CS515 Parallel Programming: Assignment #4

Due on May 1st, 2016 at 11:59pm

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Implementation details

Implementation of "C" version was straight forward and didn't cause any problems, converting Jacobi to Gauss was simple - reuse the same matrix when preforming the computation.

```
for (i = 1; i < n-1; i++) {
    for (j = 1; j < n-1; j++) { ...
        old = x[i][j]
        x[i][j] = ...
```

Conversion from Gauss-Seidel normal order to Red-Black, order is implemented by using 4 loops:

```
for (i = 1; i < n-1; i = i + 2) { // Red - odd column odd row (row + column \% 2 := 0)
    for (j = 1; j < n-1; j = j + 2) { ...

for (i = 2; i < n-1; i = i + 2) { // Red  - even column even row (row + column \% 2 := 0)
    for (j = 2; j < n-1; j = j + 2) { ...

for (i = 1; i < n-1; i = i + 2) { // Black - odd column even row (row + column \% 2 := 1)
    for (j = 2; j < n-1; j = j + 2) { ...

for (i = 2; i < n-1; i = i + 2) { // Black - even column odd row (row + column \% 2 := 1)
    for (j = 1; j < n-1; j = j + 2) { ...
```

In Chapel Implementation looks quite similar, except for language specifics:

```
forall ij in innerDomain do { const innerDomain = BD[{1..n-2,1..n-2}];
```

```
forall ij in BDr1 do { ... // const BDr1 = BD[1..n-2 by 2, 1..n-2 by 2];
forall ij in BDr2 do { ... // const BDr2 = BD[2..n-2 by 2, 2..n-2 by 2];
forall ij in BDb1 do { ... // const BDb1 = BD[1..n-2 by 2, 2..n-2 by 2];
forall ij in BDb2 do { ... // const BDb2 = BD[2..n-2 by 2, 1..n-2 by 2];
```

It can be done in two loops, however this way's advantage - there is no need to calculate correct row offset.

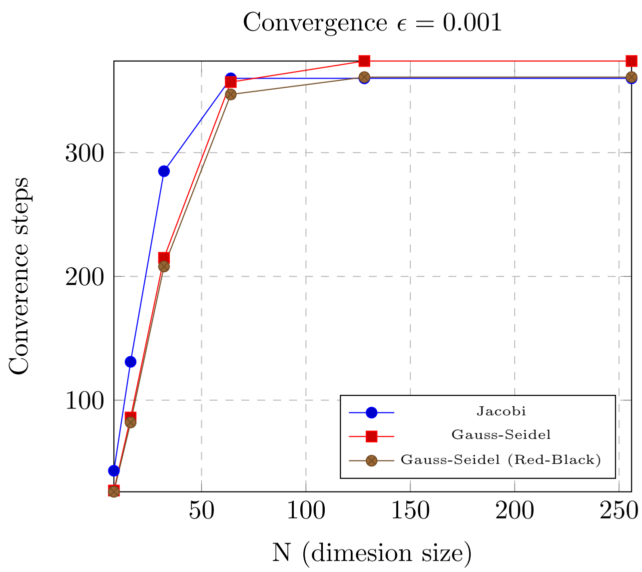
Language comparison

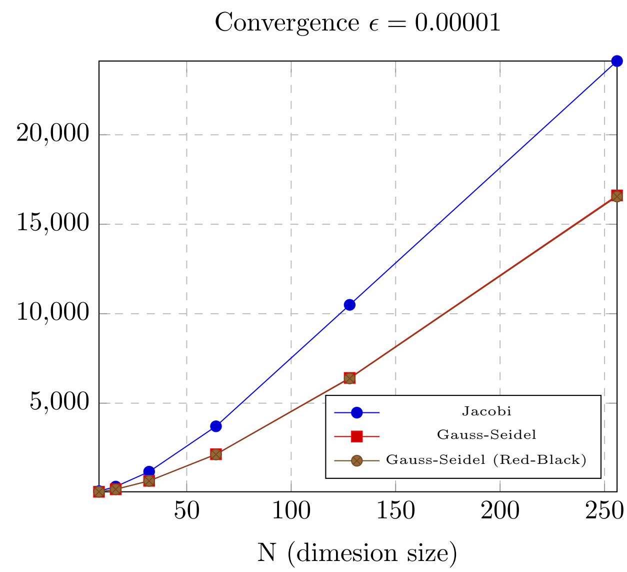
Chapel aims to make writing of parallel applications easy, and provides many built in mechanisms for this purpose. I enjoyed developing in Chapel, however the main problem with this language is performance (not sure if this is due to language problems or to my particular implementation of the Laplace algorithms). Sequential "C" is up to x9 times faster than similar shared memory algorithm in Chapel.

