Towards Petaflop Architectures

Application Emulators and Simulation

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Architectural Design using Application Emulators

Characterize performance of important applications on future architectures

– Assumptions

• application belongs to a targeted application class
• behavior of processor architecture/compiler interaction has been characterized for application class
  – project behavior of processor pipeline, cache using empirical characterizations from current architectures
  – assume that programmer and compiler will use known optimizations
  – not interested in “dusty deck” performance predictions
Application Emulators

Parameterized programs designed to mimic application computation and data movement patterns
Focus is on memory hierarchy, computational details are abstracted
   – generally also abstract L1 and L2 cache
Coarse grained, executable description of patterns of data movement and computation
Construction of Application Emulators

Sensor data processing -- data intensive applications

- Data products generated from disk based datasets
  - datasets are usually irregular
    - indexed by spatial location (position on earth, position of microscope stage)

- Spatial query used to specify iterator
  - computation carried out on data obtained from spatial query
  - computation aggregates data so that resulting data product size is significantly smaller than results of range query
AVHRR Level 1 Data
- As the TIROS-N satellite orbits, the Advanced Very High Resolution Radiometer (AVHRR) sensor scans perpendicular to the satellite’s track.
- At regular intervals along a scan line measurements are gathered to form an instantaneous field of view (IFOV).
- Scan lines are aggregated into Level 1 data sets.

A single file of Global Area Coverage (GAC) data represents:
- ~one full earth orbit.
- ~110 minutes.
- ~40 megabytes.
- ~15,000 scan lines.

One scan line is 409
Preparing The Data

Level 0 Data (radiometry)
- instrumental correction
- navigation

Level 1 Data (raw data + geo)
- resample
- projection

Level 2 Data (2-D grid)
Spatial Irregularity

VHRR Level 1B NOAA-7 Satellite 16x16 IFOV blocks
Application Emulators

Computation and data movement can be decomposed into a sequence of phases or *epochs* (loosely synchronous computational pattern)

– iterator specifies a number of independent computations
– dependencies can exist within each iteration and between phases

Data product may itself be used or may be used as part of a more complex calculation

– land cover classification
– data assimilation
– bay and estuary simulation
– virtual microscope -- morphometry, 3D reconstruction
Current Application Emulators

Scientific I/O intensive

– Titan
  • Satellite data processing
  • peer-to-peer

– Pathfinder
  • Satellite data processing
  • client-server (separate IO and Compute nodes)

– Virtual Microscope
  • Microscope image database server
  • data server (multiple simultaneous queries), peer-to-peer
Current Applications Emulators

Scientific irregular
  – Sparse Gaussian
  – Fast multipole method (Vortex dynamics)

Database
  – Data Cube
  – Data Mining
  – External Sort
Simulators

Suite of simulators that simulate to varying degrees of fidelity
All simulators abstract pipelining
Howsim carries out detailed architectural simulation using empirical and published device characteristics
Petasim carries out rough analysis that accounts for costs associated with moving data between levels of memory hierarchy
Block level data driven simulators -
  – Data driven simulators -- Fastsim, Gigasim, Dumbsim -- trace chunks of data through retrieval, data movements, processing and storage (or output to network)
Emulators coupled to simulators through incremental generation and consumption of work flow graphs
Coupling to Simulators
(Work flow Graphs)

**Titan**
- DISK READ → MESSAGE SEND → MESSAGE RECEIVE → COMPUTE
- MESSAGE SEND → MESSAGE RECEIVE → COMPUTE
- COMPUTE

**hfinder**
- I/O nodes
- MESSAGE SEND → MESSAGE RECEIVE → COMPUTE
- MESSAGE SEND → MESSAGE RECEIVE → COMPUTE

**Virtual Microscope**
- DISK READ → COMPUTE → SEND
Compiler Support for Generating Application Emulators

Used to generate work flow description used in petasim and in block level simulators

Programmer uses knowledge of application domain to write computational component of application emulator

– Compiler generates code that, at runtime produces work flow description
  • estimate computational costs and amount of data communicated between nodes in workflow graphs

– High level directives used to control granularity of work flow description
General Overview of Performance Prediction Framework

- **Applications**
- **Emulators**
- **Work flow diagram**
- **Dependency Graph**
- **Generation Tools**
  - Petasim
  - Howsim
  - Gigasim
  - Fastsim
  - Dumbsim

**Machine Configuration**
- Initial Design
- Simple hardware
- Large Scale Machines
- Simple hardware

**Applications**
- **Emulators**
- Execution Specification
  - * Abstract, simple
  - * Hand-coded

**Work flow generation**
- * Automated
Driving Applications

Sensor data and land cover characterization
Visualization and analysis of very large microscopy datasets
Circuit simulation
Stealth aircraft design
MSTAR
Combustion simulation
Bay and estuary simulation
Data mining
Data cube