Astounding Performance Looms!

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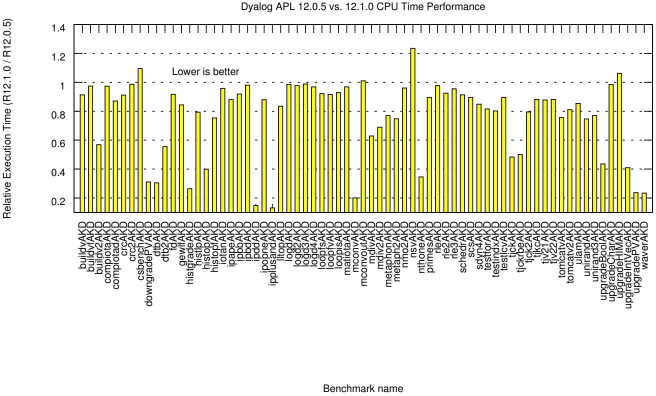
Abstract

Array languages, despite their proven advantages in time-to-solution and terse expression, continue to have a reputation for poor performance compared to imperative languages, such as C and Fortran. That reputation is about to change, thanks to recent advances in array compilation theory, APL's inherent parallelism, and the many-core computers that are now commonplace.

We showcase the state of the art of array languages, pitting interpreted APL code against compiled APL against Fortran 77 and Fortran 95, in both serial and parallel environments. We also outline how we propose to close the remaining performance gap between interpreted APL and compiled array languages.

Dyalog APL Performance: State of the Art



- Inner product speedups (ipdd, ipbd, mconv, waver)
- Grade speedups (downgradePV, upgradeHIM, upgradeIntVec)
- Generally, decent improvement across the board
- A few losers (nsv, csbench), to keep implementers humble

Compiled Array Languages

- SAC: Research Array language: Extended functional C
  - Language research projects
  - Serial performance projects (AWLF, WLF. . .)
  - Parallel performance projects
  - About 15 people working on compiler now
  - Compiler undergoing major refactoring (function spine, SAA opts)
- APEX: Research compiler: Extended flat APL, generates SAC or SISAL
- Fortran 9X: Fortran 77 with array extensions

Signal Processing

LOGD2: Acoustic signal shaping, delta modulation, first-difference

- Dyalog APL diff function

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wv = wv - eoshift(wv,-1)
return & end
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- Fortran 77 diff function

```
   subroutine diff(wv,siz)
   double precision wv(1),t,t2
   integer siz,i
   do 6 i= siz,2,-1
 6 wv(i) = wv(i) - wv(i-1)
   return & end
```

APEX/SAC Functional Array Language Serial Performance

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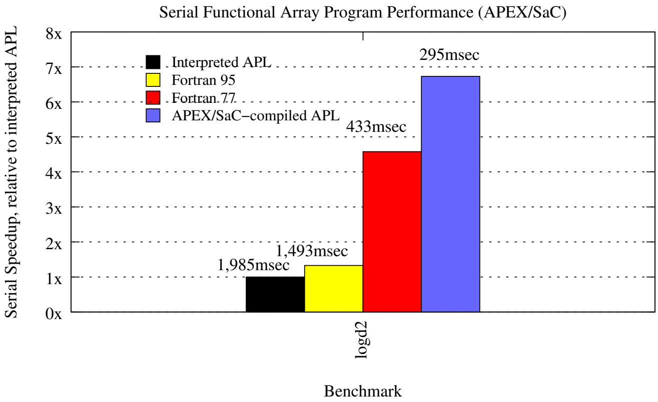

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- APL source code for `logd2`:

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main:  +/logderiv 0.5+⍳ω
logderiv:  ¯50⌈50⌊50×(diff2 ω)÷ω+0.01
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- BENEFIT: Abstract expressionism.

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- +/⌽⍳N
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- This is NOT idiom detection!

