Chapel With Polyhedral Transformation Using Autotuning

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Loop Transformation

- Manipulation of loop nest
  - Structure
  - Schedule
- Prior work: manually apply loop transformations in Chapel
  - I. J. Bertolacci et al. Parameterized diamond tiling for stencil computations with Chapel parallel iterators. ICS 2015
  - A. Sharma et al. Affine loop optimization based on modulo unrolling in Chapel. PGAS 2014
- We: Automatically applied loop transformations using recipes from script which enables integration with autotuning framework

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Contribution

- Uses C code to capture sequential computation
- Generates Chapel programs by composing polyhedral transformations on the sequential computation and mapping from iteration spaces to Chapel domains and iterator
- Demonstrates with a simple example in Chapel the benefits of applying such transformations in conjunction with autotuning

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Chapel Language

```
proc mm(A:[]real,B:[]real,
  an:int,ambn:int,bm:int){
    const D = {0..an-1, 0..bm-1};    // Domain
    var C : [D] real;                // Domain mapped array
    forall (i,j) in D do {           // Iterator
        C[i,j] = 0;
        for k in {0..ambn-1} do
            C[i, j] += A[i, k] * B[k,j];
    }
    return C;
}
```

Polyhedral Framework

- Iteration Spaces
  - A set of iteration vectors represented as integer tuples
  - Direct mapping from Chapel domain
- Transformation done by linear mapping
  - Affine loop bounds, conditional expressions, array subscripts

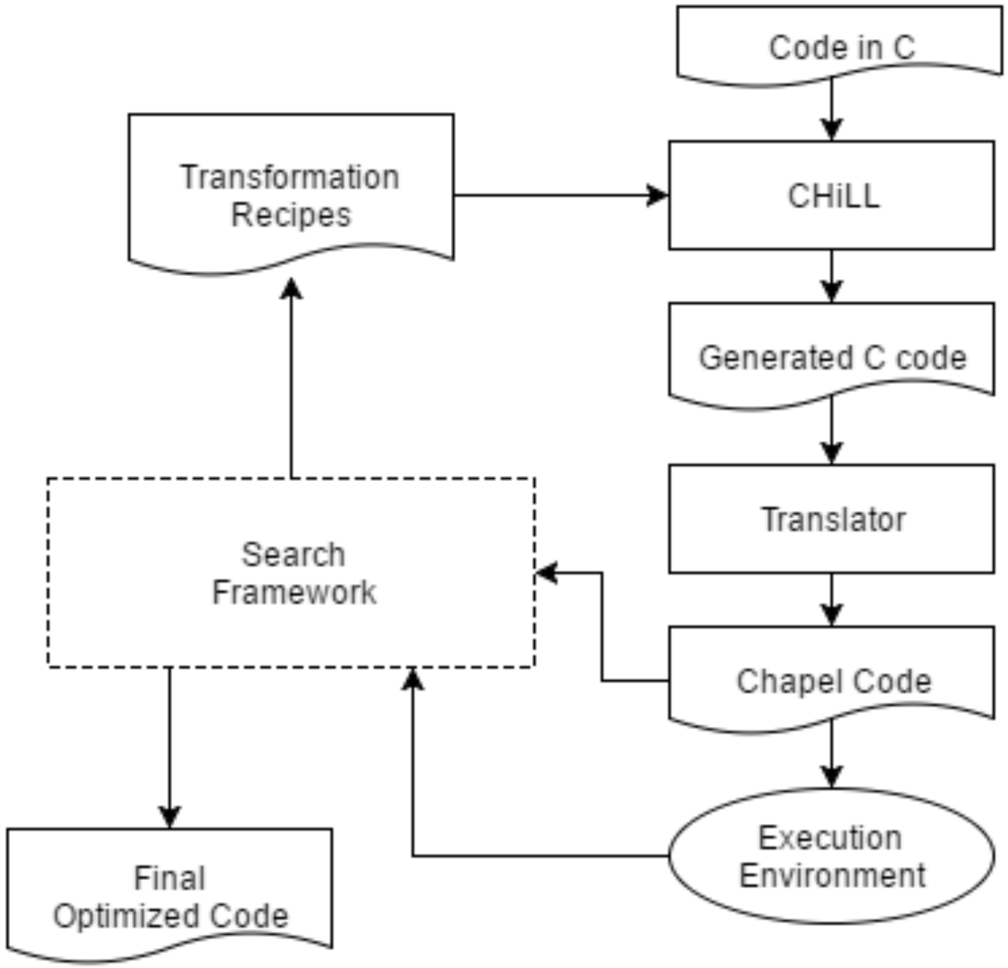
Dependence analysis

- Ensure validity of transformation and correctness of program
- Have to know the order of references to each array elements
- Cannot be applied to Chapel iterator without programmer intervention or runtime information

