Fast, Effective Dynamic Compilation

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Dynamic Compilation

What is it?

Defer some compilation to run time
Optimize code on the basis of **runtime constants**

Why do it?

Better performance
Many interesting applications have runtime constants

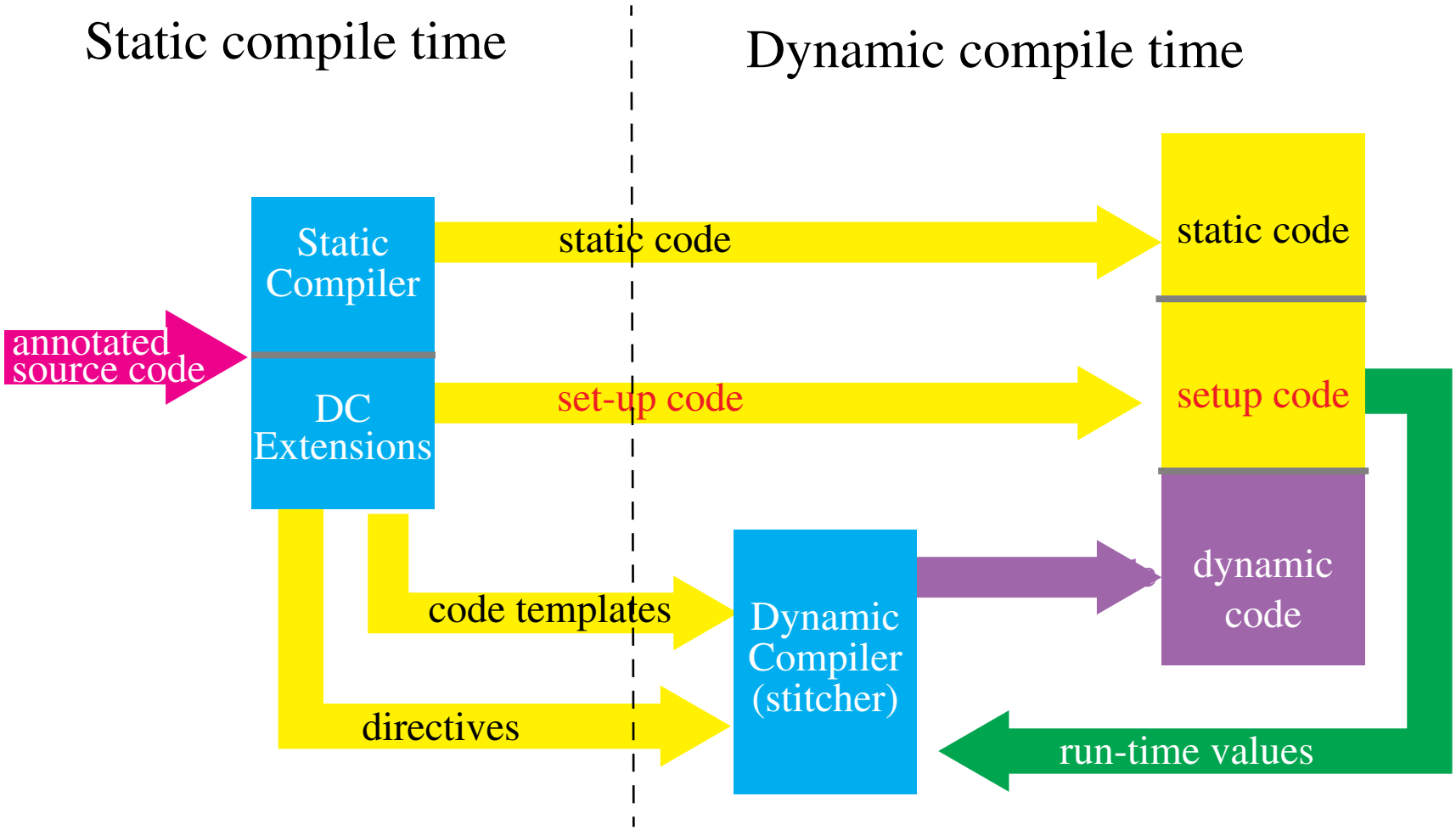
Why is it difficult?

