Future Technologies Group
Computational Research Division

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Structure of FTG

• Agenda of FTG:
  – Research in core Computer Science areas
    • Architectures, compilers, operating systems
  – as it relates to HPC architectures, systems, and applications

• Multiple projects, funding sources, and PI’s
  – “Synergistic” mix to manage FTG overall
  – Some PI’s are not in FTG (Kathy !)
  – Funding typically 1-5 years (3 is ‘norm’) – all soft money

• 12+ FTE’s and 4+ Students
  – Fractional people matrixed in and out

• Lot of interactions/collaborations with other groups in CRD, NERSC, Campus (EECS, ParLab) and outside Berkeley.
Activities in FTG

• **Parallel languages, compilers, and infrastructure (Yelick)**
  – Berkeley UPC compiler
  – UPC application development
  – Other PGAS languages (HPCS)
  – GASNet runtime system

• **Operating Systems**
  – FastOS (Iancu)
  – CheckPoint/Restart, Fault-Tolerant Backplane (FTB) (Hargrove)
Activities in FTG

- Benchmarking, performance modeling, and tuning
  - Ultrascale system evaluation with full applications (Oliker)
  - Application characterization with APEX-Map (Strohmaier)
  - Parameterized Benchmarking Probes (Oliker, Strohmaier, Yelick)
  - Auto-tuning for scientific compute kernels (Williams, Oliker, Yelick)
  - I/O benchmarking and characterization (Shalf, Shan, Oliker)
  - PERI: SciDAC institute for performance studies (Bailey)
• The Application Performance Characterization Project

Applications or Kernels

One application performance model each.

Performance Characterization

One system performance model each.
Or a representative benchmark (APEX-Map)

Target Systems

• How much precision do we loose by using an intermediate representation?
HPCC Challenge in Apex-Space

Temporal Locality

1 (Low)

Spatial Locality

M (High)

0.001 (High)

GUPS

CG_R

FFT_C

FFT_T

MM_V

CG_S

STREAM

DGEMM

HPL
Activities in FTG

• **Architectural evaluation and design**
  – Novel architecture evaluation (Oliker)
  – Testbed for the ‘Dwarfs/Motifs’ for architecture and language evaluation (Strohmaier)
  – SDSA (Science Driven System Architecture Team, NERSC) (Shalf)
  – Ultra-efficient Exascale Computing (Green Flash) (Oliker, Shalf, Wehner)
  – HFast interconnect technology (Oliker, Shalf)

• **Security**
  – Use of application signatures for Misuse/Signature Detection (Peisert)
• Parallel Communication Signatures
  – Architectural studies
  – Performance evaluation
  – Application characterization
  – System Security
Select kernel(s) \{canonical exemplars\} for each dwarf which:

- Represent a **classical example** of the dwarf, (laugh-test) nobody could argue this kernel is not an example for this dwarf
- **Important** in their own right for programming efforts and execution times
- **Simple** enough for multiple implementation,
- **Structured** for software, architecture, auto-tuning (and other) experiments,
- **Complex enough to be useful**
  - LA: more than just BLAS2 and BLAS3
  - More like a method do solve a domain problem
- Start with a set of simpler examples and add more complex ones later.
  - But keep the collection rather smaller
• Assemble a set of:
  – **Problem descriptions** (science/users problem)
    • Some might be useful for multiple dwarfs
  – **Algorithmic descriptions** (Computational Math)
  – **Scalable input data sets**
    • generators
    • across dwarfs if applicable
  – **Verification rules**
    • Different for computational and structural dwarfs
  – **Functional Implementations for these dwarfs**
    • MATLAB or other ‘high-level’ implementation

• **Not a set of ‘benchmarks’**!
  – No single code is best everywhere
  – Appropriate metrics depend on circumstances
  – But some rules/indications what to ‘time’
## Dwarfs we work on

<table>
<thead>
<tr>
<th>Dwarfs</th>
<th>Kernels we discuss</th>
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<tbody>
<tr>
<td>Structured Mesh</td>
<td>Stencils: Laplace, Gradient, Div, Curl; Order of stencils; Data structures; MultiGrid, AMR</td>
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<tr>
<td>Unstructured Mesh</td>
<td>FEM on static mesh of triangles (???)</td>
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<tr>
<td>Linear Algebra</td>
<td>Matrix Matrix Multiplication; (LU, QR), Cholesky; Eigenvalues: SVD, non symmetric eigenvalues</td>
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<tr>
<td>Sparse Linear Algebra</td>
<td>SPMV, SPTS; $A^k x$; CG, LU</td>
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<tr>
<td>N-Body Methods</td>
<td>$N^2$; cut-off; Barnes-Hut; FMM; Particle-Mesh (PIC): type of particles, meshes</td>
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<td>Spectral Methods</td>
<td>n-dim FFT (Spiral, FFTW ?)</td>
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<tr>
<td>Monte-Carlo</td>
<td>n-dim Integration ? Numerical evaluation based on (quasi)-random-sampling?</td>
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<tr>
<td>Graph Algorithms</td>
<td>Graph Traversal; Approximate Betweenness Centrality - SSCA#2 Jike’s ParLab App ?</td>
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<tr>
<td>Dynamic Programming</td>
<td>Floyd-Warshall algorithm, (Viterbi Algorithm) SSCA#1 sequence alignment kernel</td>
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<tr>
<td>Time</td>
<td>Session</td>
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<tr>
<td>9:00 a.m.</td>
<td>FTG Overview</td>
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<td>9:15 a.m.</td>
<td>SDSA Overview</td>
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<td>10:00 a.m.</td>
<td>Green Flash (Low Power Supercomputing, Optical Interconnects, etc.)</td>
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<td>10:30 a.m.</td>
<td>Break</td>
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<tr>
<td>10:45 a.m.</td>
<td>Automatic Performance Tuning</td>
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<tr>
<td>11:00 a.m.</td>
<td>The Roofline Model and Autotuning</td>
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<tr>
<td>11:20 a.m.</td>
<td>Machine Learning and Autotuning</td>
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<td>11:40 a.m.</td>
<td>Code Generation and Autotuning</td>
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<tr>
<td>12:15 p.m.</td>
<td>Working Lunch / Flash Memory Ideas</td>
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<td></td>
<td>Small group discussion</td>
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<tr>
<td>1:30 p.m.</td>
<td>Irregular Memory Optimizations on Multicore</td>
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<tr>
<td>2:00 p.m.</td>
<td>Architectural Evaluation for Graph Algorithms</td>
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<tr>
<td>2:30 p.m.</td>
<td>Discussion on Architectures and Autotuning</td>
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<tr>
<td>3:00 p.m.</td>
<td>Break</td>
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<tr>
<td>3:15 p.m.</td>
<td>Berkeley Lab Checkpoint/Restart</td>
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<td>3:45 p.m.</td>
<td>Security Research</td>
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<tr>
<td>4:15 p.m.</td>
<td>Discussion</td>
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