Non-Parametric Image Subtraction

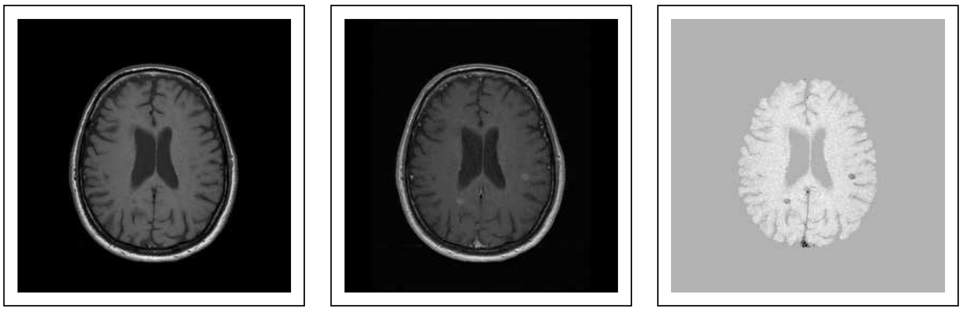
Detection of changes between pairs or sequences of images forms the basis of many image analysis tasks, from motion detection to monitoring disease progression in medical images. The simplest approach is a direct subtraction of image intensities. This approach implicitly assumes that the only differences between the images are those introduced by the process under analysis. However, in many practical applications there will also be global differences between the image pair, for example illumination differences, which contaminate the subtraction result and make further processing more complex.

A practical example of this process is provided by the task of detecting lesions in MR images of multiple sclerosis (MS) patients. This task has clinical relevance since monitoring the development of new lesions provides a measurement of disease progression. Lesion development leads to a local breakdown in the blood-brain barrier. Therefore, lesions can be visualised in MR images through the intravenous injection of a contrast agent such as GdDTPA, which leaks into the lesion site and can be seen as a region of high intensity voxels. Figure 1 shows a pair of example images taken before and after the contrast agent injection: two prominent lesions can be seen. The contrast agent can also be seen in the major vasculature, such as the saggital sinus. However, the presence of the contrast agent also leads to a global difference between the two MR image volumes. The global difference can be seen in the simple subtraction result (Fig. 1c): the enhancing tissues (lesions and vasculature) are visible, but much of the background structure of the brain is also retained. This will clearly present difficulties for any fully automatic lesion-counting algorithm based on simple subtraction.

The non-parametric image subtraction algorithm was designed to deal with the problem of detecting localised changes between image pairs in the presence of a global image difference by restating the problem as a hypothesis test. The algorithm operates by constructing a scattergram of the image intensities (Fig. 2a), and normalising it to produce the joint probability distribution of the images. Each pair of voxels from the original images specifies a set of coordinates in the scattergram. The subtraction result is produced by taking the column of the normalised scattergram passing through these coordinates, and integrating all values lower than that at the coordinates specified by the voxel pair. This process is familiar as the construction of a confidence interval, and the resulting quantity is the probability of the hypothesis that the deviation of the voxel pair from the main distribution in the scattergram was caused by the observed noise process. The algorithm therefore incorporates an implicit, bootstrapped model of global differences between the original images, allowing the identification of localised differences, which move voxel pairs away from the main distribution.

The non-parametric image subtraction result for the images in Fig. 1 is shown in Fig. 2b. Since the algorithm is effectively performing an integral transform, the subtraction result is guaranteed to have a uniform probability distribution. This leads to its noisy appearance, and provides a second, significant advantage over simple subtraction. The voxels in a simple subtraction image have arbitrary values in units of intensity: the voxels in a non-parametric image subtraction result have values of probability, with a uniform distribution (i.e. honest probabilities). This allows quantitative interpretation of the result. For example, applying a threshold at the 0.1 level is guaranteed to identify the 10% of the voxels in the original image pair that had the least common pairings of intensities: in the present case, these will be predominantly the voxels in enhancing regions. Figure 2c shows the result of the thresholding process: the lesions and vasculature are identified. It would clearly be simpler to construct a fully automatic lesion-counting algorithm based on this result than on a simple subtraction.

The non-parametric image subtraction algorithm is available in the main TINA distribution, and is implemented as the dscat button in the Imcalc tool. The User's Guide provides full usage instructions. Publications describing the algorithm are listed in the References section.



(a) (b) (c)

Figure 1: Pre (a) and post (b) contrast agent injection MR images of an MS patient. A simple subtraction (c) of the images shows the enhancing lesions and vasculature.

(a) (b) (c)

Figure 2: Scattergram (a) of the data from the MS patient images in Fig. 1, non-parametric image subtraction result (b) and thresholding of the subtraction result at 0.1, showing a cleaner image of the enhancing tissues than is possible with simple subtraction.

References

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