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Naval Force Health Protection Program Review 2020

Special Studies Project: Pixel to Mesh (PTM) and Pixel to Geometry (PTG)

Chad B. Hovey, Anirudh A. Patel, Ryan J. Terpsma
Sandia Injury Biomechanics Laboratory (SIBL)

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Chad B. Hovey, Sandia National Laboratories

Abstract:

Classification of pixel values from human CT scans has been successfully undertaken by this laboratory using the U-Net deep learning algorithm. We have also demonstrated successful conversion of pixels to voxels, as a proxy for finite volume or finite element meshes. We have called these two processes, taken in serial, Pixel To Mesh (PTM).

Within the PTM workflow, we found that the mesh step quickly became intractable when the number of voxels grew past the 10s of millions. Essentially, a map of every pixel (voxel) to a single finite volume or finite element created computational domains of excessively large and equally unnecessary mesh refinement. We briefly considered concepts of element/volume decimation and coalescence but abandoned these starts because the return on time and resource investments soon appeared significantly less compelling than an alternative approach called isogeometric analysis (IGA).

This document details our investigations using IGA in an alternative workflow that we call Pixel To Geometry (PTG). This alternative seeks to selectively use the categorized pixel values as a scaffold for construction of analytical geometric descriptions in 2D and 3D. Thereafter, we propose using the analytical geometries directly in simulation using IGA, which eliminates the mesh step.

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Special Studies: Pixel to Mesh/Pixel to Geometry

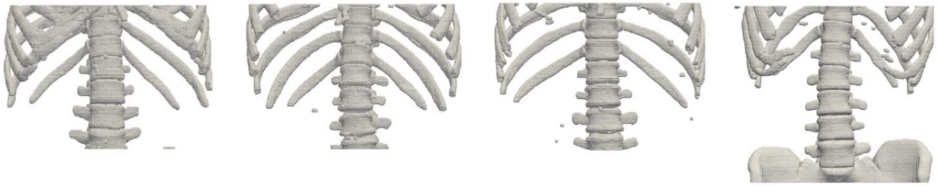
Chad B. Hovey, Sandia National Laboratories

Description: The Sandia Injury Biomechanics Laboratory (SIBL) contributes to the effort toward automating the creation of a personalized human body digital twin based on a specific patient's medical imaging.

Technical Approach: We have created a deep learning algorithm based on the U-Net architecture that is capable of recognizing bone and soft tissue in axial CT images. We stacked this layered information to build a voxel map, a proxy for subsequent finite volume or finite element meshes.

Next, we endeavor to use the same deep learning algorithm to automatically produce analytical geometry, as a more evolved strategy away from meshes and toward isogeometric analysis.

(a) medical image (b) ground truth (c) machine prediction



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

FY21-FY22 Plans:

- We plan to continue to apply our algorithms to bones and soft tissue throughout the torso. We plan to improve the robustness, reliability, and speed of our algorithms.

FY23 Plans: (As applicable)

- As of this writing, the Sandia team does not have funding beyond FY21. Were follow on funding received, our laboratory would begin work on **deployment** of the framework, creating a user community within military and university research communities.

FY20-21 Accomplishments:

- Implementation of U-Net to classify torso axial CT images on a pixel-by-pixel bases as containing bone or non-bone.

- Created torso bone anatomy (including vertebral bodies, ribs, and sternum) finite element reconstructions for twenty (20) unique patients.

- Extension of U-Net to classify the same images as bone and soft tissue.

- Motivated need for an isogeometric approach with a case study involving bones and soft tissue.

Impact Statement: We have created a machine to relieve the human of manual segmentation, a current bottleneck that impedes the goal of creating a personalized human body digital twin.

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).