

CS515 Parallel Programming: Assignment #4

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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 performing 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 BDbl do { ... // const BDbl = BD[1..n-2 by 2, 2..n-2 by 2];
forall ij in BDbl do { ... // const BDbl = 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.

Performance

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 between border locales, or by poor Implementation of PGAS features.

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”.

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, this was expected since values propagate faster, when update happens in place. Gauss-Seidel and Red-Black have about the same convergence rate, with Red-Black faster by some constant. The biggest downside of Red-Black, - need of at least two scans of the array, which introduces potential bottleneck. Shared memory version of Gauss-Seidel is usually faster, by a constant despite having a bit slower convergence rate.



