ADNI Alzheimer's Disease Neuroimaging Initiative

Brain and Ventricular Boundary Shift Integral

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Summary

We describe the processing methods in the brain and ventricular boundary shift integral (BSI). The brain and ventricles were first automatically delineated from the T_1-weighted MRI scans. The repeat scans were then registered to the baseline scans using 9-degree-of-freedom registration. The intensity inhomogeneity between the baseline and registered repeat scans was corrected using the differential bias correction. Finally, BSI was calculated over the boundaries of the brain and ventricles respectively using the registered and corrected scans.

Methods

We now describe each step in the brain and ventricular BSI in more details.

Brain delineation

The brain regions in the baseline and follow-up scans were automatically delineated using multi-atlas propagation and segmentation (MAPS) (Leung *et al.* 2011). The regions were checked by experts and edited if necessary (Freeborough *et al* 1997).

Ventricles delineation

After registering the scans to the MNI 305 atlas, the ventricles of the scans were semi-automatically delineated using intensity thresholding, region growing and mathematical morphology (Freeborough *et al* 1997).

Image registration

The baseline and repeat brain scans were registered over the delineated region (the brain or ventricles) using a 9-degree-of-freedom registration algorithm (Woods *et al.* 1998). The repeat scans were transformed using the results of the registration.

Differential bias correction

Differential bias correction (DBC) was applied to correct the intensity inhomogeneity artifacts between the baseline and transformed repeat images (Lewis and Fox 2004). A kernel radius of 5 was used in DBC.

Calculation of BSI

The union and intersection regions of the baseline and repeat regions (the brain or ventricles) were computed. After dilating the union region once and eroding the intersection region once, the boundary shift region is given by the XOR (exclusive or) of the dilated union region and the eroded intersect region.

1. For classic-BSI, the intensity of registered and DBC-corrected baseline and repeat scans were normalized by dividing by the mean intensity inside the intersect region of the baseline and repeat brain regions. BSI was calculated using a manually-chosen intensity window of [0.45, 0.65] (Freeborough and Fox 1997).

2. For KN-BSI, the intensities of CSF, GM and WM in the registered and DBC-corrected baseline and repeat scans were estimated using *k*-means clustering. Linear regression between the corresponding mean intensities (CSF, GM, WM and interior brain region) of the two scans were performed and the results were used to normalize the intensity of the two scans. The intensity window was automatically chosen to be $[I_{CSF\ mean}+I_{CSF\ sd}, I_{GM\ mean}-I_{GM\ sd}]$, where $I_{CSF\ mean}$, $I_{CSF\ sd}$, $I_{GM\ mean}$ and $I_{GM\ sd}$ are the mean and standard deviation of CSF intensity, and the mean and standard deviation of GM intensity. BSI was then calculated (Leung *et al.* 2010).

Quality control (QC)

The T_1-weighted MR images undergo a QC process to flag issues affecting measures likely to be conducted at the DRC. The images are assessed individually and as a baseline-repeat pair after the image registration to flag issues such as inconsistent image acquisition and failed registration.

Cross sectional QC (individual scan)

Every scan undergoes a review for general image quality. The following potential problems are flagged:

- Anatomical coverage
- Overall image quality
- Presence of artifacts (patient motion, aliasing, or other image artifacts)

The scan is then given an overall rating "OK", "Borderline" or "Fail", as detailed below:

Failed

There is a clear quality problem with the scan which makes it unsuitable for further analysis. The scan will not continue through the DRC analysis procedure.

Borderline

The scan is deemed of borderline quality when viewed individually. The image will continue on through the DRC analysis process and be segmented. This will be reviewed after the registration quality control step for repeat images.

OK
The scan is deemed of suitable quality when viewed individually. The image will continue on through the DRC analysis process and be segmented. This will be reviewed after the registration quality control step for repeat images.

