

Sarah Needleman – Thesis – Animations

- Shown in the animations are:
 - the raw echo 1 MRI signal intensity images,
 - the registered echo 1 MRI signal intensity images,
 - the (log) Jacobian determinants,
 - the difference between the raw images and the reference image,
 - and the difference between the registered images and the reference image.
- The animations are of a non-smoking healthy participant who was shown as an example subject throughout the thesis.
- The third image slice is displayed which contains the aorta.
- The animations present the first 120 dynamic images acquired (including the initial air-inhalation period and the first period of 100% oxygen-inhalation, gases were switched at the 60th dynamic time point).
- The log of the Jacobian determinant is plotted so that volume expansion and volume contraction occur equally about zero.
- Abbreviations include:
 - control point grid spacing, CPG,
 - locally normalised cross-correlation, LNCC,
 - and normalised mutual information, NMI.

Animation 1: Animation to illustrate the performance of **ANTs** registration.

The registered images appeared well aligned by ANTs. However, the ANTs Jacobian determinants appeared patchy which indicated the presence of highly local, likely implausible, deformations. The irregular pattern of the Jacobian determinants extended beyond the lung to cover the entire field of view, including over regions in which minimal motion was observed to have occurred (from observation of the raw signal intensity images). The amplitude of the Jacobian determinants in these regions of minimal motion, such as in the arms and shoulders, were comparable to the amplitude inside the lung in which substantial respiratory motion occurred. No structure was visible within the lung of the ANTs Jacobian determinants.

Observed in the raw images, the left diaphragm of the example subject appeared affected by through-plane motion and/or artefacts.

Animation 2: Animation to illustrate the performance of **NiftyReg** registration using a **default CPG spacing of 5 voxels**.

The registered images appeared relatively well aligned by NiftyReg using the default CPG spacing. The Jacobian determinants appeared smooth but lacked structure within the lung. In regions where little motion was observed to occur (such as in the arms and shoulders) the amplitude of the Jacobian determinants were minimal.

Animation 3: Animation to illustrate the performance of **NiftyReg** registration using a **CPG spacing of 1 voxel**.

The registered images appeared well aligned by NiftyReg using a fine CPG spacing of 1 voxel. The Jacobian determinants appeared to contain substantial structure within the lung. In regions where little motion occurred the amplitude of the the Jacobian determinants appeared minimal.

The left diaphragm appeared more stationary in the registered images compared to those produced using a coarser CPG spacing of 5 voxels (Animation 2).

Animation 4: Animation to illustrate the performance of **NiftyReg** registration using a **CPG spacing of 2 voxels**.

The registered images appeared well aligned by NiftyReg using a fine CPG spacing of 2 voxels. The Jacobian determinants appeared to contain substantial structure within the lung. The Jacobian determinants were smoother compared to those produced using a NiftyReg CPG spacing of 1 voxel (Animation 3).

Similar to the registration produced using a CPG spacing of 1 voxel (Animation 3), the left diaphragm appeared more stationary in the registered images compared to those produced using a coarser CPG spacing of 5 voxels (Animation 2).

Animation 5: Animation to illustrate the performance of **NiftyReg** registration using a **CPG spacing of 3 voxels**.

The registered images appeared well aligned by NiftyReg. Although the Jacobian determinants appeared smooth, structure was visible within the lung.

The left diaphragm of the registered images demonstrated more motion compared to the registered images produced using finer CPG spacings of 1 and 2 voxels (Animations 3 and 4, respectively).

Animation 6: Animation to illustrate the performance of **NiftyReg** registration using a **CPG spacing of 3 voxels and NMI**.

The NMI was investigated as an alternative similarity metric to the LNCC. (The LNCC was used in all previous NiftyReg registration animations.) The registered image series produced using the LNCC (Animation 5) appeared marginally better aligned than the image series produced using the NMI.

Similar to the registration produced using a CPG spacing of 3 voxels with the LNCC similarity metric (Animation 5), the left diaphragm of the registered images demonstrated more motion compared to the registered images produced using finer CPG spacings of 1 and 2 voxels (Animations 3 and 4, respectively).