Segmentation and Parcelisation of Newborn Brain MRI using Mathematical Morphology

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Outline

1. Description of the problem
2. Theoretical background
3. Process
   1. Noise estimation and noise reduction
   2. Intracranial Volume
   3. Parcellisation: left right hemisphere and cerebelum-brainstem
   4. Segmentation of White matter, Gray matter, CSF
4. Results
5. Discussion
1. Where do we come from?

- 30 weeks T1 and T2
- 40 weeks T1 and T2
1. Where do we want to go?

- CSF
- Gray matter
- White matter
- Brainstem
- Cerebellum
1. Description of the problem

- The goal is to segment
  - Structures:
    - Intracranial volume, left, right hemisphere, Cerebellum and brain stem
  - Tissues
    - White gray matter, CSF
- The difficulties are
  - White matter vs gray matter contrast to noise ratio.
  - Low spatial resolution.
  - Partial volume effect.
  - Coregistration T1 and T2.
  - Myelination ongoing process.
  - Large overlaps in intensity-based on different tissues.
2. K-means algorithm
2. Watershed algorithm
2. Mahalanobis distance

Sample data (red), Observation (green), $\text{Dist}_{\text{Euclid}} = [1.4; 2; 2.2; 2.8]$, $\text{Dist}_{\text{Mahalanobis}} = [0.65; 18; 20; 1.4]$
3.1 Noise filtering

EPSF Filter (anisotropic heat diffusion)
3.1 Noise filtering

T2 initial image

K-means (4 clusters)

Homogeneous regions = union of the eroded clusters

Diffusion flow

Kappa

Gradient
3.1 Noise filtering

Distribution of $\sigma_{\text{noise}}$ within each region

Kappa = median ( $\sigma_{\text{noise}}$ )
3.1 Noise filtering
3.2 Intracranial Volume (watershed)

Marker function

T2 image

gradient

Viscous closing = segm function

WS and cropping
3.3 Left-Right Hemispheres and Cerebelum-Brainstem

Markers function: 3 most significant lobes

WM and GM

Distance transform

K-mean (3 clusters)

CSF

Segmentation function: Viscous closing-dilation of CSF and background
A Little break?

- Up to now, we have
  - Filtered the data
  - Got the intracranial volume
  - Parcellised the intracranial volume into left, right hemisphere and cerebellum (anatomic structures)

- From now, we do
  - Get rid of the cerebellum and brainstem
  - Identify gray, white matter and CSF for each hemisphere (tissues)
3.4 Region growing

Seed computation \( \{X_i\} \) \( (\text{internal CSF, external CSF, WM}) \)
Attribute definition \( (K = \text{Curvature}, C = \text{Connexity}) \)
Loop

Compute \( \{x_i\} = \text{boundaries of } \{X_i\} \)
Compute limitation parameters \( K(x_i), C(x_i) \)
Compute minimisation parameter \( (\text{Mahalanobis}) M(x_i) \)
if \( M(x_i) = \text{min } \{M(x_i)\} \& K(x_i) < K_{Th} \& C(x_i) < C_{Th} \)
\hspace{1cm} \{X_i\} = \{X_i\} U x_i
end
if stability
\hspace{1cm} \text{relax the curvature constraint by increasing } K_{th}
end
end
3.4 Seed definition

WM seed: Most significant object after morphological opening of WM cluster

External CSF seed: Intersection of the IC internal gradient with CSF cluster

Internal CSF seed: Intersection of the dilated center of gravity with CSF cluster

K-means (3 clusters in left-right hemispheres)
3.4 Segmentation function

3 segmentation functions (Mahalanobis)

K-means (3 clusters: CSF, WM, GM) references regions

T1, T2

GM
CSF
WM
3.4 Parametric control:
Connectivity and curvature

Connectivity
\[ c(x) = \sum N(x) < \text{Th1} \]

Curvature
\[ k(x) < \text{Th2} \]
4. 3D Visualisation

Intracranial Volume

Gray Mater

White Mater

Visualisation on MATLAB
color: curvature value
5. Discussion

1. Strong points
   - Noise estimation for anisotropic diffusion
   - Intracranial volume segmentation
   - Viscosity concept with varying radius of the structuring element
   - Curvature and connectivity as constraints for the region growing
   - Mahalanobis distance to integrate T1 and T2 modalities

2. Weak points
   - The parcellisation is critical on cerebrum and cerebellum frontier
   - Myelination is a problem, varying contrast due to infant cerebral development
   - T1 – T2 coregistration

3. Technical
   - Matlab implementation
   - Simulation time from 30 to 60 minutes for a 256 by 256 by 256 voxels stack