UC Graduate BMI Presentation

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Introduction

- From Cincinnati
- B.S. Computer Engineering (UC 2008)
- M.S. Computer Science (UC 2012)
- Ph.D Computer Science and Engineering (ongoing)

Interests

Some research interests:

- Machine Learning (bioinformatics, filtering)
- Inverse Problems (min/max problems)
- Parallel Computing (CUDA, MPI)
- Distributed Computing (Mapreduce, Spark)
- Big Data

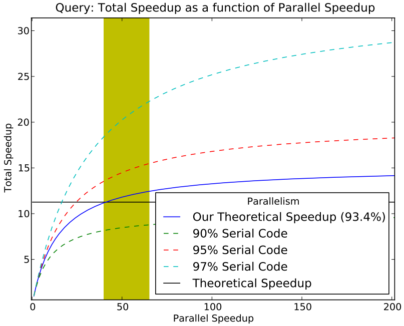
Part 1 BMI Session

- Worked with Prof. Wilsey
- Researched Parallel Algorithms for Data Clustering
- Identified Issues in Clustering and Parallelism
- Formulated ways to combat these problems
- Considered Issues of data privacy
- Advised Jordan Ross in development of Bio Blocks
  https://docs.google.com/document/d/1kES5nI4EXUOtcj9j0D9joEkIpZTgW5hKUAHx0BmjQak/pub

Parallel Clustering Algorithms

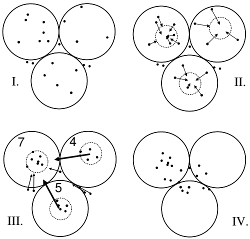
A common algorithmic theme of clustering is iterative updating:

- Format of Kmeans, EM/LDA, and Mean-Shift
- Presents a problem for parallelism (sequential bottleneck/Amdahl)
- Bad during communication



First Attempt - Cardinality Mean Shift

- Partition data across nodes
- Count partition sizes
- Move datapoints toward large partitions



Unsuccessful due to too much communication and the ever present iterative structure.

RPHash

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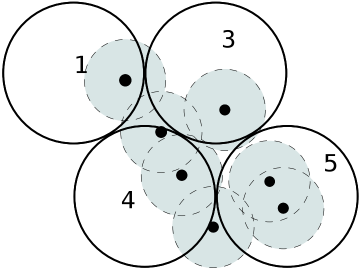
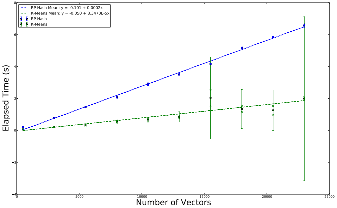
- Random Projection Hash Clustering
- Random Project vectors into a partitions of the Leech Lattice
- Count Lattice Partition Counts
- Accumulate partition counts across nodes(Θ(log-reduce))

An Addition

- Project randomly multiple times for each point
- Projected point has a distribution about the optimal projection (blurring)
- Counting and key-mapping fit well in the map reduce framework



Preliminary Results: Sequential



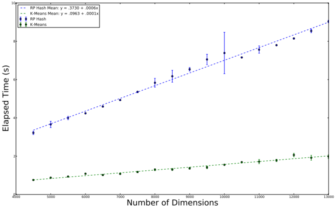


Figure : Computation Time for K-Means(green) and *RPHash*(blue) varying Vectors and Dimensions

- Worse than k-means!
- ok, since we are trading sequential complexity for parallel speedup

RP for data obfuscation

- RP is destructive mapping with possible application to deidentification attack prevention
- Important following infamous attacks
- Presidential Commison of WGS security[**?**]

$$u = \sqrt{\frac{n}{k}} R^T_{d \to s} v, v' = \sqrt{\frac{k}{n}} u^T R^{-1}_{d \to s},$$

$$s(v, v') = ||v, v'||_2,$$

$$\forall \{v, v'\} \in V, \exists \hat{v} \in V : s(v, v') > s(\hat{v}, v) \text{ where } \hat{v} \neq v$$

