

HW3: Timings and Timing Statement

Jonathan Land

My HW3 program produces timing results for the following methods: (1) the time taken to multiply the matrix and vector, (2) the normalization time, and (3) the time taken to calculate the Eigen value. As can be seen below, when compared to the serial part of the code, my program shows evidence of speedup in most cases. Within the zip file also there are graphs, if needed, with the times. The starting value was sometimes erratic, especially for matrix 4. This could be because other people were on Xeon Phil when I ran my tests. At any rate, again, there is speedup in most of all of my tests.

The following is a synopsis of timing the results on QBert and Xeon Phi with speedup and screenshots.

Timings: Q-Bert

Q-Bert: Big Matrix 3

```
[jland@qbert HW3_CODE]$ ./hw3 1 /home/public/5260-matrices/mat.big3  
  
>>Iterations: 10  
>>Eigenvalue: 10.499298266131  
>>Number Of Threads: 1  
>>Timings: Multiply Normalize Eigenvalue  
          0.910865  0.047041  0.037286  
  
[jland@qbert HW3_CODE]$ ./hw3 2 /home/public/5260-matrices/mat.big3  
  
>>Iterations: 10  
>>Eigenvalue: 10.499298266131  
>>Number Of Threads: 2  
>>Timings: Multiply Normalize Eigenvalue  
          0.542956  0.025307  0.038229  
  
[jland@qbert HW3_CODE]$ ./hw3 4 /home/public/5260-matrices/mat.big3  
  
>>Iterations: 10  
>>Eigenvalue: 10.499298266131  
>>Number Of Threads: 4  
>>Timings: Multiply Normalize Eigenvalue  
          0.285459  0.013254  0.038619  
  
[jland@qbert HW3_CODE]$ ./hw3 8 /home/public/5260-matrices/mat.big3  
  
>>Iterations: 10  
>>Eigenvalue: 10.499298266131  
>>Number Of Threads: 8  
>>Timings: Multiply Normalize Eigenvalue  
          0.164558  0.007321  0.042450  
  
[jland@qbert HW3_CODE]$ ./hw3 16 /home/public/5260-matrices/mat.big3  
  
>>Iterations: 10  
>>Eigenvalue: 10.499298266131  
>>Number Of Threads: 16
```

```
>>Timings:      Multiply   Normalize       Eigenvalue
                0.094163   0.007963   0.049985
```

Q-Bert: Big Matrix 3 Speedup Data (General)

Threads	Multiply Time	Normalize Time	Eigen Value Time	Iterations	Eigen Value Produced
1 (Tseq)	0.910865	0.047041	0.037286	10	10.499298266131
2	0.542956	0.025307	0.038229	10	10.499298266131
4	0.285459	0.013254	0.038619	10	10.499298266131
8	0.164558	0.007321	0.042450	10	10.499298266131
16	0.094163	0.007963	0.049985	10	10.499298266131

Q-Bert: Big Matrix 3 Speedup (Specific [total serial / total parallel])

Total Tseq = 0.995192

Threads	Tseq/Tpar = Speedup	Speedup
1	Tseq = 0.995192	1
2	Tseq/0.606492 = 1.640898808	2
4	Tseq/ 0.337332= 2.950185574	3
8	Tseq/ 0.214329= 4.643291388	6
16	Tseq/ 0.152111= 6.542538015	7

Q-Bert: Big Matrix 3 Screenshots

```
Terminal Shell Edit View Window Help HW3_CODE — jland@qbert:~/HW3_CODE — ssh jland@qbert.utc.edu — 141x41
>>Eigenvalue: 10.499298266131
>>Number Of Threads: 2
>>Timings:   Multiply   Normalize   Eigenvalue
             0.558409   0.025831   0.038569

[jland@qbert HW3_CODE]$ ./hw3 4 /home/public/5260-matrices/mat.big3
[
>>Iterations: 10
>>Eigenvalue: 10.499298266131
>>Number Of Threads: 4
>>Timings:   Multiply   Normalize   Eigenvalue
             0.284469   0.013607   0.039969

[jland@qbert HW3_CODE]$ g++ -o hw3 -fopenmp openMP_hw3.c
[[jland@qbert HW3_CODE]$ ./hw3 4 /home/public/5260-matrices/mat.big5
[
>>Iterations: 7
>>Eigenvalue: 5854.486686647850
>>Number Of Threads: 4
>>Timings:   Multiply   Normalize   Eigenvalue
             0.457792   0.000108   0.000582

[jland@qbert HW3_CODE]$ ./hw3 1 /home/public/5260-matrices/mat.big3
[
>>Iterations: 10
>>Eigenvalue: 10.499298266131
>>Number Of Threads: 1
>>Timings:   Multiply   Normalize   Eigenvalue
             0.918865   0.047841   0.037286

[jland@qbert HW3_CODE]$ ./hw3 2 /home/public/5260-matrices/mat.big3
[
>>Iterations: 10
>>Eigenvalue: 10.499298266131
>>Number Of Threads: 2
>>Timings:   Multiply   Normalize   Eigenvalue
             0.542956   0.025307   0.038229

[jland@qbert HW3_CODE]$ ./hw3 3 /home/public/5260-matrices/mat.big3
[
>>Iterations: 10

Terminal Shell Edit View Window Help HW3_CODE — jland@qbert:~/HW3_CODE — ssh jland@qbert.utc.edu — 141x41
>>Eigenvalue: 10.499298266131
>>Number Of Threads: 3
>>Timings:   Multiply   Normalize   Eigenvalue
             0.359275   0.017427   0.038704

[jland@qbert HW3_CODE]$ ./hw3 4 /home/public/5260-matrices/mat.big3
[
>>Iterations: 10
>>Eigenvalue: 10.499298266131
>>Number Of Threads: 4
>>Timings:   Multiply   Normalize   Eigenvalue
             0.285459   0.013254   0.038619

[jland@qbert HW3_CODE]$ ./hw3 8 /home/public/5260-matrices/mat.big3
[
>>Iterations: 10
>>Eigenvalue: 10.499298266131
>>Number Of Threads: 8
>>Timings:   Multiply   Normalize   Eigenvalue
             0.164558   0.007321   0.042450

[jland@qbert HW3_CODE]$ ./hw3 16 /home/public/5260-matrices/mat.big3
[
>>Iterations: 10
>>Eigenvalue: 10.499298266131
>>Number Of Threads: 16
>>Timings:   Multiply   Normalize   Eigenvalue
             0.094163   0.007963   0.049985

[[jland@qbert HW3_CODE]$ g++ -o hw3 -fopenmp openMP_hw3.c
[[jland@qbert HW3_CODE]$ ./hw3 1 /home/public/5260-matrices/mat.big4
>>Iterations: 10
>>Eigenvalue: -nan
>>Number Of Threads: 1
>>Timings:   Multiply   Normalize   Eigenvalue
             365.549840   0.334266   0.376843

[[jland@qbert HW3_CODE]$ g++ -o hw3 -fopenmp openMP_hw3.c
[[jland@qbert HW3_CODE]$ ./hw3 2 /home/public/5260-matrices/mat.big4
```

