Improvements in Dynamic Partitioning

Aman Arora
Snehal Chitnavis
Introduction

- Partitioning - Decomposition & Assignment
  Break up computation into maximum number of small concurrent computations that can be combined into fewer/larger tasks in assignment step.

- Types:
  - Static partitioning
  - Dynamic partitioning
Static Partitioning

- In static process partitioning, all the processes are specified before the program is executed and the system will execute a fixed number of processes.
- Problem is predictable.

Dynamic Partitioning

- In dynamic partitioning, processes can be created and started for execution during the execution of the main program using process creation constructs or system calls; processes can also be destroyed. Process creation and destruction might be done conditionally.
- Problem is unpredictable.

http://www.slideshare.net/ApacheApex/smart-partitioning-with-apache-apex-webinar
Approaches in Dynamic partitioning

- Traditional approaches -
  a) Graph partitioning
  b) Geometric partitioning

- Non-traditional approaches -
  a) Hypergraph partitioning
  b) Combinations of partitioning methods
Traditional approaches

- **Graph partitioning**
  a. Recursive Spectral Bisection
  b. Multilevel graph partitioner
  c. Diffusive graph partitioners

- **Geometric partitioning**
  a. Recursive Coordinate Bisection (RCB)
  b. Recursive Inertial Bisection (RIB)
  c. Unbalanced Recursive Bisection (URB)
  d. Space-filling curve (SFC) partitioning
Graph partitioning

1) Application’s work is represented by a graph $G(V, E)$.
2) Goal: To partition vertices so that each processor has roughly equal total vertex weight while minimizing the total weight of edges.

Graph partitioning algorithm example: Recursive Spectral Bisection (RSB)

- Proposed by Pothen et al. as the basis for computing small vertex separators for sparse matrices.
- Bisects a graph by first finding the eigenvector corresponding to the smallest non-trivial eigenvalue of the Laplacian matrix of the graph.
- Drawback: High computing cost caused by the need for solving a series of eigenvalue problems.
- RSB algorithm on the CM-5 system.
Graph partitioning algorithm example: Multilevel Graph Partitioner

A multi-level graph partitioning algorithm works by applying one or more stages.

**Multilevel Graph Partitioning**

- **3 Phases**
  - Coarsen
  - Partition
  - Uncoarsen

http://images.slideplayer.com/17/5359879/slides/slide_7.jpg
Geometric partitioning

- Subdomains - As per weights and physical coordinates of objects.
- Assign equal object weights and physically close objects are grouped together in a subdomain.

Geometric partitioning algorithms

Recursive Coordinate Bisection (RCB)

- Geometric coordinates are first partitioned into two balanced parts. Partitioning continues recursively in each part until the desired number of balanced parts has been created.
- Coordinates can be weighted, in which case the total weight in each part is balanced, rather than the number of coordinates in each part.
Computational domain is divided into two regions by a cutting plane orthogonal to the longest direction of the domain. Thus half workload in each of the sub-regions. Recursive application of the same splitting algorithm on sub regions. The algorithm is terminated when the number of sub-regions is equal to the number of processors.
Non-traditional approach

Traditional models - not sufficient for applications with -
- High-connectivity
- Heterogeneity in topology
- Non-symmetric or rectangular matrices

Hypergraph partitioning

Vertices: Objects to be partitioned
Edges: (Hyperedges) 2 or more related vertices
    Represents dependencies between any set of vertices
    Accurately represents communication volume

Hypergraph Repartitioning

- Start with the application HyperGraph.
- Add one partition vertex for each partition.
- Migrate edges connecting applications vertices to their partition vertices.
- Weigh the hyperedges.
- Scale application edge weights by Alpha (Number of application communication between repartition).
- Perform Hypergraph partitioning with partition vertices fixed.
Hypergraph Partitioning: Advantages and Disadvantages

- Partitioning goal - Equal vertices assigned to processors + minimize communications along hyperedge
- Advantages:
  - For a 1-D hypergraph model, communication volume exactly proportional to the number of cut hyperedges in the bisection case
  - Reduced communication by 30-40% (vs graph model)
- Disadvantages:
  - Optimal hypergraph partitioning is NP-hard problem.
  - More expensive than graph partitioning
Partitioning Tools

- PaToH
- hMetis
- Zoltan

Non-traditional approach

Combinations of partitioning methods

Parallel contact detection algorithm

Simulation phases -

- Phase 1: Global search identifies pairs of surface elements that are close to each other
  Partitioning method: Multilevel graph partitioner

- Phase 2: Local search computes exact locations of these surfaces.
  Partitioning method: Recursive coordinate bisection (RCB) or space-filling curve (SFC)

Data mapped between phases requires communication
Multi-constraint or Multi-phase partitioning

Each element assigned 2 weights -
  ▶ force calculations (Phase 1)
  ▶ contact computation (Phase 2).

Single decomposition to balance both these weights is computed. Eliminates communication between 2 phases.
Examples

Contact detection for crash and impact simulations
- Simulation of vehicle crashes
- Deformations
- Projectile-target penetrations
References

Questions ??