C2P-Net: Reconstructing Hidden Anatomy in Middle Ear Imaging Using Novel Complete-to-Partial Non-Rigid 3D Registration Methodology

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Middle ear disorders are common but hard to diagnose without structural imaging. Optical Coherence Tomography (OCT) offers an accessible alternative to CT, yet it produces noisy and partial 3D observations, making clinical interpretation time-consuming and challenging. Complete-to-partial registration can reconstruct hidden anatomy by aligning incomplete 3D observations with a complete reference model, analogous to placing a puzzle piece into a full picture; however, existing methods including my previous C2P-Net version fail to generalize to noisy and incomplete real-world clinical data. To address this challenge, I have advanced and validated C2P-Net to accurately reconstruct patient-derived middle ears from partial OCT scans by incorporating several fundamental innovations. The approach reformulates non-rigid registration into a two-stage optimization consisting of an initial global linear alignment, followed by a non-linear deformation. Inspired by the observation that point correspondences remain consistent under geometric transformations, the search for the non-linear deformation is guided using point-to-point correspondences, improving convergence behavior significantly. In order to avoid time-consuming correspondence search, C2P-Net identifies point-to-point correspondences using a breakthrough transformer-based neural network. The proposed approach was validated on the clinically verified DIOME OCT middle ear dataset; despite being trained in simulation, it achieved a mean deviation of 0.8 mm, illustrating strong sim-to-real abilities. Additional experiments demonstrate generalization to tumor localization and multi-view aggregation, indicating the potential of C2P-Net as a broadly applicable approach for accurate and robust complete-to-partial registration.

Awards Won:
Third Award of $1,200