A Posterization Strategy for the Registration of [123I]FP-CIT SPECT Brain Images

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Abstract: A fully automatic procedure to build a [123I]FP-CIT SPECT template in the MNI-space using only information from the source images is presented. This approach does not require the acquisition of patient-specific brain magnetic resonance image. This fully automatic procedure uses, firstly, the Otsu's method to outline the source images; secondly, a threshold strategy to posterize the source images and the template and, lastly, an affine registration algorithm by the optimization of a square root of sum of squares cost function.

1 INTRODUCTION

The low resolution and the intersubject variability between [123I]FP-CIT SPECT images renders very difficult to perform the registration of these images. For this reason, some published works performed the spatial normalization assisted by the existence of a high resolution MRI for each subject under study (van de Giessen et al., 2013; Aarts et al., 2012). Sometimes, there is not a T1-MRI available to assist the spatial registration. For that cases, we present a fully automatic method to perform the registration of [123I]FP-CIT SPECT accurately. This method surmount the difficulties of working with [123I]FP-CIT SPECT. Namely, these images exhibit a lack of anatomical information outside the striatum. Specifically, in our database, the brain image is cut and some slices in top of the brain are missing.

Figure 1(a) depicts a montage showing all the slices of a sample source image (transaxial view). Figure 1(b) displays the transaxial, coronal and sagittal view showing the maximum intensity value calculated for each in this 3 orthogonal projections of the brain 3D volume for a sample source image.

2 [123I]FP-CIT SPECT BRAIN IMAGES

40 FP-CIT SPECT brain images with bilateral, symmetrical uptake appeared in caudate and putamen nuclei. These patients were chosen to perform an FP-CIT tomographic study because of a movement disorder, but they are all labeled as non Parkinsonian's.

The images were obtained between 3 and 4 hours after the intravenous injection of 185 MBq (5 mCi) of Ioflupane-I-123, with prior thyroid blocking with Lugol's solution. The tomographic study (SPECT) with Ioflupane/FP-CIT-I-123 was performed using a General Electric gamma camera, Millennium model, equipped with a dual head and general purpose collimator. A 360° circular orbit was made around the cranium, at 3° intervals, acquiring 60 images per detector with a duration of 35 seconds per interval, each consisting of a 128×128 matrix. Transaxial image slices were reconstructed using the filtered back-projection algorithm without attenuation correction, and applying a Hanning filter (cutoff frequency equal to 0.7).Finally, the dimension of the images in this dataset is $128 \times 128 \times Z$, where Z ranges from 34 to 54 for different images.

3 POSTERIZED MNI TEMPLATE IMAGE

Some functional imaging studies match their data to a brain template from the Montreal Neurological Institute (MNI) (Holmes et al., 1998; Aubert-Broche et al., 2006). They are also used in the Statistical Parametric Mapping software (Friston et al., 2007). This MNI template is based on an average of many scans

