National Software Infrastructure for Lattice Gauge Theory

Software Co-ordinating Committee

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[Go to http://usqcd.org/ for link to Software & Documentation]

Project

QCD — extremely regular

- (Perfect) Load Balancing:
  - Uniform periodic lattice & identical sublattice per processor.
- (Complete) Latency hiding:
  - Overlap computation/communication.
- Data Parallel:
  - Operations on small 3x3 complex matrices per link.
- Critical kernel: Dirac Solver is \( \sim 90\% \) of Flop/s.

Lattice Operator: \( [D\Psi]_i^\alpha = \frac{1}{2} \sum_{x,\mu} \gamma_{\alpha\beta} U_{ij}(x) \Psi_\beta(x+\hat{\mu}) - h.c. \)

Level 1 Message Passing and Algebra

Level 2 Data Parallel API

Data-parallel Operations

- Duality and binary: \[ a(x) + b(x) \]
- Duality functions: \[ a(x), b(x), c(x), \ldots \]
- Random numbers: \[ \text{platform independent pseudo-random number generator} \]
- Fields have various types (indices):
  - Letter: A, B, C
  - Index: \( 0, 1, \ldots \)
  - Two indices: \( A_i B_j \)

Example of QDP++ Expression

Typical for Dirac Operator:

\[ v(x) = \frac{1}{2} [C_1(v(x)+v(x))] + 2v(x) \quad \forall i, n, x \in \text{even} \]

QDP++ code:

```cpp
multiSpinorLatticeColorMatrix\ u[8d];
LatticeDiracFermion psi, chi, phi;
int sa;
 psi{even} = u[sa]*shift(tau, sa) + 2*phi;
```

QCD++ Message Passing

Field: \( C(x) \)

```
Field C(x), \( x \in \mathbb{Z}^3 \)
```

Level 3 Performance

Level 3 on QCDOC

QAUC Domain Wall Fermion Inverter

Pentium 4 Infiniband Cluster at FNAL

Pentium 4 GigE Cluster at JLab

Domain Wall Fermion Inverter

Future Directions

- Integration: Optimization, Testing and Handling of components
- New Level 3 and application interfaces
- Executable for QCDOC, ATLAS, ATLAS 2, PMI, etc.
- Algorithm Research:
  - Increased performance (average tops & tops/10)
  - New physics (flavoring, resonances, SUSY, fermion signs, etc.)
- Data Grid and Meta Facility:
  - Data, Code, Job control as lab metadata (average PPDQ)
  - Unstructured Execution Environment for 3 Lab Middleware for data sharing with ILD.