

Performance comparison of approximate inference techniques used by WinBugs & Vibes against exact analytical approaches

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WinBugs & Vibes

- WinBugs
 - Uses Gibbs sampling.
 - Runs only on Windows.
 - Allows you to draw Bayesian networks (Doodles).
- Vibes
 - Uses Variational mean field sampling.
 - Built using Java, so runs on any platform.
 - Also allows drawing of Bayesian Networks.

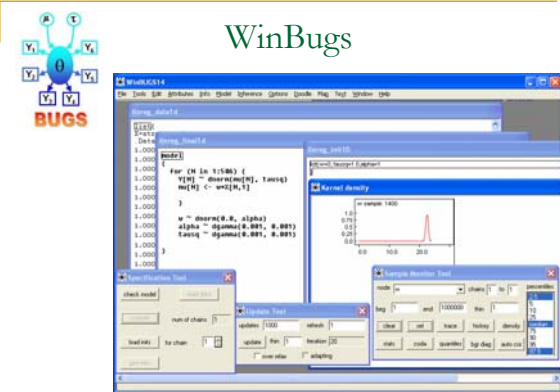
Problem Used to Test the tools:

- Linear Regression
- The same dataset we used in Homework 7.1
 - House prices in Boston area available from the UCI machine learning repository
<http://www.ics.uci.edu/~mlearn/databases/housing/>
 - 506 input data, each data item has 14 columns.
 - I have used the 14th column (house price) as the value to be predicted, and the first 1-13 columns as input features of every data item.

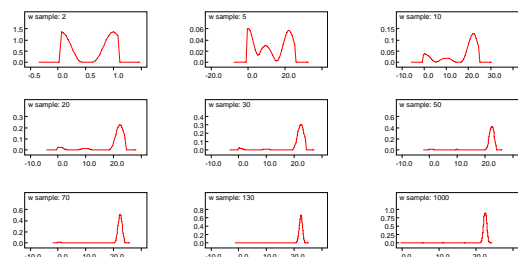
Regression Equation: $f(x; w) = w_0 + \sum_{i=1}^{13} w_i x_i$

Model Assumptions & Initializations

- Weight vector follows Normal Distributions.
- The initial mean is 0.
- For 1-D Gaussian, precision has a gamma prior with a=0.001 & b=0.001
- For 2-D Gaussian, precision has a Wishart prior with R=[1 0; 0 1] & DOF = 2.



1-D Linear Regression in WinBugs: Kernel Density Estimate of Posterior



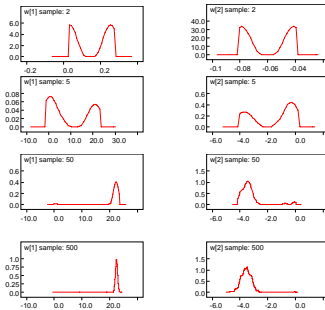
1-D: MAP Estimation Vs. Exact Results

- Final Value Using Bugs:
 - $W = 22.1287608458411$ (mean of all samples)
- Exact estimation
 - $W = 22.5328$ (mean of 14th column across all datasets)
- Converges in approximately 100 updates.

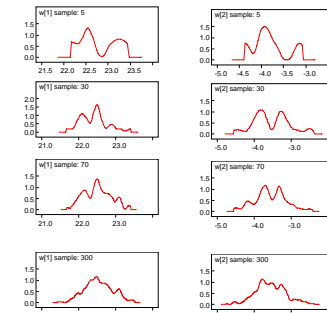
2-D Linear Regression in WinBugs

- Two separate cases analyzed to compare results with Vibes
 - Case 1: Weights are assumed to be uncorrelated (which is not generally the case, but Vibes assumes them to be so).
 - Case 2: The real case where weights are correlated & hence we have a joint Gaussian distribution over all dimensions of w .

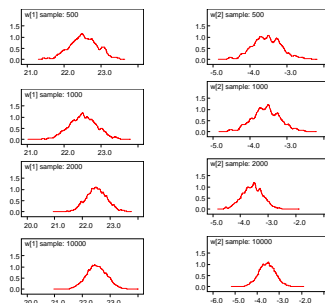
2-D Linear Regression with uncorrelated weights – KDE estimation for each dimension



2-D Linear Regression with correlated weights – KDE estimation of posterior

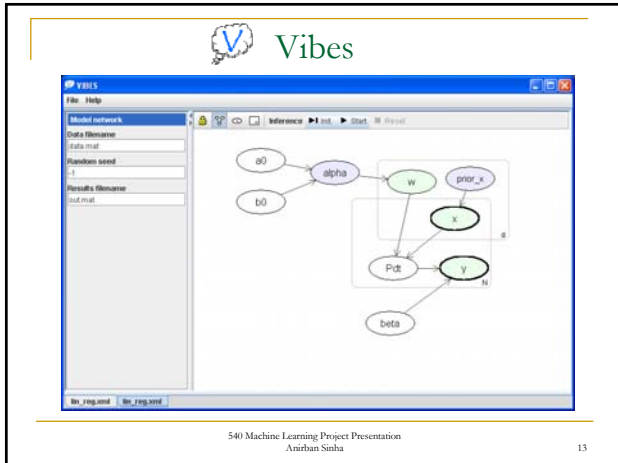


2-D Linear Regression with correlated weights – KDE estimation of posterior – Continued ...