Finite Element Analysis - 2D Jacobi Relaxation

```
double[.,.] relax( double[.,.] A) {
m = shape(A)[0];
n = shape(A)[1];
B = rotate( 0, 1, A) + rotate( 0, -1, A) +
    rotate( 1, 1, A) + rotate( 1, -1, A);
upperA = take( [1,n], A);
lowerA = drop( [m-1,0], A);
leftA = drop( [1,0], take( [m-1,1], A));
rightA = take( [m-2,1], drop( [1,n-1], A));
innerB = take( [m-2,n-2], drop( [1,1], B));
middle = cat( leftA, cat( innerB, rightA));
result = upperA ++ middle ++ lowerA;
return(result); }
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- SAC function

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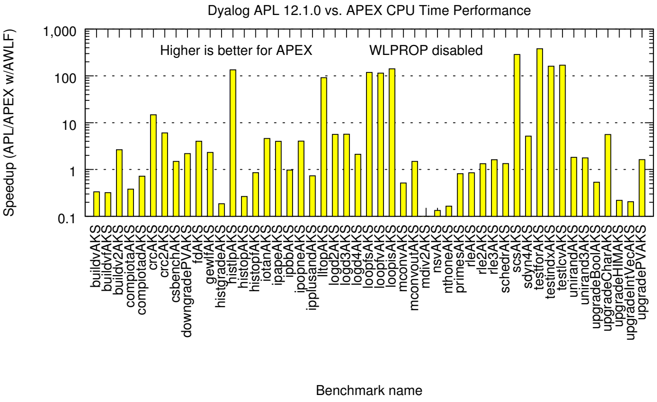
- It should compile into one loop, but not this week

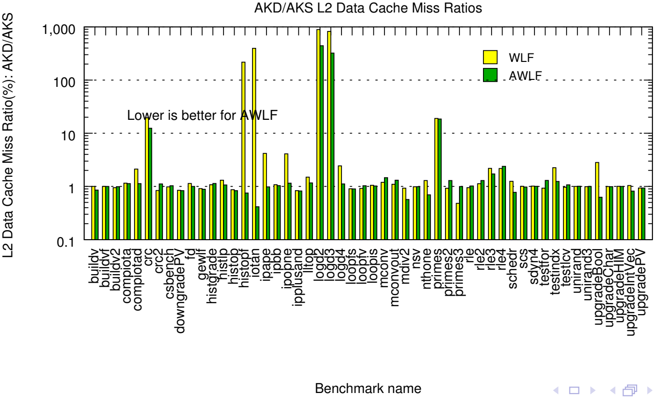
APEX Performance vs. APL



- Highly iterative code (dynamic programming `scs`, `sdyn4`) performs very well.
- FOR-loops (`buildv`, `histgrade`) & with-loops within conditionals need help.

APEX Cache Performance

- L2 cache miss rates
- AKS - Arrays of Known Shape (Fortran 77)
- AKD - Arrays of Known Dimension (APL)
- WLF - With-Loop Folding (AKS-only)
- AWLF - Algebraic With-Loop Folding (AKS and AKD)



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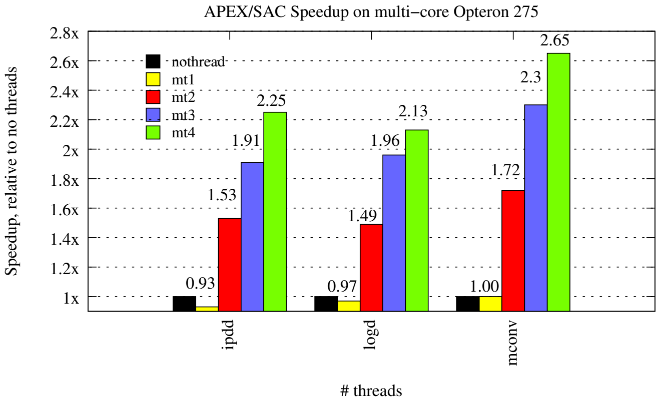
- Unlike the lamprey, both compiler and program benefit

Multi-thread APEX Performance on Opteron



