MCMC in Brain Image Analysis

Eun Young (Regina) Kim
Biomedical Engineering

Motivation

- MR Images are broadly used for Disease Research : Schizophrenia, Alzheimer, Huntington's Disease, Parkinson's, isolated clefts of the lip or palate, and many others
- Currently, Manual tracing method of MR Image is regarded as a gold standard for the analysis.
  - Labor intensive task
  - Inconsistency
  - Large scale data from multi-site
- Development of Reliable Auto-segmentation Method is Mandatory.

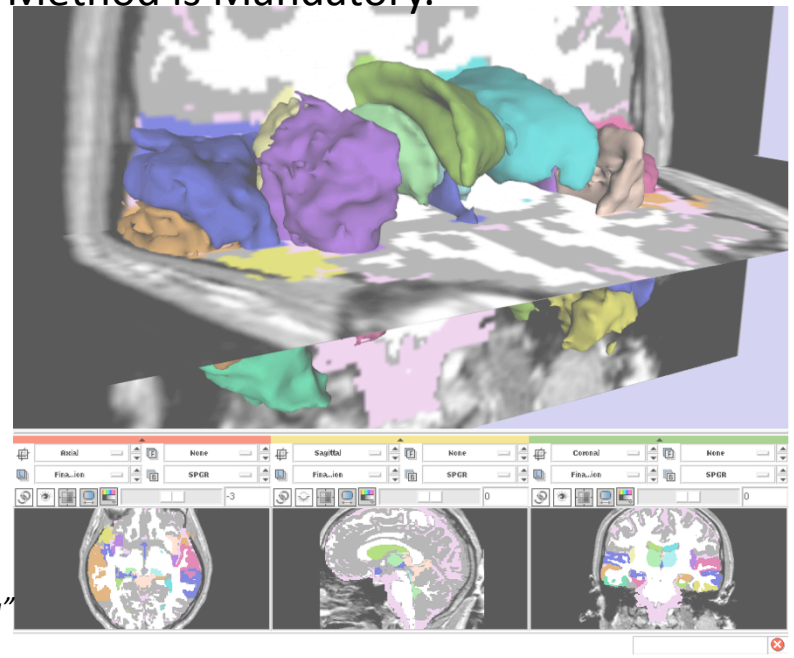


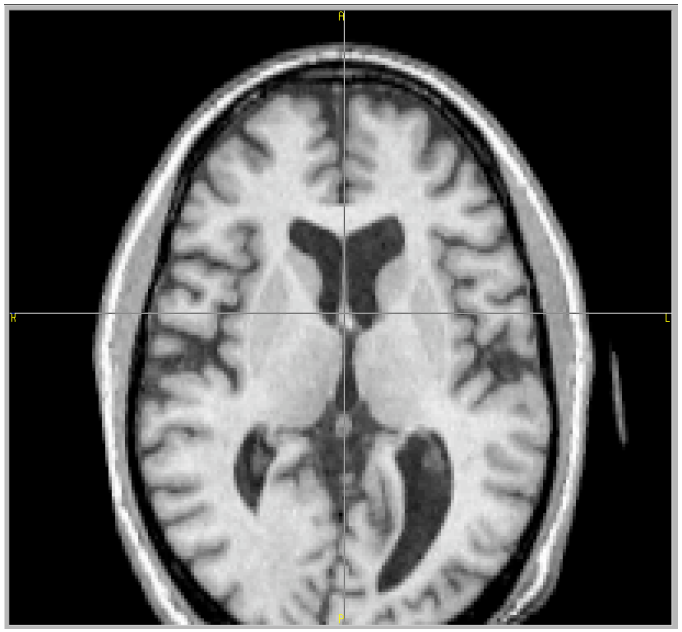
Image from "http://www.slicer.org/slicerWiki/images/f/ff/EMSegment31Structures.png"