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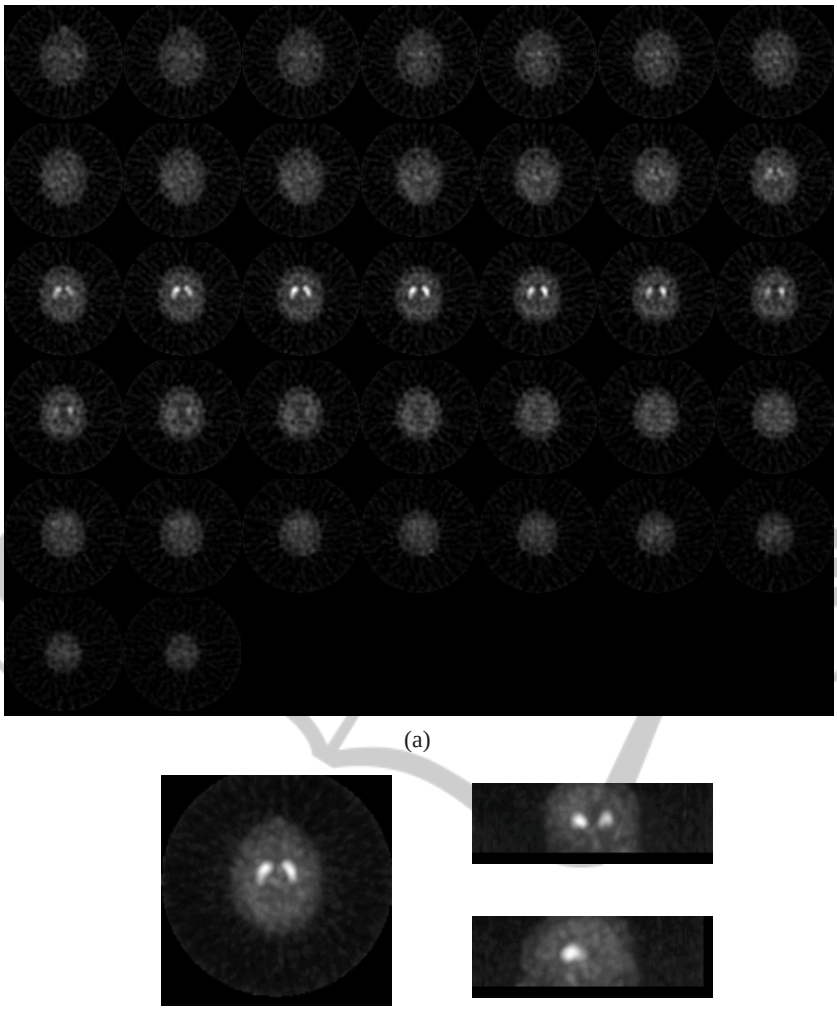


(a)

(b)

Figure 1: (a) Montage with the transaxial slices of a selected source brain image. (b) Transaxial, coronal and sagittal view showing the maximum intensity value projected in these 3 orthogonal planes for a sample source image.

of healthy young adults. We create a posterized version of the brain in the standard space MNI (Montreal Neurological Institute) of brain images using three intensity values: 0 for voxels outside the head, 1 for the head and a value in the striatum $v_s > 1$. The position of the striatum in the MNI space is taken by the information in the labeled structural brain template image provided by the MNI.

4 POSTERIZATION OF SOURCE IMAGES

Firstly, we select those voxels corresponding to the head in source images. We apply a low-pass band filter to the image by smoothing it using a Gaussian filter with the size of the convolution kernel [7 7 7] and standard deviation equal to 5. This smoothness of the image will allows us to distinguish more accurately between the intensity values inside and outside the brain. Once the source images are smoothed and the high frequency noise reduced, we use the Otsu's method to automatically perform clustering-based image thresholding, reducing the graylevel image to a binary image (Otsu, 1979). This method assumes that the source image contains two classes of voxels (head and background), then, calculates the optimum threshold separating those two classes so that their combined intra-class variance is minimal. We initially assign intensity value equal to 1 to the voxels in the head and 0 to background voxels.

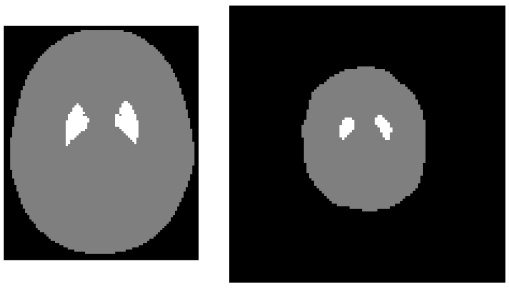


Figure 2: Transaxial slice of the posterized brain image. Left: Template in the MNI space. Right: Source image.

Then, we select the Ns voxels in the striatum with highest intensity values. We set an intensity value v_s to these selected voxels. Therefore, after posterization, the source image has three different intensity values: 0 outside the head (the background), 1 in the head (outside the striatum) and $v_s > 1$ in the striatum. Figure 2 presents a transaxial slice of the posterized brain template image and one sample source image. The striatum is the most important volume in the source image for this SPECT modality, but it is very small. The parameter v_s controls the weight of the striatum in the calculation of the cost function to perform the spatial transformation of the source images to the MNI space.

