Scalarization of Index Vectors in Compiled APL

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Abstract

High-performance for array languages offers several unique challenges to the compiler writer, including fusion of loops over large arrays, detection and elimination of scalars as arbitrary arrays, and eliminating or minimizing the run-time creation of index vectors.

We introduce one of those challenges in the context of SAC, a functional array languge, and give preliminary results on the performance of a compiler that eliminates index vectors by scalarizing them within the optimization cycle.

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- The answer is **NOT** a scalar.

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  - data-parallel nested loops: *With-Loop*
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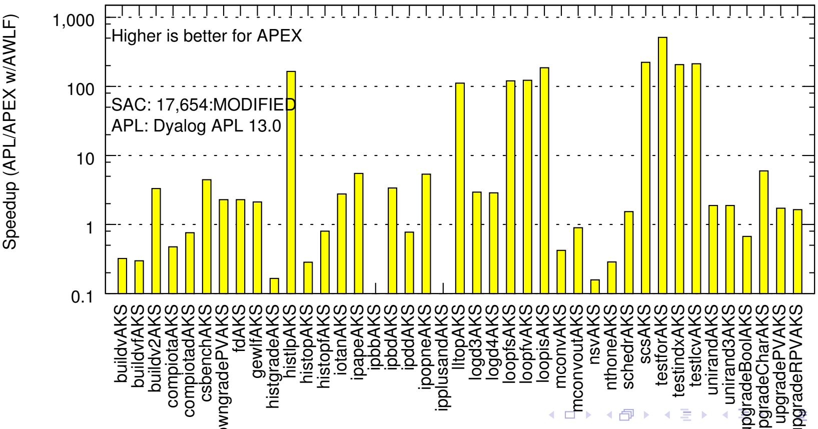
  - functional loops and conditionals as functions
- Goal: Compiled APL performance competitive with hand-coded C

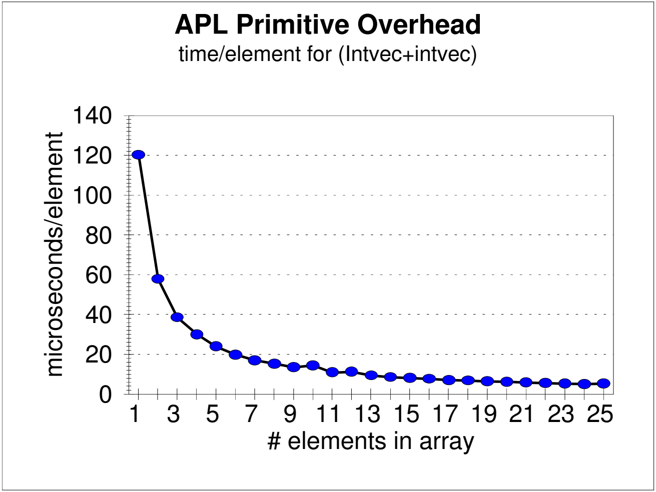
Some Reasons Why APL is Slow

- Fixed per-primitive overheads: Syntax analysis, conf checks, fn dispatch, mem mgmt
- Variable per-primitive overheads
- Index vector materialization

APL vs. APEX CPU Time Performance (2,011–09–30)



Why APL is Slow: Fixed Per-Primitive Overheads



Who suffers? Apps dominated by operations on scalars: CRC, loopy histograms, dynamic programming, RNG

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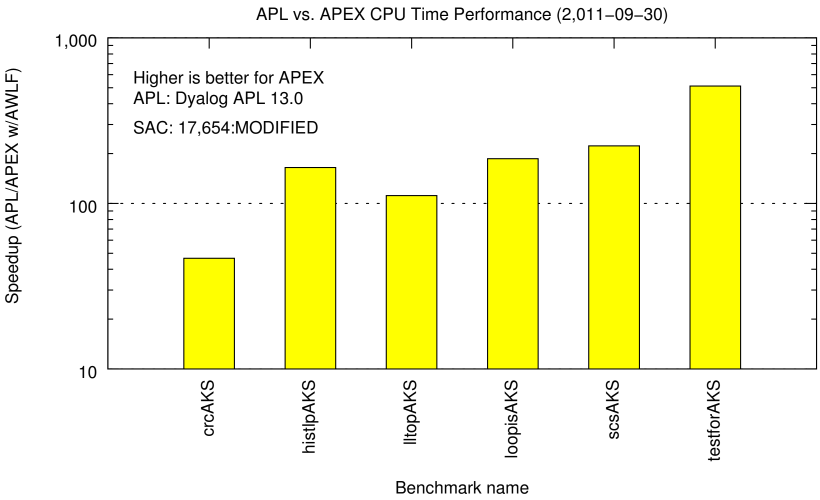

