Multi-Time Frame Helps Multi-Modal Registration: Enhancing 4D-CT and CBCT Deformable Registration with Temporal Information for Liver Cancer

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Purpose:
The challenge of registering 4D-CT and CBCT images lies in effectively utilizing temporal information to aid multi-modal registration. This study investigates how temporal features from 4D-CT can be incorporated to improve deformable registration accuracy between 4D-CT and CBCT images for liver cancer patients.
Methods:
A dataset of 40 pairs of abdominal 4D-CT and CBCT images from liver cancer patients was used, with 35 pairs for training and 5 for testing. Eight CT frames were registered to the corresponding CBCT images using the TransMorph model without temporal information (No-time info TransMorph). A new network design was proposed to enhance the registration process: (1). Mamba was used to extract and integrate temporal features into the registration process of TransMorph. (2). A dynamic feature enhancement module was introduced by incorporating the registered images as intermediate features. (3). The fused features from adjacent CT frames were included in the registration between CT frames and CBCT, and the improvements in registration accuracy were evaluated using SSIM.
Results:
Compared to No-time info TransMorph (SSIM = 0.85), the integration of temporal features resulted in the following improvements: (1). SSIM increased to 0.86 with Mamba integration,
(2). SSIM further increased to 0.87 and 0.87 with the dynamic feature enhancement and fused features from adjacent CT frames, (3). The fusion of temporal features into CT-CBCT registration provided better alignment and optimized the registration of intestinal cavities, addressing issues like gaps in upper and lower boundaries.
Conclusion:
In the registration of 4D-CT and CBCT, effectively utilizing temporal information from 4D-CT significantly improves both quantitative and qualitative registration accuracy, enhancing the performance of multi-modal deformable registration models.