Restoring functional PET Images using Anatomical MR Images

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Abstract

Due to the low signal to noise ratio and the low spatial resolution in Positron Emission Tomography (PET) images, it is desired to use apriori knowledge about the brain to address this. Several methods have been presented using styles of incorporating different models of the brain structure to e.g. enhance the resolution without additional information. We present a method using a Bayesian approach to include new structural apriori information from Magnetic Resonance (MR) images. This is possible because the tissue types in the brain, white, gray and cerebrospinal fluid (csf), have different activations levels, in average gray is 4 times higher than white and csf have no activation. Using this information extracted from the MR images from the same person gives apriori information about activation edges in the PET image.

We use a 3D Markov Random Field (MRF) model with only nearest neighbour connections and edge elements. The 3D model have the following form:

$$P(\mathbf{V}\,|\mathbf{d},\,\mathbf{p},\mathbf{q},\mathbf{r}\,,\boldsymbol{\theta}) \propto \exp\left(-E_{\text{prior}}(\mathbf{V},\mathbf{p},\mathbf{q},\mathbf{r}\,|\,\boldsymbol{\theta})\right)\cdot\exp\left(-E_{\text{noise}}(\mathbf{d}\,|\,\mathbf{V}\,,\boldsymbol{\theta})\right)$$

where $\mathbf{d}$ is the observed signal and $\mathbf{V}$, $E_{\text{prior}}(\mathbf{V},\mathbf{p},\mathbf{q},\mathbf{r}\,|\,\boldsymbol{\theta})$ is the energy or cost function for the MRF model, $E_{\text{noise}}(\mathbf{V}\,|\,\mathbf{d}\,,\boldsymbol{\theta})$ is the observations model including noise and $\boldsymbol{\theta}$ are the model parameters

$$E_{\text{prior}}(\mathbf{V},\mathbf{p},\mathbf{q},\mathbf{r}\,|\,\boldsymbol{\theta}) = \frac{\nu}{2}\sum_{i}^{I-1}(1-p_i)(V_i-V_{i+dx})^2+\frac{\nu}{2}\sum_{i}^{I-1}(1-q_i)(V_i-V_{i+dy})^2+\frac{\nu}{2}\sum_{i}^{I-1}(1-r_i)(V_i-V_{i+dz})^2$$

where the model parameters, $\boldsymbol{\theta}=\{\sigma^2,\nu\}$, are both positive. In this case the value of edge elements p_i , q_i and r_i are set using information from the MR image. As observation process we have a linear transformation with added white noise.

$$\mathbf{d}=\mathbf{AV}+\mathbf{n},\ \mathbf{n}\in N(\mathbf{0},\sigma^2\,\mathbf{I})$$

where, $\mathbf{A}$ is the linear transformation matrix e.g. the Gaussian blurring.

A result of this strategy can be seen in figure (1). And it was possible to preserve/enhance edges and avoid edge blurring on the outside of the brain.

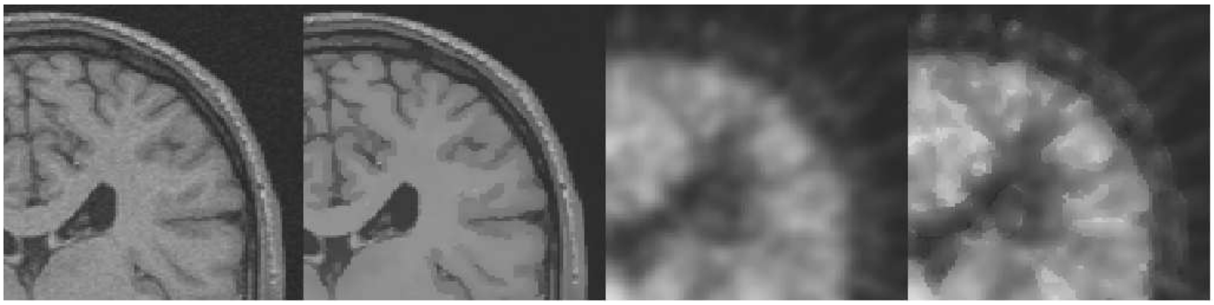

Figure 1: Most left original MR image. Middle left segmented MRI. Middle right original PET image. Most right PET using information from MRI.