

18-645: How to write fast code, Spring 2015

## **Project #1 – Multicore Optimization**

**Due: February 4, 2015, 11:00pm EDT, 8:00pm PDT**

The goal of this project is to use your understanding of parallel computing resources in a multicore microprocessor to optimize two fully functional applications. The applications are Matrix Multiple and K-means Clustering.

For a functional description of the applications, please refer to:

[http://en.wikipedia.org/wiki/Matrix\\_multiplication](http://en.wikipedia.org/wiki/Matrix_multiplication)

<http://en.wikipedia.org/wiki/K-means>

The code optimization techniques you may want to consider are explained in Module 1 and Module 2 which includes:

- Cache blocking
- OpenMP pragma-based optimizations
  - omp parallel
  - omp for
  - omp atomic
  - omp reduction
- Intrinsics Programming

## Task 0: Look at Jenkins

Jenkins is an Open Source software production management platform. It provides a web interface to keep track of the progress of the projects.

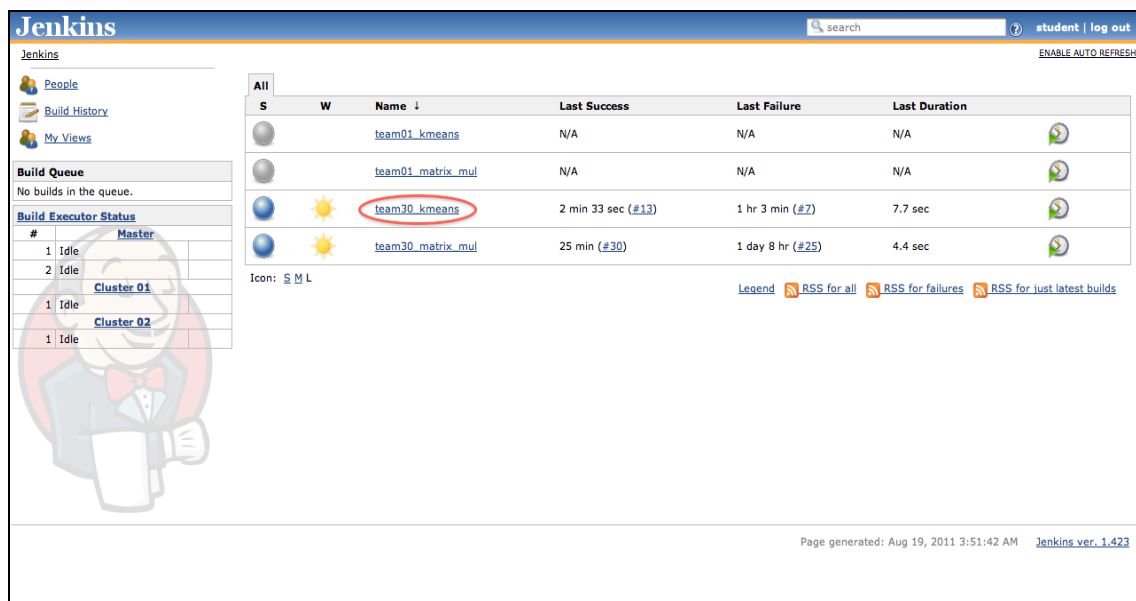
Visit

<http://fast645.info:8080>

User: student

Password: 18645

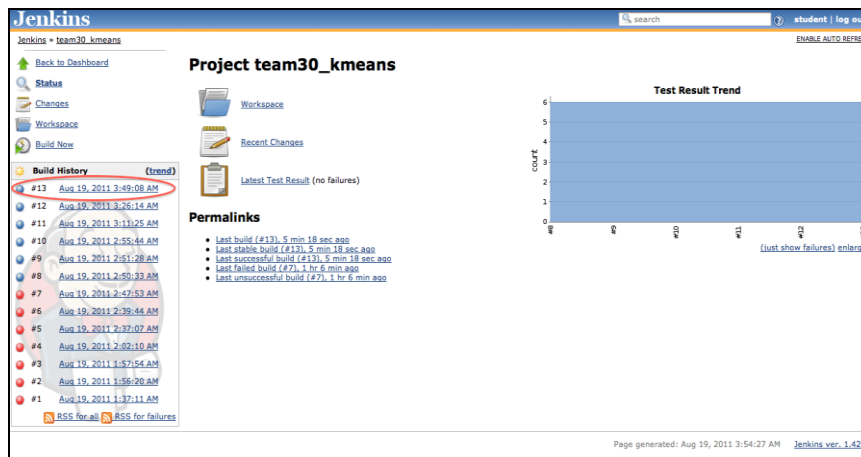
All students can view all team's results. For example to view Team30's execution results, click on the team030\_kmeans project:



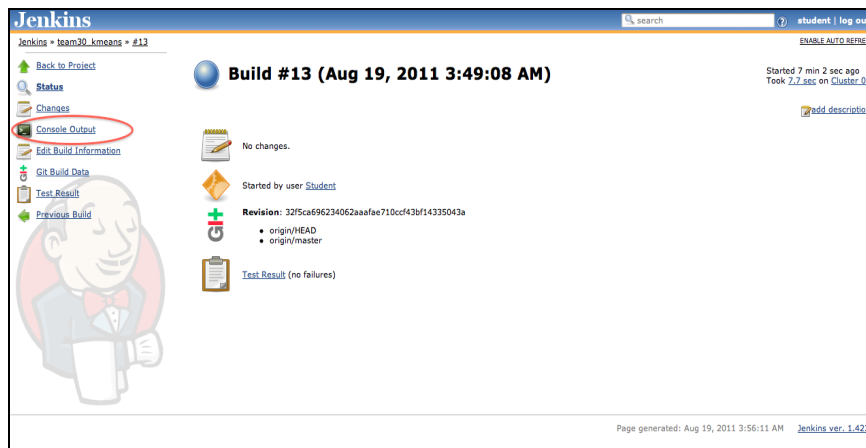
The screenshot shows the Jenkins web interface. On the left, there's a sidebar with links for 'People', 'Build History', and 'My Views'. Below these, the 'Build Queue' section shows 'No builds in the queue.' The 'Build Executor Status' section shows a table of executors: Master (1 Idle), Cluster 01 (1 Idle), and Cluster 02 (1 Idle). The main area displays a table of builds. The table has columns for 'S' (Status), 'W' (Workspace), 'Name', 'Last Success', 'Last Failure', and 'Last Duration'. The 'Name' column is sorted in descending order. The 'team30\_kmeans' build is highlighted with a red circle. Below the table, there's a legend for RSS feeds: 'RSS for all', 'RSS for failures', and 'RSS for just latest builds'. The footer shows 'Page generated: Aug 19, 2011 3:51:42 AM' and 'Jenkins ver. 1.423'.

S	W	Name ↓	Last Success	Last Failure	Last Duration
●		<a href="#">team01_kmeans</a>	N/A	N/A	N/A
●		<a href="#">team01_matrix_mul</a>	N/A	N/A	N/A
●	☀	<a href="#">team30_kmeans</a>	2 min 33 sec (#13)	1 hr 3 min (#7)	7.7 sec
●	☀	<a href="#">team30_matrix_mul</a>	25 min (#30)	1 day 8 hr (#25)	4.4 sec

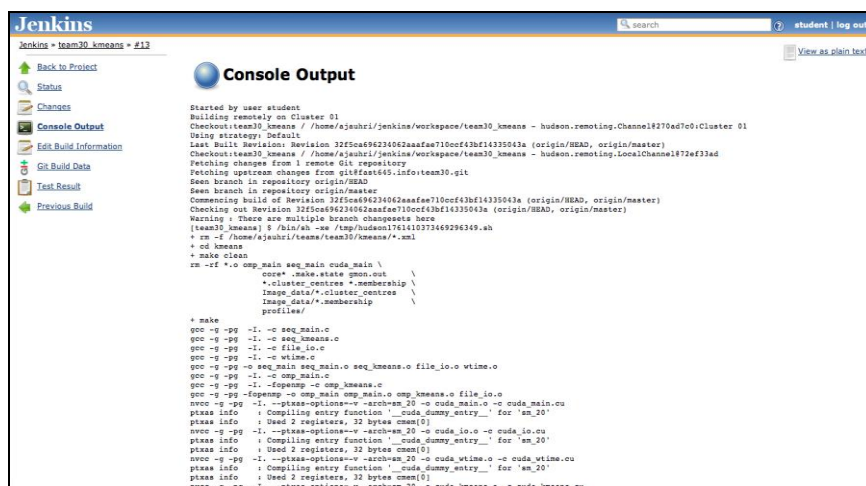
Then, click on a successful build:



To view the performance, use the Console Output link:



The performance would then be available:



Please check the console output for `matrix_mul` & `kmeans` algorithms, and answer questions 1 & 2.

**Question 1:** For your team's `matrix_mul` application, please report the runtime for sequential and OpenMP implementations.

**Question 2:** For your team's K-means project, please report:

- a) The configuration of the K-means algorithm being tested  
i.e. `numObjs`, `numCoords`, `numClusters`, `threshold`

The runtime for I/O and computation for sequential and OpenMP implementations. (Note: The console output might show results of multiple input files. You are expected to report runtime for any one input file)

## Step 1: Cloning a *git* repository

You can get the initial version of the code using (**already done if HW1 is complete**):

```
$ cd ~/645/fastcode
$ git pull origin master # To make sure you have the latest version of the code
```

## The structure of the project

```
matrix_mul:
  Makefile
  matrix_mul_01.dat
  matrix_mul_02.dat
  cuda
    Makefile
    matrix_mul.cu
    matrix_mul.h
    tests.cpp
  omp
    Makefile
    matrix_mul.cpp <== To optimize
    matrix_mul.h
    tests.cpp
  sequential
    Makefile
    matrix_mul.cpp
    matrix_mul.h
    tests.cpp
  tests
    testutil.h

kmeans
  LICENSE
  Makefile
  README
  benchmark.sh
  cuda_io.cu
  cuda_kmeans.cu
  cuda_main.cu
  cuda_wtime.cu
  file_io.c
  gmon.out
  go
  kmeans.h
  omp_kmeans.c <== To optimize
  omp_main.c
  sample.output
  seq_kmeans.c
  seq_main.c
  wtime.c
  Image_data
```

## Step 2: Code optimization

For project “matrix\_mul” OpenMP implementations, please apply your optimization only to the content of the “matrix\_multiplication” function in the file “matrix\_mul.cpp”.

