Exploiting Dependencies as Concepts for Parallel Programming

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Programming Parallel Architectures

- Traditional: OpenMP and MPI
  - Communication architecture ignored

- Architecture-aware programming
  - Existing codes cannot be ported directly to new architectures
  - New architectures come along with new programming models: one for GPUs, one for Cell and so on.

- Hardware independent programming
  - Map computations to new architectures without rewriting the problem solving code
  - Higher level abstractions needed
Bitonic Sort Dependency

OUTPUT: sorted sequence

1 bitonic sequence of length 8

2 bitonic sequences of length 4

INPUT: viewed as 4 bitonic sequences of length 2
Embedding BS DDA onto Various Hardware

GPU: NVIDIA's CUDA

MPI-code

Bitonic Sort DDA

Hypercube
module DDA
imports Equivalence;

concept DDA<type P, type B> {
  requires Substitutable<P>; requires Substitutable<B>;

  /** The signature */
  predicate rg (P p, B b);
  function P rp (P p, B b) guard rg(p,b);
  function B rb (P p, B b) guard rg(p,b);

  predicate sg (P p, B b);
  function P sp (P p, B b) guard sg(p,b);
  function B sb (P p, B b) guard sg(p,b);

  /** The axioms */
  axiom Receives (P p, B b) {
    assert sg(rp(p,b),rb(p,b));
    assert sp(rp(p,b),rb(p,b)) <-> p;
    assert sb(rp(p,b),rp(p,b)) <-> b;
  }
  axiom Supplies (P p, B b) {
    assert rg(sp(p,b),sb(p,b));
    assert rp(sp(p,b),sb(p,b)) <-> p;
    assert rb(sp(p,b),sb(p,b)) <-> b;
  }
}
DDA Concepts and Compilation Schemes

• Plain DDA concept
  – Hashmap based implementation
    • Time control, no space control
• DDA with space-time projections concept
  – Sequential implementation
    • Time and space (memory layout) control
  – Parallel execution model using MPI
    • Time and space (parallel distribution) control
    • No communication structure control (limitation of MPI)
  – CUDA / OpenCL execution model using threads
    • Time and space (kernel/block/thread/memory) control
    • Communication structure control
Run Times for DDA-based Bitonic Sort

DDA-concept implementations are portable across platforms.
DDAs as Concepts

• Application domain – compiler construction
• DDA concept – API for the user
• Predefined collection of concepts with associated computational mechanism:
  – CUDA-execution model
  – MPI
  – Hypercube
  – FPGA,
  – etc
• Portability
• User benefits from axiom-based testing tools.