2-D: MAP Estimations & Exact Results

- Final MAP estimates using Bugs (uncorrelated)
 - $w = [22.14718403715704 \ -4.078875081835429]$
 - Converges in 1000 iterations approx.
- Final MAP estimates using Bugs (correlated)
 - $w = [22.37869697123022 \ -2.90123110117053]$
 - Converges in 10,000 iterations or more.
- Exact Analytical Results
 - $w = [22.309000 \ -3.357675]$



Vibes Weaknesses

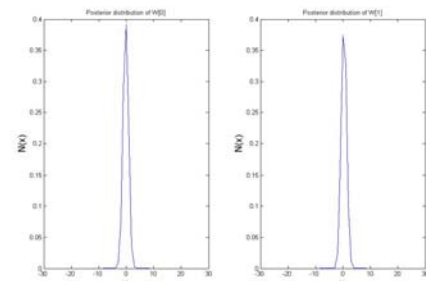
- VIBES doesn't support **conditional density models**, so an uninformative prior on input data is necessary.
- Vibes does not support multivariate Gaussian posterior distributions. Quoting John Winn in his email to me:

“Sadly, the current version of Vibes does not support multivariate Gaussian posterior distributions. Hence, it is not possible to extract a full covariance matrix. It would be a straightforward project to add multivariate Gaussians to VIBES ... Unfortunately, I do not have the time to do this. Apologies ...”

Therefore ...

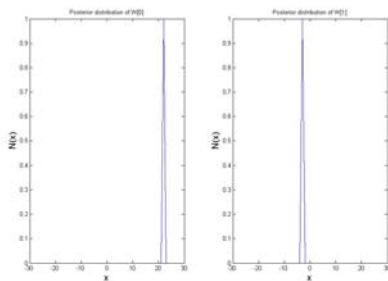
- Our network design is based on 2-D joint posterior distribution.
- However, since we can not extract full covariance matrix, I have taken 1-D plots of the posteriors for each dimensions.
- Also I have taken 2-D plot for the posterior with diagonal covariance matrix.

1-D Gaussian Posterior with each dimension taken separately



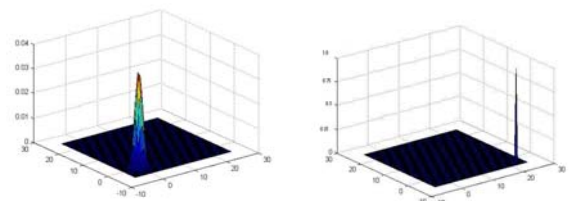
Initialization

1-D Gaussian Posterior with each dimension taken separately



After 1 iteration (converges)

2-D Posterior plots with diagonal covariance matrices



Initialization

After 1 Iteration (converges)

I had also made an AVI demo for it, which did not prove to be very effective because Vibes converges very fast in 2 iterations

MAP Estimations Compared with Exact Estimations

- 2-D weight vectors
 - Estimated $w = [22.308965 \ -3.357670]$
 - Exact $w = [22.309000 \ -3.357675]$
- 14-D weight vectors
 - Estimated weight vector:
[22.5317 -0.9289 1.0823 0.1404 0.6825 -2.0580 2.6771 0.0193 -3.1064 2.6630
-2.0771 -2.0624 0.8501 -3.7470]
 - Exact Weight Vector:
[22.5328 -0.9291 1.0826 0.1410 0.6824 -2.0588 2.6769 0.0195 -3.1071 2.6649
-2.0788 2.0626 0.8501 -3.7473]
 - Converges in approximately 88 iterations

Summary

- Vibes performs better in terms of estimated results & number of iterations (speed).
- However it is extremely limited in terms of number of distributions, models supported & available features like plots.
- WinBugs has many diverse features but no direct Matlab interface except if you use MatBugs.
- I did not find ways to plot 3D Gaussians in Bugs. Is there any?

I am grateful to ...

- Dr. Kevin Murphy, instructor, CPSC 540
- Frank Hutter, TA, CPSC 540
- John Winn, developer Vibes
- Maryam Mahdavian
- Alfred Pang

That's all folks

- Codes with instructions to run them are available from my homepage at:
<http://cs.ubc.ca/~anirbans/ml.html>
- Questions ...