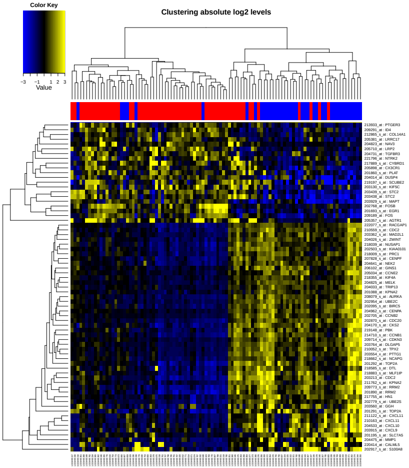
Part 1 Conclusions

- Ongoing research with NSF proposal being recommended for funding.
- Current subject of ongoing dissertation research

Part 2 BMI Session

- Worked with Prof. Medvedovic
- Learned about Gene enrichment and Gaussian Infinite Mixture Model
- Expectation Maximization(EM) in java for MLE of parameters (java)
- Attempt to parallelize GIMM directly on GPU
- Theano: CPU and GPU compiler for math in Python
- Elastic Cloud GIMM server backend

Enrichment in TreeView



Faster than Fisher tests

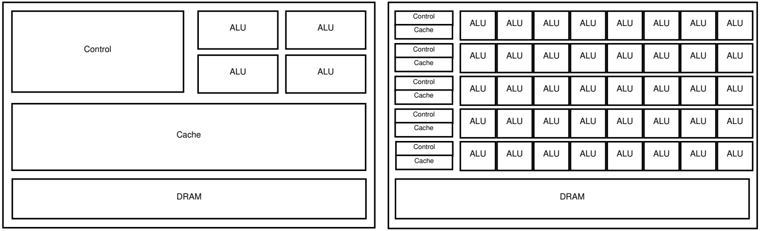
- Differential Expression is important, fisher's..
- MLE can approximate p-values via EM algorithm
- Developed a maximum-likelihood estimator in java, target hadoop
- Hadoop is a Map Reduce(MR) processing engine
- Mahout contains an MR optimized EM algorithm
- GIMM allows for mixture of prob. dist.

GIMM

Gaussian Infinite Mixture Model (sometimes IGMM)

- Instead of EM, GIMM uses Bayesian Estimation
- Gibb's is a Markov Chain Monte Carlo Algorithm
- Gibb's Sampling uses conjugate priors (Dirichlet, Inverse Wishart)
- Main Process is Sampling the Prior Distribution

GPGPU's have lots of ALUs



CPU Multiprocessor GPU Streaming Processor

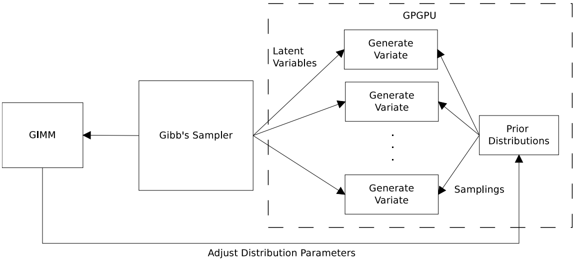
- More Arithmetic Logic Units Compared to Control Logic and Memory
- More common as more libraries leveraging GPU's are made available.
- NVIDIA implementation CUDA, also OpenCL for AMD

GPGPU for R and GIMM

Before trying to implement directly, consider existing GPGPU acceleration in R and Matlab.

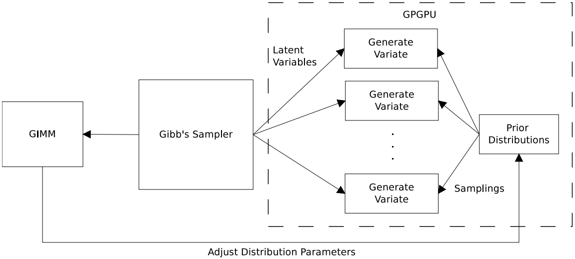
- Matlab has most Lin Alg implemented in CUDA
- Also has keywords for accessing gpu cores
- R has HiPlar - similar to Matlab (Lin Alg, Matrix)
- R can be C so also have direct cuda implementations of code
- gimmR is a compiled binary, so not very useful directly.