5 AFFINE REGISTRATION

After posterization of the MNI template and the source images, we perform the affine registration of the posterized source images to the posterized brain template in the MNI space. The 12 affine parameters are calculated using the Gauss-Newton optimization method. The cost function to minimize is the mean squared difference between the intensity values in source and template images (Salas-Gonzalez et al., 2008). Once the 12 affine parameters are calculated, we apply the affine transformation to the original source image.

6 RESULTS

We apply the proposed methodology to 40 [123I]FP-CIT SPECT brain images. Initially, we select $Ns = 400$ voxels of the striatum in each source image. We posterize them using three different levels for background (voxel intensity $= 0$), head (voxel intensity $= 1$) and striatum (voxel intensity, $v_s = 2,3,4,5,6,7,8,9,10,11,13,15$). This value ($v_s$) controls the weight of the striatum in the calculation of the cost function used to perform the affine registration. Then, we perform the affine registration of the source images to the MNI template and measure the overlap between the striatum in the source images and the template using the Jaccard Index (JI).

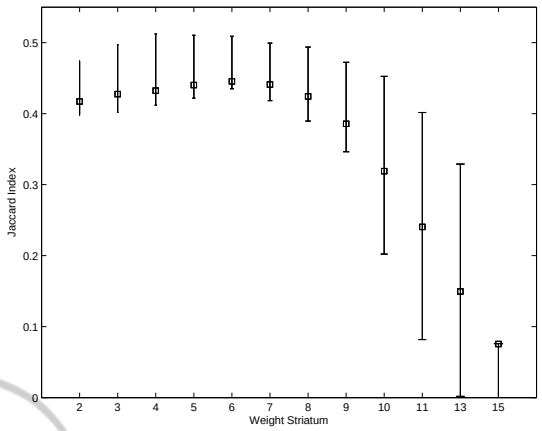


Figure 3: Mean Jaccard Index and error for varying v_s ($Ns = 400$ voxels).

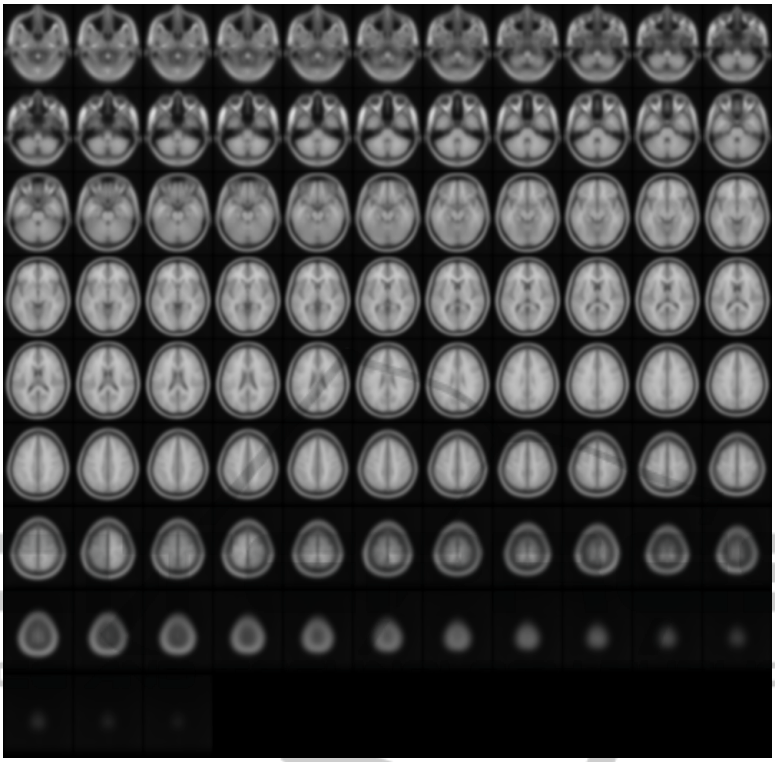
We do not expect to get a Jaccard Index near 1 because the striatum of the posterized source and template images are three-dimensional regions with different shapes and volumes, and therefore, using only affine transfomations, they are not expected to fully overlap.

Figure 3 shows the mean Jaccard Index and the error measured as the 75th and 25th percentile for each value of the weight v_s. The measured value of JI increases concomitantly with v_s up to $v_s = 6$, where the best accuracy and lower error are obtained. For higher values of v_s, the measured JI decreases and the error bar increases.