Q-Bert: Big Matrix 4

```
>>Iterations: 10
>>Eigenvalue: -nan
>>Number Of Threads: 1
>>Timings:      Multiply   Normalize   Eigenvalue
                365.549840    0.334266    0.376843

[jland@qbert HW3_CODE]$ g++ -o hw3 -fopenmp openMP_hw3.c
[jland@qbert HW3_CODE]$ ./hw3 2 /home/public/5260-matrices/mat.big4

>>Iterations: 10
>>Eigenvalue: -nan
>>Number Of Threads: 2
>>Timings:      Multiply   Normalize   Eigenvalue
                205.981373    0.166324    0.374574

[jland@qbert HW3_CODE]$ ./hw3 4 /home/public/5260-matrices/mat.big4

>>Iterations: 10
>>Eigenvalue: -nan
>>Number Of Threads: 4
>>Timings:      Multiply   Normalize   Eigenvalue
                102.218020    0.087106    0.394267

[jland@qbert HW3_CODE]$ ./hw3 8 /home/public/5260-matrices/mat.big4

>>Iterations: 10
>>Eigenvalue: -nan
>>Number Of Threads: 8
>>Timings:      Multiply   Normalize   Eigenvalue
                53.648004     0.063517    0.420894

[jland@qbert HW3_CODE]$ ./hw3 16 /home/public/5260-matrices/mat.big4

>>Iterations: 10
>>Eigenvalue: -nan
>>Number Of Threads: 16
>>Timings:      Multiply   Normalize   Eigenvalue
                28.936386     0.065839    0.479817
```

Q-Bert: Big Matrix 4 Speedup Data (General)

Threads	Multiply	Normalize	Eigen Value	Iterations	Eigen Value Produced
1	365.549840	0.334266	0.376843	10	nan
2	205.981373	0.166324	0.374574	10	nan
4	102.218020	0.087106	0.394267	10	nan
8	53.648004	0.063517	0.420894	10	nan
16	28.936386	0.065839	0.479817	10	nan

Q-Bert: Big Matrix 4 Speedup (Specific [total serial / total parallel])

Total Tseq = 366.260949

Threads	Tseq/Tpar = Speedup	Speedup
1	Total Tseq = 366.260949	1
2	Tseq/ 206.522271 = 1.7734695015048	2
4	Tseq/ 102.699393 =3.5663399587961	4
8	Tseq/ 54.132415 =6.7660190109752	7
16	Tseq/ 29.482042 =12.423187952856	12

Q-Bert: Big Matrix 4 Screenshots

```

Apple Terminal Shell Edit View Window Help HW3.CODE — jland@qbert:~/HW3.CODE — ssh jland@qbert.utc.edu — 141x41
>>Eigenvalue: 10.499298266131
>>Number Of Threads: 3
>>Timings: Multiply Normalize Eigenvalue
          0.359275  0.017427  0.038704

[jland@qbert HW3_CODE]$ ./hw3 4 /home/public/5260-matrices/mat.big3
[
>>Iterations: 10
>>Eigenvalue: 10.499298266131
>>Number Of Threads: 4
>>Timings: Multiply Normalize Eigenvalue
          0.285459  0.013254  0.038619

[jland@qbert HW3_CODE]$ ./hw3 8 /home/public/5260-matrices/mat.big3
[
>>Iterations: 10
>>Eigenvalue: 10.499298266131
>>Number Of Threads: 8
>>Timings: Multiply Normalize Eigenvalue
          0.164558  0.007321  0.042450

[jland@qbert HW3_CODE]$ ./hw3 16 /home/public/5260-matrices/mat.big3
[
>>Iterations: 10
>>Eigenvalue: 10.499298266131
>>Number Of Threads: 16
>>Timings: Multiply Normalize Eigenvalue
          0.094163  0.007963  0.049985

[[jland@qbert HW3_CODE]$ g++ -o hw3 -fopenmp openMP_hw3.c
[[jland@qbert HW3_CODE]$ ./hw3 1 /home/public/5260-matrices/mat.big4
>>Iterations: 10
>>Eigenvalue: -nan
>>Number Of Threads: 1
>>Timings: Multiply Normalize Eigenvalue
          365.549840  0.334266  0.376843

[[jland@qbert HW3_CODE]$ g++ -o hw3 -fopenmp openMP_hw3.c
[[jland@qbert HW3_CODE]$ ./hw3 2 /home/public/5260-matrices/mat.big4

```

```
Terminal Shell Edit View Window Help HW3.CODE — jland@qbert:~/HW3.CODE — ssh jland@qbert.utc.edu — 141x41  
[[jland@qbert HW3.CODE]$ g++ -o hw3 -fopenmp openMP_hw3.c  
[[jland@qbert HW3.CODE]$ ./hw3 2 /home/public/5260-matrices/mat.big4  
  
>>Iterations: 10  
>>Eigenvalue: -nan  
>>Number Of Threads: 1  
>>Timings: Multiply Normalize Eigenvalue  
365.549849 0.334266 0.376843  
  
[[jland@qbert HW3.CODE]$ g++ -o hw3 -fopenmp openMP_hw3.c  
[[jland@qbert HW3.CODE]$ ./hw3 2 /home/public/5260-matrices/mat.big4  
  
>>Iterations: 10  
>>Eigenvalue: -nan  
>>Number Of Threads: 2  
>>Timings: Multiply Normalize Eigenvalue  
205.981373 0.166324 0.374574  
  
[[jland@qbert HW3.CODE]$ ./hw3 4 /home/public/5260-matrices/mat.big4  
  
>>Iterations: 10  
>>Eigenvalue: -nan  
>>Number Of Threads: 4  
>>Timings: Multiply Normalize Eigenvalue  
102.218028 0.087106 0.394267  
  
[[jland@qbert HW3.CODE]$ ./hw3 8 /home/public/5260-matrices/mat.big4  
  
>>Iterations: 10  
>>Eigenvalue: -nan  
>>Number Of Threads: 8  
>>Timings: Multiply Normalize Eigenvalue  
53.648004 0.063517 0.420894  
  
[[jland@qbert HW3.CODE]$ ./hw3 16 /home/public/5260-matrices/mat.big4  
  
>>Iterations: 10  
>>Eigenvalue: -nan  
>>Number Of Threads: 16  
>>Timings: Multiply Normalize Eigenvalue  
28.936386 0.065839 0.479817  
  
[[jland@qbert HW3.CODE]$
```