CHiLL

- Composable High-Level Loop transformation framework
- A polyhedral transformation and code generation framework
  - Relies on autotuning to generate highly-tuned implementations for a specific target architecture
  - Uses a transformation recipe to express optimization strategy (recipe may be generated by a compiler)

Architecture Overview



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Experiment – matrix multiply

- Input in C

```
for(i = 0; i < an; i++)
for(j = 0; j < bm; j++)
{
   C[i][j]=0.0f;
   for(n = 0; n < ambn; n++)
      C[i][j] += A[i][n] * B[n][j];
}
```

- Tile sizes {8; 16; 32; 64; 128; 256}
- Distribution of the initialization code
- Tile sizes
  - Chapel's configuration variable
  - Literal constant
- Intel Haswell i7-4790K
- 16GB DDR3 RAM

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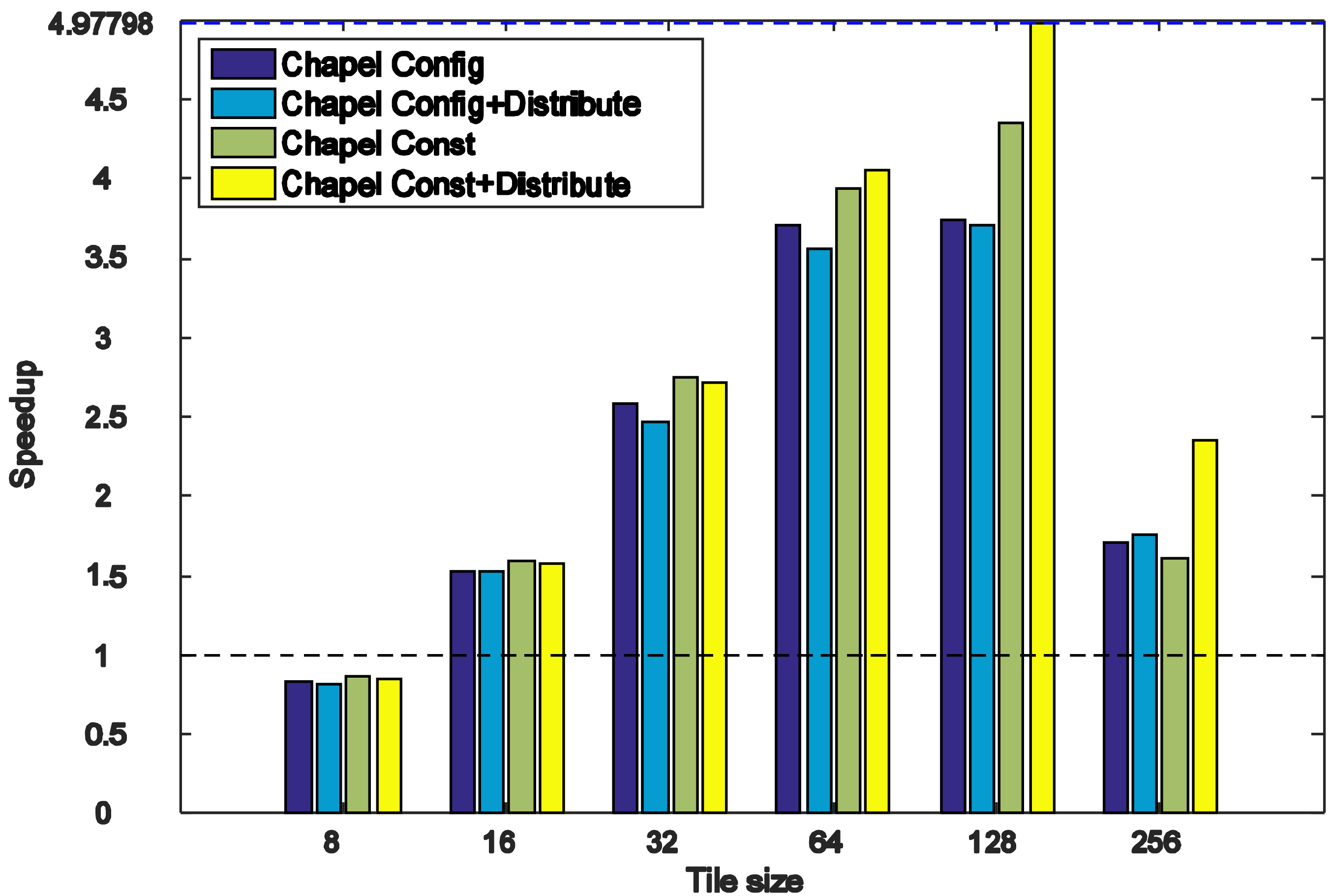
Result