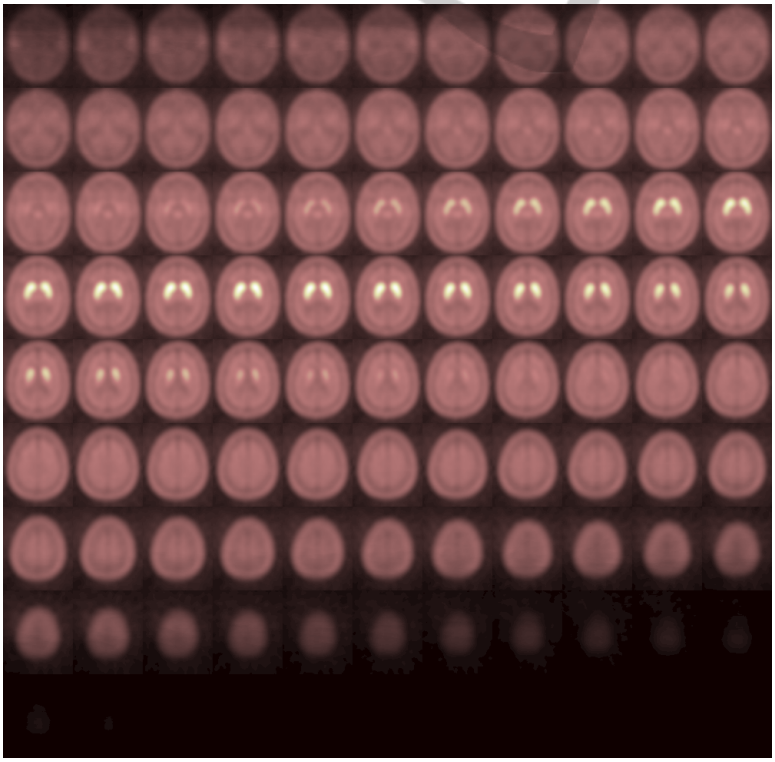
Once the posterized source images have been registered to the posterized MNI template, the estimated 12 affine parameters are applied to the original images. Then, the mean image is calculated to build the template.

Figure 4 shows all transaxial slices of the FP-CIT SPECT template built using the proposed methodology and the MRI T1 template in the MNI space. It can be visually checked that the FP-CIT template has been successfully transformed to the MNI space.

Figure 5 shows a transaxial slice of the FP-CIT SPECT Template superimposed to the T1 MRI template in the MNI space. This figure shows that the high intensity values corresponding to the striatum is accurately placed in its true anatomical position.



(a)



(b)

Figure 4: (a) T1 template in the MNI space. (b) [123I]FP-CIT SPECT template.

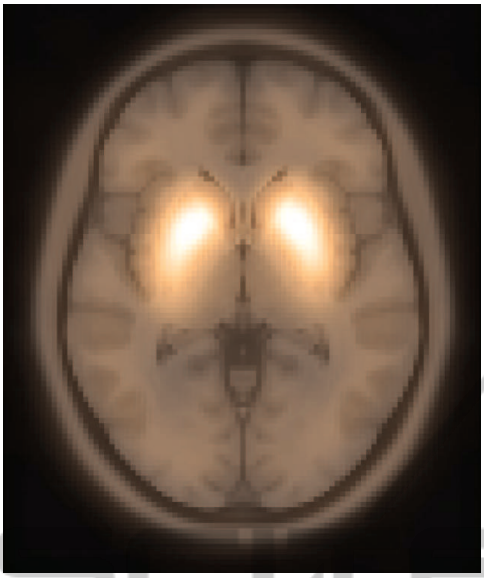


Figure 5: Brain fusion image in the MNI space: MRI and [123I]FP-CIT SPECT.

7 CONCLUSION

In this work, a procedure to build a [123I]FP-CIT SPECT template is presented. The brain images are posterized to three different intensity level (background, brain and striatum). Then, these image are registered to a previously posterized template image using a 12 parameters affine model. The proposed methodology is shown to accurately works for [123I]FP-CIT SPECT images, even when high resolution magnetic resonance image for each subject is not available.

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