Q-Bert: Big Matrix 5

```
[jland@qbert HW3_CODE]$ ./hw3 1 /home/public/5260-matrices/mat.big5
>>Iterations: 7
>>Eigenvalue: 5854.486686647850
>>Number Of Threads: 1
>>Timings:      Multiply   Normalize      Eigenvalue
                1.680182   0.000253   0.000286

[jland@qbert HW3_CODE]$ g++ -o hw3 -fopenmp openMP_hw3.c
[jland@qbert HW3_CODE]$ ./hw3 2 /home/public/5260-matrices/mat.big5
>>Iterations: 7
>>Eigenvalue: 5854.486686647845
>>Number Of Threads: 2
>>Timings:      Multiply   Normalize      Eigenvalue
                0.847879   0.000156   0.000369

[jland@qbert HW3_CODE]$ g++ -o hw3 -fopenmp openMP_hw3.c
[jland@qbert HW3_CODE]$ ./hw3 4 /home/public/5260-matrices/mat.big5
>>Iterations: 7
>>Eigenvalue: 5854.486686647850
>>Number Of Threads: 4
>>Timings:      Multiply   Normalize      Eigenvalue
                0.435829   0.000107   0.000448

[jland@qbert HW3_CODE]$ g++ -o hw3 -fopenmp openMP_hw3.c
[jland@qbert HW3_CODE]$ ./hw3 8 /home/public/5260-matrices/mat.big5
>>Iterations: 7
>>Eigenvalue: 5854.486686647845
>>Number Of Threads: 8
>>Timings:      Multiply   Normalize      Eigenvalue
                0.240864   0.000080   0.000754

[jland@qbert HW3_CODE]$ g++ -o hw3 -fopenmp openMP_hw3.c
[jland@qbert HW3_CODE]$ ./hw3 16 /home/public/5260-matrices/mat.big5
>>Iterations: 7
>>Eigenvalue: 5854.486686647850
>>Number Of Threads: 16
>>Timings:      Multiply   Normalize      Eigenvalue
                0.134105   0.000070   0.001169
```

Q-Bert: Big Matrix 5 Speedup Data (General)

Threads	Multiply	Normalize	Eigen Value	Iterations	Eigen Value Produced
1	1.680182	0.000253	0.000286	7	5854.486686647850
2	0.847879	0.000156	0.000369	7	5854.486686647850
4	0.435829	0.000107	0.000448	7	5854.486686647850
8	0.240864	0.000080	0.000754	7	5854.486686647850
16	0.134105	0.000070	0.001169	7	5854.486686647850

Q-Bert: Big Matrix 5 Speedup (Specific [total serial / total parallel])

Tseq = 1.680721

Threads	Tseq/Tpar = Speedup	Speedup
1	Tseq = 1.680721	2
2	Tseq/ 0.848404 =1.9810385146699	2
4	Tseq/ 0.436384 = 3.8514725562807	4
8	Tseq/ 0.241698 =6.9538059892924	7
16	Tseq/ 0.135344 =12.418141919849	12

Q-Bert: Big Matrix 4 Screenshot

```
MacBook-Pro:HW3_CODE jland$ ./hw3 1 /home/public/5268-matrices/mat.big5
>>Eigenvalue: 5854.486686647845
>>Number Of Threads: 2
>>Timings: Multiply Normalize Eigenvalue
  0.847879  0.000156  0.000369

[jland@qbert HW3_CODE]$ ./hw3 2 /home/public/5268-matrices/mat.big5
>>Iterations: 7
>>Eigenvalue: 5854.486686647850
>>Number Of Threads: 1
>>Timings: Multiply Normalize Eigenvalue
  1.680182  0.000253  0.000286

[jland@qbert HW3_CODE]$ g++ -o hw3 -fopenmp openMP_hw3.c
[jland@qbert HW3_CODE]$ ./hw3 4 /home/public/5268-matrices/mat.big5
>>Iterations: 7
>>Eigenvalue: 5854.486686647850
>>Number Of Threads: 1
>>Timings: Multiply Normalize Eigenvalue
  0.847879  0.000156  0.000369

[jland@qbert HW3_CODE]$ g++ -o hw3 -fopenmp openMP_hw3.c
[jland@qbert HW3_CODE]$ ./hw3 8 /home/public/5268-matrices/mat.big5
>>Iterations: 7
>>Eigenvalue: 5854.486686647845
>>Number Of Threads: 4
>>Timings: Multiply Normalize Eigenvalue
  0.435829  0.000107  0.000448

[jland@qbert HW3_CODE]$ g++ -o hw3 -fopenmp openMP_hw3.c
[jland@qbert HW3_CODE]$ ./hw3 16 /home/public/5268-matrices/mat.big5
>>Iterations: 7
>>Eigenvalue: 5854.486686647850
>>Number Of Threads: 16
>>Timings: Multiply Normalize Eigenvalue
  0.134105  0.000070  0.001169

[jland@qbert HW3_CODE]$
```

Timings: Xeon Phi

Xeon Phi: Big Matrix 3

```
jland@qbert-mic0:~/HW3_CODE$ ./program.mic 1 /home/public/5260-matrices/mat.big3
```

```
>>Iterations: 10  
>>Eigenvalue: 10.499375033368  
>>Number Of Threads: 1  
>>Timings: Multiply Normalize Eigenvalue  
38.393904 0.106494 0.020179
```

```
jland@qbert-mic0:~/HW3_CODE$ ./program.mic 2 /home/public/5260-matrices/mat.big3
```

```
>>Iterations: 10  
>>Eigenvalue: 10.499375033368  
>>Number Of Threads: 2  
>>Timings: Multiply Normalize Eigenvalue  
19.088465 0.053669 0.020904
```

```
jland@qbert-mic0:~/HW3_CODE$ ./program.mic 4 /home/public/5260-matrices/mat.big3
```

```
>>Iterations: 10  
>>Eigenvalue: 10.499375033368  
>>Number Of Threads: 4  
>>Timings: Multiply Normalize Eigenvalue  
9.479267 0.027416 0.031815
```

```
jland@qbert-mic0:~/HW3_CODE$ ./program.mic 8 /home/public/5260-matrices/mat.big3
```

```
>>Iterations: 10  
>>Eigenvalue: 10.499375033368  
>>Number Of Threads: 8  
>>Timings: Multiply Normalize Eigenvalue  
4.752295 0.014339 0.058353
```

```
jland@qbert-mic0:~/HW3_CODE$ ./program.mic 15 /home/public/5260-matrices/mat.big3
```

```
>>Iterations: 10  
>>Eigenvalue: 10.499375033368  
>>Number Of Threads: 15  
>>Timings: Multiply Normalize Eigenvalue  
2.427094 0.007861 0.076257
```

```
jland@qbert-mic0:~/HW3_CODE$ ./program.mic 30 /home/public/5260-matrices/mat.big3
```

```
>>Iterations: 10  
>>Eigenvalue: 10.499375033368  
>>Number Of Threads: 30  
>>Timings: Multiply Normalize Eigenvalue  
1.179742 0.004296 0.088156
```

```
jland@qbert-mic0:~/HW3_CODE$ ./program.mic 60 /home/public/5260-matrices/mat.big3
```

```
>>Iterations: 10  
>>Eigenvalue: 10.499375033368
```

```

>>Number Of Threads: 60
>>Timings:      Multiply   Normalize      Eigenvalue
                0.667758  0.002660  0.079749

jland@qbert-mic0:~/HW3_CODE$ ./program.mic 120 /home/public/5260-matrices/mat.big3

>>Iterations: 10
>>Eigenvalue: 10.499375033368
>>Number Of Threads: 120
>>Timings:      Multiply   Normalize      Eigenvalue
                0.459330  0.001786  0.048734

jland@qbert-mic0:~/HW3_CODE$ ./program.mic 240 /home/public/5260-matrices/mat.big3

>>Iterations: 10
>>Eigenvalue: 10.499375033368
>>Number Of Threads: 240
>>Timings:      Multiply   Normalize      Eigenvalue
                0.424924  0.001709  0.051471

