Image Segmentation: 
EM Segmenter
by
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Goal

Develop a general purpose segmenter based on a modular framework:
- fast and flexible
- requiring minimal amount of training effort
- uses probabilistic atlas as prior
Hierarchical Tree

Find Cranial Cavity:

Find Tissue:

IMAGE

BG ICC

CSF GM WM
Design of Algorithm

INFO

IMAGE

BG

ICC

CSF

GM

WM

SEGMENT
Level 1

Prior Information

IMAGE

BG

ICC

CSF

GM

WM

Input

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Hierarchical Segmenter
Level 2

Current Parameter

IMAGE

ICC

CSF

GM

WM

Input

Hierarchical Segmenter

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Modify the Tree

Find Cranial Cavity: BG ICC

Find Tissue: CSF GM WM

Find Substructures: Subcortex Cortex
EM Segmenter (Wells et al. 96)

\[ \hat{B} = \arg \max_B \log \sum_T P(T, B | I) \]
Extended Observed Data

\[ \hat{\mathcal{B}} = \arg\max_{\mathcal{B}} \log \sum_{\mathcal{T}} P(\mathcal{T}, \mathcal{B}|\mathcal{I}, \mathcal{H}) \]

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EM Implementation

Expectation Step: Calculate Weights
\[ \mathcal{W} \equiv \frac{1}{Z} P(I|T, B', H) \cdot P(T|H) \]

Maximization Step: Optimize the estimates
\[ B' \leftarrow \arg \max_B \mathcal{W} \log P(B|I, T, H) \]
Definition of Weights

\[ \mathcal{W} \equiv \frac{1}{Z} P(I|T, B', H) \cdot P(T|H) \]

Intensity Model
Wells \( P(I|T = j, B') \equiv \mathcal{N}(I; B' + \mu_j, \Sigma_j) \)
Modified \( P(I|T = j, B', H) \equiv \mathcal{N}(I; \zeta_H^T(B' + \mu_j), \zeta_H^T \Sigma_j \zeta_H) \)

Spatial Prior
Wells* \( P(T = j) \equiv F_j \)
Modified \( P(T = j|H) \equiv (1 - \lambda_H) \cdot \frac{1}{d} + \lambda_H \cdot F_j \)
Hierarchical Implementation

Input
Images

Labels
Hierarchy

Hierarchical Segmenter

EMSegmenter

Output
Label Map

Priors
Current Bias
Image of ROI

Map of ROI
Updated Bias

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Alternative Prior Model

Simultaneous Registration and Segmentation


Shape Based Segmentation


Implementation in 3D Slicer
EM Segment Workflow

Select Application

Define Preprocessing
Define Task

Tcl Script

Define Pre-processing
EM Segment Workflow

Select Application
Define Preprocessing

Specify Inputs
- Hierarchy
- Target Images
- Atlas Images
Define Hierarchy
EM Segment Workflow

Select Application

Define Preprocessing

Specify Inputs

Hierarchy  Target Images  Atlas Images

Preprocess (Example)

Target Image Normalization  Target-to-target Registration  Atlas-to-target Registration
EM Segment Workflow

Select Application

Define Preprocessing

Specify Inputs
- Hierarchy
- Target Images
- Atlas Images

Preprocess (Example)
- Target Image Normalization
- Target-to-target Registration
- Atlas-to-target Registration

Tune Parameters
- Weights
- Intensity
- Smoothing
EM Segment Workflow

Select Application

Define Preprocessing

Specify Inputs

Hierarchy

Target Images

Atlas Images

Preprocess (Example)

Target Image Normalization

Target-to-target Registration

Atlas-to-target Registration

Tune Parameters

Weights

Intensity

Smoothing

Segmentation

EM Segmentation
Interacting with EM Segmenter

- Fine-tune Setting to Application
- Apply Setting to New Scan
- Command Line Module
Human Brain

Psychiatry Neuroimaging Lab
BWH
Lesion Detection

Progression of Multiple Sclerosis lesions

courtesy of Istvan Csapo
Non-Human Primates

Measuring Alcohol and Stress Interactions with Structural and Perfusion MRI
courtesy of Chris Wyatt
CT Hand Bone Segmentation

Developing patient-specific kinematic models

courtesy of Austin Ramme and Vince Magnotta
Detect internal hemorrhage in the field setting
Segmentation of Microscopy Images

courtesy of Brad Davis

Detecting patterns in biology

Kilian M. Pohl Application
Astronomy Images

Initiative in Innovative Computing, Harvard

Detecting Star Forming Regions

courtesy of Michelle Borkin
Publications


Papers are accessible through https://www.rad.upenn.edu/sbia/Kilian.Pohl/publications
Slicer3 Documentation

• Documentation
  http://www.slicer.org/slicerWiki/index.php/
  Modules:EMSegmentTemplateBuilder3.6

• Developer Page
  Projects:ARRA:SlicerEM:Developer

• NIH Progress Report

• Bug Report
  http://www.na-mic.org/Bug/
Thank You