High-Performance Workflow Primitives for Image Registration and Segmentation

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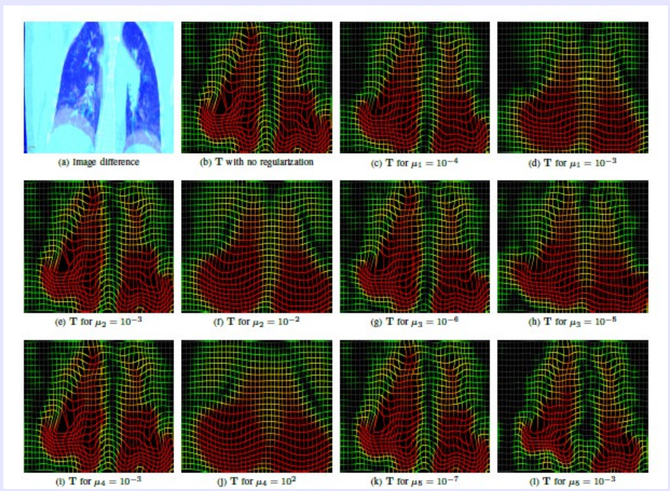
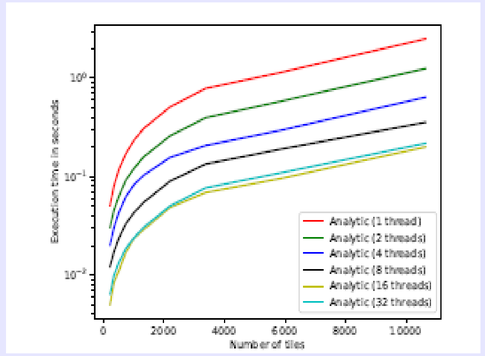
Project Motivation

Image registration and segmentation are vital enabling technologies for addressing many complex, data driven problems. Examples include individualized medical treatment where disease progression is monitored by analyzing MRI, CT, or ultrasound images over time; identifying anatomical structures in medical images; recognizing objects and people in video footage; and extracting imageable biometrics such as fingerprints, faces, and the iris. Images and videos can now be easily acquired at a rate that far surpasses our capacity to perform advanced image analysis. For this reason, advanced registration and segmentation algorithms are not routinely used for many large-scale and time sensitive applications because they require more processing time than is available.

High-Performance Analytical Regularizers

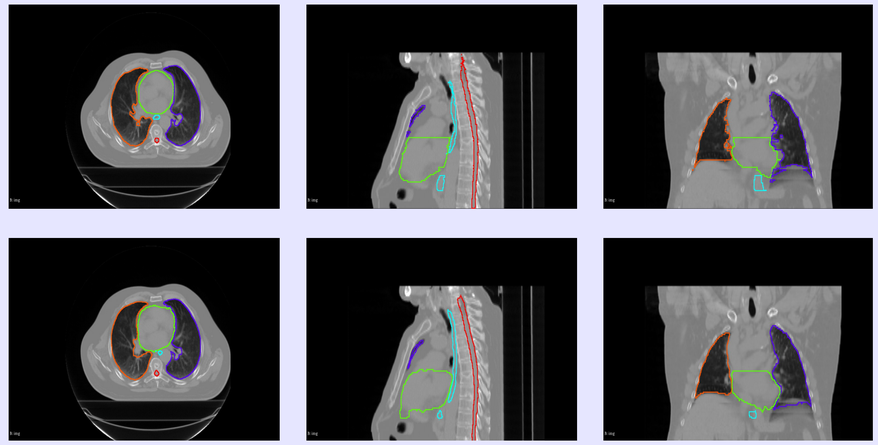




Multi-core implementations of analytical regularizers run two orders of magnitude faster than central-differencing.

Image registration lacks a unique mapping between voxels of the two images being registered and must be confined to only physically meaningful transforms by regularizing it via an appropriate penalty term which be calculated numerically or analytically. The numerical approach is computationally expensive and analytical methods are preferable. Our generalized mathematical framework accommodates five distinct types of analytical regularizers: diffusion, curvature, linear elastic, third-order, and total displacement. Multi-core implementations of these regularizers demonstrate significant speed up.

Multi-Atlas Segmentation



Segmentation using the best registration and fusion strategy for left/right lungs, heart, esophagus, and spinal cord in axial, sagittal, and coronal views (second row). Manual contours are shown in the first row.

Deformable registration is the most important step in the multi-atlas segmentation pipeline. The image to be segmented is registered against the atlas, a combination of an image of an anatomical site and the corresponding manual segmentation, to estimate the segmentation. Multi-atlas segmentation mitigates the effect of errors associated by combining multiple atlases, and is performed in computationally efficient fashion using high-performance deformable registration tools.

Outreach and Dissemination

PI Sharp meets with physics undergraduate students at PhysCon 2019 in Providence to offer advice on careers and graduate study in medical physics. PhysCon is hosted by the physics honor society Sigma Pi Sigma, and is the largest gathering of undergraduate physics students in the US.

Contact and Visit

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