GIMM Parallel



- Find parallelizable portions of GIMM (sampler)
- Most of the time spent generating samples
- Performance modeling this part in c and python

GIMM Parallel



- Major Part is the Gibb's Sampler
- Can random distributions be sampled faster
- Fast gamma variate and Gaussian variates
- How do we overlap transfers to improve SPU occupancy and minimize sequential bottleneck

Fast Uniform Random Numbers

- From GPU Gems Nvidia
- Implement a wallace pool prng
- Based on Walsh-Hadamard Matrix
- GPU-based Wallace generator provides a speedup of 26 times

GIMM Parallel

- CUDA installation had many issues, but eventually mostly worked (glu libs were broken)
- A direct CUDA implementation with occupancy tuning would likely be optimal
- Could not fit inverse-wishart code into a single thread's memory
- Global memory is very slow
- Implemented simpler Gaussian sampler
- Issues with data transfer bottleneck are apparent in naive code
- A CUDA implementation is realizable but would require tuning.

GIMM in Python

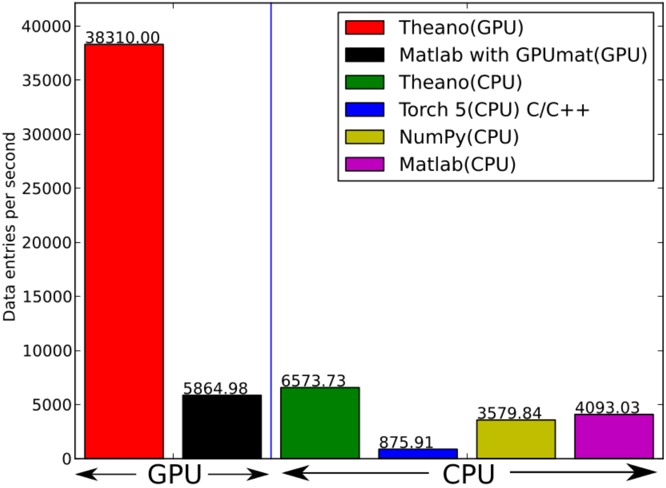
- Scripting Languages are slow, why is this here?
- Pylab/Numpy Give fast access to c functions, like R
- Implement a Gibb's Sampler in python not very fast even with pypy (4x slower than c)
- But there are more inventive ways to interpret Python

Use Theano In Python

Theano is a mathematic expression compiler

- Mathematical expressions are defined in python
- Theano uses many parallel optimized functions from BLAS to turn operations into SIMD vector operations
- Theano supports transparent CUDA (GPGPU) conversion
- overlapped data transfer is automatically performed by Theano

Theano Performance Possibilities



conference.scipy.org/scipy2010/slides/james_bergstra_theano.pdf

Theano Use

- Functions as python module
- Add static decorators to datatypes
- Convert function into expression graphs
- Compile expression graphs into optimized c or gpu code

Theano Performance Possibilities

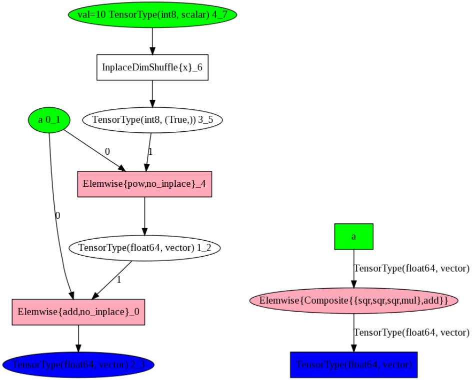
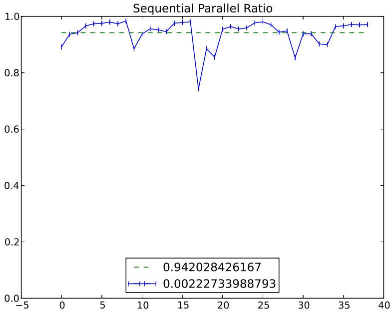