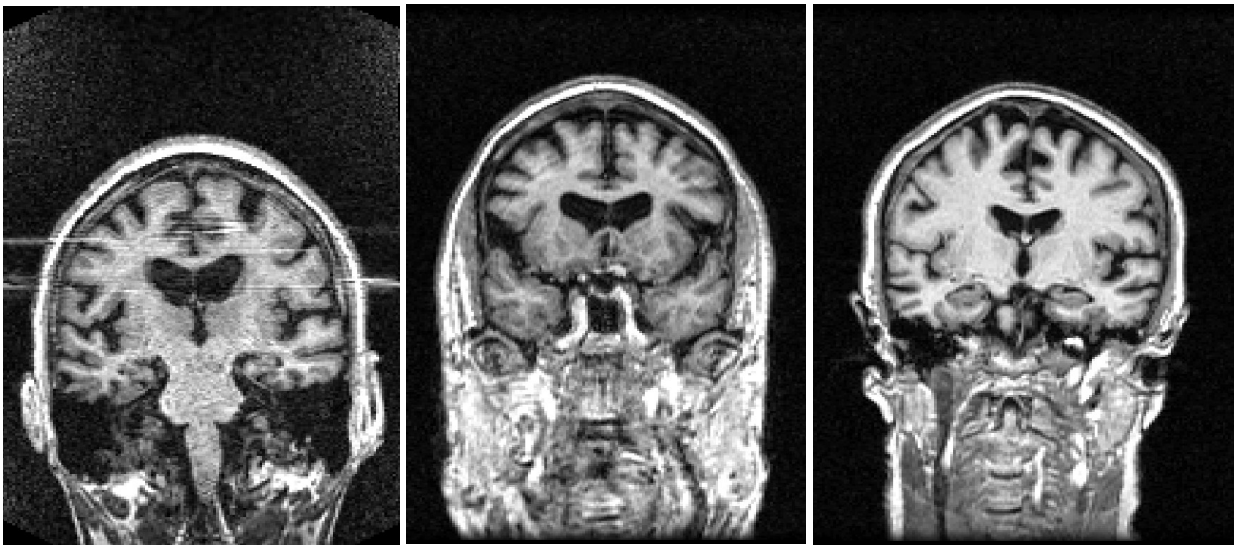


Figure 1: Examples of cross-sectional QC ratings: "Failed", "Borderline", and "Good" (from left to right).

Longitudinal QC (baseline and repeat scan pair)

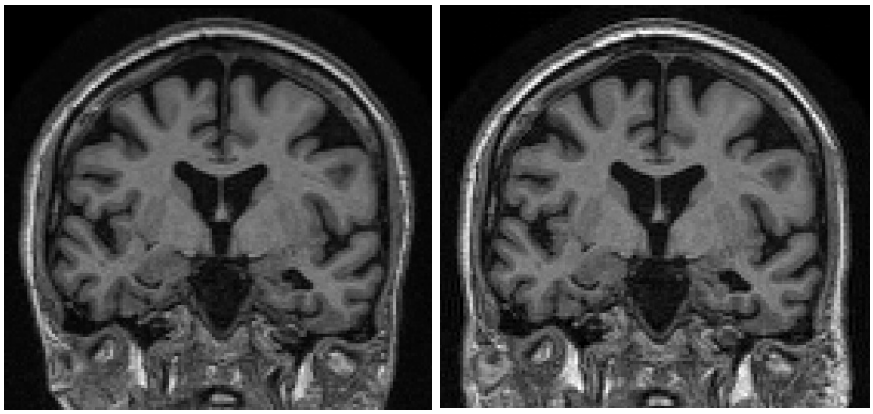
Once longitudinal data is available, registrations can be performed. These undergo an additional QC step, looking at longitudinal continuity; the following problems are recorded in a text based comment.

- Change in scan acquisition protocol between scans
- Change in quality between scans (contrast, noise etc)
- Change in position within scanner between scans causing grad-warp problems (should be less of an issue)
- Registration problems

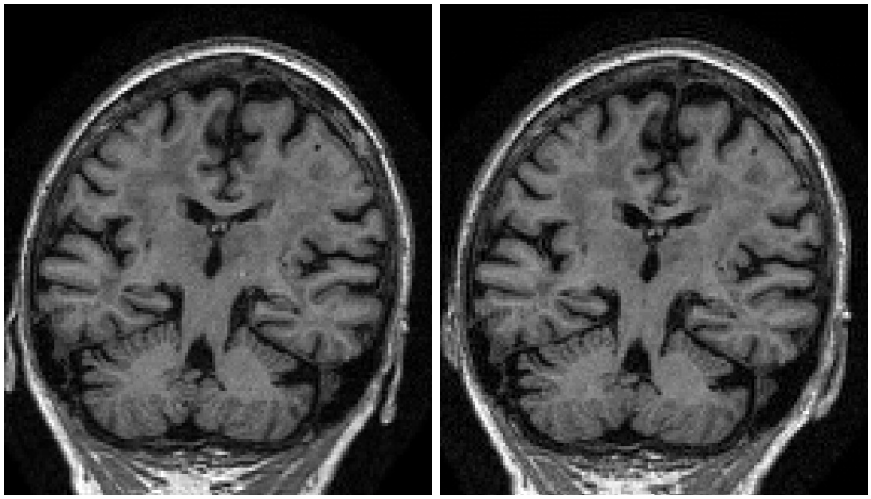
The quality of the longitudinal data is then given a numeric rating, see below:

Registration rating	Meaning
1	Good
2	Acceptable
3	Borderline acceptable
4	Fail / unacceptable
5	Significant non-disease related pathology effects measure

