A Locally Adaptive, Intensity-based Label Fusion Method for Multi-atlas Auto-segmentation

Fusion of segmentation results from multiple atlases are often necessary for atlas-based auto-segmentation (ABAS), since it typically yields more robust and accurate results than using a single atlas alone\(^1\). The STAPLE method\(^2\) has been one of the most widely used methods for multi-atlas label fusion\(^1\), but it has the weakness of ignoring the image data and only using the label maps when computing the label fusion.

The proposed intensity-based label fusion method computes the final label probability \(P(x)\) as a weighted average of individual atlas labels \(L_i\), whereas the weights \(w_i\) are location-dependent and adaptive to local image similarity between the subject image \(S\) and each aligned atlas \(A_i\) as measured by the local cross-correlation-coefficients (LCC):

\[
P(x) = \frac{1}{\sum_i w_i} \sum_{i=1}^M w_i(x; S, A_i) L_i(x), \quad \text{and} \quad w_i(x) = \exp(\text{LCC}(x; S, A_i)/h),
\]

where \(h\) is a scaling parameter that can be determined adaptively\(^3\). To further account for atlas-registration errors, \(L_i(x)\) in Equation (1) is replaced by a refined estimation for each atlas according to:

\[
\tilde{L}_i(x) = \frac{1}{\sum_j w_j} \sum_{j \in R(x)} w_j(S(x), A_i(y_j)) L_i(y_j),
\]

where \(R(x)\) denotes a local neighborhood of \(x\). The weights \(w_j\)'s are defined similarly as in (1). In addition, only a subset of \(y_j\)'s with the largest LCC values are included to compute the weighted summation in (2) to reduce excessive smoothing.

The figure below compares the accuracy of the proposed method and the STAPLE method for the segmentation of 7 structures using multi-atlas ABAS. The improvement in accuracy is obvious and statistically significant.

\(^3\)P. Coupe, J. Manjon, and et al., NeuroImage 54(2), 940-954, 2011.