Chapel Iterators: Providing Tiling for the Rest of us

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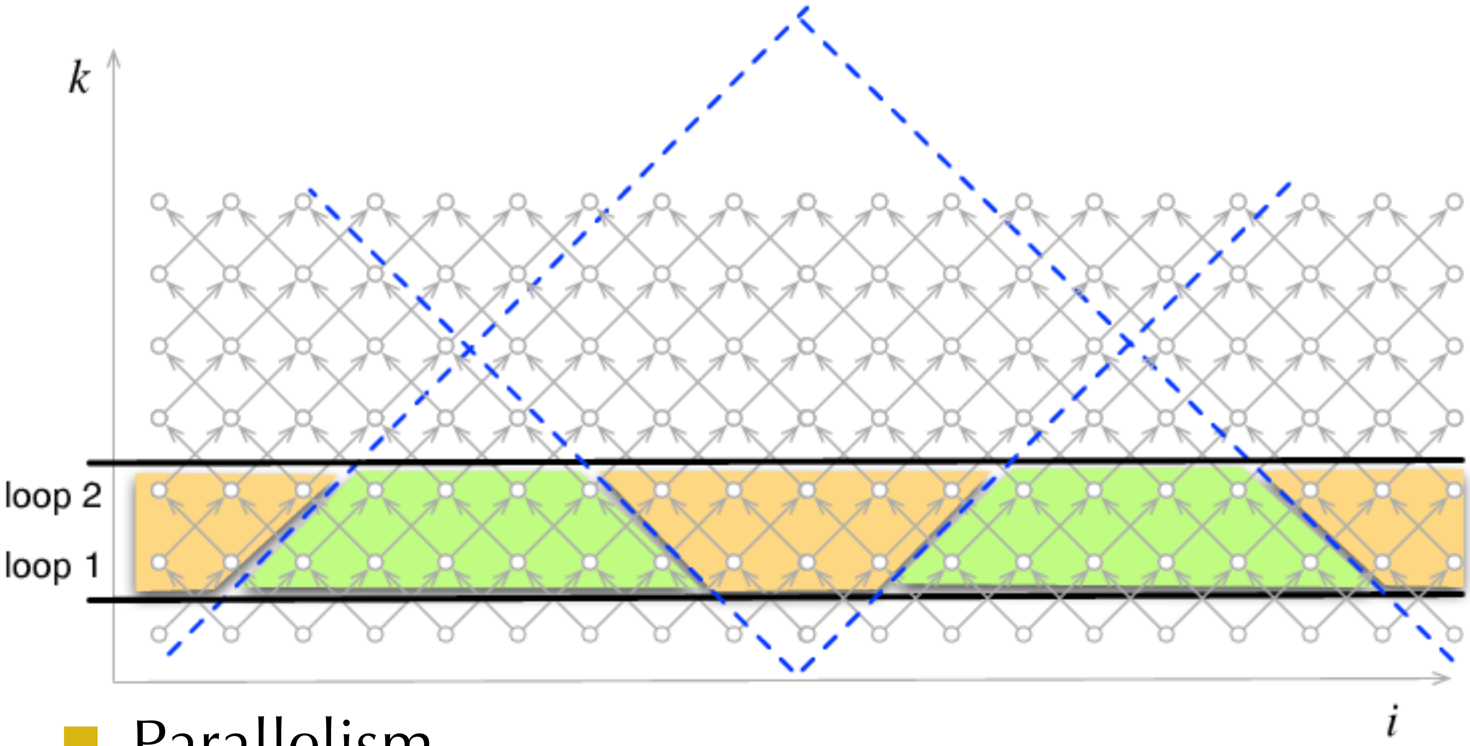
Problem

```
for t in 0..T {
  for x in 1..N do
    A[t,x] = (B[t,x-1] + B[t,x] + B[t,x+1])/3;
  A <=> B;
}
```

- Stencil computations are everywhere
  - Partial Differential Equations
  - Image Processing
  - Cellular Automata
- Naïve parallelization, can be faster than serial
  - **Does not scale with the addition of cores!**