- Matrix product (ipdd)

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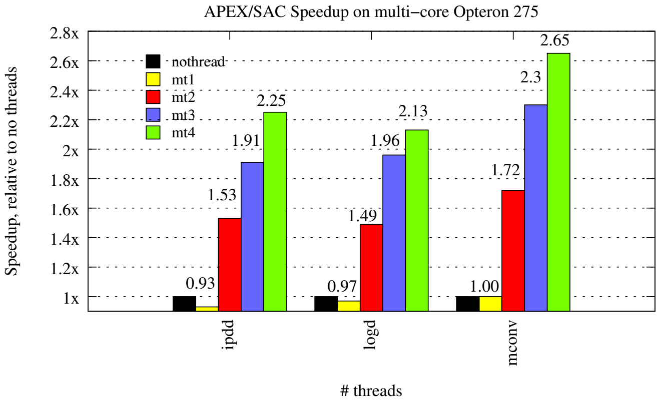

- Matrix product (`ipdd`)
- Acoustic signal processing (`logd`)

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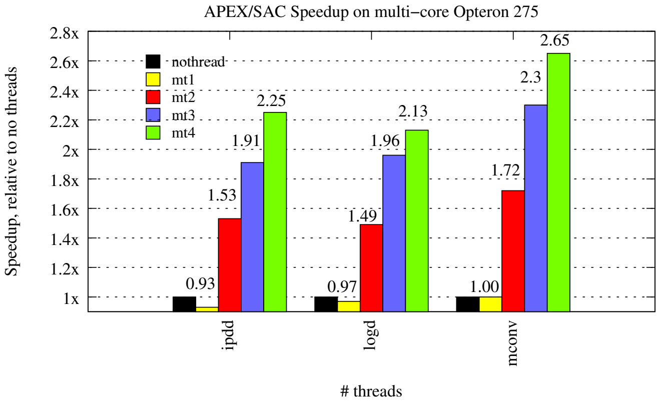

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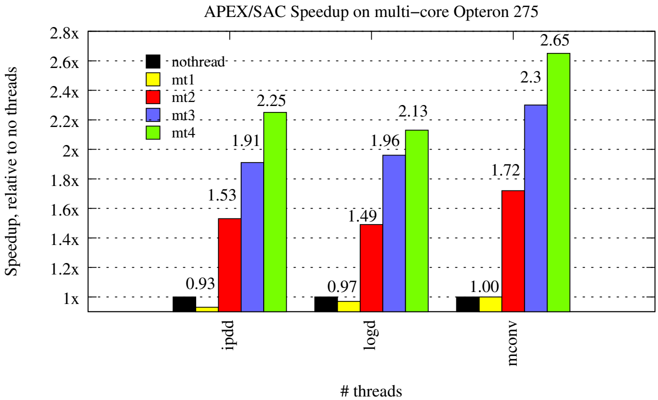

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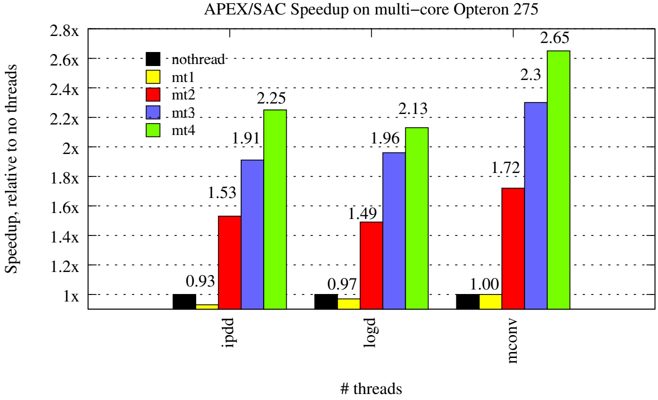

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- Acoustic signal processing (**logd**)
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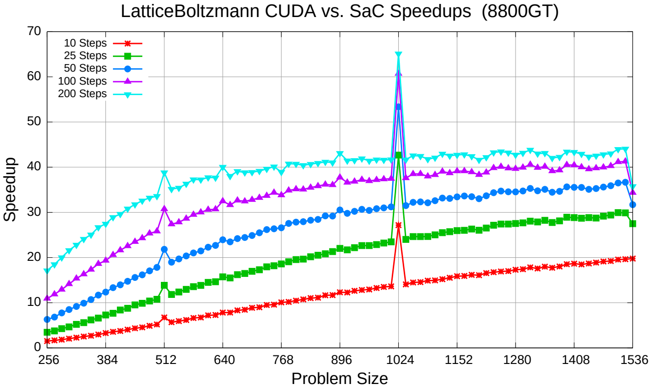
- Today, **logd2** about 12X faster than APL on a 4-core box
- There are more optimizations to come. Soon.

Computational Fluid Dynamics With CUDA Back End



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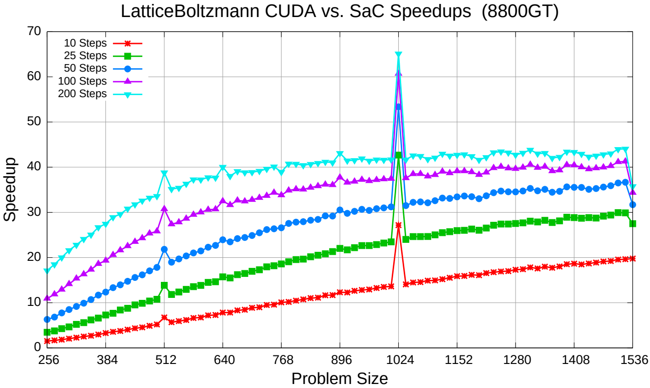

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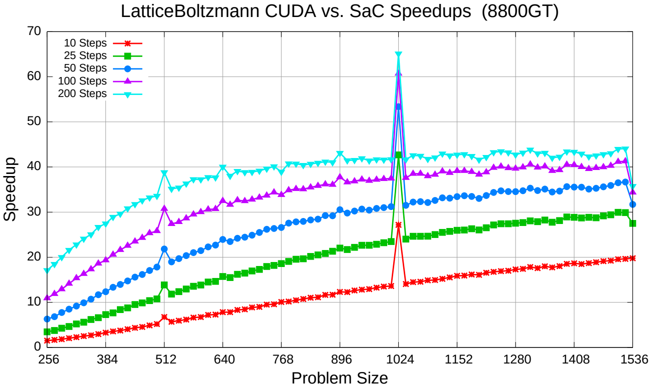

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- MuTC project in EU, UK
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  - Simulated linear speedup with 50K threads
  - Prototype SAC MuTC back-end exists

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- Today: ⎕na calls to APEX
- access to optimized code

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  - multi-core execution
  - access to CUDA
  - Some overhead due to array copying across interface
  - $\longrightarrow$ Slower for very small computations

- Tomorrow:
  - APEX performance improvements continue (2X-20X)

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  - Fastpath ⎕na call from APL to compiled code
    - Reduce and/or eliminate array copying across interface

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- Tomorrow:
  - APEX performance improvements continue (2X-20X)
  - Fastpath `⎕na` call from APL to compiled code
    - Reduce and/or eliminate array copying across interface
  - JIT compiler for interpreted APL:
    - `A + B × ⍳ C` $\longrightarrow$ One parallel loop, no temp arrays
    - Reduce "each" hell: less memory fragmentation, much faster
    - Perhaps compile some class of dynamic functions
    - Compiled function cache

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- Optimistic Algebraic With-Loop Folding

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- Traditional approach: One compiler for each language, each target system
- The GCC approach:
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References

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Thank you!

Questions?