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Naval Force Health Protection Program Review 2021

Pixel to Mesh (PTM) and Pixel to Geometry (PTG)

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Sandia Injury Biomechanics Laboratory (SIBL)

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Special Studies: Pixel to Mesh/Pixel to Geometry

Chad B. Hovey, Sandia National Laboratories

Abstract:

We are investigating automation enhancements to the engineering analysis workflow that begins with human medical images (e.g., CT scans) and ends with personalized injury risk assessments.

To date, our laboratory has successfully demonstrated automated pixel classification from human CT scans using a U-Net deep learning algorithm. We have shown successful conversion of pixel stacks to voxel skeleton anatomy, as a proxy for finite volume or finite element meshes. We have called these two processes, taken in serial, Pixel to Mesh (PTM). We found that the mesh step quickly became intractable when the number of voxels grew past the 10s of millions. A map of every pixel (voxel) to a single finite volume or finite element created computational domains of excessively large element populations due to unnecessary mesh refinement.

We are currently investigating spline-based down-sampling techniques that can give rise to an alternative analysis methodology known as isogeometric analysis (IGA). We call this process variation Pixel to Geometry (PTG). Within this context, we are investigating avenues to automatically recover finite element meshes to support legacy analyses methods.

We hope to achieve three main outcomes from this research: Accelerated and automated segmentation, mesh generation, and parametric refinement. These three outcomes will help to accelerate development of the patient-specific human digital twin, ultimately leading to personalized injury risk assessments.

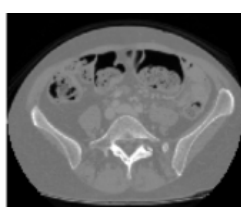
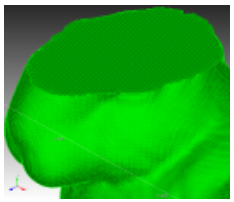
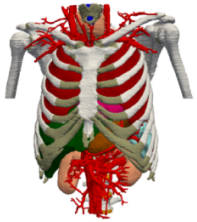
Special Studies: Pixel to Mesh/Pixel to Geometry

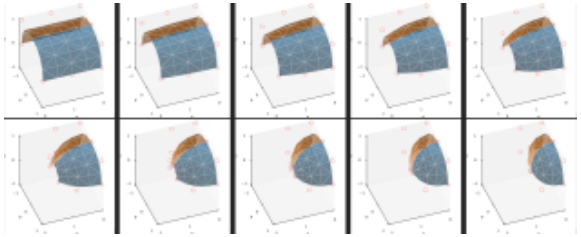
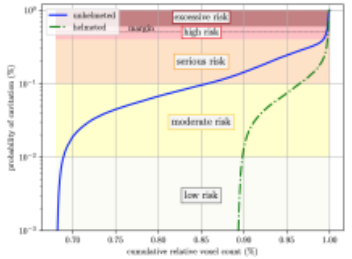
Chad B. Hovey, Sandia National Laboratories

Description: The Sandia Injury Biomechanics Laboratory (SIBL) contributes innovative approaches to ease and eliminate current segmentation and meshing bottlenecks, toward the goal of developing a patient-specific human digital twin.

Technical Approach: To address the segmentation bottleneck, we have created a deep learning algorithm based on U-Net architecture that can recognize bone and soft tissue in axial CT images.

To address the meshing bottleneck, we are currently investigating spline-based down-sampling techniques that can give rise to an alternative analysis methodology called isogeometric analysis (IGA). We are investigating avenues to automatically recover finite element meshes to support legacy and more traditional analyses methods.

- **PERFORMERS:** Sandia Injury Biomechanics Laboratory (SIBL)

FY22-FY23 Plans:

- Assess current state-of-the-art approaches to each data transformation step within the Pixel to Geometry and Mesh workflows.
- Demonstrate pixel-scaffold spline and mesh approaches on classical computational geometry exemplar benchmarks, as well as on human anatomical structures.

FY24 Plans: (As applicable)

- FY24: We will focus on deployment and utilization of the SIBL Geometry Engine framework, creating a user community within military and university research communities.

FY21-22 Accomplishments:

- Implementation of SIBL Geometry Engine for Bezier and B-spline curves, surfaces, and volumes.
  - Open source: https://github.com/sandialabs/sibl
  - Python 3.8 object-oriented (OOP) and functional (FP) design
  - Professional grade software:
    - Automated continuous integration (CI)
    - Proof of code quality (currently > 140 tests)
    - Code coverage watermarks
    - Standards-compliant Black code style
- Demonstrated geometry creation and point (pixel) down-sampling.
- Extensive documentation (currently 155 pages) on underlying theory.

Impact Statement: We seek to ease and eliminate current segmentation and meshing bottlenecks, toward development of a patient-specific human digital twin and personalized injury risk assessments.

Naval Need: The Navy needs the ability to create many personalized digital twins, not just a single class of generic twins (e.g., AF5, AM95).

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