```

Xeon Phi: Big Matrix 3 Speedup Data (General)

Threads	Multiply	Normalize	Eigen Value	Iterations	Eigen Value Produced
1	38.393904	0.106494	0.020904	10	10.499375033368
2	19.088465	0.053669	0.020904	10	10.499375033368
4	9.479267	0.027416	0.031815	10	10.499375033368
8	4.752295	0.014339	0.058353	10	10.499375033368
15	2.427094	0.007861	0.076257	10	10.499375033368
30	1.179742	0.004296	0.088156	10	10.499375033368
60	0.667758	0.002660	0.079749	10	10.499375033368
120	0.459330	0.001786	0.048734	10	10.499375033368
240	0.424924	0.001709	0.051471	10	10.499375033368

Xeon Phi: Big Matrix 3 Speedup (Specific [total serial / total parallel])

Tseq = 38.521302

Threads	Tseq/Tpar = Speedup	Speedup
1	Tseq = 38.521302	1
2	Tseq/ 19.163038= 2.0101876330882	2
4	Tseq/ 9.538498= 4.0385081592511	4
8	Tseq/ 4.824987= 7.98371104419568	5
15	Tseq/	15

	2.511212=	
	15.339725200421	
30	Tseq/ 1.272194= 30.279424364523	30
60	Tseq/0.750167= 51.350301999421	51
120	Tseq/ 0.50985 = 75.554186525449	76
240	Tseq/ 0.478104= =80.5709678229	81

Xeon Phi: Big Matrix 3 Screenshots

```

Terminal Shell Edit View Window Help HW3_CODE — jland@qbert:~/HW3_CODE — ssh jland@qbert.utc.edu — 158x47
jland@qbert-mic0:~/HW3_CODE$ ./program.mic 2 /home/public/5260-matrices/mat.big3
>>Iterations: 10
>>Eigenvalue: 10.499375033368
>>Number Of Threads: 1
>>Timings: Multiply Normalize Eigenvalue
    38.393904      0.106494      0.020179

[jland@qbert-mic0:~/HW3_CODE$ ./program.mic 4 /home/public/5260-matrices/mat.big3
>>Iterations: 10
>>Eigenvalue: 10.499375033368
>>Number Of Threads: 2
>>Timings: Multiply Normalize Eigenvalue
    19.088465      0.053669      0.020904

[jland@qbert-mic0:~/HW3_CODE$ ./program.mic 4 /home/public/5260-matrices/mat.big3
>>Iterations: 10
>>Eigenvalue: 10.499375033368
>>Number Of Threads: 4
>>Timings: Multiply Normalize Eigenvalue
    9.479267      0.027416      0.031815

[jland@qbert-mic0:~/HW3_CODE$ ./program.mic 8 /home/public/5260-matrices/mat.big3
>>Iterations: 10
>>Eigenvalue: 10.499375033368
>>Number Of Threads: 8
>>Timings: Multiply Normalize Eigenvalue
    4.752295      0.014339      0.058353

[jland@qbert-mic0:~/HW3_CODE$ ./program.mic 15 /home/public/5260-matrices/mat.big3
>>Iterations: 10
>>Eigenvalue: 10.499375033368
>>Number Of Threads: 15
>>Timings: Multiply Normalize Eigenvalue
    2.427094      0.007861      0.076257

[jland@qbert-mic0:~/HW3_CODE$ ./program.mic 30 /home/public/5260-matrices/mat.big3
>>Iterations: 10
>>Eigenvalue: 10.499375033368
>>Number Of Threads: 30
>>Timings: Multiply Normalize Eigenvalue
    1.179742      0.004296      0.088156

jland@qbert-mic0:~/HW3_CODE$
```

```
Terminal Shell Edit View Window Help HW3_CODE — jland@qbert:~/HW3_CODE — ssh jland@qbert.utc.edu — 158x47
>>Iterations: 10
>>Eigenvalue: 10.499375033368
>>Number Of Threads: 8
>>Timings:   Multiply   Normalize   Eigenvalue
              4.752295   0.014339   0.058353

[jland@qbert-mic0:~/HW3_CODE$ ./program.mic 15 /home/public/5260-matrices/mat.big3
>>Iterations: 10
>>Eigenvalue: 10.499375033368
>>Number Of Threads: 15
>>Timings:   Multiply   Normalize   Eigenvalue
              2.427094   0.007861   0.076257

[jland@qbert-mic0:~/HW3_CODE$ ./program.mic 30 /home/public/5260-matrices/mat.big3
>>Iterations: 10
>>Eigenvalue: 10.499375033368
>>Number Of Threads: 30
>>Timings:   Multiply   Normalize   Eigenvalue
              1.179742   0.004296   0.088156

[jland@qbert-mic0:~/HW3_CODE$ ./program.mic 60 /home/public/5260-matrices/mat.big3
>>Iterations: 10
>>Eigenvalue: 10.499375033368
>>Number Of Threads: 60
>>Timings:   Multiply   Normalize   Eigenvalue
              0.667758   0.002660   0.079749

[jland@qbert-mic0:~/HW3_CODE$ ./program.mic 120 /home/public/5260-matrices/mat.big3
>>Iterations: 10
>>Eigenvalue: 10.499375033368
>>Number Of Threads: 120
>>Timings:   Multiply   Normalize   Eigenvalue
              0.459330   0.001786   0.048734

[jland@qbert-mic0:~/HW3_CODE$ ./program.mic 240 /home/public/5260-matrices/mat.big3
>>Iterations: 10
>>Eigenvalue: 10.499375033368
>>Number Of Threads: 240
>>Timings:   Multiply   Normalize   Eigenvalue
              0.424924   0.001709   0.051471

[jland@qbert-mic0:~/HW3_CODE$
```

Xeon Phi: Big Matrix 4: N/A (As stated in matrix file via QBert)