For project “kmeans” OpenMP implementations, please make your changes only to the content of the “omp\_kmeans” functions in files “omp\_kmeans.c”. Testing data for kmeans can be downloaded from below, assuming that you are working from a GHC Machine:

```
$ # To be performed by each team member
$ cd ~/645
$ wget https://cmu.box.com/shared/static/6odccg52untmq8p9szsk24m7wr84ptz2.gz -O 18645_spring_15_data.tar.gz
$ tar -xzf 18645_spring_15_data.tar.gz
$ # This should create a folder named data within ~/645
```

**NOTE: Please **DO NOT** add kmeans testing data (kmeans01.dat ~ kmeans04.dat) to your git repository. They bloat the repository.**

**NOTE: It is crucial that your **DO NOT** change the interface. Any changes in the interface could result in your work not testable by our test infrastructure and you will receive no credit.**

To compile the code, simply type “Make” in the project directory.

To run the code and see runtime:

For kmeans:

```
./omp_main -i ~/645/data/kmeans01.dat -n 3
```

For matrix\_mul:

```
./matrix_mul -i ../matrix_mul_02.dat
```

Commit your code frequently to your local repository by doing:

```
git commit -a -m "description"
```

### Step 3: Push your changes to the server

To share your optimizations with us, you will need to “push” the changes to the remote repository.

```
git push origin master
```

<http://www.kernel.org/pub/software/scm/git/docs/everyday.html>

## Step 4: Look at Jenkins

Visit <http://fast645.info:8080>

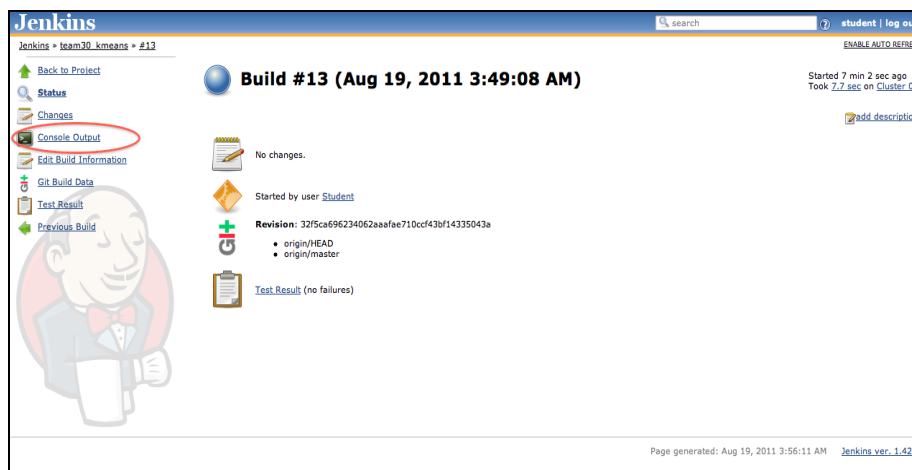
User: student

Password: 18645

Check the Jenkins website to see if your project ran through properly. Make sure you are looking at your team's project!

Then, click on the latest build:

To view the performance, use the Console Output link:



## Step 5: Is the performance good enough?

If yes, look at the other application. If no, go back to step 2 and try another optimization. You are expected to try at least 3 optimizations per application.



## Grading criteria

- 5% - Task 0 Answers
- 30% - Correctness - Correctness of the results (program output)
- 30% - Performance –
  - MatrixMultiply:  
For OpenMP version, achieving **at least 5X** speed up compared to **sequential version** (SUM of all the testcases – matrix\_mul\_02.dat)
  - K-means:  
For OpenMP version, achieving **at least 1.5x** speedup compared to current **OpenMP version** (SUM of all the tests)
- 25% - Write up – Clearly describing, for each performance optimization,
  - how the speed up works
  - what is the expected speed up
  - what is the observed speed up
  - an explanation of any difference between the expected and observed speed ups
- 10% - Code quality - Good coding practices and well commented code

## Guidelines for the write up:

Minimum of one 8.5x11 page write-up for each optimization. The write up should include:

- Optimization goal:
  - Hardware resources being optimized toward?  
(cache? SIMD? multicore?)
  - What is the specification of the hardware you are optimizing for?
- Optimization process:
  - Data considerations
  - Parallelization considerations
- Optimization results:
  - Performance before optimization
  - Performance after optimization

Two teams with the fastest project in the class will be asked to do a 10min presentation each on what they tried.

We will look at the code of the slowest two implementations as a class. The class will discuss why their code is slow.