Purpose: To study the feasibility of a novel 2D/3D image registration method, called Projection Metric Learning for Shape Kernel Regression (PML-SKR), in supporting on-board x-ray imaging systems to perform real-time image-guided radiation therapy in the lung.

Methods: PML-SKR works in two stages: planning and treatment. At planning stage, firstly it parameterizes the patient's respiratory deformation from the patient's treatment-planning Respiratory-Correlated CTs (RCCTs) by doing PCA analysis on the inter-phase respiratory deformations. Secondly, it simulates a set of training projection images from a set of deformed CTs where their associated deformation parameters are sampled within 3 standard deviations of the parameter's values observed in the RCCTs. Finally, it learns a Riemannian distance metric on projection intensity for each deformation parameter. The learned distance metric forms a Gaussian kernel of a kernel regression that minimizes the leave-one-out regression residual of the corresponding deformation parameter. At treatment stage, PML-SKR interpolates the patient's 3D deformation parameters from the parameter's values in the training cases using the kernel regression with the learned distance metrics.

Results: We tested PML-SKR on the NST (Nanotube Stationary Tomosynthesis) x-ray imaging system. In each test case, a DRR (dimension: 64x64) of an x-ray source in the NST was simulated from a target CT for registration. The target CTs were deformed by normally distributed random samples of the first three deformation parameters. We generated 300 synthetic test cases from 3 lung datasets and measured the registration quality by the mTRE (mean Target Registration Error) over all cases and all voxels at tumor sites. With PML-SKR's registrations, the average mTRE and its standard deviation are down from 10.89±4.44 to 0.67±0.46 mm using 125 training projection images. The computation time for each registration is 12.71±0.70 ms.

Conclusion: The synthetic results have shown PML-SKR's promise in supporting real-time, accurate, and low-dose lung IGRT.

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