Xeon Phi: Big Matrix 5

```
jland@qbert-mic0:~/HW3_CODE$ ./program.mic 1 /home/public/5260-matrices/mat.big5
>>Iterations: 7
>>Eigenvalue: 5855.083011348443
>>Number Of Threads: 1
>>Timings:      Multiply      Normalize Eigenvalue
                4.047646    0.000672  0.000452

jland@qbert-mic0:~/HW3_CODE$ ./program.mic 2 /home/public/5260-matrices/mat.big5
>>Iterations: 7
>>Eigenvalue: 5855.083011348444
>>Number Of Threads: 2
>>Timings:      Multiply      Normalize Eigenvalue
                1.705184    0.000429  0.000728

jland@qbert-mic0:~/HW3_CODE$ ./program.mic 4 /home/public/5260-matrices/mat.big5
>>Iterations: 7
>>Eigenvalue: 5855.083011348443
>>Number Of Threads: 4
>>Timings:      Multiply      Normalize Eigenvalue
                0.869168    0.000292  0.000816

jland@qbert-mic0:~/HW3_CODE$ ./program.mic 8 /home/public/5260-matrices/mat.big5
>>Iterations: 7
>>Eigenvalue: 5855.083011348444
>>Number Of Threads: 8
>>Timings:      Multiply      Normalize Eigenvalue
                0.514616    0.000242  0.001102

jland@qbert-mic0:~/HW3_CODE$ ./program.mic 15 /home/public/5260-matrices/mat.big5
>>Iterations: 7
>>Eigenvalue: 5855.083011348444
>>Number Of Threads: 15
>>Timings:      Multiply      Normalize Eigenvalue
                0.257884    0.000210  0.001742

jland@qbert-mic0:~/HW3_CODE$ ./program.mic 30 /home/public/5260-matrices/mat.big5
>>Iterations: 7
>>Eigenvalue: 5855.083011348444
>>Number Of Threads: 30
>>Timings:      Multiply      Normalize Eigenvalue
                0.173771    0.000252  0.001925

jland@qbert-mic0:~/HW3_CODE$ ./program.mic 60 /home/public/5260-matrices/mat.big5
>>Iterations: 7
>>Eigenvalue: 5855.083011348444
>>Number Of Threads: 60
>>Timings:      Multiply      Normalize Eigenvalue
                0.137900    0.000286  0.003324

jland@qbert-mic0:~/HW3_CODE$ ./program.mic 120 /home/public/5260-matrices/mat.big5
```

```

>>Iterations: 7
>>Eigenvalue: 5855.083011348444
>>Number Of Threads: 120
>>Timings:      Multiply      Normalize Eigenvalue
                0.166795      0.000276  0.005073

jland@qbert-mic0:~/HW3_CODE$ ./program.mic 240 /home/public/5260-matrices/mat.big5

>>Iterations: 7
>>Eigenvalue: 5855.083011348444
>>Number Of Threads: 240
>>Timings:      Multiply      Normalize Eigenvalue
                0.282633      0.000479   0.009532

```

Xeon Phi: Big Matrix 5 Speedup Data (General)

Threads	Multiply	Normalize	Eigen Value	Iterations	Eigen Value Produced
1	4.047646	0.000672	0.000452	7	5855.083011348444
2	1.705184	0.000429	0.000728	7	5855.083011348444
4	0.869168	0.000292	0.000816	7	5855.083011348444
8	0.514616	0.000242	0.001102	7	5855.083011348444
15	0.257884	0.000210	0.001742	7	5855.083011348444
30	0.173771	0.000252	0.001925	7	5855.083011348444
60	0.137900	0.000286	0.003324	7	5855.083011348444
120	0.166795	0.000276	0.005073	7	5855.083011348444
240	0.282633	0.000479	0.009532	7	5855.083011348444

Xeon Phi: Big Matrix 5 Speedup (Specific [total serial / total parallel])

Tseq = 4.04877

Threads	Tseq/Tpar = Speedup	Speedup
1	Tseq = 4.04877	4
2	Tseq/ 1.706341= 2.372778946295	2
4	Tseq/ 0.870276= 4.6522827241013	5
8	Tseq/ 0.51596= 7.8470617877355	8
15	Tseq/ 0.259836= 15.582020967072	16
30	Tseq/ 0.175948= 23.011173755882	23
60	Tseq/	29

	0.14151=	
	28.611193555226	
120	Tseq/ 0.172144= 23.519669578957	24
240	Tseq/ 0.292644= 13.835137573297	14

Xeon Phi: Big Matrix 5 Screenshots

```

Terminal Shell Edit View Window Help HW3_CODE — jland@qbert:~/HW3_CODE — ssh jland@qbert.utc.edu — 158x47
>>Eigenvalue: 5855.083011348444
>>Number Of Threads: 1
>>Timings:   Multiply   Normalize   Eigenvalue
             4.047646   0.000672   0.000452

[jland@qbert-mic0:~/HW3_CODE$ ./program.mic 2 /home/public/5260-matrices/mat.big5
>>Iterations: 7
>>Eigenvalue: 5855.083011348444
>>Number Of Threads: 2
>>Timings:   Multiply   Normalize   Eigenvalue
             1.765184   0.000429   0.000728

[jland@qbert-mic0:~/HW3_CODE$ ./program.mic 4 /home/public/5260-matrices/mat.big5
>>Iterations: 7
>>Eigenvalue: 5855.083011348444
>>Number Of Threads: 4
>>Timings:   Multiply   Normalize   Eigenvalue
             0.869168   0.000292   0.000816

[jland@qbert-mic0:~/HW3_CODE$ ./program.mic 8 /home/public/5260-matrices/mat.big5
>>Iterations: 7
>>Eigenvalue: 5855.083011348444
>>Number Of Threads: 8
>>Timings:   Multiply   Normalize   Eigenvalue
             0.514616   0.000242   0.001102

[jland@qbert-mic0:~/HW3_CODE$ ./program.mic 15 /home/public/5260-matrices/mat.big5
>>Iterations: 7
>>Eigenvalue: 5855.083011348444
>>Number Of Threads: 15
>>Timings:   Multiply   Normalize   Eigenvalue
             0.257824   0.000210   0.001742

[jland@qbert-mic0:~/HW3_CODE$ ./program.mic 30 /home/public/5260-matrices/mat.big5
>>Iterations: 7
>>Eigenvalue: 5855.083011348444
>>Number Of Threads: 30
>>Timings:   Multiply   Normalize   Eigenvalue
             0.173771   0.000252   0.001925

[jland@qbert-mic0:~/HW3_CODE$ ./program.mic 60 /home/public/5260-matrices/mat.big5

