Applications Working Group
MOPHC

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Charge Questions

- **What would you do with ‘smarter’ memory?**
- **What is wrong with the other groups? What should they do about it?**
- **How do we deal with existing code? How do we support applications that current architectures do not support? How do we transition from old to new?**

- **Other groups**
  - Architectures
  - Programming models/software

- **Random comments**
  - What is a ‘smarter memory?’
  - Should applications developers care if the memory is based on CMOS, carbon nanotubes, springs, or whatever?

Motifs: Sparse methods

- **Structure grids**
  - Non-unit stride:
    - Iterating over different dimensions.
    - Visiting different slices.
- **Unstructured grids:**
  - Gather/scatter:
    - Iterating w/ indirect references.
    - Irregular connectivity patterns.
- **Spectral (FFTs)**
  - Non-unit strides
- **Adaptive (structured and unstructured)**
  - Time varying data structures.

Motif: Database/Informatics

- **1-touch**
- **Interference between simultaneous**
  - Heavy access to uniform array
  - Irregular access random
- **Scratchpad memory could help: Cray-2 local memory**
- **Similar to PDEs?**

Motifs: Others

- **Graph traversal**
  - Reorderings
  - Non-PDE graphs
- **Monte Carlo**
- **Virtualization**
  - Indirections

Challenges

- **Performance of indirect addressing**
  - Level of concurrency in memory system?
- **Transparency of memory performance**
  - Automation or the tools to understand and optimize it manually
- **Keep reliability above suspicion**
  - No silent data corruption (Contrast: Disk systems)
- **Not enough memory: “30% barrier”**
  - Need ability to get high capacity at lower cost

Smart Memory (1)

- **Effective use of bandwidth/power**
  - Every bit read should be used
  - Wasted sharing; No bit left behind
  - No bit in the cache that is not reused
- **Scatter/gather, non-unit stride**
- **Predictable performance model**
  - Deterministic behavior
- **Introspective memory**
  - Gives usage stats
  - Memory footprint, hotspots, …
- **Remote atomic memory op**
  - Memory transfer plus operation
- **Fine grain memory synchronization**
  - Cray MTA – full/empty bits
  - Transactional memory

Smarter Memory (2)

- **Clear, Replicate itself**
- **DMA within memory**
- **Garbage collection**
- **Searches**
  - Look for a pattern
  - Content addressable memory
- **Configurable memory**
  - Example: Runtime declarable scratchpad
  - Part of variable declarations

Related Programming Model Features

- **Expressible locality**
  - Example: 1-touch
  - Affinity: Work and data
  - Replication: ghost nodes
- **Portability: Language markups**
  - Define a scratchpad memory in your language
  - Define a cam in your language
- **Introspective memory: Usage stats**
- **Performance transparency through the programming model to the hardware**

What we are willing to do and not do

- **Willing to do**
  - Add directives/pragmas
  - Willing to evolve to address system design changes
- **Not willing to do**
  - Abandon existing code base
  - Adopt non-portable programming features
    - Exception: specialized kernels
- **Reluctant to**
  - Use brand new languages to address these problems (unless we can introduce it incrementally)
  - Abandon current programming models
    - Multi-level programming models MPI+OpenMP

Bonus Slides

Dwarfs (so far) – LBL, UCB

- Finite State Machine
- Combinatorial Logic
- Graph Traversal
- Structured Grids
- Dense Linear Algebra
- Sparse Linear Algebra
- Spectral Methods (FFT)
- Dynamic programming
- N-Body methods
- MapReduce
- Back-track/branch and bound
- Graphical Model Inference
- Unstructured Grids
- Others ???

Some ORNL/DOE Codes

Science domain	Code	Structured grids	Unstructured grids	FFT	Dense linear algebra	Sparse linear algebra	Particles	Monte Carlo
Accelerator physics	T3P		X			X		
Astrophysics	CHIMERA	X			X	X	X	
	VULCAN/2D		X		X			
Biology	LAMMPS			X			X	
Chemistry	MADNESS		X		X			
	NWCHEM			X	X			
	OReTran	X		X	X			
Climate	CAM	X		X			X	
	POP/CICE	X				X	X	
	MITgcm	X				X	X	
Combustion	S3D	X						
Fusion	AORSA	X		X	X			
	GTC	X				X	X	X
	GYRO	X		X	X	X		
Geophysics	PFLOTRAN	X	X			X		
Materials science	QMC/DCA				X			X
	QBOX			X	X		X	
Nanoscience	CASINO						X	X
	LSMS	X			X			
Nuclear energy	NEWTRNX		X		X	X		
Nuclear physics	CCSD				X			
QCD	MILC	X						X

Random

- **None cacheable memory**
  - Configurable caches
- **Gathers, scatters**
- **Readonly**
- **Synchronization mechanisms**
- **Remote, atomic memory operations**
- **Memory to memory operations**
- **Efficient use of existing bandwidth**
  - Transferring only the data that you plan to use