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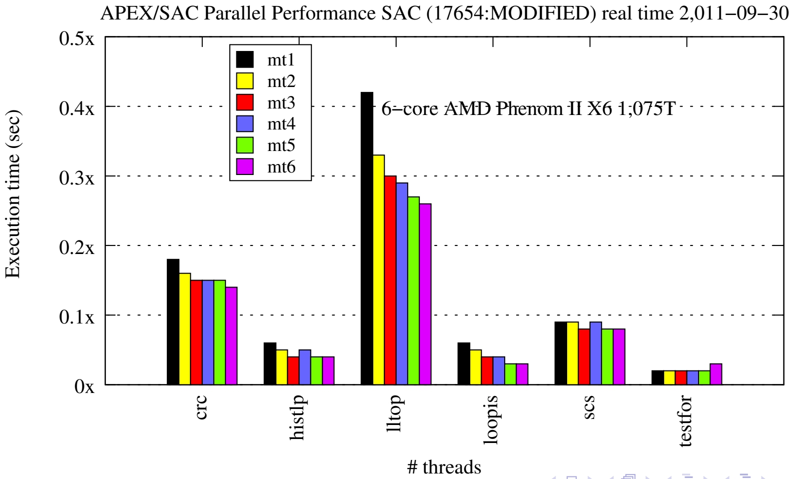
- Scalar-dominated apps have good serial speedup...
- but poor parallel speedup



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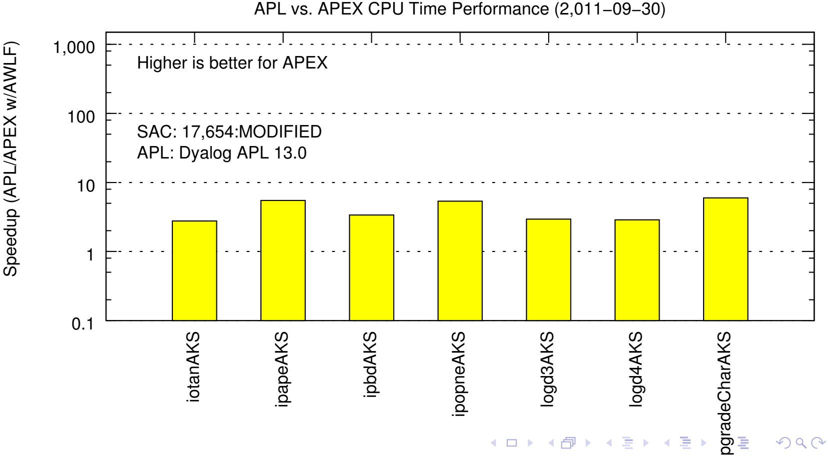

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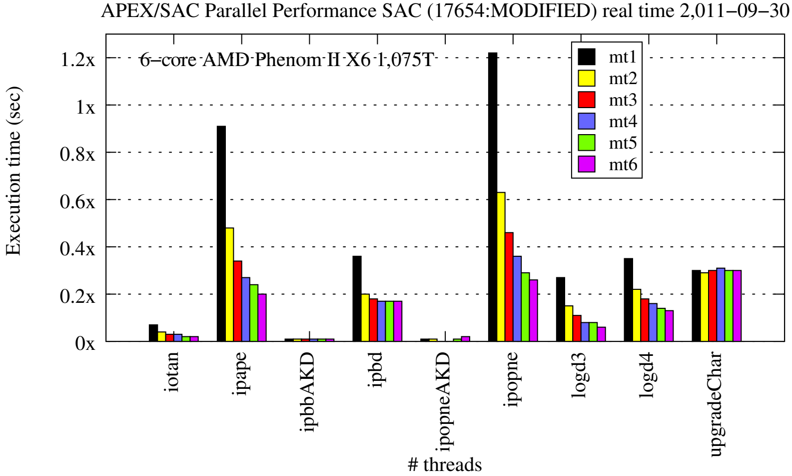

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- `[i,pi]` and `[pi,i]` are materialized index vectors
- A few simple changes to scalarize index vectors:

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tmp = a[;i]
a[;i] = a[;pi]
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- A few simple changes to scalarize index vectors:
  ```
  tmp = a[;i]
  a[;i] = a[;pi]
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  ```
- Matrix divide model now runs twice as fast!

Why Materialized Index Vectors are Expensive

- Materialization of `[i,pi]` and `[pi,i]`:

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- Materialization of `[i,pi]` and `[pi,i]`:
- (* for indexing part)
  *Increment reference counts on `i` and `pi`
  Allocate 2-element temp vector
  Initialize temp vector descriptor
  Initialize temp vector elements
  *Perform indexing
  Deallocate 2-element temp vector
  *Decrement reference counts on `i` and `pi`

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- Who suffers? Matrix divide, compress, deal, dynamic programming
- Who suffers? Inner products that use the CDC STAR-100 algorithm
- `800x800 ipplusandAKD` CPU time: 45 minutes!

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IV = [ i, j, k]
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- Implication: `offset` calculation may be liftable (LIR)

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- IVE: If `IV` can be represented as scalars, eliminate `vect2offset`. Before:

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- Unfortunately...

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- This is where we came in!
- So, what can we do?
- A kludged LIR to deal with this was deemed tasteless

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- *e.g.*, unroll `IV+1`, guard and extrema functions..
- *e.g.*, extend existing optimizations, such as CF
- The Good News: I had already scalarized many index vectors for Algebraic With-Loop Folding!

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- Even More Good News: More parallelism is coming

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- Characterize your application, then we can provide an answer.