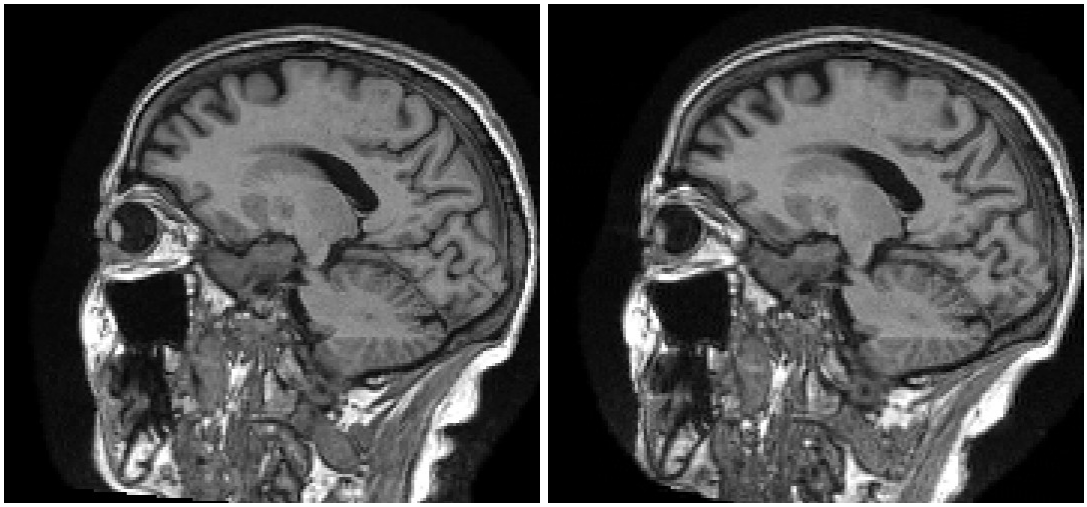
Examples of the registration ratings are show below (left – baseline scan, right – repeat scan).



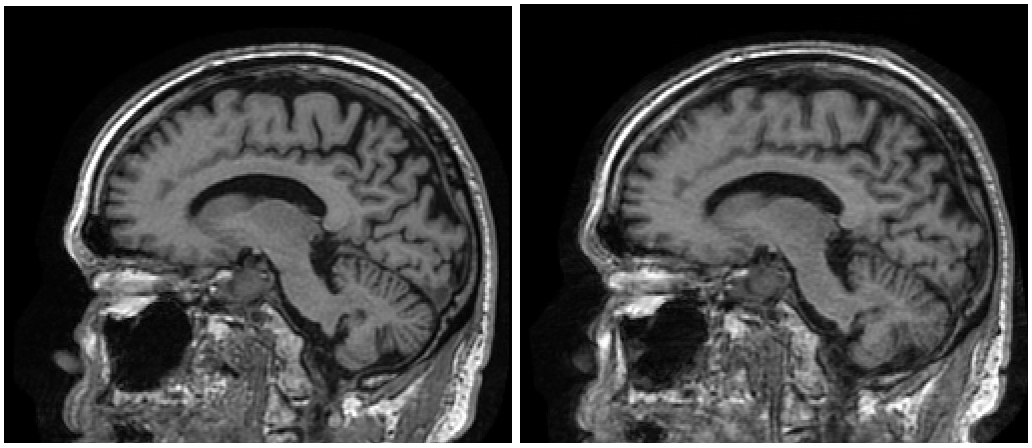
Registration rating 1



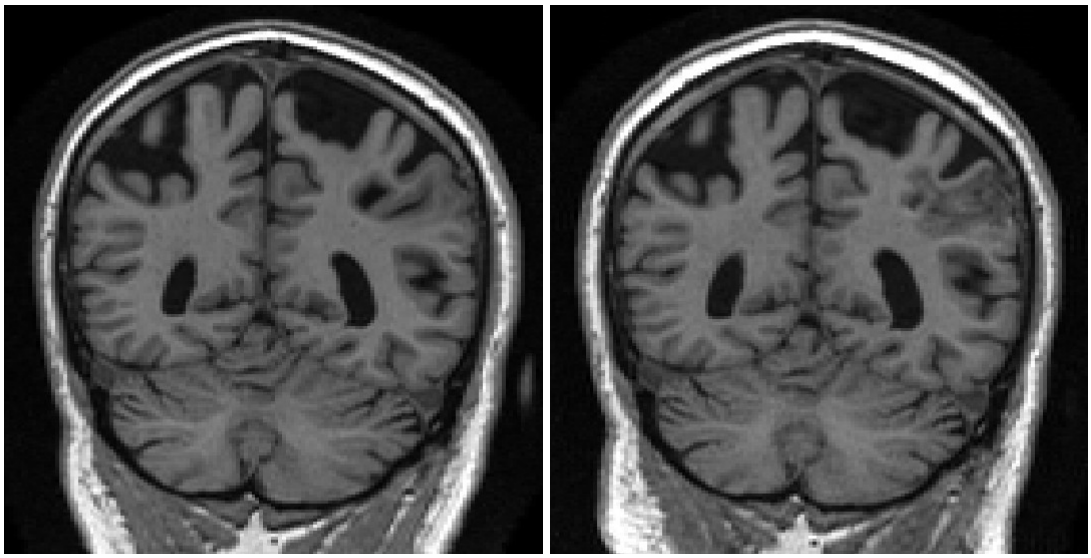
Registration rating 2
(Minor motion artifacts in the repeat scan)



Registration rating 3
(Some motion artifacts in the repeat scan)



Registration rating 4
(Significant motion artifacts in the repeat scan)



Registration rating 5
(Significant pathology in the repeat scan)

Version Information

This is the first version.

Dataset Information

This methods document applies to the following dataset(s) available from the ADNI repository:

Dataset Name	Date Submitted
UCL - Fox Lab BSI measures [ADNI GO/2]	31 October 2012

References

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