Diamond-Slab Tiling



- Parallelism
- Data Locality
  - Cache re-re-re-use

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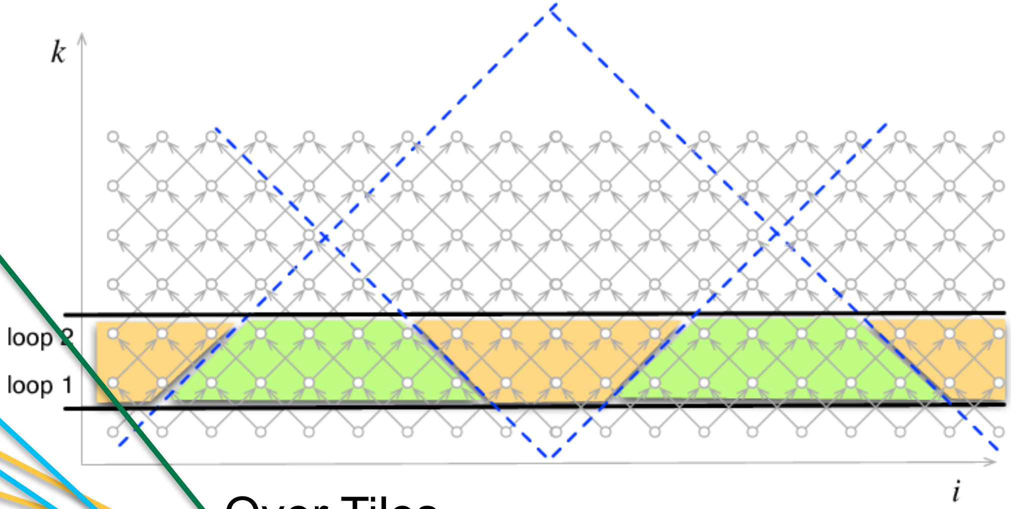
Diamond-Slab Tiling

```
int write, read;
int t0, t1, x0, x1, dx0, dx1;
int t, x;
for( t0 = 1; t0 <= T; t0 += timeBand ) {
 t1 = min(t0 + timeBand - 1, T);
 dx0 = 1;
 dx1 = -1;
 for( x0 = tiles_A_start; x0 <= upperBound; x0 += betweenTiles ){
 x1 = x0 + width_max - 1;
 read = (t0 - 1) & 1;
 write = 1 - read;
 if( x0 <= lowerBound ) {
  for( t = t0; t<= t1; ++t ){
   int minVal = min(x1 + dx1 * (t - t0), upperBound );
    for( x = lowerBound; x <= minVal; ++x)
     stencil( read, write, x );
    read = write;
    write = 1 - write;
   }}
  else if( x1 >= upperBound ){
   for( t = t0; t<= t1; ++t ){
    for( x = max(x0 + dx0 * (t - t0), lowerBound); x <= upperBound; ++x)
     stencil( read, write, x );
    read = write;
    write = 1 - write;
   }}
  else {
   for( t = t0; t<= t1; ++t ){
    int minVal = min(x1 + dx1 * (t - t0), upperBound );
    for( x = max(x0 + dx0 * (t - t0), lowerBound); x <= minVal; ++x)
     stencil( read, write, x );
    read = write;
    write = 1 - write;
   }}}
 dx0 = -1;
 dx1 = 1;
 for( x0 = tiles_B_start; x0 <= upperBound; x0 += betweenTiles ){
  x1 = x0 + width_min - 1;
  read = (t0 - 1) & 1;
  write = 1 - read;
  if( x1 >= upperBound ){
   for( t = t0; t <= t1; ++t ){
    for( x = max( x0 + dx0 * (t - t0), lowerBound); x <= upperBound; ++x)
     stencil( read, write, x );
    read = write;
    write = 1 - write;
   }}
  else {
   for( t = t0; t<= t1; ++t ){
    int minVal = min(x1 + dx1 * (t - t0), upperBound);
    for( x = max(x0 + dx0 * (t - t0), lowerBound); x <= minVal; ++x)
     stencil( read, write, x );
    read = write;
    write = 1 - write;
   }}}}
```



