Medical Image Processing for Diagnostic Applications

Filtering in Spatial Domain

Online Course – Unit 23
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Topics

Homomorphic Unsharp Masking

Polynomial Surface Fitting

Summary

Take Home Messages

Further Readings

Homomorphic Unsharp Masking

Apply mean normalization.

Homomorphic Unsharp Masking

Homomorphic Unsharp Masking (HUM) is one of the simpler IIH correction methods, and also the most commonly used approach. HUM requires the computation of:

- the global mean value μ of the intensity distorted image,
- local mean values $\mu_{i,j}$ evaluated in a neighborhood of each pixel (i, j).

If the multiplicative model is used, the estimated intensity corrected value $f_{i,j}$ is then computed pixelwise in the following manner:

$$f_{i,j} = \frac{\mu}{\mu_{i,j}} g_{i,j}.$$

Homomorphic Unsharp Masking

A few remarks on homomorphic unsharp masking:

- This IIH-correction method relies on the assumption that the local means in an image are equal to the global mean in the absence of IIH.
- Differences between the global and local means are thus caused by the bias field only.
- This assumption only holds if the neighborhood used for computing the local mean contains a representative sample of the tissue types in the image.
- The size of the neighborhood has to be chosen carefully which is an experimental problem.

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Polynomial Surface Fitting

Approximate the low frequency bias field in the additive model by a multivariate regression polynomial and eliminate the bias by subtraction.

Polynomial Surface Fitting

The basic idea:

1. The logarithmized image is considered as a 2-D function, where the pixel coordinates (i, j) denote the sampling points and the intensities $\log g_{i,j}$ denote the associated function values.
2. Fit a parametric, smooth surface to the logarithm of the intensity values.
3. Estimate the parameters by minimizing the sum of squared differences of the surface points and the logarithmized image intensities.
4. The resulting surface is then subtracted from the logarithmic image.

Polynomial Surface Fitting

Recalling our approach for spatial distortion correction, we define now a parametric mapping for intensity undistortion:

- we consider the image point at (i, j),
- we assume separable base functions,
- and thus require univariate base functions $b_k : \mathbb{R} \rightarrow \mathbb{R}$, $k = 0, \ldots, d$, and
- the coefficients of the polynomials b_k in i and j are denoted by $u_{k,l} \in \mathbb{R}$.

Accordingly, the polynomial that approximates the bias field is defined by:

$$g_{i,j} \approx \sum_{k=0}^{d} \sum_{l=0}^{d-k} u_{k,l} b_k(i) b_l(j).$$

Polynomial Surface Fitting

The resulting least square estimation problem is:

$$[\hat{u}_{k,l}] = \underset{u_{k,l}}{\arg\min} \sum_{i,j=0}^{N-1} \left\| g_{i,j} - \sum_{k=0}^{d} \sum_{l=0}^{d-k} u_{k,l} b_k(i) b_l(j) \right\|^2 .$$

This optimization problem can be solved by computing the SVD of the associated measurement matrix.

The final bias field estimate is:

$$b_{i,j} = \sum_{k=0}^{d} \sum_{l=0}^{d-k} \hat{u}_{k,l} b_k(i) b_l(j).$$

Exercise: Compute the measurement matrix for $b_k(i) = i^k$ and $b_l(j) = j^l$, and think about a proper scaling.

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Take Home Messages

- Spatial filtering can also be used for bias field correction. In homomorphic unsharp masking the local means are adapted to the global mean.
- Similar to the undistortion algorithms from earlier units, a polynomial can be used to estimate and correct the bias field.

Further Readings

The webpage of the National High Magnetic Field Laboratory can be one starting point for more detailed information regarding MRI. For an initial overview of the technology, the following article is worth reading:

MRI: A Guided Tour by Kristen Coyne.

If you want to know more about segmentation of MR images, e. g., consult

the Google Scholar record of ‘Sandy’ Wells’ publications.

Another article worth reading is this survey paper on algorithms for intensity correction methods:

Zujun Hou. “A Review on MR Image Intensity Inhomogeneity Correction”. In: *International Journal of Biomedical Imaging* 2006.Article ID 49515 (Feb. 2006), pp. 1–11. DOI: 10.1155/IJBI/2006/49515