Goal

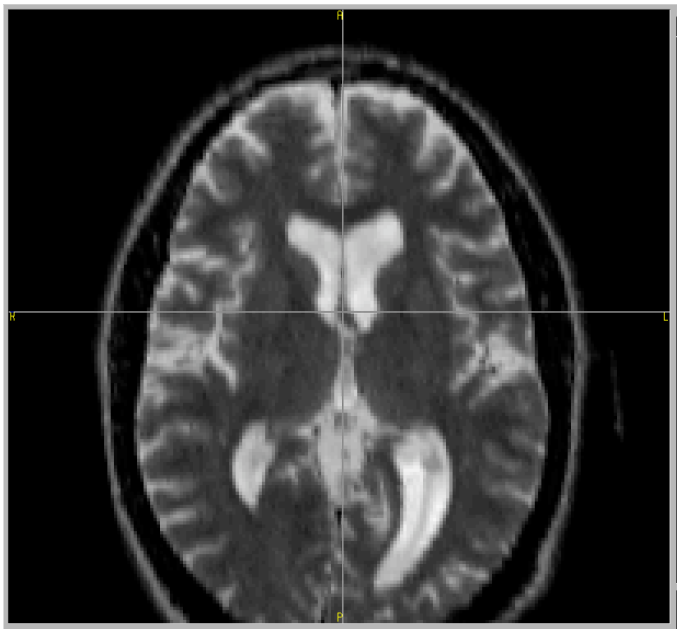
- Base understanding of MCMC procedure for brain image processing
- Procedure understanding thru toy example
- Possibility of MCMC in MR image processing in compare with EM algorithm

Image processing?

- Volumetric measurements for 3 major tissue type
  - Grey matter, White matter and Cerebral fluid
- Given Multi-modality MR images