Over Tiles
Edge Tile Conditions
Within Tile Iteration
Stencil Call (Actual Work)

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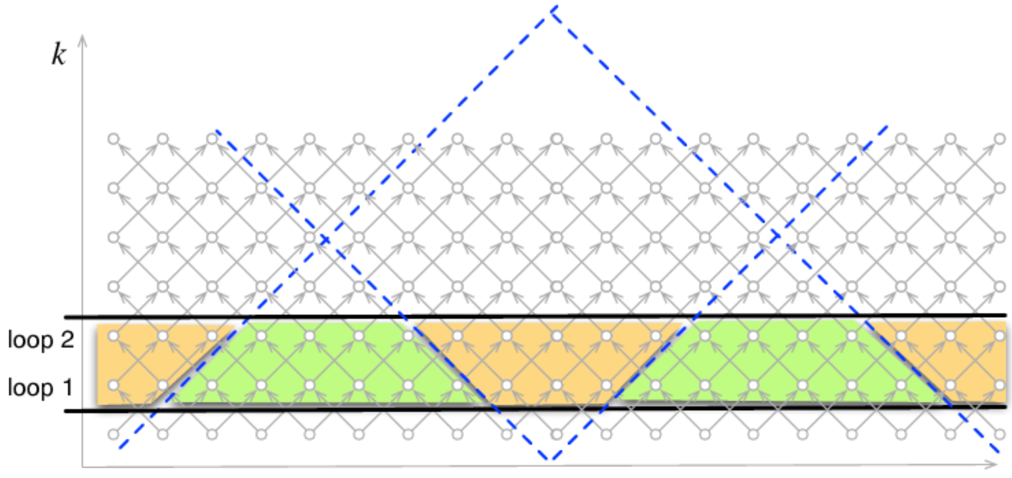
Diamond-Slab Tiling

```
int write, read;
int t0, t1, x0, x1, dx0, dx1;
int t, x;
for( t0 = 1; t0 <= T; t0 += timeBand ) {
 t1 = min(t0 + timeBand - 1, T);
 dx0 = 1;
 dx1 = -1;
 for( x0 = tiles_A_start; x0 <= upperBound; x0 += betweenTiles ){
 x1 = x0 + width_max - 1;
 read = (t0 - 1) & 1;
 write = 1 - read;
 if( x0 <= lowerBound ) {
  for( t = t0; t<= t1; ++t ){
   int minVal = min(x1 + dx1 * (t - t0), upperBound);
    for( x = lowerBound; x <= minVal; ++x)
     stencil( read, write, x );
    read = write;
    write = 1 - write;
   }}
  else if( x1 >= upperBound ){
   for( t = t0; t<= t1; ++t ){
    for( x = max(x0 + dx0 * (t - t0), lowerBound); x <= upperBound; ++x)
     stencil( read, write, x );
    read = write;
    write = 1 - write;
   }}
  else {
```



```
forall (read, write, x) in diamondSlabIterator(tileSize, domainSpace, stencilDepth)
{
            stencil( read, write, x );
}
```

```
   }}
  else {
   for( t = t0; t<= t1; ++t ){
    int minVal = min(x1 + dx1 * (t - t0), upperBound);
    for( x = max(x0 + dx0 * (t - t0), lowerBound); x <= minVal; ++x)
     stencil( read, write, x );
    read = write;
    write = 1 - write;
   }}}}
```

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Current Findings

- It works!
  - We observe speedups over serial C:

Language	Naïve Parallel	Diamond-Slab Tiling
Chapel	5.96x	6.85x
OpenMP + C	7.70x	13.05x

- It's good code!
  - Manageable
  - Meaningful
  - Magni-***fast***-cent

The Road Ahead

- Dear Santa,
  - Unified Parallel Iterators (Not Leader-Follower)
  - Decreased Environment Complexity

- Future Work
  - Lets greet and beat OpenMP + C performance
  - Efficient, domain generalizable iterators
  - Automated tile size calculations; not experiments