4.97798
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Speedup
Chapel Config
Chapel Config+Distribute
Chapel Const
Chapel Const+Distribute
8
16
32
64
128
256
Tile size

Stencil Computations

- Operations on structured grids
- MiniGMG
  - Geometric multigrid benchmark
  - Uses stencil computations extensively especially in smooth and residual operators
- CHiLL on MiniGMG
  - P. Basu (2015) Compiler Optimizations and Autotuning for Stencils and Geometric Multigrid. PhD thesis. University of Utah

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Stencil Optimizations

- Communication avoiding optimizations
  - Wavefront(loop fusing)
  - Deeper ghost zones with redundant computation

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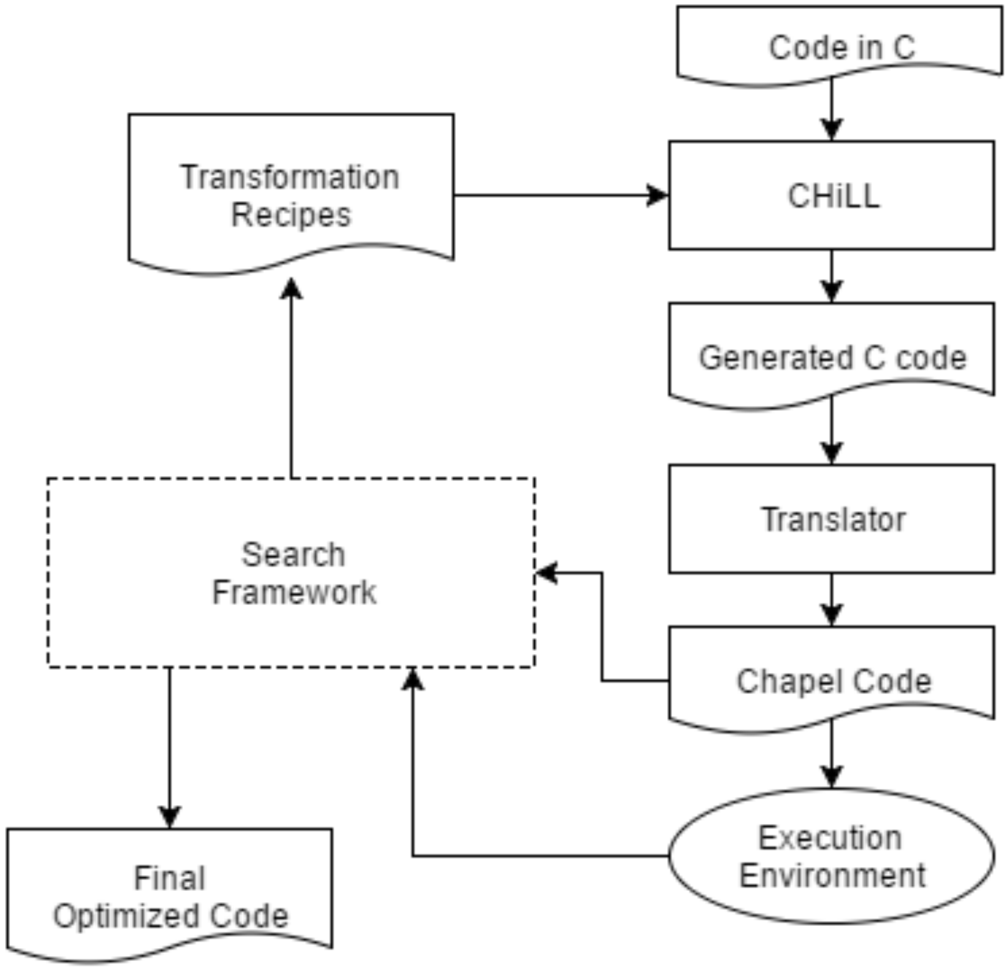
User-defined library

- StencilDist library
- Problems
  - Can’t guarantee correctness(dependence)
  - Handwrite optimized code
  - Generality concern