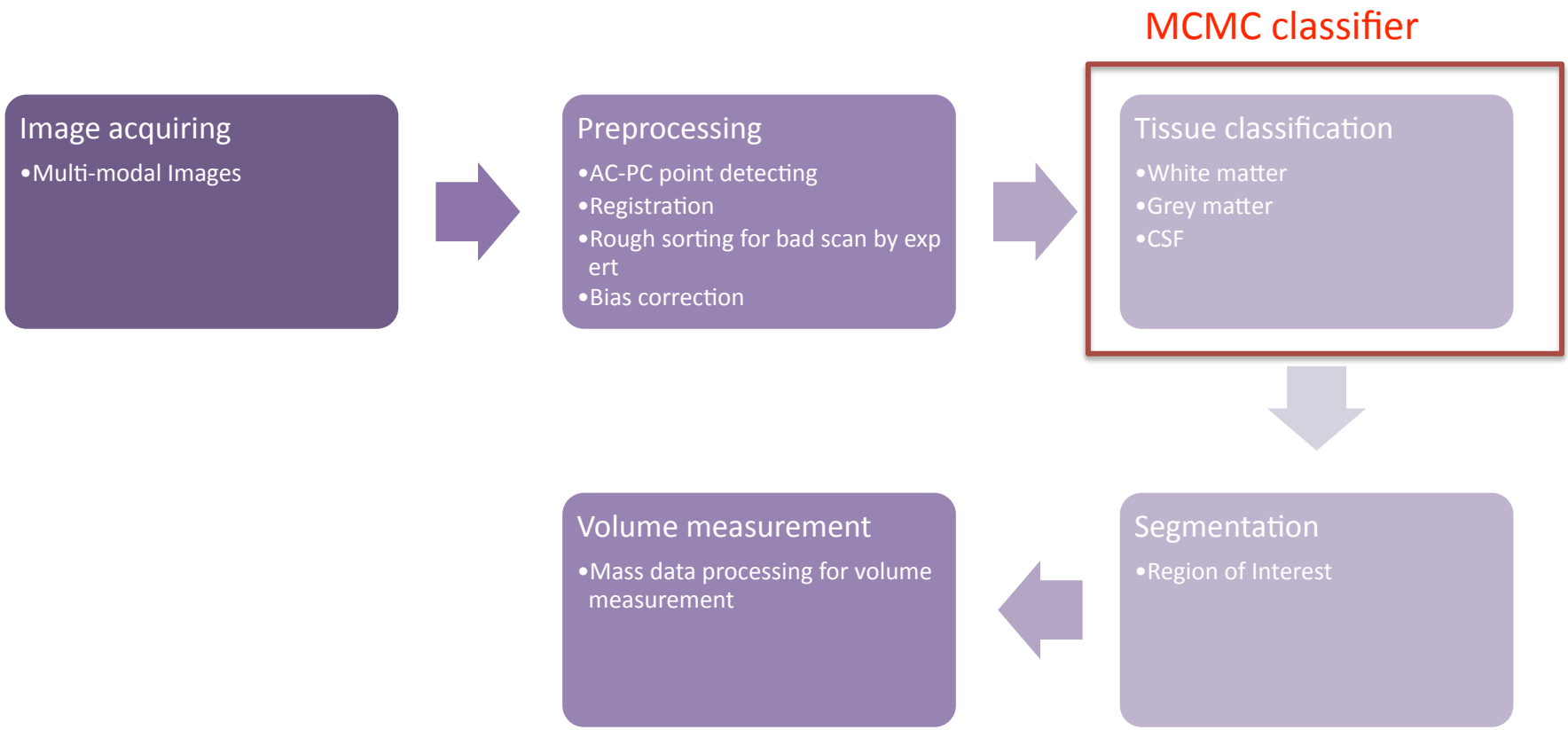


T1-weighted Image



T2-weighted Image

Pipe line of Image processing



Existing EM procedure

- Input
  - T1- and T2-weighted images
  - Spatial Priors
    - White matter, grey matter and CSF
  - Brain Atlas
- Registering Atlas to the subject space
- Until *converge* do *EM procedure*
  - Expectation step
  - Maximization step
- Generate tissue classified image

MCMC model specification for plug-in model using C++

- $Y_i = (Y_{T1i}, Y_{T2i})$ for all i and j = tissue type
- Y ~ Bivariate Multinormial (μ , Σ)
- Priors : from spatial probability maps (from 500 subjects)
- The covariance matrix were fixed for simplicity of the model for now.

Code with C++

- 35 #include <stocc.h> *
- 36 #include <randomc.h> *

… …

- 1384 template <class TInputImage, class TProbabilityImage>
- 1385 void
- 1386 EMSegmentationFilter <TInputImage, TProbabilityImage>
- 1387 ::ComputeBayesPosteriors(bool fullRes)
- 1388 {