```

```
Terminal Shell Edit View Window Help HW3_CODE — jland@qbert:~/HW3_CODE — ssh jland@qbert.utc.edu — 158x47
>>Iterations: 7
>>Eigenvalue: 5855.083011348444
>>Number Of Threads: 8
>>Timings:   Multiply   Normalize   Eigenvalue
              0.514616   0.000242   0.001102

[jland@qbert-mic0:~/HW3_CODE$ ./program.mic 15 /home/public/5260-matrices/mat.big5
>>Iterations: 7
>>Eigenvalue: 5855.083011348444
>>Number Of Threads: 15
>>Timings:   Multiply   Normalize   Eigenvalue
              0.257884   0.000216   0.001742

[jland@qbert-mic0:~/HW3_CODE$ ./program.mic 30 /home/public/5260-matrices/mat.big5
>>Iterations: 7
>>Eigenvalue: 5855.083011348444
>>Number Of Threads: 30
>>Timings:   Multiply   Normalize   Eigenvalue
              0.173771   0.000252   0.001925

[jland@qbert-mic0:~/HW3_CODE$ ./program.mic 60 /home/public/5260-matrices/mat.big5
>>Iterations: 7
>>Eigenvalue: 5855.083011348444
>>Number Of Threads: 60
>>Timings:   Multiply   Normalize   Eigenvalue
              0.137900   0.000286   0.003324

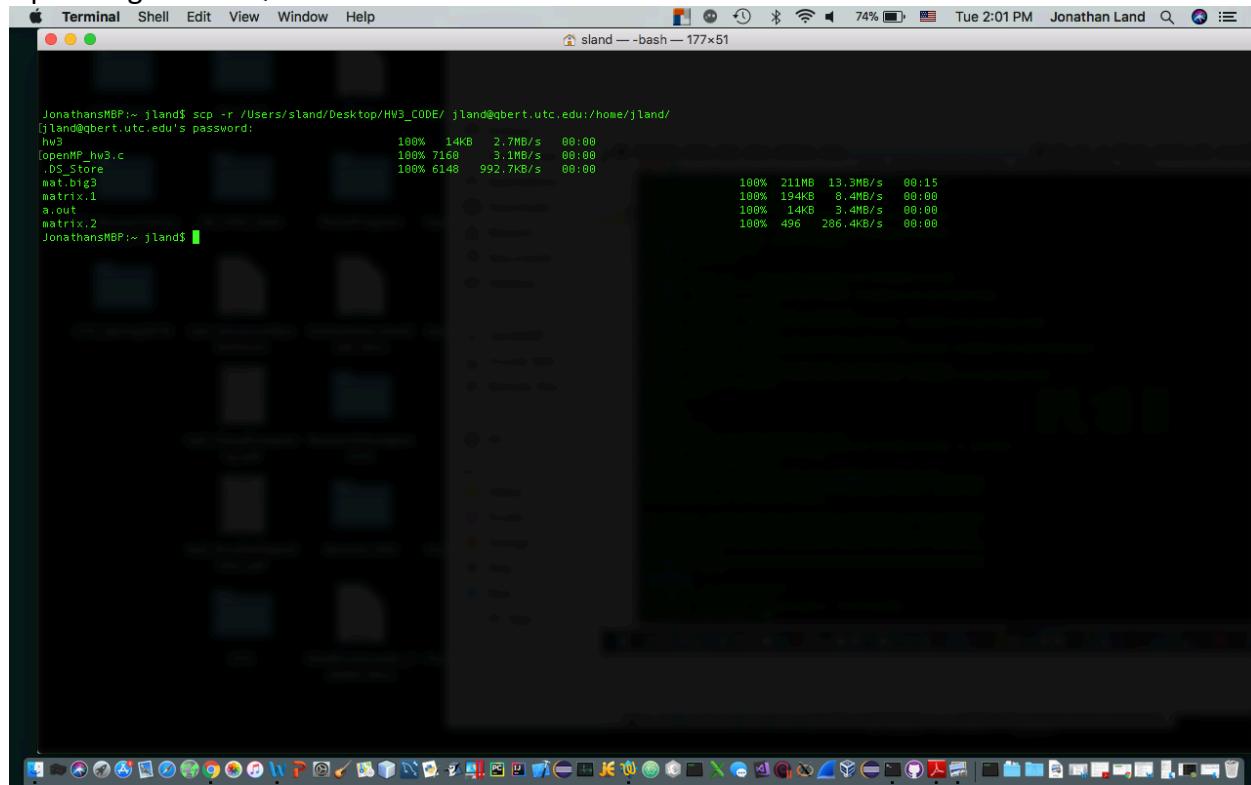
[jland@qbert-mic0:~/HW3_CODE$ ./program.mic 120 /home/public/5260-matrices/mat.big5
>>Iterations: 7
>>Eigenvalue: 5855.083011348444
>>Number Of Threads: 120
>>Timings:   Multiply   Normalize   Eigenvalue
              0.166795   0.000276   0.005073

[jland@qbert-mic0:~/HW3_CODE$ ./program.mic 240 /home/public/5260-matrices/mat.big5
>>Iterations: 7
>>Eigenvalue: 5855.083011348444
>>Number Of Threads: 240
>>Timings:   Multiply   Normalize   Eigenvalue
              0.282633   0.000479   0.009532

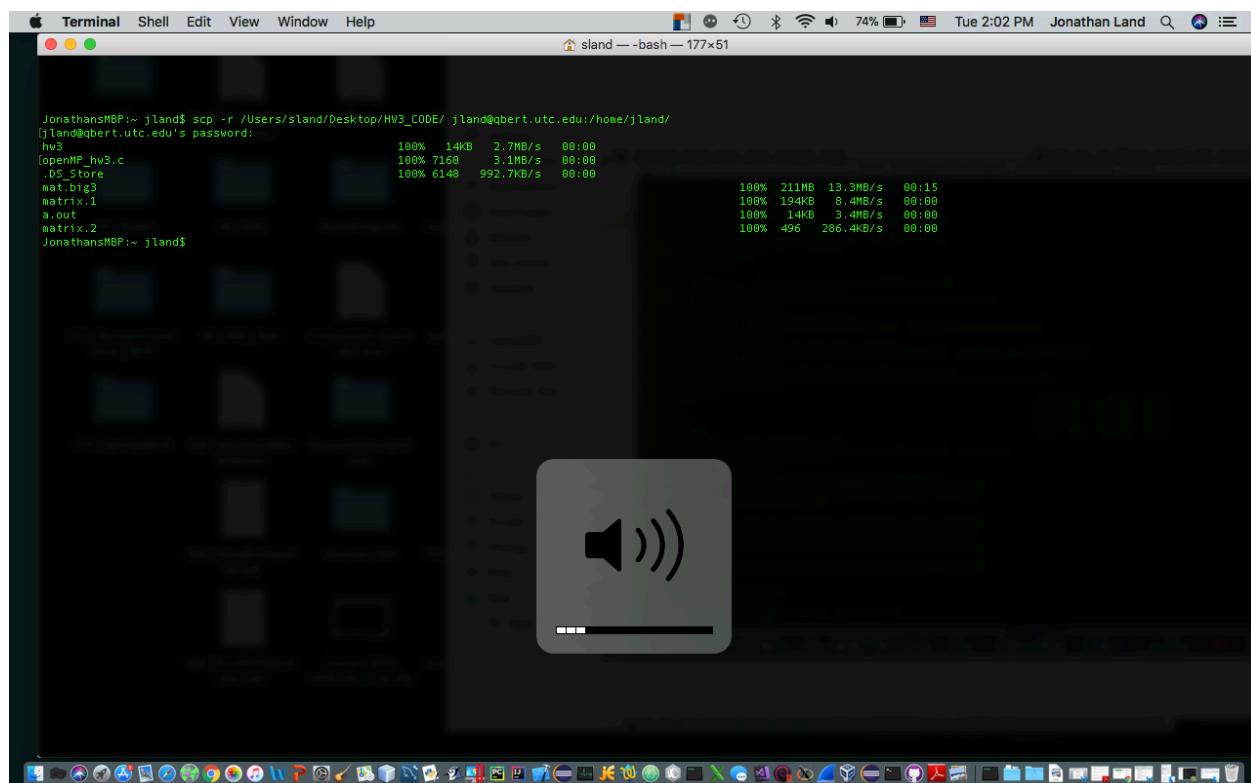
[jland@qbert-mic0:~/HW3_CODE$
```

