DISCONTINUITY PRESERVING CONVEX IMAGE REGISTRATION MODEL FOR MRI OF THE LUNG

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Introduction: Early detection of chronic lung disease and early treatment are the cornerstones of respiratory medicine. Chest X-ray, the current gold standard, however, often fails to detect early signs of ventilation problems such as inhomogeneities. To detect structural abnormalities, multibreath gas washout, plethysmography and CO-diffusion tests are used. There is thus an urgent need for X-ray radiation free imaging methods for structural abnormalities in the lung. In vivo MRI of the lung in clinical practice is obstructed by many reasons, such as the biophysical property of the lung parenchyma, the physiological motion of the lung, respiratory and cardiac motion, blood flow and diffusion. The success of morphological and functional lung imaging represents one of the final frontiers in MRI. The newly developed ultra-fast steady state free precession (SSFP) imaging concepts in combination with dedicated image registration methods for fast functional and morphological MRI, allow us to study the lung both statically, e.g. at inhalation and/or exhalation, and also dynamically during respiration without any X-ray exposure. In this abstract we describe a novel image registration approach that is able to handle the discontinuous motions fields that appear due to sliding of the lung along the chest wall. These motion fields are then used to determine the ventilation and perfusion maps.

Methods: We propose a novel and accurate method for registration of lung MR images which can handle the displacement field due to the respiration. We minimize the following energy functional

$$E(\mathbf{w}) = \int_\Omega \mathbf{w}^T S_\rho(\nabla_3 I)\mathbf{w}\, dx + \lambda \int_\Omega \sqrt{\nabla \mathbf{w}^T S_\sigma(\nabla_2 I)\nabla \mathbf{w}}\, dx,$$

to obtain the displacement field **w** from image sequences *I*, where S_ρ, S_σ are the motion and structure tensor, ∇ is gradient operator, ρ, σ are rotationally symmetric convolution kernel and λ is a weighting constant. The proposed method combines the CLG [1] and TVL1 [2] methods with anisotropic smoothness term based on additional (local) directional variations in order to take into account the variations in the neighborhood of the motion fields. The directional variations are obtained from the analysis of eigenvalues of the resulting structure tensor. The energy is then minimized by using the fast primal-dual method.

Results: We implemented the proposed method on lung images acquired on a 1.5T Avanto MR Imager (Siemens Healthcare, Germany) using an Ultra-fast SSFP sequence with the following parameters: In-plane resolution: 1.846 x 1.846 mm; TR: 1.36ms; TE: 0.52ms; Slice thickness: 8mm; matrix size: 204x208; Flip angle: 25°; number of images:200. The experimental results of the method, together with the comparison with other state of the art methods, are shown. In Fig 1, we showed the registration result (bottom,left) of image #30 (top,right) in the sequence to the first image (top, left) and its motion field (bottom,right). As can be seen, the method is robust with respect to the discontinuity. As a quantitative and qualitative evaluation, we registered all images in the sequence to the first and measured the mean squared error (MSE) between the registered images and the first image. As shown in Fig 2., the MSE of the proposed method is lower than other state of the art methods.

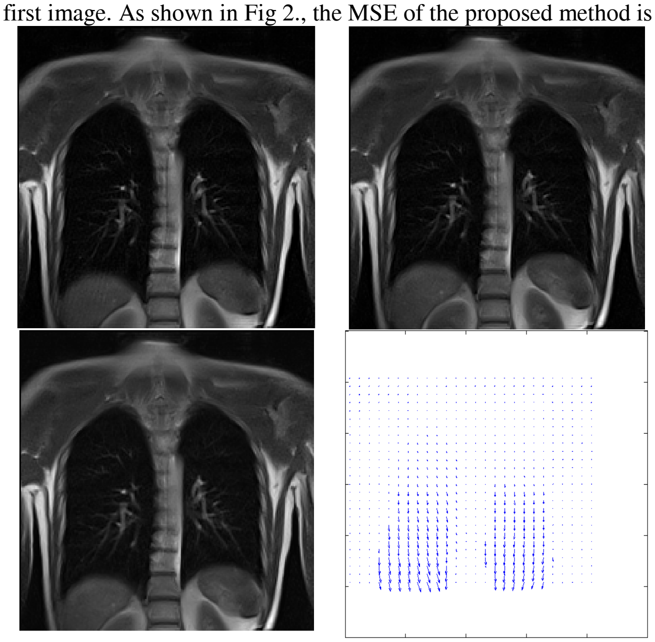

Fig 1. Top row: Reference and template images. Bottom row: Registered template image and its motion field.

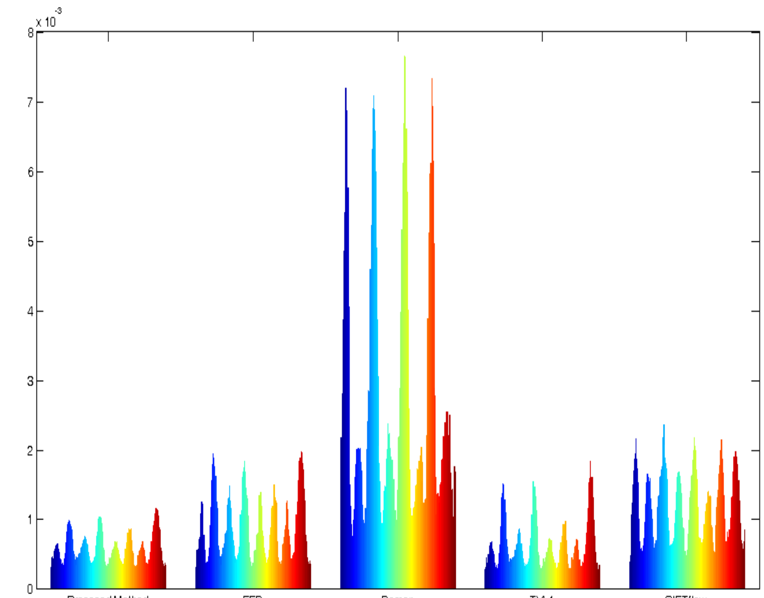

Fig 2. MSE of all registered images with respect to the first image of the proposed method, FFD [3], Demon [4], TVL1 [2] and SIFTflow [5].

Conclusion: We have proposed a novel and accurate image registration method which can handle discontinuities caused by the perpetual breathing motion. The preliminary results have shown that our proposed registration method of MRI lung sequence outperformed the state of the art image registration methods.

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