… …

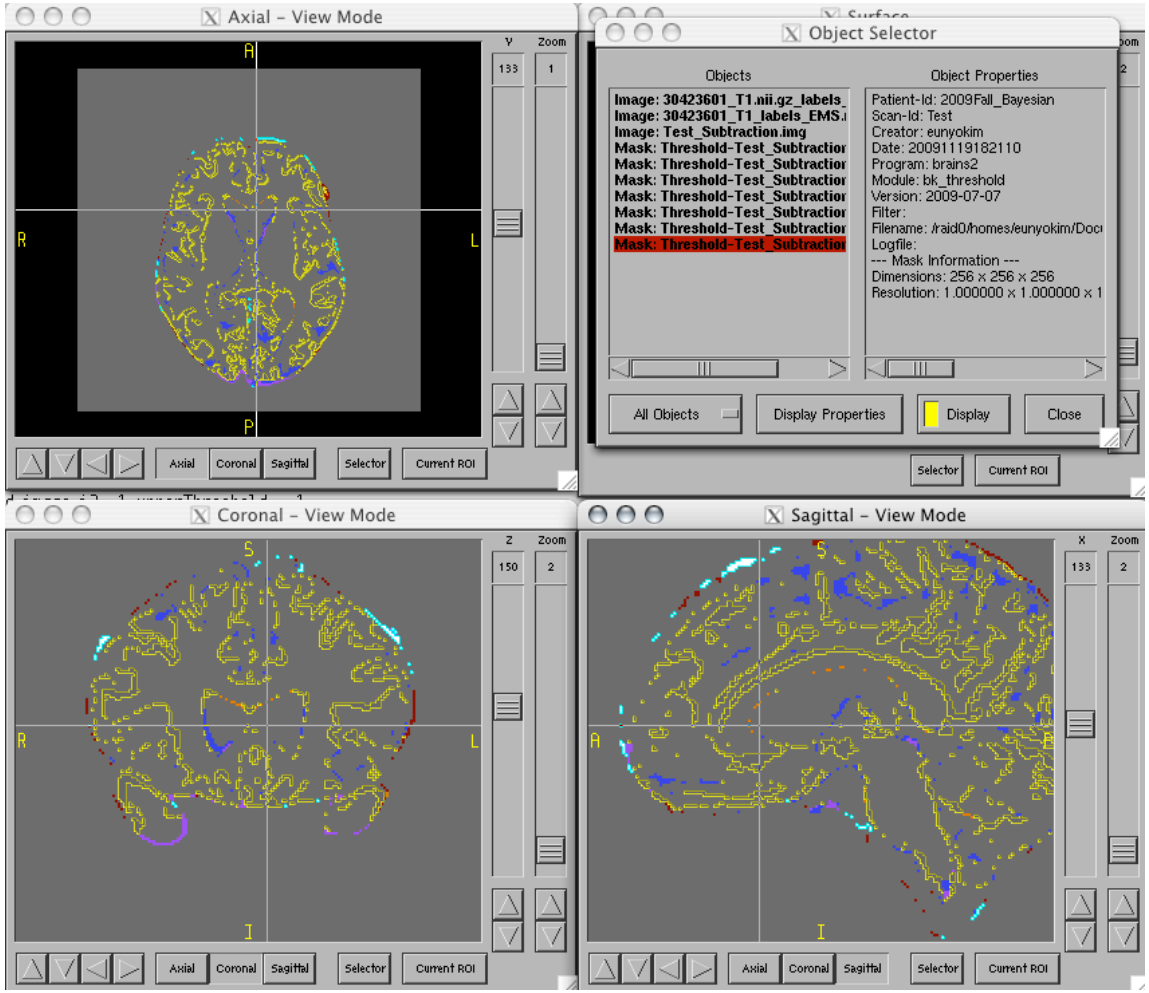
- 1529 }

** http://www.agner.org/random/?e=0,19#0*

Code with C++

```
1426  //==========  Generate Random Number ==========//
1427
1428  double Mean[numChannels];
1429  //Initial Value Assign
1430  for(unsigned int ichan=0; ichan<numChannels; ichan++){
1431    random[ichan][iclass][0]=m_Means(ichan,iclass);
1432    Mean[ichan]=0;
1433
1434  }
1435  //sampling (just for ichan =2 case!!!
1436  for(unsigned int iter=1; iter<MAX_ITER+1 ; iter++){
1437    random[1][iclass][iter]= ( rho * random[2][iclass][iter-1] + c*random_normal.Normal( 0 , 1 ));
1438    random[2][iclass][iter]= ( rho * random[1][iclass][iter]   + c*random_normal.Normal( 0 , 1 ));
1439    std::cout << "PLOT:  T1 : " << random[1][iclass][iter]<<
1440                      "T2 : " << random[2][iclass][iter]<<std::endl;
1441  }
1442
1443  int count=0;
1444  for(unsigned int iter=MAX_ITER/2; iter<MAX_ITER+1 ; iter++){
1445    Mean[1] += random[1][iclass][iter];
1446    Mean[2] += random[2][iclass][iter];
1447    count++;
1448  }
1449  Mean[1]=Mean[1]/count;
1450  Mean[2]=Mean[2]/count;
1451  //================================================//
```

Result comparison between EM and Bayes



Grey = No differences

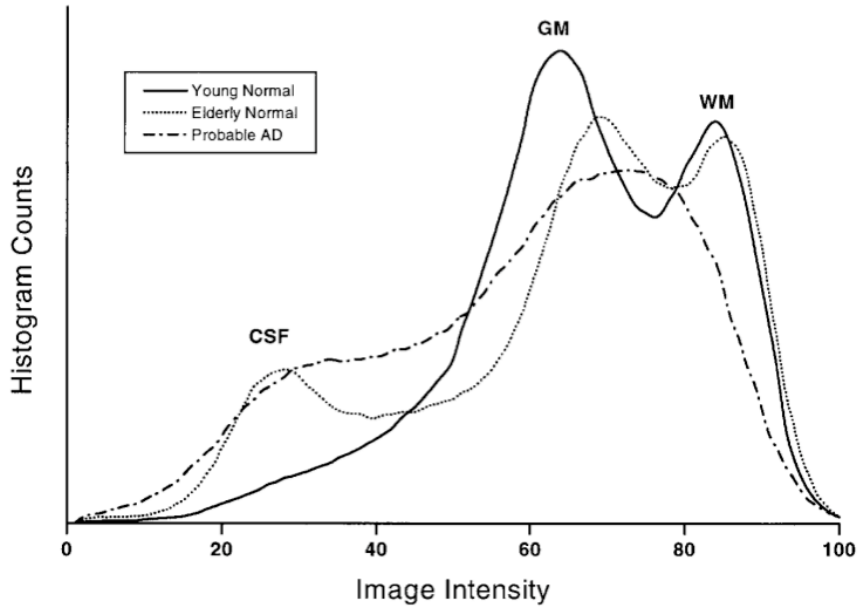
Toy example

- The better result, need to set for distribution for covariance matrix.
- Do not have any specific C++ library which support the Wichart distribution
- WinBug or R?
  - Large data size
  - 256*256*256 = 16,777,216 voxel to process!
- Rcpp and Rincide*
  - Library which we can use for connecting C++ and R applications.