Miscellaneous Screenshots

Uploading files to QBert



```
JonathansMBP:~ jland$ scp -r /Users/sland/Desktop/HW3_CODE/ jland@qberty.utm.edu:/home/jland/
[jland@qberty.utm.edu's password:
hw3          100%  14KB   2.7MB/s  00:00
openMP_hw3.c 100% 7160    3.1MB/s  00:00
.DS_Store    100% 6148   992.7KB/s  00:00
mat.bigr3    100% 211MB  13.3MB/s  00:15
matrix.1     100% 194KB  8.4MB/s  00:00
a.out        100% 14KB   3.4MB/s  00:00
matrix.2     100% 496    286.4KB/s  00:00
JonathansMBP:~ jland$
```



```
JonathansMBP:~ jland$ scp -r /Users/sland/Desktop/HW3_CODE/ jland@qberty.utm.edu:/home/jland/
[jland@qberty.utm.edu's password:
hw3          100%  14KB   2.7MB/s  00:00
openMP_hw3.c 100% 7160    3.1MB/s  00:00
.DS_Store    100% 6148   992.7KB/s  00:00
mat.bigr3    100% 211MB  13.3MB/s  00:15
matrix.1     100% 194KB  8.4MB/s  00:00
a.out        100% 14KB   3.4MB/s  00:00
matrix.2     100% 496    286.4KB/s  00:00
JonathansMBP:~ jland$
```

ssh into QBert

```
apple-MBP:~ jland$ scp -r /Users/sland/Desktop/HW3_CODE/ jland@qbert.utc.edu:/home/jland/
[jland@qbert.utc.edu's password:
hw3          100%   14KB   2.7MB/s  00:00
openMP_hw3.c 100% 7160    3.1MB/s  00:00
.DS_Store    100% 6148   992.7KB/s  00:00
mat_big3     100% 211MB  13.3MB/s  00:15
matrix.1      100% 194KB   8.4MB/s  00:00
a.out        100% 14KB   3.4MB/s  00:00
matrix.2      100% 496   286.4KB/s  00:00
[jonathansMBP:~ jland$ ssh jland@qbert.utc.edu
[jland@qbert.utc.edu's password:
Last login: Tue Mar  6 12:23:32 2018 from 10.129.149.86
#####
Welcome to qbert; if you use this cluster for published research, please use
the following excerpt to cite this cluster:
This material is based upon work supported by the National Science Foundation
under Major Research Instrumentation (MRI) Grant No. 1229213. Any opinions,
findings, and conclusions or recommendations expressed in this material are
those of the authors and do not necessarily reflect the views of the National
Science Foundation
#####
[jland@qbert ~]$ 

apple-MBP:~ jland$ scp -r /Users/sland/Desktop/HW3_CODE/ jland@qbert.utc.edu:/home/jland/
[jland@qbert.utc.edu's password:
hw3          100%   14KB   2.7MB/s  00:00
openMP_hw3.c 100% 7160    3.1MB/s  00:00
.DS_Store    100% 6148   992.7KB/s  00:00
mat_big3     100% 211MB  13.3MB/s  00:15
matrix.1      100% 194KB   8.4MB/s  00:00
a.out        100% 14KB   3.4MB/s  00:00
matrix.2      100% 496   286.4KB/s  00:00
[jonathansMBP:~ jland$ ssh jland@qbert.utc.edu
[jland@qbert.utc.edu's password:
Last login: Tue Mar  6 12:23:32 2018 from 10.129.149.86
#####
Welcome to qbert; if you use this cluster for published research, please use
the following excerpt to cite this cluster:
This material is based upon work supported by the National Science Foundation
under Major Research Instrumentation (MRI) Grant No. 1229213. Any opinions,
findings, and conclusions or recommendations expressed in this material are
those of the authors and do not necessarily reflect the views of the National
Science Foundation
#####
[jland@qbert ~]$ ls
HW3_CODE PosixProgram
[jland@qbert ~]$ cd HW3_CODE/
[jland@qbert HW3_CODE]$ ls
a.out hw3 mat_big3 matrix.1 matrix.2 openMP_hw3.c
[jland@qbert HW3_CODE]$ 
```

ssh into Xeon Phi (mic0)

The screenshot displays two terminal windows on a Mac OS X desktop. The top terminal window shows the user generating an RSA key and connecting to the Xeon Phi cluster (mic0). The bottom terminal window shows the execution of a C++ program using OpenMP to solve a large matrix eigenvalue problem.

Top Terminal Window (SSH Connection):

```
[jland@qbert HW3_CODE]$ ssh-keygen && cat ~/.ssh/id_rsa.pub >> ~/.ssh/authorized_keys
Generating public/private rsa key pair.
Enter file in which to save the key (/home/jland/.ssh/id_rsa):
Enter passphrase (empty for no passphrase):
Enter same passphrase again:
Your identification has been saved in /home/jland/.ssh/id_rsa.
Your public key has been saved in /home/jland/.ssh/id_rsa.pub.
The key fingerprint is:
ee:5b:91:3a:f3:86:ac:cc:fb:52:27:6e:ec:70:20:c8 jland@qbert
The key's randomart image is:
+--[ RSA 2048]----+
| . E
| . . S o
| . O=...
| O.=++
| ++=.
| .*=o.

[jland@qbert HW3_CODE]$ ssh mic0
The authenticity of host 'mic0 (172.31.1.1)' can't be established.
RSA key fingerprint is b0:53:67:5a:0e:c:b:c1:4f:1c:3c:da:9f:67:83:d4.
Are you sure you want to continue connecting (yes/no)? yes
Warning: Permanently added 'mic0,172.31.1.1' (RSA) to the list of known hosts.
[jland@qbert-mic0:~$ exit
logout
Connection to mic0 closed.
[jland@qbert HW3_CODE]$ ssh jland@qbert.utm.edu
Last login: Tue Mar  6 14:09:49 2018 from 10.129.149.86
#####
Welcome to qbert; if you use this cluster for published research, please use
the following excerpt to cite this cluster:
This material is based upon work supported by the National Science Foundation
under Major Research Instrumentation (MRI) Grant No. 1229213. Any opinions,
findings, and conclusions or recommendations expressed in this material are
those of the authors and do not necessarily reflect the views of the National
Science Foundation
#####
[jland@qbert ~$ ls
HW3_CODE PosixProgram
[jland@qbert ~$ cd HW3_CODE/
[jland@qbert HW3_CODE]$ ls
a.out hw3 mat_Big3 matrix_1 matrix_2 openMP_hw3.c
[jland@qbert HW3_CODE]$ icc -Wall -fopenmp -mmic openMP_hw3.c -o program .mic
```