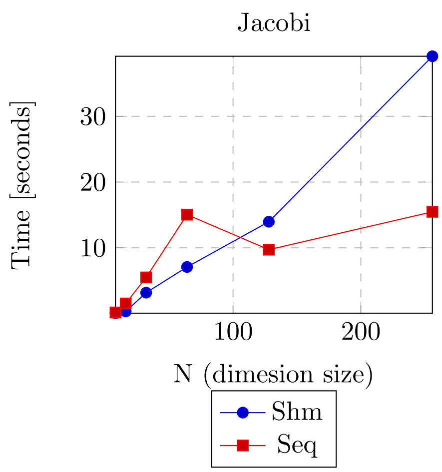
Distributed version written in Chapel required very little modifications to the original code - only correct mapping to the locales, however it was even slower than shared memory, with number locales doubled performance is slowed down by x2. This was unexpected result and I researched other possible implementation provided by Cray. Evaluating of Distributed Jacobi by Cray on linuxlab showed generally the same pattern - significant performance issues. Such a significant slowdown can be explained by high cost of communication of border locales. I omitted distributed results for $nl > 2$, since they take too long to run.
In distributed version I verified locales affinity by creating functions with exactly the same semantics as Jacobi - Gauss methods, except instead of performing computation it records locale ID".

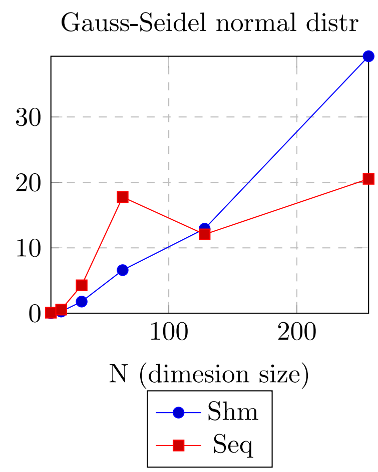
Performance analysis

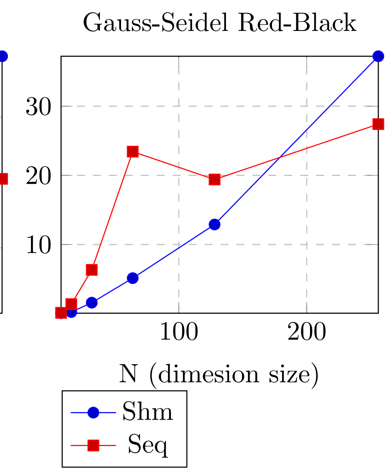
Convergence of all implementations is almost identical with insignificant deviations $\pm\%1 - 2$. Gauss-Seidel convergence rate (both versions), is around %40 better than Jacobi's, this was expected since values propagate faster, when update happens in place.

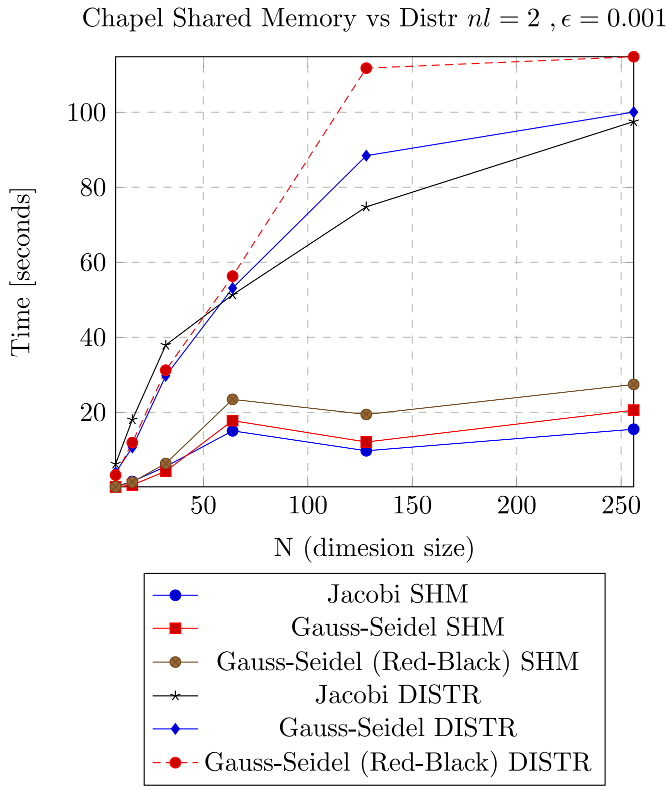

Convergence $\epsilon = 0.001$
Converence steps
100
200
300
50
100
150
200
250
N (dimesion size)
Jacobi
Gauss-Seidel
Gauss-Seidel (Red-Black)


Convergence $\epsilon = 0.00001$
5,000
10,000
15,000
20,000
50
100
150
200
250
N (dimesion size)
Jacobi
Gauss-Seidel
Gauss-Seidel (Red-Black)


Jacobi
Time [seconds]
10
20
30
100
200
N (dimesion size)
Shm
Seq


Gauss-Seidel normal distr
0
10
20
30
100
200
N (dimesion size)
Shm
Seq


Gauss-Seidel Red-Black
10
20
30
100
200
N (dimesion size)
Shm
Seq


Chapel Shared Memory vs Distr $nl = 2$, $\epsilon = 0.001$
Time [seconds]
100
80
60
40
20
50
100
150
200
250
N (dimesion size)
Jacobi SHM
Gauss-Seidel SHM
Gauss-Seidel (Red-Black) SHM
Jacobi DISTR
Gauss-Seidel DISTR
Gauss-Seidel (Red-Black) DISTR