Tradeoff: *fast dynamic compile time* vs. *higher code quality*

Our solution:

Do maximum work at static compile time

Dynamic Compiler Framework



Example: Cache Lookup

```
cacheResult cacheLookup(void *addr, Cache *cache) {

  unsigned blockSize = cache->blockSize;
  unsigned numLines = cache->numLines;
  unsigned tag = (unsigned) addr / (blockSize * numLines);
  unsigned line = ((unsigned) addr / blockSize) % numLines;
  setStructure *setArray = cache->lines[line];
  unsigned associativity = cache->associativity;
  int set;

            for (set = 0; set < associativity; set++) {
   if (setArray[set].tag == tag) return CacheHit;
  }
  return CacheMiss;

}
```

Cache Lookup Example: Template Code

```
cacheResult cacheLookup(void *addr, Cache *cache) {

 dynamicRegion {

  unsigned tag = (unsigned) addr /    ;
  unsigned line = ((unsigned) addr /    ) %    ;
  setStructure *setArray =    [line];



  unrolled for (set) {
    if (setArray[    ].tag == tag) return CacheHit;

  }
  return CacheMiss;

 }
```

Cache Lookup Example: End Result

4-way associative, 32 byte cache block

```
unsigned tag = (unsigned)addr >> 14;
unsigned index = ((unsigned)addr >> 5) & 511;
setStructure *setArray = cacheLines[index];
if (setArray[0].tag == tag) return CacheHit;
if (setArray[1].tag == tag) return CacheHit;
if (setArray[2].tag == tag) return CacheHit;
if (setArray[3].tag == tag) return CacheHit;
return CacheMiss;
```

Dynamic optimizations:

- constant propagation
- constant folding
- strength reduction
- complete loop unrolling

Preliminary Results

Benchmark	Run-time Constant Configuration	Asymptotic Speedup	Break-even Point
Reverse-polish stack-based desk calculator	polynomial expression in x & y	1.7	916 interpretations
Scalar-matrix multiply	the scaling factor	1.6	31K multiplies
Sparse matrix-vector multiply	200x200 matrix, 10 elements/row, 5% density	1.8	2650 matrix multiplies
	96x96 matrix, 5 elements/row, 5% density	1.5	1850 matrix multiplies
Event dispatcher in SPIN	7 predicate types, 10 event guards	1.4	722 dispatches
Quicksort record sorter	4 keys	1.2	3050 records

Future Work

Faster dynamic compile time:

- Merge set-up code, stitcher directives and stitcher
- Lazy vs. eager stitching

Expand repertoire of optimizations:

- Register allocation at runtime
- Scheduling between unrolled loop iterations

Handling more applications:

- Runtime constants that can change
- Inlining
- Multi-way loop unrolling

The Holy Grail:

- Automatic identification of dynamic regions & runtime constants

```
 dynamicRegion(cache) {

  unrolled

  }

 }
}
```

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```
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  setStructure *setArray = cache->lines[line];
  unsigned associativity = cache->associativity;
  int set;

 for (set = 0; set < associativity; set++) {
   if (setArray[set].tag == tag) return CacheHit;
  }
  return CacheMiss;

}
```

Cache Lookup Example with Annotations

```
cacheResult cacheLookup(void *addr, Cache *cache) {

dynamicRegion(cache) {
  unsigned blockSize = cache->blockSize;
  unsigned numLines = cache->numLines;
  unsigned tag = (unsigned) addr / (blockSize * numLines);
  unsigned line = ((unsigned) addr / blockSize) % numLines;
  setStructure *setArray = cache->lines[line];
  unsigned associativity = cache->associativity;
  int set;

 unrolled for (set = 0; set < associativity; set++) {
   if (setArray[set].tag == tag) return CacheHit;
  }
  return CacheMiss;
 }
}
```