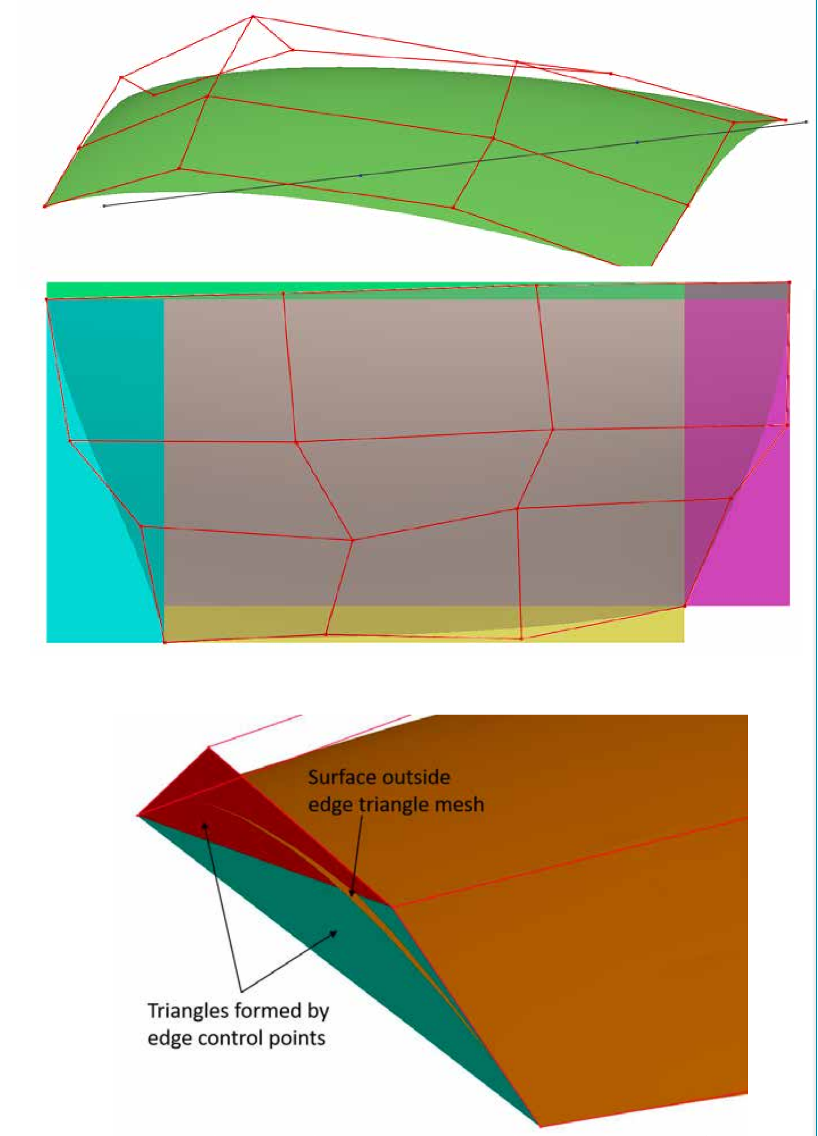
Element Decomposition into Bezier patches

GPU accelerated voxelization of Iso-geometric analysis on NURBS surface using ray tracing



UNIQUE FEATURES

- Initial parameters are computed by intersecting ray with triangle mesh formed by control point mesh. This reduces number of iterations needed to identify intersection.
- Two approaches (edge bounding box and edge triangle mesh) were implemented to handle cases where ray intersects the surface but not the triangle mesh.
- Both approaches were either computationally intensive or missed some intersections. Hence mutually orthogonal multi-directional ray casting method was implemented.
- Since most of the computation is done on GPU, the data transfer is minimal. Since, the voxelization is directly performed on the GPU, it can be directly visualized using GPU ray casting.