Bottom Terminal Window (Program Execution):

```
[jland@qbert HW3_CODE]$ g++ -o hw3 -fopenmp openMP_hw3.c
[jland@qbert HW3_CODE]$ ./hw3 16
>>Iterations: 18
>>Eigenvalue: 10.499375033368
>>Number Of Threads: 16
>>Timings:   Multiply      Normalize      Eigenvalue
              0.092140     0.007939     0.049640

[jland@qbert HW3_CODE]$ g++ -o hw3 -fopenmp openMP_hw3.c
[jland@qbert HW3_CODE]$ ./hw3 16 /home/
/home/  home.backup/
[jland@qbert HW3_CODE]$ ./hw3 16 /home/public/5260-matrices/mat
mat_big3    mat_big4    mat_big5    matrices.org  matrices.txt  matrix_1    matrix_2
[jland@qbert HW3_CODE]$ ./hw3 16 /home/public/5260-matrices/mat_big4

>>Iterations: 18
>>Eigenvalue: -nan
>>Number Of Threads: 16
>>Timings:   Multiply      Normalize      Eigenvalue
              28.952657     0.074135     0.538486

[jland@qbert HW3_CODE]$ ./hw3 8 /home/public/5260-matrices/mat_big4

>>Iterations: 18
>>Eigenvalue: -nan
>>Number Of Threads: 8
>>Timings:   Multiply      Normalize      Eigenvalue
              53.191103     0.063443     0.425774

[jland@qbert HW3.CODE]$ ssh-keygen && cat ~/.ssh/id_rsa.pub >> ~/.ssh/authorized_keys
Generating public/private rsa key pair.
Enter file in which to save the key (/home/jland/.ssh/id_rsa):
Enter passphrase (empty for no passphrase):
Enter same passphrase again:
Your identification has been saved in /home/jland/.ssh/id_rsa.
Your public key has been saved in /home/jland/.ssh/id_rsa.pub.
The key fingerprint is:
ee:5b:91:3a:f3:86:ac:cc:fb:52:27:6e:ec:70:20:c8 jland@qbert
The key's randomart image is:
+--[ RSA 2048]----+
| . E
| . . S o
| . O=...
| O.=++
| ++=.
| .*=o.
```

sland — jland@qbert:~/HW3_CODE — ssh jland@qbert.utc.edu — 116x49

```
[jland@qbert ~]$ cd HW3_CODE/
[jland@qbert HW3_CODE]$ ls
a.out  hw3  mat_big3  matrix.1  matrix.2  openMP_hw3.c
[jland@qbert HW3_CODE]$ g++ -fopenmp openMP_hw3.c
[bash: g++: command not found
[jland@qbert HW3_CODE]$ g++ -fopenmp openMP_hw3.c
[jland@qbert HW3_CODE]$ ./hw3 4
>>Iterations: 10
>>Eigenvalue: 10.499375033368
>>Number Of Threads: 4
>>Timings:   Multiply   Normalize   Eigenvalue
              0.275842   0.013354   0.030931

[jland@qbert HW3_CODE]$ g++ -fopenmp openMP_hw3.c
[jland@qbert HW3_CODE]$ ./hw3 8
>>Iterations: 10
>>Eigenvalue: 10.499375033368
>>Number Of Threads: 8
>>Timings:   Multiply   Normalize   Eigenvalue
              0.150875   0.007238   0.041959

[jland@qbert HW3_CODE]$ g++ -fopenmp openMP_hw3.c
[jland@qbert HW3_CODE]$ ./hw3 16
>>Iterations: 10
>>Eigenvalue: 10.499375033368
>>Number Of Threads: 16
>>Timings:   Multiply   Normalize   Eigenvalue
              0.092140   0.007939   0.049648

[jland@qbert HW3_CODE]$ g++ -fopenmp openMP_hw3.c
[jland@qbert HW3_CODE]$ ./hw3 16 /home/
home/    home.backup/
[jland@qbert HW3_CODE]$ ./hw3 16 /home/public/5260-matrices/mat
mat_big3  mat_big4  mat_big5  matrices.org  matrices.txt  matrix.1  matrix.2
[jland@qbert HW3_CODE]$ ./hw3 16 /home/public/5260-matrices/mat.big4

>>Iterations: 10
>>Eigenvalue: -nan
>>Number Of Threads: 16
>>Timings:   Multiply   Normalize   Eigenvalue
              28.952657   0.074135   0.538486

[jland@qbert HW3_CODE]$ ./hw3 8 /home/public/5260-matrices/mat.big4
>>Iterations: 10
>>Eigenvalue: -nan
```

sland — jland@qbert:~/HW3_CODE — ssh jland@qbert.utc.edu — 116x49

```
>>Iterations: 10
>>Eigenvalue: -nan
>>Number Of Threads: 8
>>Timings:   Multiply   Normalize   Eigenvalue
              53.191103   0.063448   0.425774

[jland@qbert HW3_CODE]$ ssh-keygen && cat ~/.ssh/id_rsa.pub >> ~/.ssh/authorized_keys
Generating public/private rsa key pair.
[Enter file in which to save the key (/home/jland/.ssh/id_rsa):
[Enter passphrase (empty for no passphrase):
[Enter same passphrase again:
Your identification has been saved in /home/jland/.ssh/id_rsa.
Your public key has been saved in /home/jland/.ssh/id_rsa.pub.
The key fingerprint is:
ee:5b:91:3a:f3:06:ac:cc:fb:52:27:6e:ec:78:20:c0 jland@qbert
The key's randomart image is:
+---[ RSA 2048]----+
| . |
| . |
| E |
| . |
| . |
| . S o |
| . O=.. |
| O.=**. |
| +**+. |
| *o=.. |
+-----]

[jland@qbert HW3_CODE]$ ssh mic0
The authenticity of host 'mic0 (172.31.1.1)' can't be established.
RSA key fingerprint is b0:59:67:5a:0c:0e:cb:bc:4f:1c:3c:da:9f:6f:83:d4.
[Are you sure you want to continue connecting (yes/no)? yes
Warning: Permanently added 'mic0,172.31.1.1' (RSA) to the list of known hosts.
[jland@qbert-mic0:~$ exit
logout
Connection to mic0 closed.
[jland@qbert HW3_CODE]$ ssh jland@qbert.utc.edu
Last login: Tue Mar  6 14:09:49 2018 from 10.129.149.86
#####
Welcome to qbert; if you use this cluster for published research, please use
the following excerpt to cite this cluster:

This material is based upon work supported by the National Science Foundation
under Major Research Instrumentation (MRI) Grant No. 1229213. Any opinions,
findings, and conclusions or recommendations expressed in this material are
those of the authors and do not necessarily reflect the views of the National
Science Foundation
#####
[jland@qbert ~]$ ls
HW3_CODE  PosixProgram
```