Mini-Project 1 – Multicore Programming
Due: Monday, Feburary 28th, 11:59PM EST

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/K-Means

The code optimization techniques you may want to consider include:

- Cache blocking

- OpenMP pragma-based optimizations
  - omp parallel
  - omp for
  - omp atomic
  - omp reduction

- Intrinsics Programming

Grading Criteria

- 30% - Correctness - Correctness of the results (program output)

- 30% - Performance
    - `matrix_mul/omp/matrix_mul.cpp` (Matrix Multiply):
      Achieve **at least a 2x** speed up compared to the current **OpenMP version** (SUM of all the testcases on `matrix_mul_03.dat`)
    - `kmeans/omp_kmeans.c` (K-means):
      Achieve **at least a 5x** speed up compared to the current **OpenMP version** (SUM of all tests)

- 30% - Write up - For each performance optimization explored, describe clearly:
    - 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

The three teams with the fastest implementations will present the techniques they attempted in a 10-minute presentation during the project review session.

Mini-Project 1 - Setup

Step 1: Download the initial version of the code

```
$ cd ~/
$ cp /afs/andrew.cmu.edu/course/18/646/MP1/18646_MP1.tar.gz ~/
$ tar xzvf 18646_MP1.tar.gz
$ ln -s /afs/andrew.cmu.edu/course/18/646/MP1/data/*.dat ~/18646_MP1/data/
$ tree 18646_MP1
18646_MP1
├── data
│   ├── kmeans01.dat -> /afs/… …/data/data/kmeans01.dat
│   ├── kmeans02.dat -> /afs/… …/data/data/kmeans02.dat
│   ├── kmeans03.dat -> /afs/… …/data/data/kmeans03.dat
│   └── kmeans04.dat -> /afs/… …/data/data/kmeans04.dat
├── kmeans
│   ├── file_io.c
│   ├── kmeans.h
│   ├── Makefile
│   ├── omp_kmeans.c          <<== To optimize (K-Means)
│   ├── omp_main.c
│   ├── seq_kmeans.c
│   ├── seq_main.c
│   └── wtime.c
└── matrix_mul
    ├── matrix_mul_01.dat
    ├── matrix_mul_02.dat
    ├── matrix_mul_03.dat
    ├── omp
    │   ├── Makefile
    │   ├── matrix_mul.cpp  <<== To optimize (Matrix Multiply)
    │   ├── matrix_mul.h
    │   └── tests.cpp
    └── tests
        └── testutil.h

5 directories, 20 files
```

Step 2: Optimize your code

- For the project "**<u>matrix_mul</u>**", please apply your optimization only to the content of the "`matrix_multiplication`" function in "`matrix_mul/omp/matrix_mul.cpp`".

- For the project "**<u>kmeans</u>**", only make changes to the file "`kmeans/omp_kmeans.c`".

Note: DO NOT change the function interface. Any changes in the interface could result in your work not working in our test infrastructure and you will receive no credit.

To compile the code, simply type "`make`" in the appropriate project directory.

For **matrix_mul**:
```
$ cd ~/18646_MP1/matrix_mul/omp
$ make
$ ./matrix_mul -i ../matrix_mul_03.dat -o
```

For **kmeans**:
```
$ cd ~/18646_MP1/kmeans
$ make
$ ./omp_main -i ~/18646_MP1/data/kmeans03.dat -n 32
```

Step 3: Submit your optimized code (`matrix_mul.cpp` and `omp_kmeans.c`) and project write up to gradescope

Submit your optimized version of `matrix_mul.cpp` to the Matrix Multiply programming assignment on gradescope: https://www.gradescope.com/courses/357643/assignments/1789253

Submit your optimized version of `omp_kmeans.c` to the K-Means programming assignment on gradescope: https://www.gradescope.com/courses/357643/assignments/1789251

Submit your team project writeup to:
https://www.gradescope.com/courses/357643/assignments/1789255