http://dirk.eddelbuettel.com/code/rcpp.html

Difficulties in making toy example

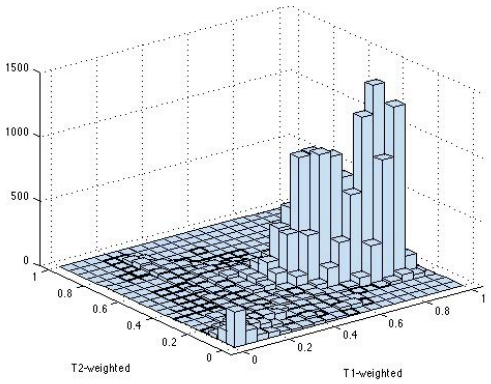
- No convergence
- Appeared to be no distribution no correlation at all
- Interpolating problem



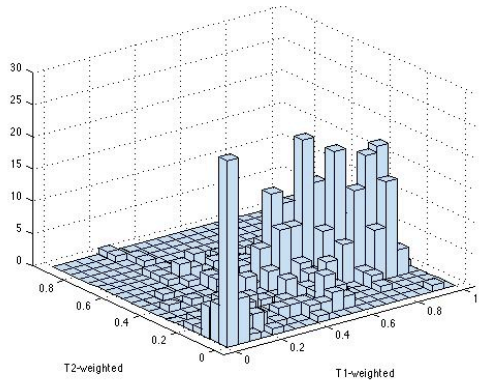
Kostopoulos et al. … of feedforward and probabilistic neural networks for the automatic classification of brain …. Proc 1st Int. Conf. from Scientific Computing to …

Distribution for each tissue class

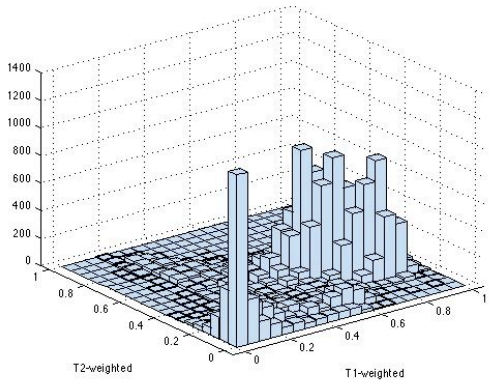
White matter

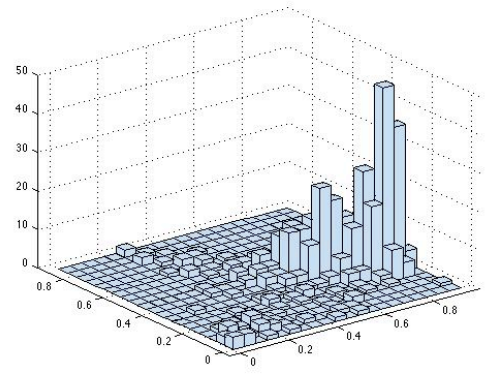


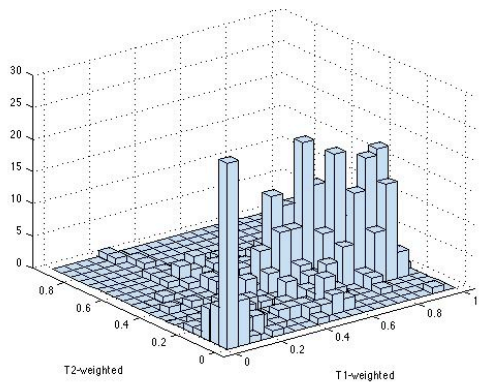
Grey matter

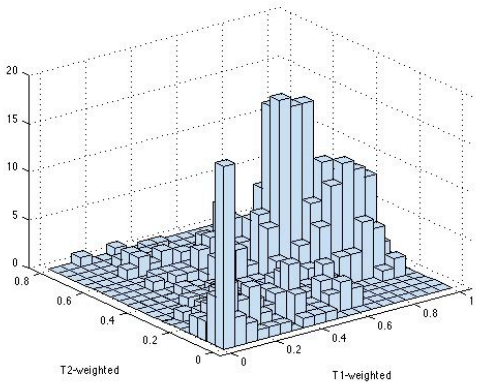


CSF









Conclusion

- Need to have efficient program language to rapid computation
- Winbug and R is good for statistical procedure including random number generation but impractical to use in large data set due to slow computation of control sequences.
- Have seen that Bayes approach may as good as EM algorithm through the fixed covariance matrix model.