High-Throughput, Accurate Image Contour Detection

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Image Contour Detection
• Image contour detection is fundamental to image segmentation and many other computer vision problems
  - gPb (global Probability of boundary) is currently the most accurate detector
  - However, it takes 5.8 minutes to process a small image (481 x 321 = 0.15MP)
  - This limits its applicability

Gradient Maps to Global Segmentation

Hybrid Lanczos Eigensolver
• Our problem, then, is to find the k smallest eigenvalues with their eigenvectors from a large, symmetric, real sparse matrix (n=width*height=354,401 for a 321 x 481 image)
• The Lanczos Algorithm is well suited for this problem
• Exterior eigenvalues converge quickly
  - We only need a few of the smallest eigenvalues
• Inside the Lanczos iteration loop
  - SpMV routine; NUMA aware
  - BLAS routines; saxpy,sdot,snrm2,sscal
• Calculating the eigenvalues of the small symmetric matrix
  - LAPACK routines; dstevz
• Calculating the eigenvectors
  - LAPACK routines; dstein
  - BLAS3 routines; sgemm

Optimizations
• Parallelization using HardThreads API
  - Lightweight exploitation of data parallelism
  - Bare-metal access to hardware resources
    - on x86/Linux, we emulate this by pinning threads to HW contexts
    - on RAMP, we implemented first-class HW support for this mechanism
• Tuned synchronization primitives (atomics, barriers)
• Algorithmic transformations
  - Generalized eigensolver -> Lanczos x Cullum-Willoughby
  - NUMA-aware memory allocation
    - Significant latency reduction for multi-socket systems
• Loop unrolling, cache blocking for SpMV
  - Lower inst. count improves in-order SPARC performance considerably

Time Breakdown & Speedup

Conclusions & Future Work
• We achieved 7.5x speedup against the original MATLAB/C++ implementation
• We achieve qualitatively similar accuracy across the BSDS test suite of 100 test images
• Our parallel implementation executes portably on x86 and RAMP
• This motivating real-world application will help drive parallel computer architecture research via the RAMP port