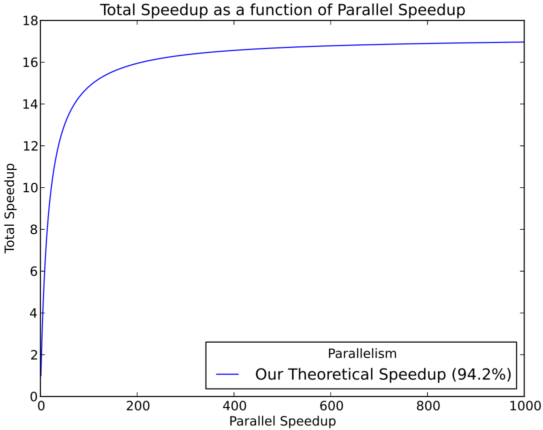
Figure : (http://deeplearning.net/software/theano/tutorial/symbolic_graphs.html)

Performance Profile IGMM



- Majority of processing occurs in the pdf generation
- 94.2% can be sped up by focusing here
- pdf generation is naively parallel

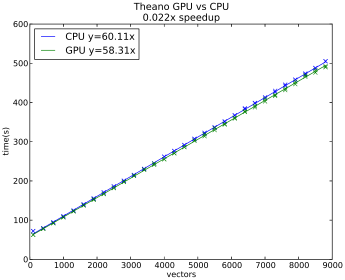
Applying Amdahl's Law

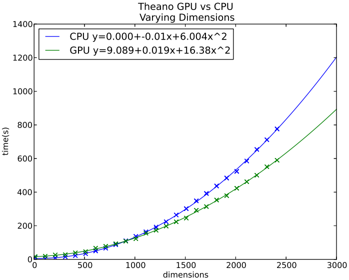


Applying Amdahl's Law on 94.2% sequential to parallel ratio.

Theano GPU vs CPU

Real World Speedup?



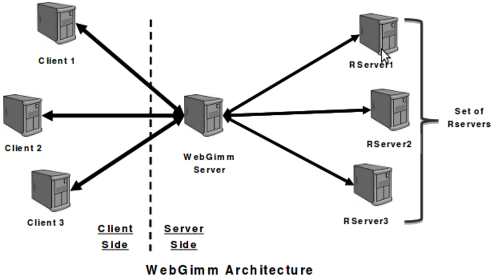


- Cost of JIT and cpu→gpu transfer times
- Dimension calls are vector ops in Theano,
  - More data per DMA transfer cycle

A step back to see what is really needed

- Individual problems aren't really big data problems
- The issue is more of user load balancing and resource allocation (and unallocation)
- Load balancing independent jobs is parallel
- This suggested utilizing elastic computing services

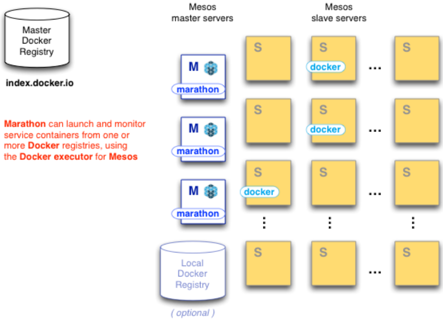
WebGimm



eh3.uc.edu/gimm/webgimm/files/deployment.pdf

- A webserver and backend processing model
- GIMM server backends exist but are fixed to physical available machines
- Elastic cloud services can spin up an down lxc containers as needed

Docker and LXC



tctechcrunch2011.files.wordpress.com/2013/09/mesos-docker-1.png

- Created a linux container with the GIMM server modules for dynamic creation

Distributed Frameworks

- Attempted to setup internal cluster
- Attempts with Mesos, Cloudera and Pivotal phd could not be properly configured
- More custom method with just lxc and standard installations

Work In Progress

- Setting up docker containers
- Automating creation and destruction of containers
- Updating WebGimm interface to control container creation
- Security of creation credentials

Conclusions

- Attempts to find more efficient parallel implementations of GIMM proved difficult
- Some methods are promising such as Theano
- The Container of the GIMM Server could very likely be launched in an elastic cloud for dynamic resource allocation, or internal to a University network