Multi-locale Stencil



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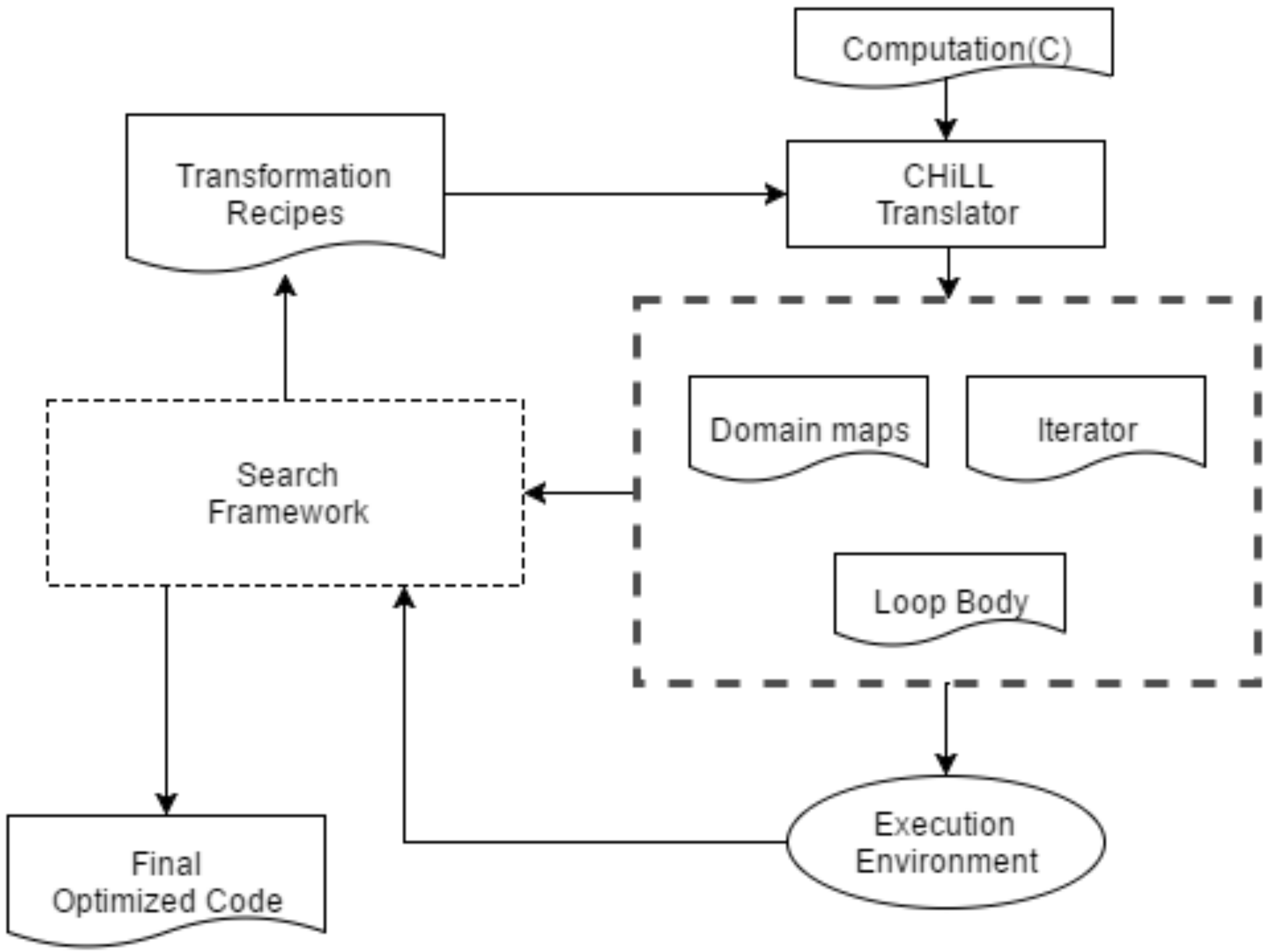
Multi-locale Stencil



Multi-locale Stencil

- Programmer writes simple serial code fragments
- Recipes provided by programmer or generated by autotuner
- Behind-the-scene generation of distributed computation and distributed data
- Produce fine-tuned code without programmer's rewriting

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Conclusion

- Integrating Chapel with CHiLL
  - Instantly enables a lot of different optimization techniques that can be composed in complex sequences
  - Autotuning can be used to find the best performing combination of transformations under target architecture

Future work

- Expanding the domain of autotuning by generating and tuning domain maps and iterators
- Relaxing the transformation requirements by generalize to non-affine loop bounds and subscripts that employ indirection through an index array

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Questions?

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