Nonlinear Point-Based Registration of Mouse Kidney MR Images

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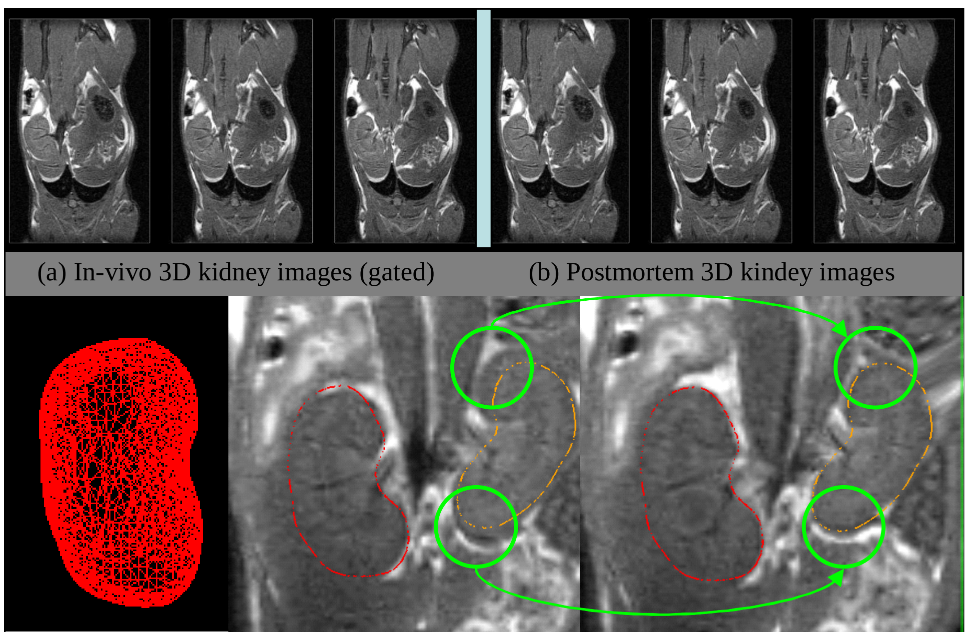
Abstract: We present preliminary results from the application of point-based non-linear registration methods on high-field mouse kidney images. The ultimate goal of this work is the construction of a statistical shape atlas for the mouse kidney, which is the key first component of our strategy for segmentation of structural images and the quantification of functional images of the same mouse. We acquire high-resolution in-vivo and postmortem MR image data using the spin-echo technique. The kidneys were segmented interactively using a custom developed technique [Ref1], and are aligned into the same space using an extended robust point matching algorithm [Ref2]. The results indicate that the registration is highly accurate. The next step is the acquisition of more data-sets and construction of a probabilistic atlas for the kidneys.

Methods: For the purpose of constructing the atlas we acquired images from eight, eight-week old C57BL6 wild type mice. All imaging was performed on a Bruker 4.0T/40 cm bore animal system using a T2-weighted 3D Multi-spin multi-echo sequence (MSME), with a TE=15 ms. This spin-echo sequence has excellent signal-to-noise properties and is relatively robust to susceptibility artifacts. In-vivo images (figure a) were first acquired using respiratory gating, a FOV=4.0x2.5x1.8 and an imaging matrix of 256x128x32. Animals were then sacrificed and a high resolution 3D scan was acquired using the same FOV and image matrix 256x128x64 (figure b). Immediately before and after the 3D post-mortem scan a single coronal slice was acquired through the middle of the FOV in order to verify that there were no significant effects of necrosis present in the images. An expert user performed the original surface extraction of both the left and right kidneys from the images in a semi-interactive fashion using a software platform originally designed for segmenting the left ventricle of the heart [Ref1], which was customized for this application. The segmentation resulted in a set of two labeled surfaces, one for the left and one for the right kidney. The surfaces were then interpolated and sampled to 0.15 mm spacing (approximately the image resolution shown in (c) below) and then smoothed using a non-shrinking surface technique using methodology described in our previous work [Ref2]. The sampling process resulted in a set of labeled points representing each pair of kidney surfaces. The registration was performed using the extended robust point matching method [Ref2]. This method consists of two alternating steps, (i) a fuzzy correspondence estimation step and (ii) a transformation estimation step. The process was optimized using a deterministic annealing strategy, which gradually reduces the fuzziness of the correspondence (high to low) and the regularization applied to the transformation estimate.

Results: Results for both linear and non-linear registrations of the kidneys are shown in the figure (d,e). The registration procedure was completely automated and was able to cope with initial misalignments of the kidneys of the order of 30°. This was not possible using standard surface matching methods such as the iterative closest point algorithm (ICP) [Ref3] and is a direct consequence of the fuzzy correspondence method. Standard intensity-based registration methods (e.g. [Ref4]) also failed to produce an adequate registration as a result of the variations of the intensities of surrounding tissue (e.g. presence/absence of surrounding fat.) We also note that, while the linear affine registration (figure d) captures the overall shape of the kidney, the non-linear step (figure e) is needed to successfully align the tips of the kidneys.



(a) In-vivo 3D kidney images (gated) (b) Postmortem 3D kindey images

(c) 3D surface model (d) Linear Registration (e) Nonlinear registration

Conclusions: We demonstrate the feasibility of applying the non-rigid RPM registration technique for the construction of statistical atlases for mouse kidney segmentation. We are currently working on collecting enough data-sets (10-20) for the construction of such an atlas (from postmortem data) and its application to the segmentation task (for in-vivo data.)

References: [Ref1] Omitted (Provides Identifying Information), [Ref2] Omitted (Provides Identifying Information)

[Ref3] Besl PJ and McKay ND, A Method for registration of 3D Shapes. IEEE PAMI 1992

[Ref4] Rueckert D et al. Non-rigid registration using free-form deformations: Application to breast MR images, IEEE TMI 1999