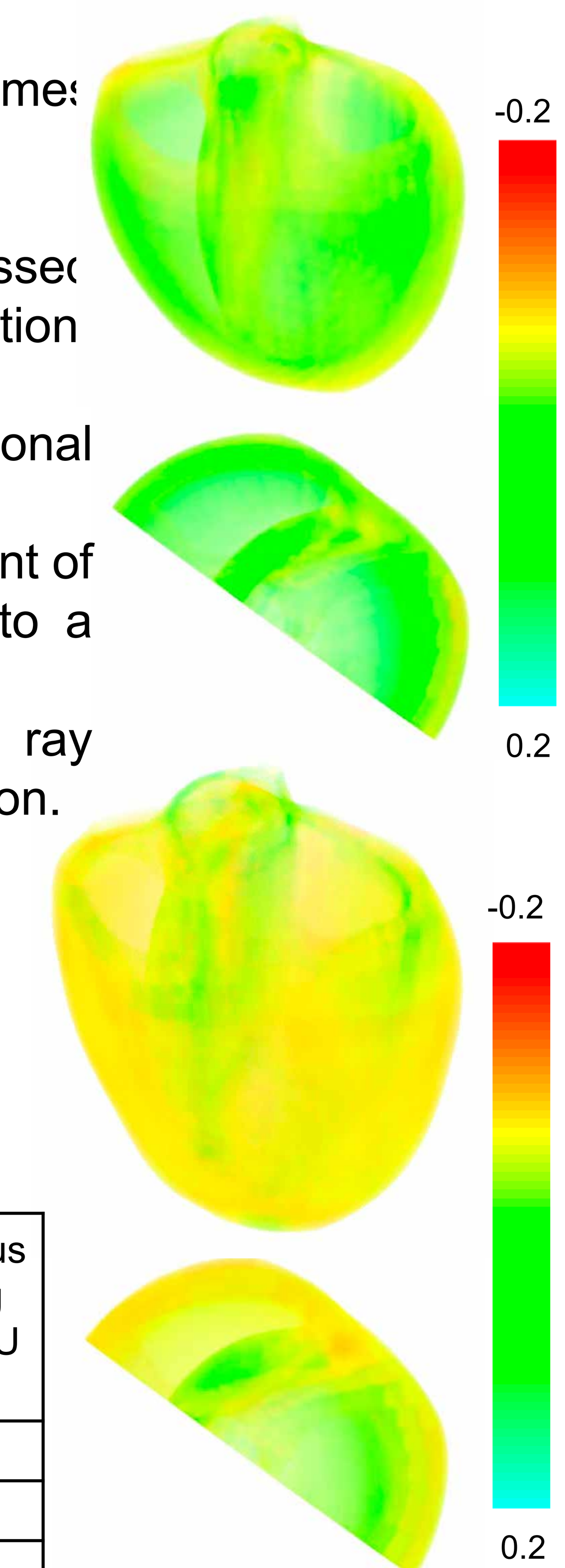
Ray missing triangle mesh , two possible solution for it

RESULTS AND CONCLUSION

- The testing is performed on NVIDIA Tesla V100
- Algorithm is run on 2 chamber heart model IGA data with 200 frames for animation.
- Voxelization resolution is tested for 64^3, 128^3, 256^3
- With this algorithm structure, Set of frames can be processed simultaneously in real time. This includes performing intersection voxelization and assigning analysis results.
- These results includes ray casting done from 3 mutually orthogonal direction to obtain complete model.
- In this IGA, each element has 27 gauss points values. Assignment of analysis results is performed by finding closest gauss point to a voxel. This process is also carried out in GPU.
- This algorithm can be expanded to any IGA analysis or just ray casting on any NURBS element to identify its properties or location.

Resolution	Initial Parameter	Intersections Obtained	Post Processed and Voxelized
64^3	49676	32664	20537
128^3	199696	129739	81934
256^3	799934	521265	328146

Resolution	Frames processed	Available memory on GPU (GB)	Data files read time on CPU (sec)	Memory after all data allocation on GPU (GB)	Simultaneous processing time on GPU (sec)
64^3	200	33.726	~11	33.096	5.517
128^3				29.427	6.605
256^3				0.067	12.9



Cardiac von Mises Strains

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